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**Sign Size Design Review of TTM Signs  
FINAL REPORT**

**Submitted by:**

Arup URS Consortium

**In Partnership with :**

University of Leeds

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## Glossary of Terms

Term	Meaning / Definition
AfZ	Aiming for Zero
Between-subjects	Experimental design where each participant is randomly allocated to a single test condition. There is no controlling for unsystematic variation between participants because different samples experience different test conditions.
CAN	Control Area Network
Chapter 8	Traffic Signs Manual Chapter 8 – Traffic Safety Measures and Signs for Road Works and Temporary Situations (2009)
CPOM	Client Package Order Manager - representing the Employer, usually acting as the Project Sponsor for a Work Package.
DfT	Department for Transport
DMRB	Design Manual for Roads and Bridges
HA	Highways Agency
Headway	The time that it would take a vehicle to reach the same position on the road as the lead vehicle if the current speed was maintained
HFS	High Frequency Steering
Mixed ANOVA	A parametric multi-factor analysis technique
PC	Personal Computer
POM	Appointed by Arup URS Consortium to be responsible for managing delivery of the Work Package and the Consortium's performance in accordance with the Framework Quality Plan.
PRC	Percent Road Centre
RTI	Road Traffic Incident
SDLP	Standard Deviation of Lateral Position
TSRGD	Traffic Signs Regulations and General Directions (2002)
TTM	Temporary Traffic Management
UoL	University of Leeds
UoLDS	University of Leeds Driving Simulator
Within-subjects	Experimental design where each participant experiences all test conditions to minimise unsystematic variation between participants.
WPQP	Work Package Quality Plan

## Executive Summary

This project has been conducted in response to the actions included in the Traffic Signs Review:

*“Highways Agency (HA) research has demonstrated that a significant number of drivers do not understand some roadwork related traffic signs, indicating lane closures or contra-flow working on dual carriageways, particularly ones carrying a more complicated or infrequently seen message. The HA intend to undertake a review of the current level and provision of roadwork related signs, including re-designing a number of signs that were not readily understood to make them simpler.” (DfT 2011)*

There are proposals from industry on optimising the design of a number of Temporary Traffic Management (TTM) signs as well as making the process of design quicker and cheaper. However, this project was tasked with reviewing the previous research and proposed designs before conducting trials in a driver simulator, to compare the performance of the Revised Signs.

Where possible it has been the aspiration of the Highways Agency that as a result of this trial sign comprehension should be improved. However, it is expected that simplifying may lead to smaller signs thereby realising a manual handling benefit and cost savings.

This project has taken a structured and systematic method towards developing a revised approach for designing TTM signs in order to meet the project aim:

*To investigate options for revising the design of TTM road layout signs to improve comprehension, whilst maintaining or reducing the size of the signs.*

As a result of a literature review and stakeholder consultation a revised approach to the design of TTM signs has been developed. These resulting Revised Signs have been taken forward for simulator trials, and the results analysed to identify how driver performance is affected.

Analysis of the results has shown that driver performance was comparable, with no statistically significant difference. However, by adopting the revised approach to designing TTM signs it is considered that overall comprehension should improve and that the size relevant signs can reduce on average by 47%.

It is therefore considered that the following recommendations should be taken forward:

- The potential that consistency in design offers (in terms of design automation, design cost savings, site efficiencies, and potential to develop supporting tools such as roller blinds) should be explored.
- Consultation should be conducted with key stakeholders to discuss concepts and seek wide agreement to changes.
- Conduct an on-road trial of the revised sign designs to validate the simulator trial.
- Subject to successful trials these revised sign designs should be incorporated into the subsequent revisions of TSRGD and/or Chapter 8 as appropriate.

One other recommendation which has been raised by industry during the consultation for this project but not directly related to this tasks aims is:

- Further investigation should be conducted into manual handling aspects of Traffic Management. Consideration should be given to ergonomic working methods and how the signage infrastructure (A-frames, signs, sandbags etc.) can be adapted to support this objective.

# 1. Introduction

This project has been conducted in response to the actions emanating from the Traffic Signs Review (2011):

*“Highways Agency (HA) research has demonstrated that a significant number of drivers do not understand some roadwork related traffic signs, indicating lane closures or contra-flow working on dual carriageways, particularly ones carrying a more complicated or infrequently seen message. The HA intend to undertake a review of the current level and provision of roadwork related signs, including re-designing a number of signs that were not readily understood to make them simpler.” (DfT 2011)*

There are proposals from industry on optimising the design of a number of Temporary Traffic Management (TTM) signs as well as making the process of design quicker and cheaper. These designs followed on from previous research into driver comprehension (Jamson, 2008) which demonstrated that the level of understanding of the red patches and central reservation symbols on Temporary Traffic Management (TTM) signs is relatively low. However, it is recognised that road users still have a good understanding of the sign’s meaning through the lane arrows.

Although sign size is an important issue it has been the aspiration of the Highways Agency that as a result of this trial sign comprehension should be improved. However, it is expected that simplifying may lead to smaller signs thereby realising a manual handling benefit and cost savings.

Therefore, this project was tasked with reviewing the previous research and proposed designs before conducting trials in a driver simulator, to compare the performance of the revised designs.

## 1.1 Task Aim

The overall aim of this task is:

*To investigate options for revising the design of TTM road layout signs to improve comprehension, whilst maintaining or reducing the size of the signs.*

Any assessment of the revised approach to designing relevant TTM signs shall be against the following desired outcomes:

- Increased comprehension [50%];
- Reduced sign size – realising improved manual handling and thereby contributing to Aiming for Zero (AfZ) [35%]; and,
- Cost savings (in terms of manufacturing and design issues) [15%].

## 1.2 Task Objectives

In order to achieve the above aim the following sub-tasks were undertaken:

- A **Literature Review** (Section 2) – the identification and review of relevant information and research on sign design and comprehension, building upon previous work completed for the HA on sign comprehension as well as works commissioned by wider sources.
- Development of **Revised Design Approach** (Section 3) – the application of findings from the literature review to design revised TTM signs.
- Development of a **Trial Methodology** (Section 4) – to enable the robust assessment of the revised TTM sign designs against the existing Chapter 8 signs.
- Analysis of the **Trial Results** (Section 5) – to identify how driver performance is affected by the revised TTM signs.
- Development of **Conclusions and Recommendation** (Section 6).

## 1.3 Approach

Our approach to the task was designed to provide the HA with a robust, accurate and comprehensive methodology to understand the outputs from previous research and use those outputs to propose an alternative approach to the design of TTM signs which would likely yield an improvement in sign comprehension.

In order to fulfil the task objectives and sub-aims, in accordance with our Best Person for the Job ethos it was decided that collaboration with the University of Leeds (UoL) should be sought. This gave access to a multidisciplinary team of psychologists, social scientists, physiologists, engineers, human factors experts and computer scientists. UoL has expertise and a long-established track record in studying driver behaviour, monitored in both laboratory settings and real-world field trials, including previous collaboration with both the HA and the DfT. The UoL Driving Simulator (UoLDS) allows driving simulator trials to be conducted in a safe and highly controlled setting. Complex and innovative scenarios can be created within a realistic driving environment.

## 1.4 Scope

The project scope is limited to the research and evaluation (via simulation study) of TTM design and methods of improving sign comprehension. However, other benefits such as reduced sign size and/or cost savings have been sought where possible, but not to the detriment of improved sign comprehension.

The signs which are relevant to this task include those contained in Traffic Signs Regulations and General Directions (TSRGD) Schedule 12 Part I, which indicate a changed road layout.

It is also important to recognise that these signs are used throughout the UK and not just on the HA network. Therefore, before any change is implemented liaison is required with all relevant stakeholders representing the various Highways Authorities.

Any changes in scope or objectives which are presented in the proposal submission have been agreed between the Package Order Manager (POM) and Client Package Order Manager (CPOM). These are documented in the Task's Work Package Quality Plan.

## 2. Literature Review

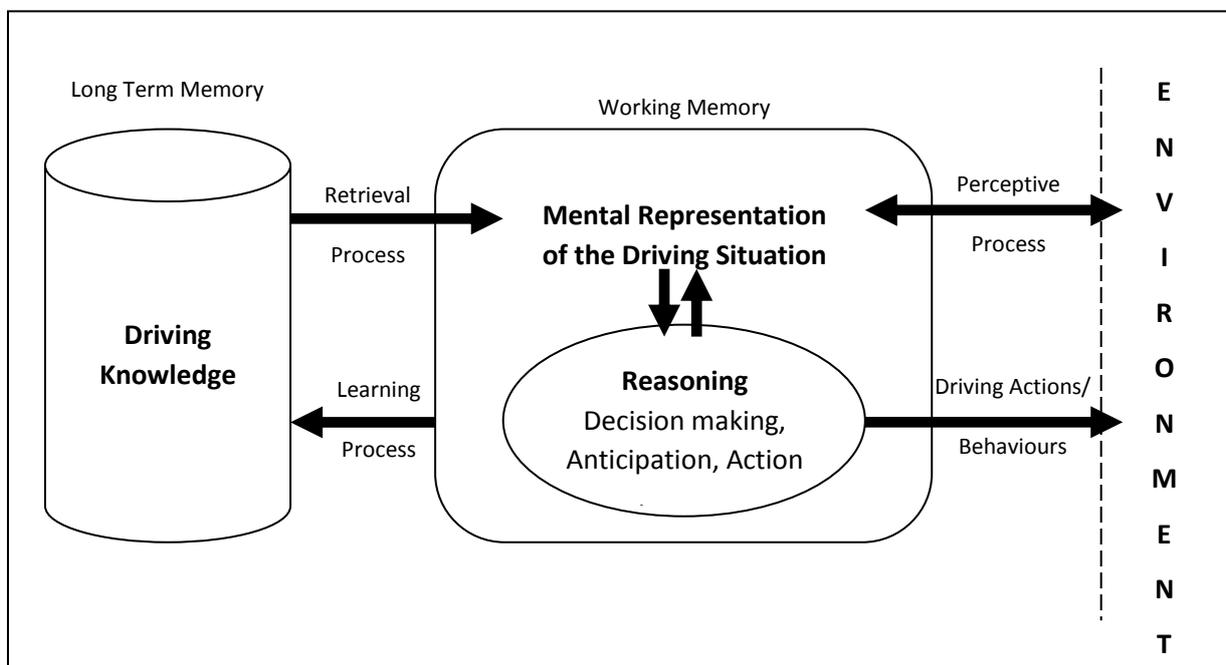
A review of relevant literature and research has been conducted to identify and understand sign comprehension and best practice for simulator trials.

### 2.1 The Driving Process

Driving is a complex task that requires: visual perception of objects on or beside the road; monitoring of other vehicles; information processing; and, decision making in a dynamic condition (Kaber et al., 2012). Bellet *et al.* (2009) also suggested that the act of driving is a complex process, however he summarised the process into four interlinked stages. These include:

- Selection of information from the environment in accordance with own goals and driving demands;
- Understanding the current situation and anticipating its future progression;
- Taking decisions to act appropriately; and,
- Managing own cognitive resources.

Figure 1 shows a simplistic representation of the human cognitive process. As the main benefit being sought by this task is improved comprehension of TTM signs it is the perceptive process of signing which needs to be understood and developed accordingly. By aiding the perceptive process the outcomes of this task will be intuitive and subsequently improve the drivers' mental representations and therefore their behaviour.



**Figure 1** Simplistic schema of human cognition in relation to driving (From Bellet *et al.*, 2009)

This task will not consider making improvements to the 'Reasoning' and 'Driving Knowledge' elements (as shown in Figure 1) as improvements here can only be achieved through education or experience. It has been shown that simple training can improve sign comprehension (Ward et al., 2004). However, Ward et al. (2004) also state that education should not replace improvements in sign design as it cannot be guaranteed that every driver will be exposed to the educational material. It is therefore recommended that signage should be intuitive and guessable. Ng and Chan (2007) propose strategies for designing signage to increase its guessability.

It should also be noted that it will be the "Driving Actions/Behaviours" which will be measured during the simulator trials, which is arguably the part of the driving process which matters most (Kirmizioglu and Tuydes-Yaman, 2012). However, there is a disconnect between comprehension and behaviour; just because a driver understands a sign does not necessarily mean that they will act there and then to the message. Therefore, a written questionnaire should be used after the simulator trial to further assess sign comprehension.

## 2.2 Sign Comprehension

The main purpose of traffic signs is to convey relevant information to the road user (Räsänen and Hornberry, 2006). The information may take many forms, ranging from standardised symbolic warning signs to bespoke textural descriptions of planned works or an upcoming event. Regardless of what information they convey, signs play an important role in explaining to the road user what to expect and how they should behave.

Consequently, the ability for road users to understand signs is absolutely key to their function. In fact, understanding of signs is regarded as the most important design factor for traffic signs (Dewar, 1988). Other criteria such as conspicuity, reaction time and legibility distance are of less importance (Dewar, 1988). Signs that are not understood fail to convey their message and can lead to confusion type errors, divert attention away from driving (Ward et al., 2004), and possibly result in RTIs (Underwood et al., 2002a).

As human resources are finite (Bellet et al., 2008), not all of the available roadside information can be processed dynamically therefore the driver must adapt their searching to extract relevant information in order to build up a useful mental representation of the situation (Crundall et al., 2004; Bellet et al., 2009). This is particularly true on the approach to roadworks where drivers have a number of visual and mental tasks to perform. The monitoring and maintenance of appropriate speed/position as well as monitoring other users' actions takes precedence, often at the expense of sign comprehension (Hössinger and Berger, 2012). In fact, due to the volume of information available and the associated processing requirements, it is thought that drivers often make decisions and act in uncertainty (Bellet et al., 2009).

The effect of road signs and markings on safety statistics is not widely reported or studied, probably due to the difficulty in attributing their contribution to an event accurately (Räsänen and Hornberry, 2006). However, analysis of STATS19 data for the UK highlights that in 2011 there were 1,703 accidents within roadworks. There were 579 accidents which had the contributory factor "Failed to Look" associated. Four of these 579 accidents resulted in fatalities and 53 resulted in serious injuries. It was also noted that a total of 244 accidents were associated with the contributory factor "Temporary road layout (e.g. contraflow)". It should be noted that while the total number of accidents in roadworks in 2011 is known, the

contributory factors are not necessarily recorded at each accident and are based upon the attending police officers best judgement.

Despite the importance of signs it has been widely reported that the understanding of many signs is low (Castro et al., 2007; Shinar et al., 2003). Comprehension has also been shown to vary widely depending upon the sign type, i.e. 17% for a pedestrian warning sign to 78% for a speed limit sign (Castro et al., 2007).

It is unsurprising that signs which attract a high level of enforcement, such as speed limit signs (Kirmiziloglu and Tuydes-Yaman, 2012), or those which are encountered frequently are the most well known (Ben-Bassat and Shinar, 2006). Shinar et al. (2003) demonstrated the part familiarity played during a questionnaire based survey which showed the respondents understood 77.9% of local signs, whereas only 32.4% of non-local signs were correctly identified.

The way in which a message is presented is also thought to have an effect upon comprehension; obligatory signs for example have been shown to be better understood and acted upon compared to prohibitory signs (Castro et al. 2005). Additionally, DfT (2011) reported high levels of sign comprehension when drivers were asked to explain the meaning of signs which were displayed with environmental context.

## 2.3 Improving Sign Comprehension

The literature reviewed suggests many approaches that can be taken to improve the comprehension of traffic signs. The most obvious way of improving comprehension is through education however, the use of education is beyond scope for this task.

To improve sign comprehension from a design perspective it is important that all signs adhere to standardisation of colour and layout. Signs within roadworks in the UK have a yellow background with black borders and features. In a similar vein popular stereotypes can be incorporated to reinforce messages, for example the colour 'Red' is used to indicate prohibition, warning or danger (Shinar et al. 2003).

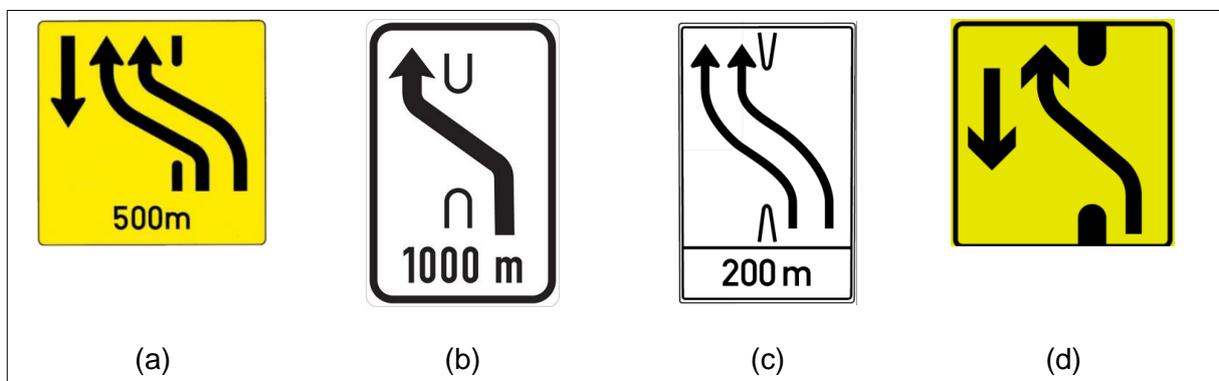
In addition to these ubiquitous methods of improving comprehension there have been a number of specific traffic sign related strategies proposed within recent research. For example, increasing a traffic signs adherence to ergonomic principles has been cited as a method of improving comprehension. These according to Ben-Bassat and Shinar (2006) are:

- **Spatial compatibility** – the physical arrangement in space, relative to the position of information and directions;
- **Conceptual compatibility** – the extent to which symbols and codes conform to people’s associations;
- **Physical representation** – the similarity between the content of the sign and the reality it represents;
- **Familiarity** – the extent to which the driver is familiar with the sign from his or her driving experience; and,
- **Standardisation** – the extent to which the codes used for different dimensions, such as colour and shape, are consistent for all signs.

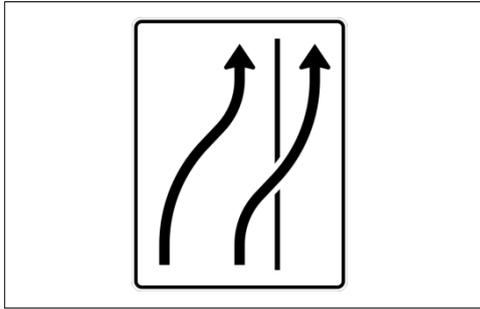
To increase a signs adherence to the above ergonomic principles it is recognised that a designer only really has control over the spatial and conceptual compatibility of the sign. Therefore, it is suggested that to improve adherence to these principles either something needs to be added to the sign (reducing the abstraction from the ‘real world’) or the iconography needs to be changed (so that meaning is more obvious).

An alternative approach could be to simplify signs to increase the driver’s accessibility to the important and relevant information. Accessibility could be improved by removing sign features which are less understood or are unnecessary. Jamson (2008) suggested that drivers may not fully understand certain elements of signage, such as the lines denoting the hard shoulder and central reserve. However, whilst the removal of features may make the signs simpler, these changes may negatively affect the adherence to ergonomic principles and subsequently comprehension.

There are conflicting views surrounding the importance of design elements if we look towards Europe. Figure 2 (a-d) show representative contraflow signs for Austria, Czech Republic, Germany and Norway respectively. Figure 3 shows how the hard shoulder is represented in Germany. It is interesting to note that in each of these signs the elements which remain are those that the road user is interacting with, i.e. they are crossing either the hard shoulder or central reserve. However, the road work areas, marked in red in the UK signs, have been removed thus enabling much simpler and slimmer signs to be produced which do not appear to worsen the sign’s adherence to ergonomic principles from a drivers perspective.



**Figure 2** Signs showing how contraflows are represented in various countries across Europe: (a) Austria; (b) Czech Republic; (c) Germany; and, (d) Norway.



**Figure 3** Showing how the hard shoulder is represented in Germany.

Accessibility to ‘relevant’ information can also be aided by the addition of cues to make it easier for the driver to identify the information which is relevant to them. In a driving scenario this would include the development of a standard sign plate with lane markings. This would potentially allow road users to look at only the information relevant for their lane. The use of visual cues has been shown to improve accessibility on other complex signs, such as bi-lingual signs (Jamson, 2004).

As well as changing the sign face the sign placement could have a positive effect on sign comprehension. Such an approach could include the use of repeated signs. Castro et al. (2007) demonstrated that repetition of signs in sequence can increase understanding. In fact, this was particularly useful where symbolic signs were used and where the driver is required to make a manoeuvre. However, it was noted that the type of sign being repeated needed to be of the same type (i.e. Picture-Picture); if different types were used (Picture-Word) drivers’ reaction time worsens (Castro et al., 2007). These findings may suggest that drivers build up their knowledge of a sign each time that they see a repetition; they extract some information from the first sign and then enhance or confirm their understanding with exposure to subsequent signs.

It should be noted, that if the use of repeated signs is developed further, consideration needs to be given towards the overall effect of ‘clutter’. Ho et al. (2001) stated that reducing clutter improves sign comprehension. Consequently, the introduction of too much clutter, thereby increasing driver’s cognitive demands, may reduce comprehension. So any approach which increases the number of signs will also require full assessment against Chapter 8 guidelines and the HA’s AfZ policy.

## 2.4 Evaluating Sign Changes

From the beginning of this task it was recognised that any revised approach to sign design would need to be subjected to thorough testing in a driving simulator. Therefore, the following sections present experimental factors which were encountered during the research into sign comprehension.

### 2.4.1 Trial Participants

In order to highlight design issues, and enable any outcomes to be robust and safe, it is recommended that those driver groups who are most likely to experience difficulty with new signing are used during the trials.

Shinar et al. (2003) used a method which evaluated sign comprehension amongst groups of drivers who were likely to have the lowest understanding. The groups used in these experiments included:

- Novice drivers;
- Older drivers;
- Tourists;
- Problem drivers; and,
- University students.

The characteristics associated with each of these driver groups are discussed in the following paragraphs.

The issues associated with novice drivers have been extensively researched and reported. Novice drivers have been shown to limit their searching of the road environment (Underwood et al., 2002b) and focus their attention on a smaller area closer to the vehicle than experienced drivers (Crundall et al., 1999, Bellet et al., 2008). They tend to concentrate on what they believe are the most important/dangerous features (Crundall and Underwood, 1998). However, novice drivers consistently rate hazards lower than experienced drivers and respond more slowly to the same hazard (Scialfa et al., 2012). Novices also find hazards which are smaller, in the periphery or appear from behind an obstruction, a particular problem (Scialfa et al., 2012).

Failure to search effectively could potentially result in a Road Traffic Incident (RTI) (Underwood et al., 2002a). As a result, novice drivers are at a greater risk of involvement in RTIs than more experienced road users (Forsyth et al., 1995; McKnight and McKnight, 2003). Wells et al. (2008) identified that 20% of novice drivers were involved in an accident during the 6 months after passing their test. Additionally, 70% of novice drivers had at least one near miss in the same timeframe.

It has been suggested that the lack of searching demonstrated by novice drivers is not due to reduced mental resources as a result of having to concentrate on vehicle control. It is thought to be due to reduced experience and a poor understanding of what might happen (Underwood et al., 2002b). The effect that experience has on the RTI likelihood for novice drivers has been quantified by Forsyth et al. (1995) who stated that 38% of the reduced risk over a novices' first year of driving is solely attributable to increased experience.

In terms of sign comprehension novice drivers are more likely to understand local signs which they are familiar with, or have been tested on, but they are less likely to understand signs which they have not seen before (Shinar et al., 2003). This, in addition to the increased accident risk, makes them ideal candidates for the simulator trials.

Older drivers are also thought to limit their searching. This, in addition to other reasons (such as age related reduction in sensory, cognitive and physical functions) makes them as a group more susceptible to involvement in accidents (Underwood et al., 2002a; Horswill et al., 2008). Shinar et al. (2003) suggested that there are three main reasons for the "poor performance" of older drivers:

- They restrict driving to local area and hours of daylight;
- Due to knowledge of the area they focus all their effort on attention to the traffic; and,
- Some signs will have been introduced since they were licensed.

However, in addition to ignoring signs as Shinar et al. (2003) suggest, other research has stated that older drivers need longer to read signs and make decisions (Castro et al., 2007). This is supported by Kaber et al. (2012) who state that age reduces the ability to understand complex environments. This is particularly worrisome in a dynamic, and to some extent bespoke, environment such as roadworks.

Other groups identified by Shinar et al. (2003) as being likely to have problems with sign comprehension include: tourists; problem drivers (i.e. repeat violators); and, students. Shinar et al. (2003) suggests that both tourists and problem drivers may be less likely to comprehend and act upon signs. However, it is not considered practical to recommend that either of these groups are used in the planned simulator trials. It is unclear from Shinar et al. (2003) why university students were included in their cohort for trials. Regardless of their reasoning, it is not recommended that this group is specifically sought for participation in the simulator trials as there is no suggestion that students would offer a significantly different or valid perspective to other user groups.

## 2.4.2 Data Collection

This section will discuss some of the findings relating to how data has been collected by others in similar sign comprehension trials.

### **Pre-Trial**

During the literature review it has been found that when conducting a trial or survey the researchers often collect demographic data to support the analysis of findings. Richards et al. (2005) analysed behaviour against seven variables, however there may have been some issues associated with linkage between different variables (i.e. age, mileage, experience).

The level of detail captured by researchers can vary significantly. Shinar et al., (2003) captured some basic biographical information whereas Kirmiziloglu and Tuydes-Yaman (2012) captured a range of driver characteristics to include:

- Age;
- Gender;
- Educational background;
- Occupation;
- Driving licence class;
- Years of driving;
- Occupational driving requirement;
- Average inner and outer city distance driven per year; and,
- Number of traffic fines in the last 5 years.

Pre-trial data collection was further developed by Richards et al. (2005), who made participants complete a map reading ability test, to enable further analysis of trial findings.

Taking these approaches forward it is recommended that detailed biographical details are captured from trial participants, and consideration should be given towards conducting a brief pre-trial sign comprehension test.

### **Trial**

The methods used for the simulator trial will be based upon previous research and experience of the UoL Institute for Transport Studies (ITS).

However, the following paragraphs present several points which were noted during the literature review which have relevance to the trial design.

Open ended questions are used in the majority of relevant studies (Kirmiziloglu and Tuydes-Yaman, 2012; Ben-Bassat and Shinar, 2006; Shinar et al. 2003; Ward et al. 2004); this is justified in Ben-Bassat and Shinar (2006) to avoid multiple choice questions enabling the participant to 'work out' the right answer. To evaluate understanding Kirmiziloglu and Tuydes-Yaman (2012) used the following questions:

- "Have you seen this sign?" – To assess familiarity with signs.
- "What does this sign mean?" – To assess comprehension.
- "What should be done when this sign is seen?" – To assess reactive behaviour (this is seen by some as more important than being able to describe the signs meaning).

It was also noted that a scoring system was used in several studies (Ben-Bassat and Shinar, 2006; Shinar et al. 2003; Ward et al. 2004) to evaluate the accuracy of responses. Correct answers score positive marks and answers which are the opposite to the signs' meaning (or in some cases dangerous) are given negative scores. However, studies vary as to how to deal with incorrect or missing answers.

## 2.5 Research Summary

This literature review has presented a brief discussion of sign comprehension and simulator trial best practice to ensure that this project applies builds upon previous research and delivers effective change 'on-network'.

The key messages emanating from this literature review include:

- The previous research which has been used as a basis for this project did not incorporate context into the assessment of understanding. Mainly because the issue was identified 'in passing' and was not the focus of the previous research.
- Adherence to the ergonomic principles is important to ensure that a sign is well understood.
- Targeting trial participants who belong to 'at risk' groups would seem sensible to increase the change of an issue arising.
- Demographic data should be collected from the trial participants to enable more detailed analysis of the trial findings.
- An assessment of trial participant's base knowledge should also be included to enable informed analysis.

Consequently the following Section will further consider the first two of these key messages, before recommending a revised approach to the design of TTM signs. Section 3 will incorporate the other findings as part of the trial methodology.

It is believed that designing signs which closely adhere to the five ergonomic principles will lead to signs which are more clearly understood. However, it should be noted that Keber et al., (2012) suggested that simulator experiments should be validated through 'on-road' trials. Therefore, consideration should be given towards this suggestion early to ensure that findings are captured prior to the re-publication of TSRGD in 2014.

### 3. Revised Design Approach

To address the issues raised during the literature review, and develop a revised approach to sign design, the following steps were taken:

- The literature review highlighted the importance of the ergonomic principles to driver comprehension. Therefore, to identify how signs adherence to the ergonomic principles can be improved an expert assessment of a selection of signs was conducted.
- In parallel a general survey of preference was conducted to understand whether the red areas or black lines were valued by road users.
- Consideration of the development options following the literature review, expert assessment and preference survey in order to produce revised sign designs.

#### 3.1 Expert Assessment

The following section outlines the approach and reasoning behind the expert assessment questionnaire and its findings.

##### 3.1.1 Ergonomic Assessment Questionnaire

A total of 15 experts were recruited to provide assistance with the ergonomic assessment of the relevant signs. The experts predominantly had backgrounds in human factors and psychology. Two of the experts were from URS' own human factors team (who were not involved in this task at this point) and the remaining were from European academic institutions.

The experts were presented with a 12 page questionnaire containing six questions, one for each sign being assessed (a full copy is included in Annex 1). The six signs which were chosen for the expert assessment incorporated one or more of the design elements which had been highlighted previously as being poorly understood, specifically black lines, representing the hard shoulder and central reserve, as well as and the red areas denoting roadworks.

The first part of the questionnaire presented the experts with a TTM central panel with its associated top and bottom panel options for reference.

The first question asked the experts to describe what they felt the sign would mean to all road users. This was asked to reinforce the experts study of the signs, and also by using the phrase "all road users" encourage them to think of vehicles other than cars (i.e. motorbikes and HGVs).

Next the experts were asked to score the sign (1 = poor; 10 = Excellent) for spatial and conceptual compatibility with justification for their score. To ensure consistent understanding the following definitions were provided:

- Spatial Compatibility is the physical arrangement in space, relative to the position of information and directions (i.e., the direction in which the road is turning is presented by an arrow's turn in the sign); and,
- Conceptual Compatibility is the extent to which symbols and codes fit the associations most people have for the concept (e.g., an airplane sign will present a nearby airport).

Only spatial and conceptual compatibility were assessed because this project did not have the ability or authority to effect change of standardisation or familiarity (the latter of which can only be achieved for a new sign through education). Likewise *'Physical representation'* was also considered beyond the project teams control as this relies upon designers interpretation of the roadworks and environment.

Once spatial and conceptual compatibility was considered by the experts, the most important question with regards the task objectives was posed:

*"How can the design of [the] sign be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?"*

This was then followed up with:

*"How can the design of the optional top and bottom panels be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?"*

### 3.1.2 Results

The results of the expert assessment specifically regarding their adherence to the ergonomic principles of spatial and conceptual compatibility are presented in Table 1. Review of these average scores indicate that the sample signs adhere relatively well to the experts expectation of spatial and conceptual compatibility. However, because these scores are relative no absolute meaning should be inferred.

**Table 1:** Average scores of the expert assessment regarding spatial and conceptual compatibility

Sign Reference	Sign	Spatial Compatibility	Conceptual Compatibility
7201		7.67	8.17
7210		7.29	7.14
7211.1		6.67	7.00
7230		7.25	7.25
7235		7.50	7.20
7240		8.00	8.25

The most valuable outcome of the questionnaire for this project are the responses given by experts with regards how the sample signs could be revised in order to improve the spatial and conceptual compatibility scores. These are presented in Table 2.

**Table 2:** Quotes from experts regarding how the sign designs can be revised to improve the spatial and/or conceptual compatibility scores.

Add contraflow lane to RHS [Right Hand Side] of sign.	Improve relative spacing of lanes to better illustrate widths, degrees of movement/freedom.
Alter graphic to show that lane 3 is narrower.	Is the red essential? Quite attention grabbing relative to the essential info.
Change 2.0m to 2m looks like 20. Remove ANY VEH and [possibly] change red colour.	More compact sign face. Split sign into two.
Clarify graphically the number of lanes open on left and right carriageways.	Not sure red area needed.
Could add other road marking info.	Omit red area on bottom right and replace with narrow lane.
Could the full set of lanes of lanes be shown to better communicate the road layout and requirements?	Parallel arrows.
Could write M1 above each of the narrowed columns.	Possible inconsistency with the stay in lane and width restriction - if HGV in outside lane should they move over or stay in lane?
Delete ANY VEH and metricate distances.	Possibly shallower swoop of arrows from right to left.
Delete central reserve and hard shoulder lines. Delete ANY VEH. Reduce size of sign face.	Right hand lane section would not be wider.
Don't really need the red area. Would be useful to know how far until the turn off.	Smooth corner of red area. Make radii of arrows the same.
Dotted lines to indicate lanes and include hard shoulder line. Remove red areas.	Split sign into two - one containing lane restrictions other containing steering inputs/direction.
Extend dotted line.	

Whilst there is some overlap between these responses, there are a wide range of revisions which could be made to improve spatial and conceptual compatibility of the relevant TTM signs. These will be considered further in Section 3.3.

## 3.2 Preference Survey

This assessment of preference regarding sign design was conducted to identify the importance of specific sign elements (black lines and red areas). This was essential to confirm or refute the theory that these elements were poorly understood, and that their removal would improve comprehension.

### 3.2.1 Preference Questionnaire

This questionnaire was compiled using: the existing Chapter 8 designs; European style designs (shown in Figure 2 and 3) which maintain the black lines; and, an alternative design which just maintained the red areas.

A copy of the questionnaire is presented in Annex 2 for reference.

### 3.2.2 Results

The overall results of preference survey are presented in Table 3. Review of these preferences indicate that people prefer the existing sign design in comparison to either option which removes some of the detail.

**Table 3:** Overall results of the preference survey

Preference for:		
Existing Sign	European Style	Alternative Design
63.7%	26.4%	9.9%

Table 4 has been included to demonstrate the preference trends for each participant. It appears that each participant either tends to lean towards Chapter 8 and European style or the European and Alternative styles. Only 3 of the 23 surveyed liked signs across all three of the sign styles.

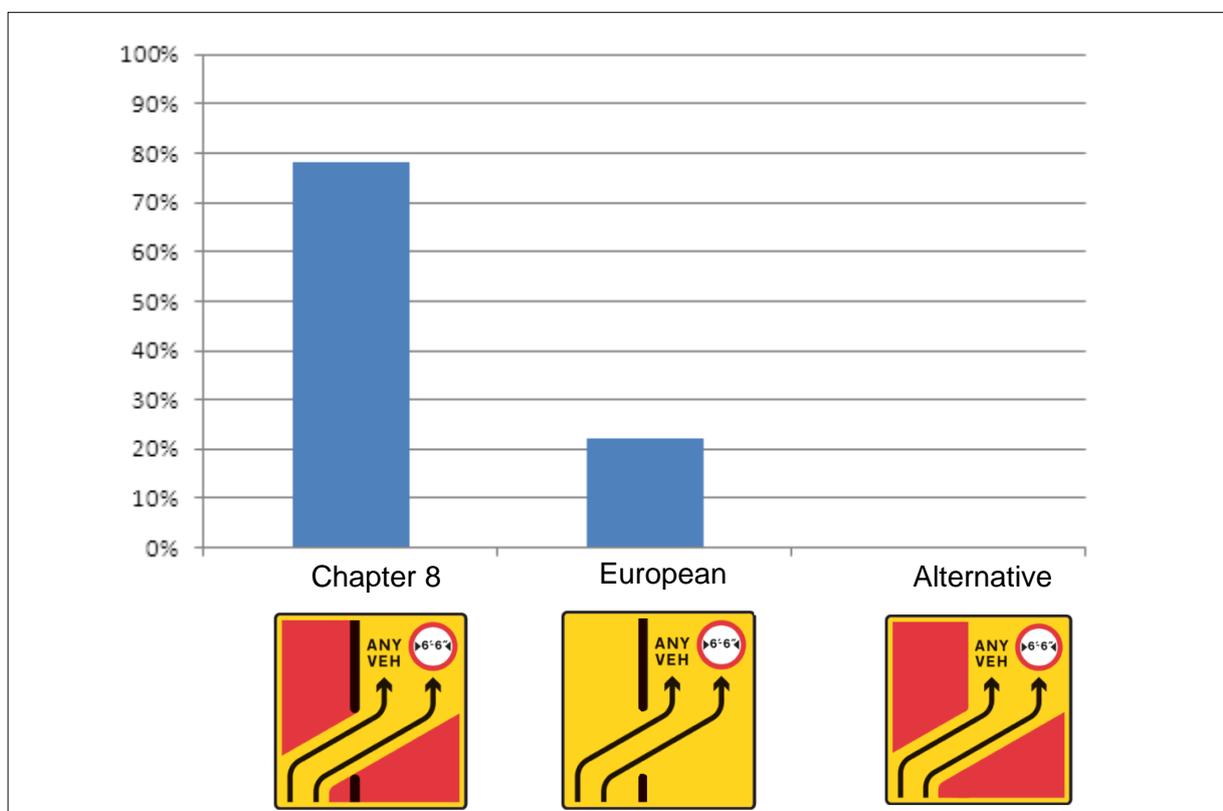
**Table 4: Results by participants**

Person	Positive Preference		
	Existing Sign	European Style	Alternative Design
1	4		
2	3	1	
3	1	3	
4	4		
5	4		
6		2	2
7	3	1	
8	3		
9	4		
10	4		
11	4		
12	2	1	1
13	2	1	1
14	3	1	
15	2	2	
16	3	1	
17	2	1	1
18	3	1	
19		3	1
20	2	2	
21	4		
22	1	3	
23		1	3

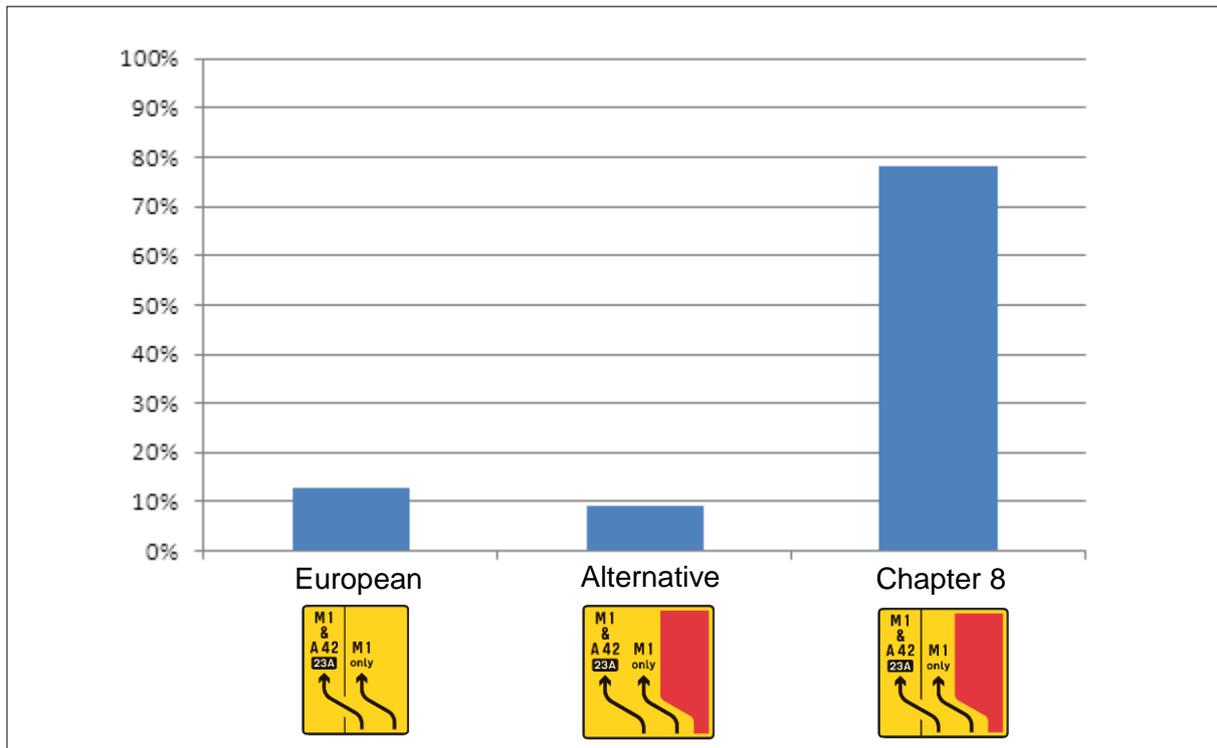
The following graphs break this overall result down to the level of each question. Figures 4, 5 and 7 show a clear preference for the existing Chapter 8 style signs. Figure 6 indicated a preference for the European style sign, but the Chapter 8 variant is a close second.

With regards the sign design elements the key points demonstrated by the results and comments made by those surveyed are:

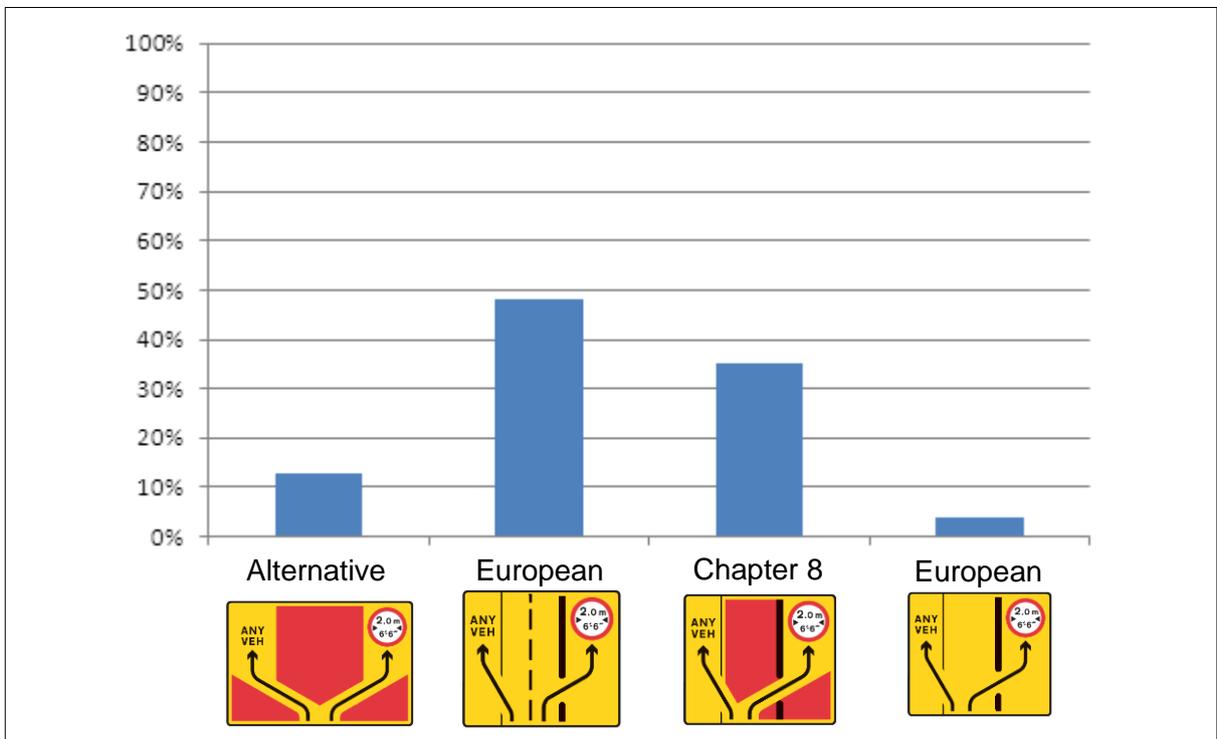
- Figure 4 indicates that it is important to show the ‘feature’ being crossed;
- Figure 5 suggests that both the black lines and the red areas are required to show movement from one lane to another;
- Figure 6 shows that black lines are important but some form of ‘reference frame’ (i.e. road areas or road markings) are required to put the sign elements into context; and,
- Figure 7 highlights that road users do recognise the difference between parallel and narrowing arrows and that the red area indicates an obstruction causing the narrowing.



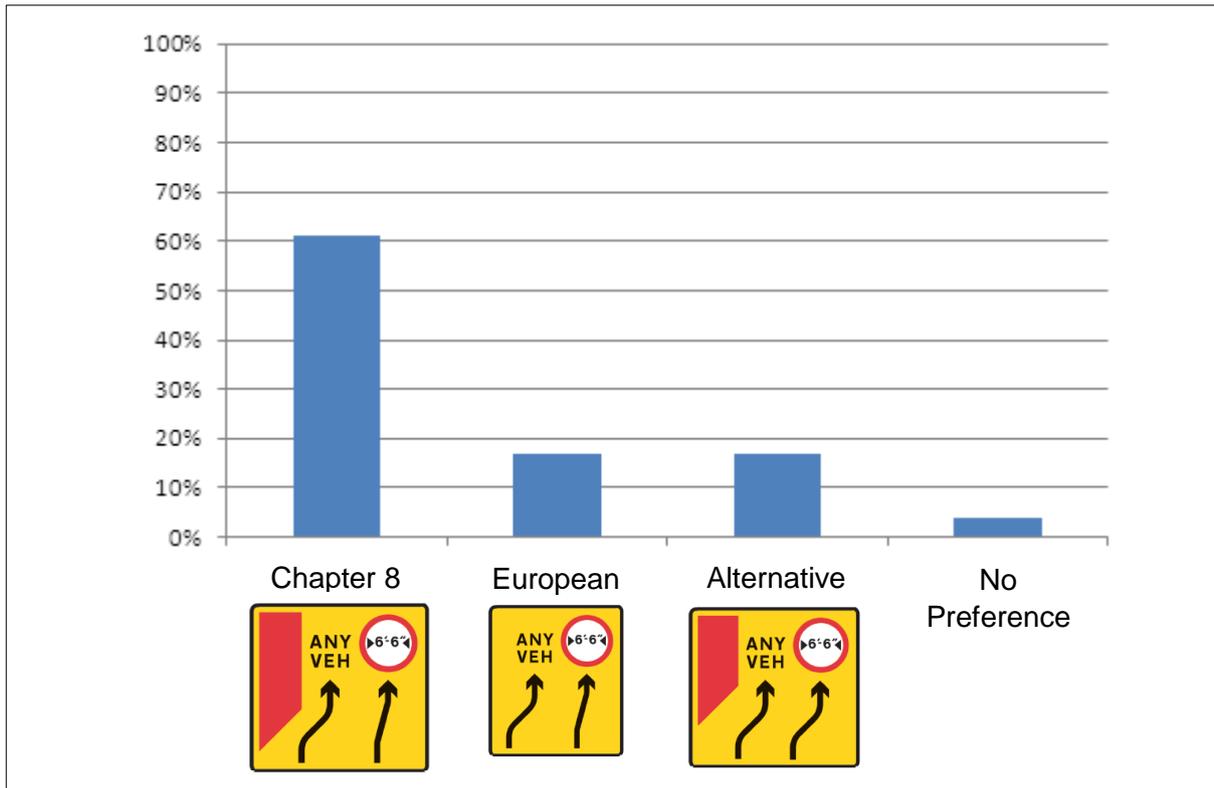
**Figure 4:** Which sign most clearly conveys that all lanes are to cross the central reserve?



**Figure 5:** Which sign most clearly conveys that Lane 1 vehicles are to move on to the hard shoulder and Lane 2 vehicles are to move to Lane 1?



**Figure 6:** Which sign most clearly conveys traffic is moving on to hard shoulder and crossing the central reserve?

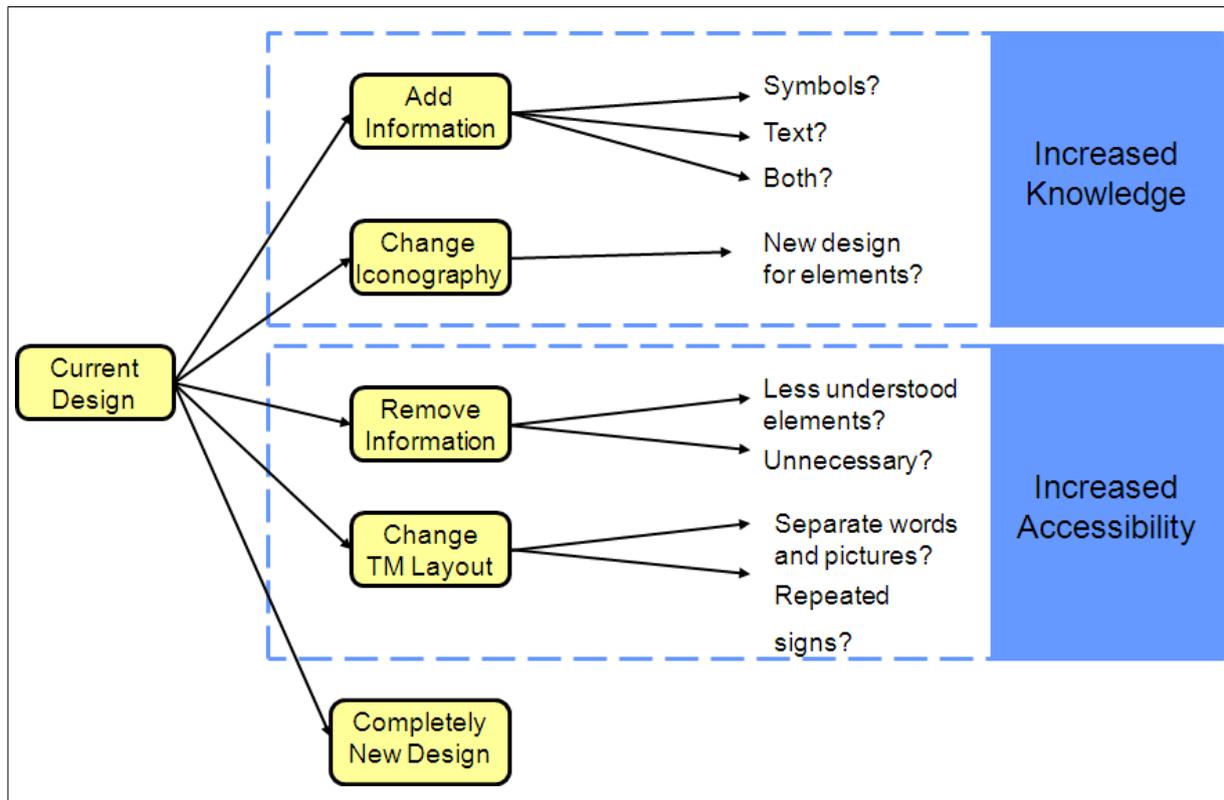


**Figure 7:** Which sign most clearly conveys that the lanes ahead are narrower than normal?

In general it is felt that road users value both the black features and red areas on signs depending upon the circumstances. Therefore, rather than restrict the use of one of these important elements, their use should be maintained and other options considered to meet the project aspirations.

### 3.2.3 Considering the Development Options

As a result of the literature review, the ergonomic assessment and preference survey, a range of development options for redesigning the relevant TTM signs was identified. These are shown in Figure 8.



**Figure 8:** Development options for revised sign design to improve comprehension.

The recommendations that were proposed by the experts in Table 2 (Section 3.1.2) were examined against the full range of relevant signs in TSRGD to assess their appropriateness and suitability for implementation. This ‘reality check’ found that many of the recommended elements and design options could not be applied consistently to all relevant signs.

Consequently, this review narrowed down the design options considerably to:

- Maintaining black lines and red areas;
- Reducing the size of the red areas to fit with the size constraints of the rest of the sign;
- Introducing a yellow space between the red areas and black lines;
- Having lane width that is conceptually correct;
- Using standard arrow construction; and,
- Using angular finish to the central reserve.

Additional improvements to sign design which would lead to reduced sign sizes were also identified. These include:

- ‘Splitting’ the messages so that these signs only tell you about lane changes and not other restrictions.
- Removal of some of the panel options such as “Get in lane” or “Stay in lane”. Many of the experts could not see the point in these messages.
- Use ‘85th percentile” speeds – at least where road works are enforced.

After some consultation it was decided that all of the recommended design options would be pursued with the exception of the use of 85<sup>th</sup> percentile speeds (beyond our scope) and standardised arrow construction. The latter was decided against as it constrained sign design too much and reduced the possible size reduction benefits. Additionally, during a

visit to a Traffic Management contractor it became apparent that the vinyl printing/cutting technology, at a relatively low cost, was much better than the original business case suggested.

### 3.2.4 Benefits of Sign Redesign

Implementation of the revised approach to sign design is likely to achieve the following benefits:

- More accurate representation will improve spatial compatibility therefore improving comprehension;
- Improved accessibility to relevant information therefore improving comprehension;
- Reduced sign sizes will improve manual handling;
- Smaller signs may lead to fewer carriageway crossings during TTM situations; and,
- The angular finishes will reduce waste material thereby realising cost savings.

These benefits are in line with the project aims stated in Section 1.1.

## 4. Trial Methodology

This section outlines the approach and methodology used during the simulator trials to assess the effect of the revised approach to sign design on road user behaviour.

### 4.1 Experimental design

The driving simulation exercise was undertaken using the University of Leeds Driving Simulator (UoLDS). The UoLDS provides a safe environment for the development and testing of virtual scenarios with experimental data collection tailored to the exact requirements of a particular investigation. In this case, the UoLDS allowed the evaluation of driver responses to sign designs under controlled experimental conditions.

In the driving simulator, every driver can experience an identical testing situation. This systematic variation in road, vehicle or traffic conditions is difficult to achieve in the real world. Driving performance and other physiological measures can be easily measured to allow accurate interpretation of behavioural indicators.

A summary of the experimental design is presented below:

- 40 participants were recruited;
- Two TTM scenarios were selected for test: Narrow Lanes and Contraflows.
- Each participant completed 12 drives, each taking around 7 minutes to complete;
- Each drive contained one Narrow Lane or one Contraflow scenario (four drives contained a narrow lanes scenario; eight drives contained a contraflow scenario);
- Each drive was characterised by a specific sign layout, traffic flow and driving lane;
- Drivers were presented with signs whose design was based on existing Chapter 8 guidance or the revised approach (as shown in Section 4);
- The Narrow Lanes scenario featured one sign that was applicable to the revised approach to designing TTM signs;
- The Contraflow scenario featured eleven signs that were applicable to the revised approach to designing TTM signs;
- A within-subjects design was employed, whereby each participant experienced all experimental conditions (i.e. all 12 drives). This approach is considered the 'Gold Standard' of experimental design due to the minimisation of unsystematic variation between participants in different conditions, thus aiding the detection of *systematic variance* (variation that results from the manipulation of the variable of interest);
- The order of drives was counterbalanced between participants;
- Drivers were encouraged to drive in Lane 2 in the Narrow Lanes scenarios and either Lane 1 or Lane 2 in the Contraflow scenarios (to experience all types of signing);
- Drivers reported on the workload that they experienced in each of the 12 drives.

The following sections provide an outline of the testing facilities, the trial design and process.

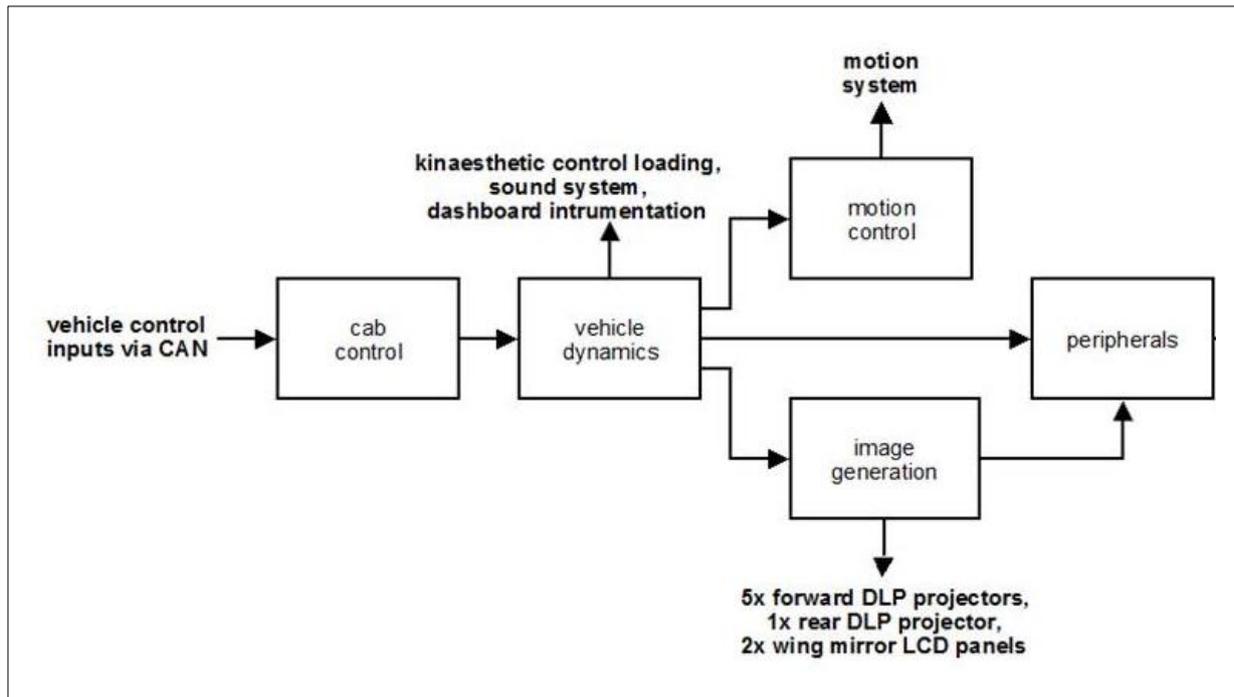
## 4.2 University of Leeds Driving Simulator

The study was conducted on a second-generation, motion-base, high fidelity driving simulator (see Figure 9). The simulator vehicle is an adapted 2005 Jaguar S-type vehicle cab with fully-functional internal controls and dashboard instrumentation. Participants operate the simulator vehicle as they would any automatic transmission vehicle in the real-world.



**Figure 9:** University of Leeds Driving Simulator facility

The simulation is run on a local network of eight Personal Computers (PCs) (Figure 10). The simulator vehicle's internal Control Area Network (CAN) transmits information about driver control of the simulator vehicle from the vehicle to one of the eight Linux-based PCs ('cab-control' PC) that manage the simulation. The 'cab-control' PC receives data via an on-board CAN card and transmits it to a PC that runs the vehicle dynamics model via an Ethernet connection. The 'vehicle dynamics' PC feeds information back to the driver via the 'cab-control' PC to simulate realistic driving cues so that the driver sees (visual dashboard display), hears (auditory stimuli via an 80W 4.1 sound system such as engine, transmission and background noise), and feels (steering torque and brake pedal sensation) like they are driving a real vehicle. This connection creates an ecologically valid simulation of various sensory components of the driving environment. The 'vehicle dynamics' PC also feeds forward into motion control and image generation.



**Figure 10:** Network schematic for the University of Leeds Driving Simulator

The simulator vehicle is enclosed inside a spherical projection dome (4m diameter) to create an immersive driving environment and reduce interference from external visual and auditory stimuli. An ‘image generation’ PC with two ATI 9800 graphics cards is responsible for the images seen by the participant. The images generated (rendered at 60 frames per second) are presented over eight channels to create a real-time, fully textured 3-D graphical scene of the virtual world. Six channels are projected forwards on to the inner surface of the dome using ProjectionDesign F22 and 3D-Perception HMR-15 DLP projectors. The front three projectors (F22) of the forward channels have a resolution of 1920x1200 pixels with a horizontal field of view of 190°. The flanking two projectors (HMR-15) display the peripheral forward view at 1024x768, forming a seamless total forward field of view of 250°. The rear channel (40° at 1024x768) is viewed only through the vehicle’s rear view mirror. The pixel density of the three central forward channels is 2.1 arcmin per pixel, reducing to 4.1 arcmin per pixel for the peripheral forward and rear channels. The vertical field of view is 45°. All channels are frame-locked to avoid any “tearing” of the visual image. The composite image is corrected and colour balanced using an external ProjectionDesign MIPS WB1920 unit. Two further ‘image generation’ PCs, each hosting a single nVidia FX4500 card are used to generate the two rearward displays seen in the vehicle’s wing mirrors. Each physical mirror contains a 7” Lilliput wide-angled LCD panel, achieving a resolution of 800x480 pixels.

The simulator incorporates an eight degree of freedom motion system. High and medium frequency lateral accelerations (e.g. a lane change) are simulated by sliding the whole vehicle cab and dome configuration along a railed gantry. Low frequency, sustained cues (e.g. a long, sweeping curve) are simulated using the tilt co-ordination of a 2.5t payload, electrically-driven hexapod. The whole gantry can also slide longitudinally along tracks to mimic the vehicle’s acceleration and braking. The 10m long rails and tracks allow 5m of effective travel in each direction. The motion-base enhances the fidelity of the simulator by providing realistic inertial forces to the driver during braking and cornering. It also provides life-like high frequency heave, allowing the simulation of road roughness and bumps. The

performance of the motion system is controlled by an additional ‘*motion control*’ PC running a version of real-time Linux. This ensures the timely arrival, over Ethernet, of the driven vehicle’s calculated linear and rotational accelerations and velocities, transmitted from *vehicle dynamics*.

The simulator system collects data relating to driver behaviour (vehicle controls), the vehicle (position, speed, accelerations, etc.) and other autonomous vehicles in the scene (e.g. identity, position and speed) at a rate of 60Hz. Eye-tracking data is collect using a Seeing Machines faceLAB v5.0 stereo camera pair, which allows the recording of many eye-related variables of both driver attention (e.g. gaze location, fixation duration) and driver state (e.g. eye-closure, pupil diameter, blink rate).

### 4.3 The Virtual Environment

The roadway and scenarios used in the driving simulator are modelled in-house at the UoL. The road network was created by modelling individual “tiles” with varying length, curvature, and environmental features, which are then joined together. This construction process was followed to create a series of motorway driving routes incorporating the appropriate TTM scenarios.

As previously stated, the two TTM scenarios that were selected for the simulator trial were:

- Narrow Lanes; and,
- Contraflow.

These two scenarios were chosen because they had previously been used for HA simulator studies, therefore offered modelling efficiencies.

#### 4.3.1 Narrow Lanes

The ‘Narrow Lanes’ scenario incorporates virtual roadworks on the verge thereby causing a narrowing of the remaining lanes. The model is 7km long with the lane narrowing starting at 3.3km and extending to 6.7km. A 50mph speed limit is signed on the approach and throughout the works.

#### Relevant Signs for Narrow Lane

Table 5 shows the signs for this scenario which are relevant to this project. The Chapter 8 sign is produced for reference and the revised sign introduced; which is based upon the design guidelines outlined in Section 3.2.3.

A drawing of the full Chapter 8 Traffic Management layout used during the trial is included in Annex 3 for reference.

**Table 5:** Sign redesign for Narrow Lanes simulator trial scenario

Sign	Chapter 8	Revised	Description of Changes
7235			<ul style="list-style-type: none"> <li>• Top panel removed;</li> <li>• Lane restrictions removed; and,</li> <li>• Red areas reduced.</li> </ul>

### 4.3.2 Contraflow

The 'Contraflow' scenario incorporates roadworks in Lanes 1, 2 and 3 of the participants carriageway, with lane 1 diverting to the hard shoulder and Lanes 2 and 3 diverting into a contraflow (the latter shown in Figure 11). The model is 7km long with the lane movements starting at 3.3km and extending to 6.7km. A 50mph speed limit is signed on the approach and throughout the works.



**Figure 11:** View from the inside of the driving simulator dome (at start of the contraflow)

A drawing of the full Chapter 8 Traffic Management layout is included in Annex 3 for reference.

#### Relevant Signs for Contraflow

Table 6 shows the signs for this scenario which are relevant to this project. The Chapter 8 signs are produced for reference and the revised signs introduced; which are based upon the design guidelines outlined in Section 3.2.3.

**Table 6:** The revised signs for the Contraflow simulator trial scenario

Sign	Chapter 8	Revised	Description of Changes
7210			<ul style="list-style-type: none"> <li>Red areas reduced; and,</li> <li>Gap between red areas and central reserve.</li> </ul>
7212			<ul style="list-style-type: none"> <li>Top and bottom panels removed;</li> <li>Destination information removed;</li> <li>Red areas reduced; and,</li> <li>Gap between red areas and central reserve.</li> </ul>
7212 (200yds)			<ul style="list-style-type: none"> <li>Top panel removed;</li> <li>Destination information removed;</li> <li>Red areas reduced; and,</li> <li>Gap between red areas and central reserve.</li> </ul>
7216			<ul style="list-style-type: none"> <li>Top panel removed;</li> <li>Red areas reduced; and,</li> <li>Gap between red areas and central reserve.</li> </ul>
7216 (200yds)			<ul style="list-style-type: none"> <li>Top panel removed;</li> <li>Red areas reduced; and,</li> <li>Gap between red areas and central reserve.</li> </ul>
7230			<ul style="list-style-type: none"> <li>Bottom panel removed;</li> <li>Destination information removed; and,</li> <li>Red area reduced.</li> </ul>
7230 (200yds)			<ul style="list-style-type: none"> <li>Top panel removed;</li> <li>Destination information removed; and,</li> <li>Red area reduced.</li> </ul>
7231			<ul style="list-style-type: none"> <li>Top panel removed;</li> <li>Red areas reduced; and,</li> <li>Gap between red areas and central reserve.</li> </ul>
7231 (200yds)			<ul style="list-style-type: none"> <li>Red areas reduced; and,</li> <li>Gap between red areas and central reserve.</li> </ul>
7237			<ul style="list-style-type: none"> <li>Top panel removed; and,</li> <li>Red areas reduced.</li> </ul>
7237 (200yds)			<ul style="list-style-type: none"> <li>Red areas reduced.</li> </ul>

### 4.3.3 Driving Scenarios

Twelve different driving scenarios were developed. Each was characterised by a specific TTM scenario (Narrow Lanes or Contraflow), sign layout and design (Chapter 8 or Revised), traffic flow (High = 1,400 vehicles/lane/hour, Low = 800 vehicles/lane/hour) and driving lane (Lane 1 or 2).

Table 7 shows the twelve scenarios developed. Each driving scenario consisted of a typical UK motorway with lane widths, markings and junction layouts as described in Chapter 5 (Road Markings) of the Traffic Signs Manual (2003). The virtual motorway is made of straight and curved segments (curve radius between 750m and 1,000m) in accordance with the Design Manual for Roads and Bridges (DMRB).

**Table 7:** Summary of the twelve driving scenarios

Scenario no.	TTM Scenario	Sign	Traffic Flow (vehicles/lane/hour)	Driver asked to drive in....
1	Narrow Lanes	Existing Chapter 8	800	Lane 2
2	Narrow Lanes	Existing Chapter 8	1,400	Lane 2
3	Narrow Lanes	Revised Signs	800	Lane 2
4	Narrow Lanes	Revised Signs	1,400	Lane 2
5	Contraflow	Existing Chapter 8	800	Lane 1
6	Contraflow	Existing Chapter 8	1,400	Lane 1
7	Contraflow	Existing Chapter 8	800	Lane 2
8	Contraflow	Existing Chapter 8	1,400	Lane 2
9	Contraflow	Revised Signs	800	Lane 1
10	Contraflow	Revised Signs	1,400	Lane 1
11	Contraflow	Revised Signs	800	Lane 2
12	Contraflow	Revised Signs	1,400	Lane 2

Order effects can confound the findings of a within-subjects design if not considered in the experimental set-up. For example, in a study with two experimental conditions, A and B, it is essential that different participants perform the two conditions in different orders – 50% of participants should perform Condition A before Condition B, whilst the remaining 50% should perform Condition B before Condition A. This experimental consideration is called *counterbalancing*, and in this case a counterbalancing exercise was performed to minimise the influence of scenario presentation order on the results of the experiment. The balanced Latin square method was used to create twelve different scenario orders that were each

used within the participant sample. The resulting order of the scenarios following this counterbalancing exercise can be seen in Annex 4.

## 4.4 Driving data

The following Section introduces the main variables that were monitored during the simulator trials.

### 4.4.1 Speed (mean speed, speed variability)

A driver's accident risk has been shown to increase by 5% for each 1 mph increase in mean speed (Finch, Kompfner, Lockwood, and Maycock, 1994). Speed also affects accident severity (Andersson and Nilsson, 1997; Aarts & van Schagen, 2006). As a result, changes in mean speed following the revision of roadworks signage should be addressed due to the potential impacts on driver safety. An increase in mean speed would suggest a cause for concern.

Speed variability is also used to assess the safety of drivers' performance. High speed variability implies poorer control of the vehicle, with possible contributory factors including increased driver workload or distraction from the driving task. The changes in signage have the potential to affect speed variability. However, this measure is also strongly influenced by the density and behaviour of surrounding traffic.

### 4.4.2 Headway

Headway is a measure of the driver's ability to maintain a safe time gap to the vehicle in front. It is defined as the time that it would take the participant vehicle to reach the same position on the road as the lead vehicle, if the current speed was maintained. Shorter headways have been associated with increased accident risk (Jonah, 1986). The simulator records the proportion of time that a driver spends at a 'safety-critical' headway of less than two seconds. An increase in the proportion of time spent at short headways with the revised signs would imply a negative impact on driver safety.

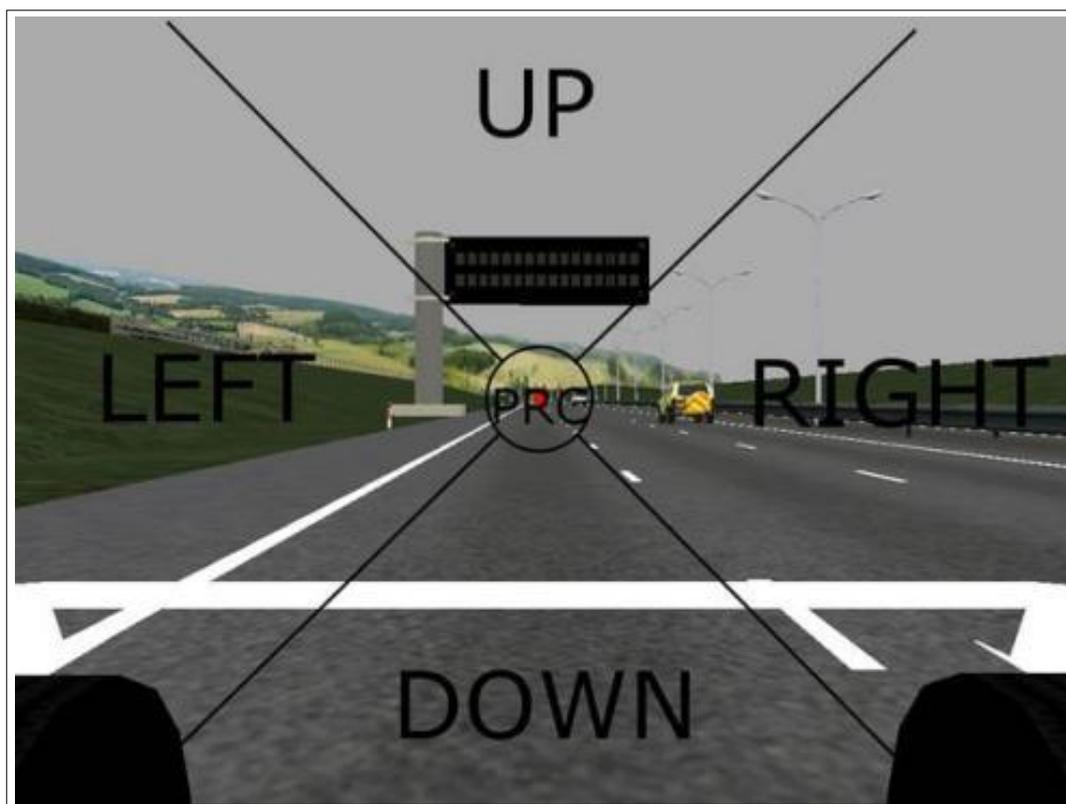
### 4.4.3 Lateral control (standard deviation of lane position, high frequency steering)

Standard Deviation of Lane Position (SDLP) is a measure of the side-to-side motion of the vehicle. It shows how accurately drivers maintain their chosen lane position, thus indexing road tracking errors. If constant lane position is assumed to reflect good vehicle control, then increased SDLP indicates poorer steering performance (Brookhuis, de Vries and de Waard, 1991). This variable is commonly used to assess impairment in driver performance resulting from distraction (Jamson et al., 2004).

High Frequency Steering (HFS) is an additional measure of vehicle control, involving the recording of the number of times that a driver reverses the direction of the steering wheel (by greater than 1°). A high 'reversal rate' indicates poorer control of the vehicle (McLean & Hoffman, 1975), often due to increased driver workload and associated difficulties in accurately monitoring and modulating their lane position.

#### 4.4.4 Eye-tracking measures (percent road centre, percent road left, percent road right)

The changes in the sizes and content of the Revised Signs have the potential to cause differing impacts on driver visual behaviour. For example, signs may place different demands on the driver in terms of information extraction, and therefore may require that drivers look away from the road ahead for different amounts of time. The movement of drivers' gaze away from the forward roadway has been shown to impair vehicle control (Östlund et al., 2004) and slow the detection of safety-critical events (Olsson and Burns, 2000). It is therefore important to consider how well drivers are able to maintain their attention to the road whilst observing signage during the Narrow Lanes or Contraflow scenarios, due to the potential for impacts on safety. Eye-tracking provides us with a reliable and sensitive physiological measurement of drivers' attention to the central region of the road ahead (Victor, Harbluk and Engström, 2005). *Percent Road Centre (PRC)* is a measure of the proportion of driver gazes that fall within a 6° circular region, centred on the driver's most frequent fixation location. The remainder of the scene in front of the driver is divided into quadrants, for which gaze proportions can also be measured (Figure 12).



**Figure 12:** Illustration of eye-tracking measurement zones

#### 4.5 Subjective data

The NASA-TLX, multi-dimensional workload scale was administered immediately after each route was driven. The tool has been demonstrated to be simple to use and with good sensitivity to experimental manipulations of driver workload in the simulator environment (Hart, 2006). The measurement tool uses six linear scales (Mental Demand, Physical

Demand, Temporal Demand, Performance, Effort and Frustration). Participants are required to mark a single point on each scale to convey the workload experienced for that dimension during the prior experimental drive. The concept of 'workload' and the subscales are explained fully to participants before administration. Participants were also required to complete a questionnaire testing their comprehension of a selection of UK road signs. Participants were presented with an additional questionnaire in which they were asked to compare the effectiveness of the presentation of each pair of signs (Chapter 8 versus Revised). This metric was intended to index driver preference within each pair of signs.

## 4.6 Participants

The following sections describe two key considerations regarding participant selection: sample size; and, demographics.

### 4.6.1 Sample Size

Forty participants were recruited from the UoLDS database. This sample size was calculated using the following standard formula:

$$N = 2 \times K \cdot (s/d)^2$$

Where:

- *s* = standard deviation of drivers speed;
- *d* = difference between baseline and experimental condition;
- *K* is taken from a standard look-up table which incorporates both the required level of statistical significance (95%) and the power.

In order to estimate sample size the magnitude of expected behaviour changes, and the level of statistical power required, must be known. We based our calculations on data obtained in a previous driving simulator experiment for the Highways Agency, which also investigated how changes in signage affected driver behaviour.

For simplicity (and because it provides a handle on real-world effects), we used speed behaviour demonstrated in the previous study as a basis for these calculations. Whilst speed is not the only variable of interest in this study it does from our experience provided the best yardstick for the sample size calculations.

By using this formula, and the speed data from the previous study, the sample size was calculated as 38.81. Therefore, the expected number of participants required for a statistically robust study is around 40.

A statement regarding the statistical confidence of the sample size is included in Annex 14 for reference.

### 4.6.2 Demographics

Participants were assigned to one of two groups (20 members per group) based on their driving experience (Low Experience and High Experience). The criterion used to determine inclusion in a particular experience group was cumulative mileage since passing of the driving test, as outlined below:

- *High experience*: Cumulative mileage in excess of 50,000 miles; and,
- *Low experience*: Cumulative mileage less than 5,000 miles.

This method effectively polarised the two groups, ensuring that the between group differences were maximised. However, it should be recognised that the nomenclature used here is more relative than absolute. Low experience was sought in response to the research described in Section 2.4.1. The “High” experience group represents typical road users who have been driving for a number of years, to act as control.

It should be noted that the two experience groups were balanced for gender and a representative sample of driver ages were tested. As a consequence of prioritising sampling based on driver experience, the low experience group had a lower mean age than the high experience group. Further details of the trial participants are included in Annex 5 for reference.

## 4.7 Procedure

Participants were sent a Participant Briefing Document (see Annex 7) and asked to attend the UoL driver simulator facility at a specified time. On arrival at the simulator facility, consent was obtained from each participant, along with details about the participant and their driving history.

Prior to the simulator trial, participants were asked to complete a questionnaire to capture and assess their general knowledge and understanding of road signs. High experience drivers outscored low experience drivers on average. The analysis was performed with questionnaire score as a covariate. However, the absence of an effect of this factor on performance has resulted in its omission from the report.

The improved score from high experienced drivers is likely because the quiz contained signs that might be considered less common, and thus greater driver experience may have increased the likelihood of these signs being seen previously. A copy of the questionnaire and the full results are included for reference in Annex 8 and 9 respectively.

Following this, drivers were taken into the simulator for a familiarisation driving exercise, during which time the experimental task was explained. Once the participant was comfortable with the simulator controls and the experiment they began the first of their twelve drives. Drivers performed the experiment in blocks of four drives, interspersed with rest periods to mitigate the effects of fatigue. After each drive, a workload questionnaire was completed. All twelve drives were completed in a single testing session.

Drivers were instructed to drive as they would normally. No specific instructions were provided regarding speed adherence. No specific events were choreographed, with traffic acting naturalistically, with predefined preferred speed and headways and overtaking behaviour.

The experiment concluded with the participant completing a signs preference questionnaire.

## 4.8 Analysis techniques

Mixed ANOVA (a parametric, multi-factor analysis technique) was used to analyse the effects of the following factors on each driving performance variable:

- *Within-subjects factors:*
  - Sign: Chapter 8 or Revised;
  - Traffic: High or low density; and,
  - Lane: Lane 1 or Lane 2 (applicable to contraflow scenarios only).
- *Between-subjects factors:*
  - Driving experience: High or low.

Parametric analysis techniques were chosen after data were checked for normality (Kolmogorov-Smirnov test) and homogeneity of variance (Levene test). These are two necessary tests to ensure that the assumptions of mixed ANOVA testing are not violated. The within-subjects design applied in this study reduces unsystematic variability in performance (e.g. individual differences), but also violates the ANOVA assumption of independence of scores. In accordance with standard statistical procedures, the Mauchly's test of sphericity was performed on the data and the Greenhouse-Geisser correction applied in cases where the assumption of non-spherical data was violated (Field, 2005).

The analysis involved testing for main effects of each of the above factors on performance. A main effect describes the unique effect of an independent variable on an outcome variable (i.e. looking for differences in drivers' mean speed when driving on a road with Chapter 8 Signs compared to when driving on a road with Revised Signs – *a main effect of sign type on mean speed*). The analysis also tests for interaction effects. These are the combined effect of two or more independent variables on an outcome variable (i.e. looking for a difference in the way in which drivers in the two experience groups manage their speed around Chapter 8 and Revised Signs – *an interaction of sign type and driver experience on mean speed*).

In cases where a significant main effect or interaction was found, further post-hoc testing was conducted to determine the precise nature of the effect in question.

The above analysis was repeated for each of the objective variables tested. The data was divided by road section for analysis purposes. Road sections were created in two ways:

- *Block:* This approach divided the road into segments of equal distance (100m) to allow focused analysis of driver performance in short sections of the drive. This was specifically used to report on driver performance on the approach to each sign.
  - *Variables – mean speed, speed variability, percent road centre/left/right*
- *Zonal:* This approach divided the road into five segments of unequal distance to reflect the part of the roadworks scenario that the participants were driving through. These sections were called *approach, lane change, lead in, works and end of works*.
  - *Variables – mean speed, speed variability, time headway, standard deviation of lateral position, high frequency steering, percent road centre/left/right..*

Subjective workload data was analysed using mixed ANOVA with the same within-subjects and between-subjects factors as those included in the objective performance analysis. However, it was not feasible to collect a workload rating from participants in relation to each zone or sign in a particular drive, and thus the subjective data provides a general impression of the overall drive rather than being specific to a single segment of the drive.

## 5. Results of Simulator Trial

The following Sections will present the high level findings of the simulator trial’s main variables. Full results from the trials, including variables not reported here because of their non-significance, can be found in Annex 9.

### 5.1 Driver Performance – Narrow Lanes Scenarios

This section presents the results of the analysis of each driving performance variable for the five zones of the Narrow Lanes scenarios. The focus of the analysis is on whether driving performance differs between the Chapter 8 and the Revised Sign (shown below). The Narrow Lanes scenario contained only one fixed plate sign that differed between the Chapter 8 and the revised sign routes, shown in Table 8. As a result, an effect of the change in sign type would be expected for the *Lane Change* section only. The effect of driving experience and traffic flow on performance was also considered, and more details can be found in Annex 9.

**Table 8:** Relevant signs and there location for the narrow lanes scenario

<b>Location</b>	<b>Chapter 8 Signs</b>	<b>Revised Signs</b>
<b>Approach (0-2600m)</b>	No relevant signs	No relevant signs
<b>Lane Change (2600-3200m)</b>		
<b>Lead In (3200-4300m)</b>	No relevant Signs	No relevant Signs
<b>Works (4300-6400m)</b>	No relevant Signs	No relevant Signs
<b>End of Works (6400-6790m)</b>	No relevant Signs	No relevant Signs

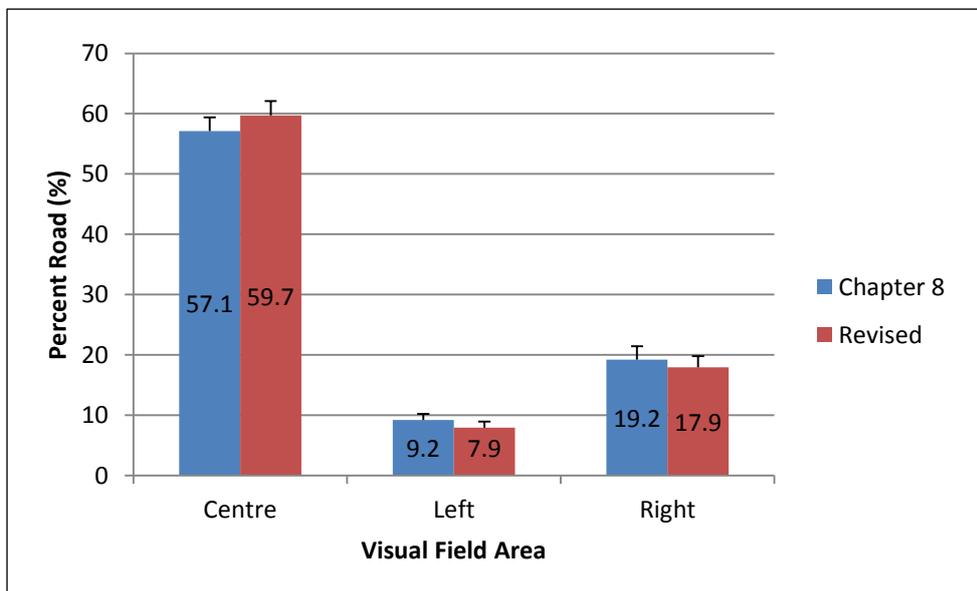
Table 9 summarises the results from the Narrow Lanes driving assessments for all driving zones.

**Table 9: Summary of driver performance across the Narrow Lanes driving assessment scenarios across all driving zones**

Performance Variable	Findings
Mean speed	There is <b>no significant difference</b> in mean speed between scenarios with Chapter 8 sign and those with the revised sign. This implies that the revised design does not have an impact on drivers' speed choice.
Speed variance	There is <b>no significant difference</b> in speed variability between the scenarios with Chapter 8 sign and those with revised sign. This implies that the revised design does not have an impact on drivers' speed variability. However, during the Lead In section, drivers showed greater speed variation (a non-significant trend) following the presentation of the Chapter 8 sign compared to the revised sign. The near significant interaction term for the Lead In section shows that this is due to low experience drivers showing greater speed variability in the Chapter 8 section compared to the revised section. High experience drivers showed consistent speed variability regardless of sign type.
Percent (proportion of time looking) road centre	There is <b>no significant difference</b> in the time spent looking at the road centre when presented with the existing Chapter 8 or revised signs. It should be noted that a difference might only be expected in the section in which the sign under test occurs (Lane Change). However, in the End of Works section, both high and low experience drivers showed a tendency (a non-significant trend) for looking more towards the road centre with the revised signs compared to the Chapter 8 signs. This difference was more pronounced with the low experience drivers.
Percent (proportion of time looking) road left	There is <b>no significant difference</b> in the time spent looking to the left of the road when presented with the existing Chapter 8 or revised signs. However, in the Approach and End of Works sections, high experience drivers looked more towards the left of the visual field (a non-significant trend). This might imply more advanced visual scanning behaviour amongst high experience drivers.
Percent (proportion of time looking) road right	There is <b>no significant difference</b> in the time spent looking to the right of the road when presented with the existing Chapter 8 or revised signs.
Time headway (proportion of time spent at headways less than 2 seconds)	There is <b>no significant difference</b> in time spent at short time headways between scenarios with the Chapter 8 sign and those with the revised sign. This implies that the revised design does not have an impact on time headway.
Standard deviation of lateral position (a measure of lateral control)	There is <b>no significant difference</b> in standard deviation of lateral position between scenarios with the Chapter 8 sign and those with the revised sign, with the exception of the End of Works Zone where drivers showed a <b>greater deviation</b> in lateral position in scenarios with the Chapter 8 sign.
High frequency steering (a measure of lateral control of the vehicle)	There is <b>no significant difference</b> in high frequency steering between scenarios with the Chapter 8 sign and those with the revised sign. This implies that the revised design does not have an impact on high frequency steering.

A further assessment of behaviour on approach to the revised sign (200m approach to the 7235 sign) showed that there was **no significant difference** in mean speed or speed variance on approach to the Chapter 8 sign compared to the revised sign. When the specific location of the sign is focused on, there remains no evidence of an impact of the sign design on longitudinal control of the vehicle.

There was a near significant difference between mean percent road centre on scenarios with the Chapter 8 sign and those with the Revised Sign. On average, drivers looked towards the road centre for 2.6% less of the time when approaching the Chapter 8 sign compared to the revised version. This result might imply that drivers require less time to extract the information from the revised version. This increased attention to the road centre with the revised sign is reflected in the lower proportion of time spent glancing to the left or right of the visual field compared to the approach to the existing Chapter 8 sign (Figure 13).



**Figure 13:** Glance behaviour during 7235 sign reading distance

## 5.2 Driver Performance – Contraflow Scenarios

This section presents the results of the analysis of each driving performance variable for the five zones of the Contraflow scenarios. The focus of the analysis is on whether driving performance differs between the Chapter 8 and Revised Signs. The Contraflow scenarios contained only eleven signs that were revised. The signs which were relevant to each scenario are included in Table 10.

Performance variables were assessed for each zone of the route (Approach, Lane Change, lead In, Works and End of Works) and for each revised sign. Table 11 summarises the results from the Contraflow driving assessments for all driving zones and for all signs.

**Table 10: Relevant signs and there location for the Contraflow scenario**

Location	Use Hard Shoulder		Use Contraflow	
	Chapter 8 Signs	Revised Signs	Chapter 8 Signs	Revised Signs
<b>Approach (0-2600m)</b>	No relevant signs	No relevant signs	No relevant signs	No relevant signs
<b>Lane Change (2600-3200m)</b>				
<b>Lead In (3200-4300m)</b>				
				
				
				
				
<b>Works (4300-6400m)</b>				
				
				
				
<b>End of Works (6400-6790m)</b>	No relevant Signs	No relevant Signs	No relevant Signs	No relevant Signs

**Table 11: Summary of driver performance across the Contraflow driving assessment scenarios across all driving zones and all signs**

Performance variable	Findings
Mean speed	There is <b>no significant difference</b> in mean speed between scenarios with Chapter 8 signs and those with revised signs. This implies that the revised designs do not have an impact on drivers' speed choice.
Speed variance	There is <b>no significant difference</b> in speed variability between the scenarios with Chapter 8 signs and those with revised signs. This implies that the revised designs do not have an impact on drivers' speed variability.
Percent (proportion of time looking) road centre	There is <b>no significant difference</b> in the time spent looking at the road centre when presented with the existing Chapter 8 or revised signs, <b>with the exception of during the Approach</b> to roadworks zone.  In the Approach zone, drivers looked towards the centre of the road significantly more in the revised signs scenarios compared to the Chapter 8 signs scenarios. This trend was also present (although a non-significant trend) in the Lane Change and End of Works sections.
Percent (proportion of time looking) road left	There is <b>no significant difference</b> in the time spent looking to the left of the road when presented with the existing Chapter 8 or revised signs.
Percent (proportion of time looking) road right	There was a <b>near significant tendency</b> for drivers to look more to the right-hand side of the driving scene in scenarios with Chapter 8 signs compared to scenarios with revised signs. This tendency was observed in the Approach and End of Works sections.
Time headway (proportion of time spent at headways less than 2 seconds)	There is <b>no significant difference</b> in time spent at short time headways between scenarios with Chapter 8 signs and those with the revised signs. This implies that the revised designs do not have an impact on time headway.
Standard deviation of lateral position (a measure of lateral control of the vehicle)	There is <b>no significant difference</b> in standard deviation of lateral position between scenarios with the Chapter 8 signs and those with the revised signs. This implies that the revised designs do not have an impact on standard deviation of lateral position.
High frequency steering (a measure of lateral control of the vehicle)	There is <b>no significant difference</b> in high frequency steering between scenarios with the Chapter 8 sign and those with the revised sign, with the exception of in the Lead In section of the route.  In the Lead In section, greater high frequency steering manoeuvres were observed on the Chapter 8 sign routes than the revised sign routes. This suggests that the revised sign designs do not cause impairments in lateral control of the vehicle, relative to the existing Chapter 8 signs.

The results indicate that the Revised Signs do not have an impact on driver performance on the approach to the signs when compared to Chapter 8 signs. A higher amount of time spent looking at the road centre in the scenario with the revised 7230 sign, compared to the Chapter 8 7230 sign, indicates that the revised sign requires a lower level of viewing and

comprehension (i.e. it is easier to understand at the glance) than the Chapter 8 sign. Similarly, a lower amount of time spent looking at the road left in the scenario with the revised 7216 sign, compared to the Chapter 8 7216 sign, also indicates that the revised sign requires a lower level of viewing and comprehension (i.e. it is easier to understand at the glance) than the Chapter 8 sign.

### 5.3 Driver Workload

The assessment of objective driving performance is enhanced by the addition of metrics that measure driver impressions of their own performance. The NASA-TLX workload scale is one such metric that allows drivers to score the demand or difficulty of a task.

This metric is typically used in driving simulator studies to measure mental workload of the driver. Drivers were asked to complete the workload questionnaire after each of their twelve drives. Ratings for each subscale were compared using mixed ANOVA. In addition, the same analysis was performed on the total workload score (the summation of the ratings).

Six factors are known to contribute to the overall level of mental workload that people feel when they perform a task; mental demand, physical demand, time pressure, performance, effort and frustration level. The following six questions were posed to participants to measure these six factors.

- **Mental Demand** refers to any mental activity required by performing the driving task. That is how much thinking, deciding, looking, searching etc. was required when you were driving. Was the driving task easy/simple (low) or complex/demanding (high)?
- **Physical Demand** refers to any physical activity required when driving. For example, operating accelerator, brake or steering wheel and adjusting stereo settings. Was it easy/restful (low) or strenuous and laborious (high)?
- **Time Pressure** refers to how hurried or harassed you felt while driving. Was the pace of driving slow and leisurely (low) or rapid and rushed (high)
- On average, how satisfied were you with your **performance** when driving?
- **Effort** refers to how hard you had to work (mentally and physically) to achieve your level of performance when driving. Was little effort (low) or a large amount of effort (high) required?
- **Frustration Level** refers to how relaxed or stressed you felt while driving. Did you feel secure, content, relaxed and complacent (low) or insecure, discourage, irritated stressed and annoyed (high)?

Participants were asked to place a vertical line at the appropriate point on a scale from low to high for each of the above six questions.

An analysis of responses from the participants shows that in the Narrow Lanes scenarios, there is **no significant difference** in workload scoring (subscales or total workload) between the Chapter 8 and Revised Signs. Therefore, the revised approach recommended for the design of TTM signs does not appear to increase the level of workload experienced by the driver.

Similarly, in the Contraflow scenarios there is **no significant difference** in workload scoring (subscales or total workload) between the Chapter 8 and Revised Signs indicating that the revised approach recommended for the design of TTM signs does not appear to increase the level of workload experienced by the driver.

However, it is worth noting that total Workload (and the Effort and Frustration subscales) was judged to be greater when driving in Lane 2 compared to Lane 1 and in all cases high density traffic increased workload ratings relative to low density traffic. This implies that the manipulation of traffic density resulted in a noticeable change in driver workload/difficulty of the driving task.

A copy of the driver workload questionnaire and full questionnaire results are included in Annexes 10 and 11 respectively.

## 5.4 Driver Preference

Driver preference was assessed at the end of the trials using a questionnaire. Participants were asked to compare pairs of signs (Chapter 8 versus Revised) and rate which sign conveyed information most clearly. This questionnaire was administered after all drives were completed. Participants were able to choose a preferred sign, or select neither if they had no preference.

With the exception of signs 7210 and 7231(200yds), participants stated a preference for Chapter 8 signs over the revised signs.

It should be noted that the metric of driver preference was administered in the absence of a meaningful driving context. Without competing driving task demands, it is not surprising that the signs conveying the most information tended to be rated most favourably. This component of the experimental design perhaps biased drivers towards favouring the more information-dense signs (i.e. typically the Chapter 8 sign when the two signs differed in information content).

However, the most worthwhile results to examine are possibly those for the signs which only contain design changes rather than varied amounts of text/symbols. These are shown in Table 12.

**Table 12:** Showing preference votes for each pair of signs tested.

Sign Reference	Prefer Chapter 8 Sign	Neither	Prefer Revised Sign
7210	 10	7	 19
7231 (200yds)	 2	15	 19
7237 (200yds)	 32	0	 4

By examining Table 12 it can be seen that there is no clear preference (Chapter 8 versus Revised) when considering just those signs that are almost identical. For 7210 and 7231(200yds) there appears to be a slight bias towards the revised signs, however, there is a very strong preference for the Chapter 8 version of 7237(200yds).

Full results for the assessment of driver preference are included in Annex 13.

## 5.5 Sign Size

Table 13 overleaf presents the potential size reductions which are possible for each sign. On average these 12 signs have been reduced by 47% without any perceived detriment in driver performance or visibility of signs. In fact in some cases the revised signs take less time to 'read' therefore comprehension/safety is likely to be improved.

**Table 13: Possible change in sign sizes following adherence to new design principles**

Sign Reference	Chapter 8			Revised			Change			
	Sign	Height (mm)	Width (mm)	Area (mm <sup>2</sup> )	Sign	Height (mm)	Width (mm)	Area (mm <sup>2</sup> )	Absolute (mm <sup>2</sup> )	Percentage
7210		2010	2340	4703400		1645	1785	2936325	1767075	37.6%
7212		3210	4170	13385700		1645	2295	3775275	9610425	71.8%
7212 yds		3210	4170	13385700		2145	2295	4922775	8462925	63.2%
7216		2530	2300	5819000		1645	2185	3594325	2224675	38.2%
7216 yds		3030	2300	6969000		2145	2185	4686825	2282175	32.7%
7230		3940	3030	11938200		2030	1825	3704750	8233450	69.0%
7230 useHS		4240	3030	12847200		2295	2040	4681800	8165400	63.6%
7231		2910	2640	7682400		1630	1665	2713950	4968450	64.7%
7231 yds		2330	1955	4555150		2170	1665	3613050	942100	20.7%
7235		3180	3330	10589400		1870	1810	3384700	7204700	68.0%
7237		2320	1560	3572400		1570	1560	2449200	1123200	31.4%
7237 yds		2145	1560	3346200		2070	1560	3229200	117000	3.5%

We have consulted with a number of TM contractors asking for their views regarding a size reduction of this magnitude and the responses received include:

*“The removal of extraneous elements is to be welcomed. The likes of “GET/STAY IN LANE”, “NOW” and the various text/roundels found above arrowheads only serve to increase sign size and add to reading times. The reduced content signs will be far easier for drivers to comprehend. Of equal importance, these smaller signs will be much easier to handle on site and be more easily located on “tight” sites than existing designs. So both the driver and the operatives benefit from these proposals.”*

*Andy Sturrock (Senior Engineer at A-one+)*

*“As a Traffic Management company we would like to thank you and your team for your efforts, from your findings and proposals it is clear that you have listened to our point of view and the reduction in the size of these signs will make a significant change to the associated dangers our men take on a daily basis. We actively encourage our men to report any work related issues through our Incident Observation Occurrence Report, the manual handling of these signs has been reported on numerous occasions....we look forward to reporting back to our workforce that their voice has been heard.”*

*Kev Richardson (Training Manager HWMartin)*

## 6. Conclusions and Recommendations

This project has taken a structured and systematic method towards developing a revised approach for designing TTM signs in order to meet the project aim:

*To investigate options for revising the design of TTM road layout signs to improve comprehension, whilst maintaining or reducing the size of the signs.*

To achieve this aim we have conducted a literature review which identified relevant information and research on sign design and comprehension. We have also conducted an expert ergonomic assessment and a preference survey to understand what design features road users' value, and how the signs could be revised to improve comprehension.

As a result of the literature review and consultation we have been able to develop a revised approach to design of TTM signs. These Revised Signs have subsequently been taken forward for simulator trials, and the results analysed to identify how driver performance is affected.

The analysis of the results has shown that driver performance between the two sets of signs was comparable, with no statistically significant difference. However, by adopting the revised approach to designing TTM signs it is considered that overall comprehension should improve and that the size relevant signs can reduce on average by 47%.

Consequently this is likely to realise safety, manual handling and cost benefits to the Highways Agency and contractors.

### 6.1 Recommendations

It is therefore considered that the following recommendations should be taken forward:

- The potential that consistency in design offers (in terms of design automation, design cost savings, site efficiencies, and potential to develop supporting tools such as roller blinds) should be explored.
- Consultation should be conducted with key stakeholders to discuss concepts and seek wide agreement to changes.
- Conduct an on-road trial of the revised sign designs to validate the simulator trial.
- Subject to successful trials these revised sign designs should be incorporated into the subsequent revisions of TSRGD and/or Chapter 8 as appropriate.

Other recommendations not directly related to the findings of the simulator trials include:

- Further investigation should be conducted into manual handling aspects of Traffic Management. Consideration should be given to ergonomic working methods and how the signage infrastructure (A-frames, signs, sandbags etc.) can be adapted to support this objective.

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## Annex 1. Ergonomic Assessment Questionnaire

### Traffic Management Signs Ergonomic Assessment

Please study the following sign (#1) and optional panels before answering the subsequent questions:



Optional top panels:



Optional bottom panels:



Please describe what this sign means to all relevant road users?

<b>Please score the above sign against “Spatial Compatibility” (1 = poor; 10 = Excellent)</b>									
Spatial Compatibility is defined as – the physical arrangement in space, relative to the position of information and directions (i.e., the direction in which the road is turning is presented by an arrow’s turn in the sign)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>Please score the above sign against “Conceptual Compatibility” (1 = poor; 10 = Excellent)</b>									
Conceptual Compatibility is defined as – the extent to which symbols and codes fit the associations most people have for the concept (e.g., an airplane sign will present a nearby airport)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>How can the design of sign #1 be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

<b>How can the design of the optional top and bottom panels be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

Please study the following sign (#2) and optional panels before answering the subsequent questions:



Optional top panels:



Optional bottom panels:



Please describe what this sign means to all relevant road users?

Blank area for describing the sign's meaning to road users.

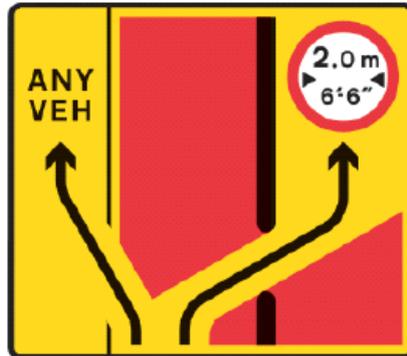
<b>Please score the above sign against “Spatial Compatibility” (1 = poor; 10 = Excellent)</b>									
Spatial Compatibility is defined as – the physical arrangement in space, relative to the position of information and directions (i.e., the direction in which the road is turning is presented by an arrow’s turn in the sign)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>Please score the above sign against “Conceptual Compatibility” (1 = poor; 10 = Excellent)</b>									
Conceptual Compatibility is defined as – the extent to which symbols and codes fit the associations most people have for the concept (e.g., an airplane sign will present a nearby airport)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>How can the design of sign #2 be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

<b>How can the design of the optional top and bottom panels be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

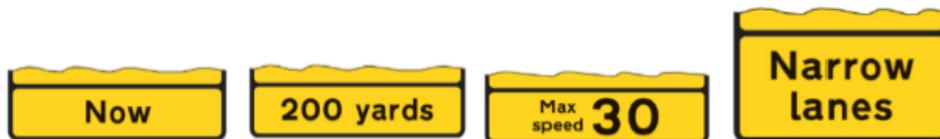
Please study the following sign (#3) and optional panels before answering the subsequent questions:



Optional top panels:



Optional bottom panels:



Please describe what this sign means to all relevant road users?

Blank area for describing the sign's meaning to road users.

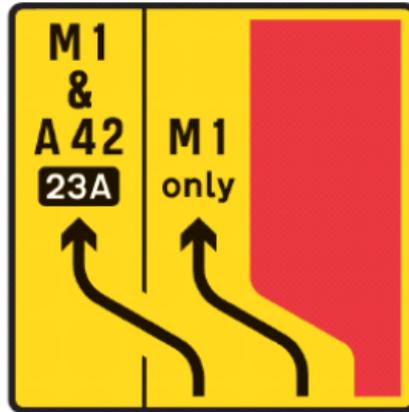
<b>Please score the above sign against "Spatial Compatibility" (1 = poor; 10 = Excellent)</b>									
Spatial Compatibility is defined as – the physical arrangement in space, relative to the position of information and directions (i.e., the direction in which the road is turning is presented by an arrow's turn in the sign)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>Please score the above sign against "Conceptual Compatibility" (1 = poor; 10 = Excellent)</b>									
Conceptual Compatibility is defined as – the extent to which symbols and codes fit the associations most people have for the concept (e.g., an airplane sign will present a nearby airport)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>How can the design of sign #3 be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

<b>How can the design of the optional top and bottom panels be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

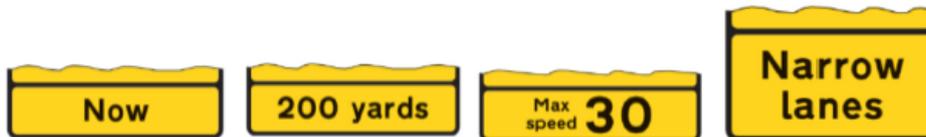
Please study the following sign (#4) and optional panels before answering the subsequent questions:



Optional top panels:



Optional bottom panels:



Please describe what this sign means to all relevant road users?

Empty space for describing the sign's meaning.

<b>Please score the above sign against "Spatial Compatibility" (1 = poor; 10 = Excellent)</b>									
Spatial Compatibility is defined as – the physical arrangement in space, relative to the position of information and directions (i.e., the direction in which the road is turning is presented by an arrow's turn in the sign)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>Please score the above sign against "Conceptual Compatibility" (1 = poor; 10 = Excellent)</b>									
Conceptual Compatibility is defined as – the extent to which symbols and codes fit the associations most people have for the concept (e.g., an airplane sign will present a nearby airport)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>How can the design of sign #4 be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

<b>How can the design of the optional top and bottom panels be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

Please study the following sign (#5) and optional panels before answering the subsequent questions:



Optional bottom panels:



Please describe what this sign means to all relevant road users?

<b>Please score the above sign against “Spatial Compatibility” (1 = poor; 10 = Excellent)</b>									
Spatial Compatibility is defined as – the physical arrangement in space, relative to the position of information and directions (i.e., the direction in which the road is turning is presented by an arrow’s turn in the sign)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>Please score the above sign against “Conceptual Compatibility” (1 = poor; 10 = Excellent)</b>									
Conceptual Compatibility is defined as – the extent to which symbols and codes fit the associations most people have for the concept (e.g., an airplane sign will present a nearby airport)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>How can the design of sign #5 be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

<b>How can the design of the optional top and bottom panels be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

**Please study the following sign (#6) and optional panels before answering the subsequent questions:**



**Optional bottom panels:**



**Please describe what this sign means to all relevant road users?**

Empty space for describing the sign's meaning.

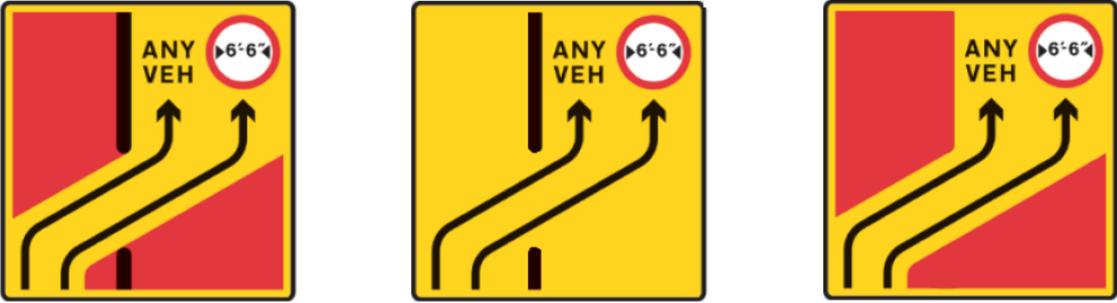
<b>Please score the above sign against "Spatial Compatibility" (1 = poor; 10 = Excellent)</b>									
Spatial Compatibility is defined as – the physical arrangement in space, relative to the position of information and directions (i.e., the direction in which the road is turning is presented by an arrow's turn in the sign)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>Please score the above sign against "Conceptual Compatibility" (1 = poor; 10 = Excellent)</b>									
Conceptual Compatibility is defined as – the extent to which symbols and codes fit the associations most people have for the concept (e.g., an airplane sign will present a nearby airport)									
1	2	3	4	5	6	7	8	9	10
<b>Please justify your scoring:</b>									

<b>How can the design of sign #6 be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

<b>How can the design of the optional top and bottom panels be changed (elements added or removed) to improve the scores for spatial and conceptual compatibility?</b>									

## Annex 2. Preference Survey Questionnaire



A B C

Which of these signs most clearly conveys:

- All lanes to cross the central reserve.



A B C

Which of these signs most clearly conveys:

- Lane 1 vehicles are to move on to the hard shoulder.
- Lane 2 vehicles are to move to Lane 1.

A B C D

Which of these signs most clearly conveys:

- Lane 1 vehicles are to move on to the hard shoulder.
- Lane 2 vehicles are to move to cross the central reserve.

A B C

Which of these signs most clearly conveys:

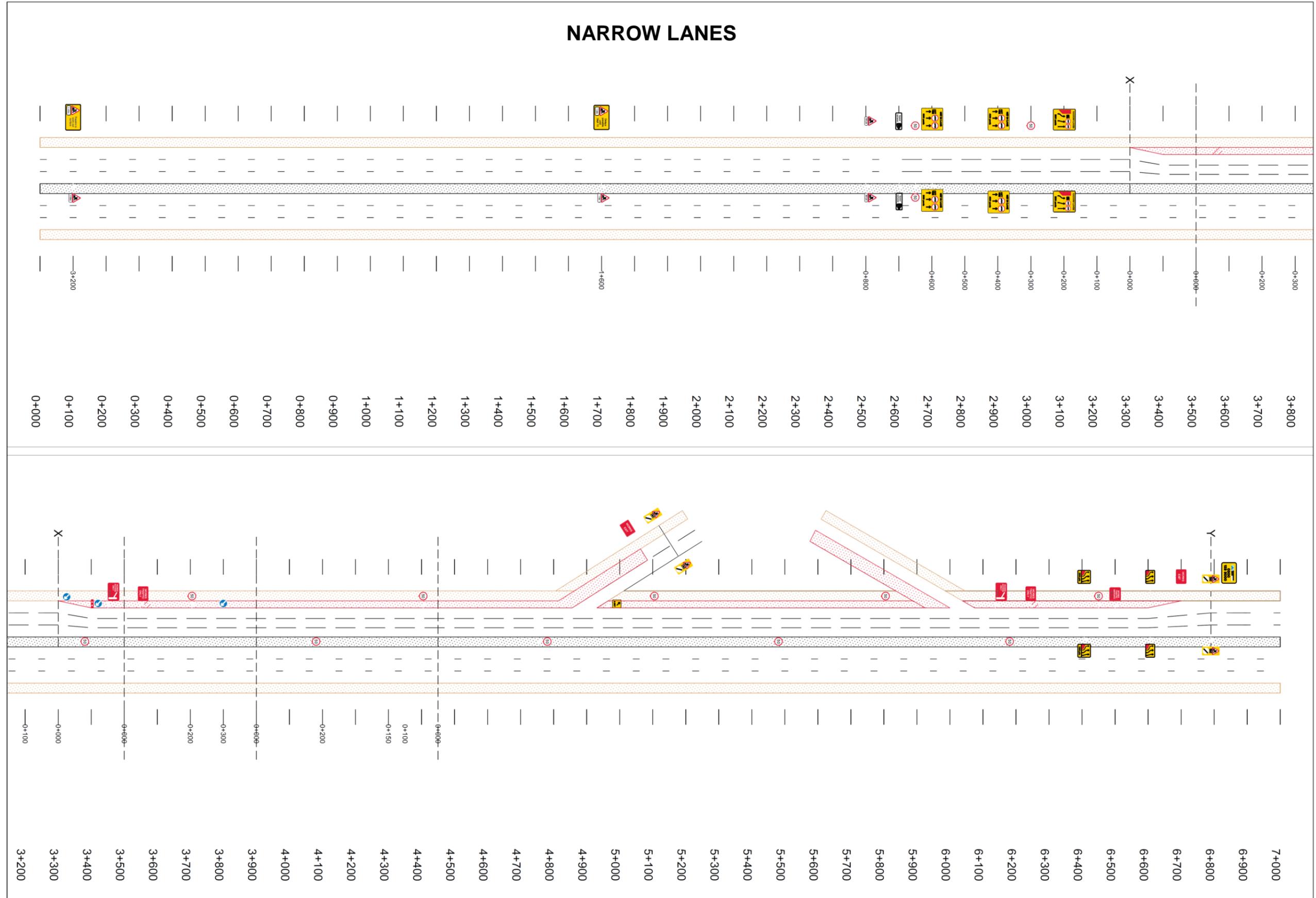
- Lanes ahead are narrower than normal.

A B

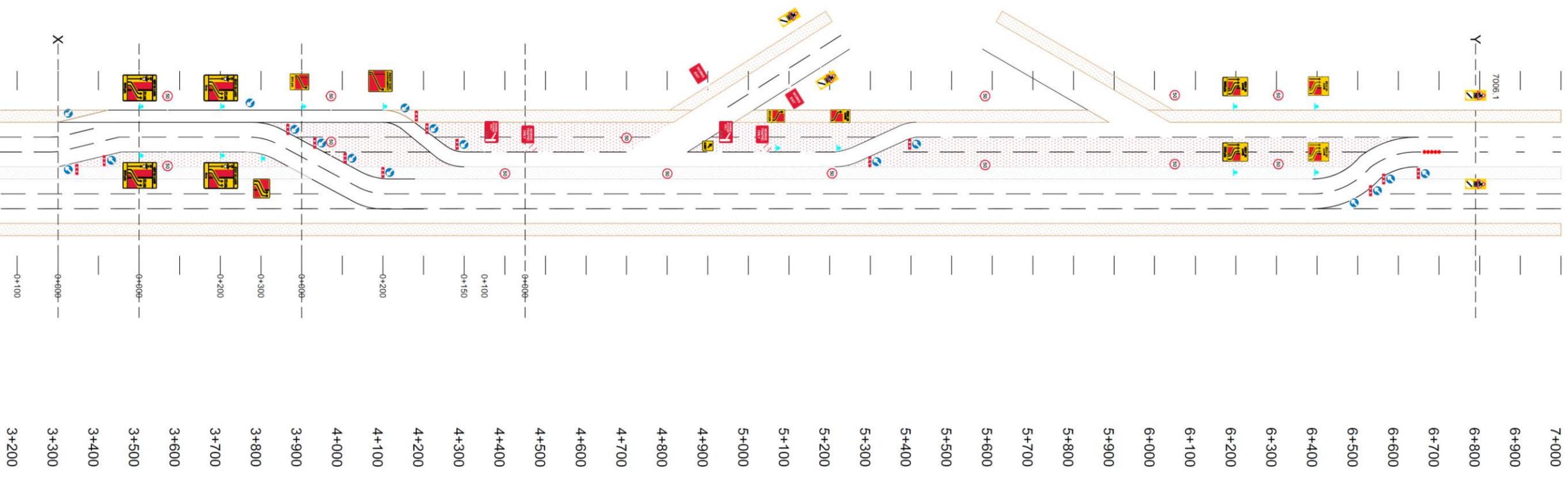
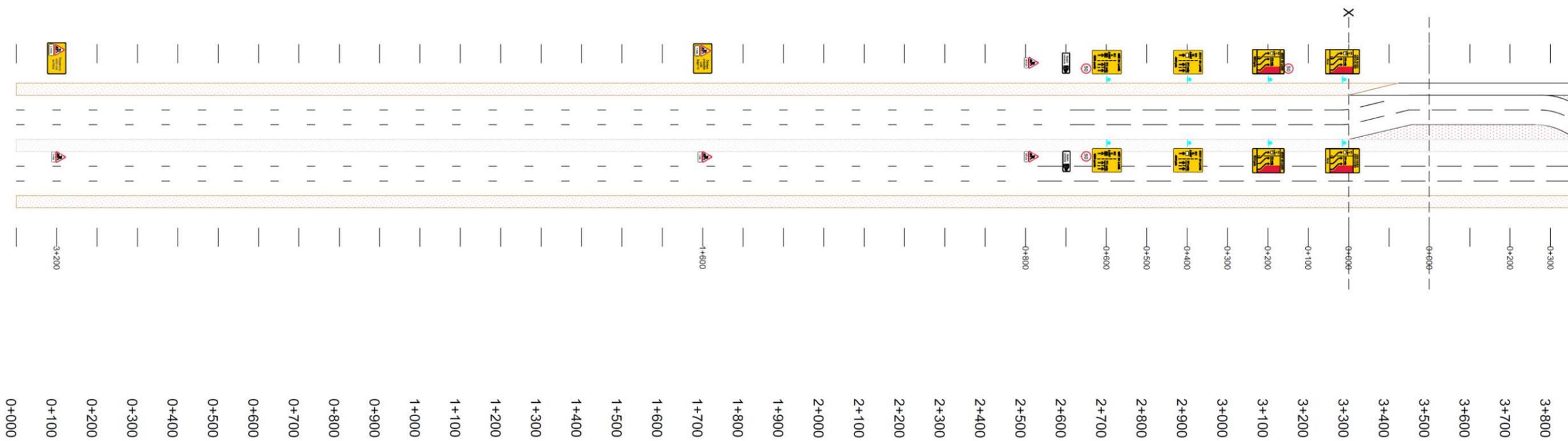
Which of these signs most clearly conveys:

- Exit for A563 is within the roadworks ahead.

Annex 3. Traffic Management Layout Drawings



# CONTRAFLOW



## Annex 4. Scenario Order Following Counterbalancing

Balanced Latin square counterbalancing method:

Participant	Drive 1	Drive 2	Drive 3	Drive 4	Drive 5	Drive 6	Drive 7	Drive 8	Drive 9	Drive 10	Drive 11	Drive 12
1	8	11	5	12	2	4	6	7	10	3	1	9
2	9	12	6	1	3	5	7	8	11	4	2	10
3	10	1	7	2	4	6	8	9	12	5	3	11
4	1	4	10	5	7	9	11	12	3	8	6	2
5	3	6	12	7	9	11	1	2	5	10	8	4
6	4	7	1	8	10	12	2	3	6	11	9	5
7	12	3	9	4	6	8	10	11	2	7	5	1
8	7	10	4	11	1	3	5	6	9	2	12	8
9	6	9	3	10	12	2	4	5	8	1	11	7
10	11	2	8	3	5	7	9	10	1	6	4	12
11	5	8	2	9	11	1	3	4	7	12	10	6
12	2	5	11	6	8	10	12	1	4	9	7	3
13	8	11	5	12	2	4	6	7	10	3	1	9
14	9	12	6	1	3	5	7	8	11	4	2	10
15	10	1	7	2	4	6	8	9	12	5	3	11
16	1	4	10	5	7	9	11	12	3	8	6	2
17	3	6	12	7	9	11	1	2	5	10	8	4
18	4	7	1	8	10	12	2	3	6	11	9	5
19	12	3	9	4	6	8	10	11	2	7	5	1
20	7	10	4	11	1	3	5	6	9	2	12	8
21	6	9	3	10	12	2	4	5	8	1	11	7
22	11	2	8	3	5	7	9	10	1	6	4	12
23	5	8	2	9	11	1	3	4	7	12	10	6
24	2	5	11	6	8	10	12	1	4	9	7	3
25	8	11	5	12	2	4	6	7	10	3	1	9
26	9	12	6	1	3	5	7	8	11	4	2	10
27	10	1	7	2	4	6	8	9	12	5	3	11
28	1	4	10	5	7	9	11	12	3	8	6	2
29	3	6	12	7	9	11	1	2	5	10	8	4
30	4	7	1	8	10	12	2	3	6	11	9	5
31	12	3	9	4	6	8	10	11	2	7	5	1
32	7	10	4	11	1	3	5	6	9	2	12	8
33	6	9	3	10	12	2	4	5	8	1	11	7
34	11	2	8	3	5	7	9	10	1	6	4	12
35	5	8	2	9	11	1	3	4	7	12	10	6
36	2	5	11	6	8	10	12	1	4	9	7	3
37	6	9	3	10	12	2	4	5	8	1	11	7
38	11	2	8	3	5	7	9	10	1	6	4	12
39	5	8	2	9	11	1	3	4	7	12	10	6
40	2	5	11	6	8	10	12	1	4	9	7	3

## Annex 5. Trial Participant Information

Participant	Age	Annual mileage	Experience	Experience group (1=low; 2=high)
1	26	600	5	1
2	26	10,000	8	2
3	24	20,000	7	2
4	35	0	20	1
5	25	20,000	8	2
6	49	12,000	32	2
7	22	600	5	1
8	18	500	1	1
9	56	5,000	25	2
10	37	500	20	1
11	22	1,500	4	1
12	38	12,000	21	2
13	43	15,000	25	2
14	32	1,000	1	1
15	58	10,000	38	2
16	52	10,000	34	2
17	61	7,000	44	2
18	30	6,000	12	2
19	25	0	7	1
20	54	6,000	33	2
21	26	6,000	8	2
22	22	750	4	1
23	25	2,000	7	1
24	37	8,000	20	2
25	30	1,500	12	1
26	65	5,000	40	2
27	67	10,000	48	2
28	37	1,000	20	1
29	28	500	8	1
30	23	500	5	1
31	44	5,500	20	2
32	38	12,000	21	2
33	44	15,000	26	2
34	22	0	0	1
35	59	8,000	40	2
36	24	1,000	4	1
37	27	500	8	1
38	61	1,100	40	1
39	19	100	0	1
40	45	1,000	24	1

## Annex 6. Trial Participant Briefing Document



### **PARTICIPANT BRIEFING (Temporary Traffic Management)**

#### ***Background***

The study in which you have been invited to participate, seeks to investigate how drivers' behave in standard motorway conditions. The project is funded by the Highways Agency and will help us to more fully understand the interaction between the driver and the roadway, so ensuring that road design remains as safe as possible. Your payment for participation in this study is £30.

#### ***The simulator***

The University of Leeds Advanced Driving Simulator is a controlled and safe environment in which to study driver behaviour. From the outside, the two major items that can be seen are the motion system and the large, white projection dome. Inside, is a Jaguar S-type vehicle cab. All the controls in the simulator work as expected and the instrument panel also operates displaying speed, engine revs and various warning lights.



Entry to the simulator dome is via a boarding platform and you will be accompanied into the simulator by the researcher.

#### ***Practice drive***

You will first have the opportunity for a practice drive, to allow you to become familiar with the simulator. The researcher will explain all of the driving controls of the Jaguar prior to your practice drive and remain with you throughout. Only when you feel comfortable will you be asked to continue. Please feel free to ask any questions that you have.

The simulator has a motion system which recreates the dynamic forces we feel as we drive a vehicle. Your first drive may feel a little odd, especially when accelerating, braking or cornering. However, don't worry, this is true for everybody who drives the simulator for the first time and these feelings usually subside after a few minutes of driving.

Experience has shown us that new simulator drivers tend to set off too quickly, making control of the car difficult. Please start slowly and gradually increase your speed during the practice drive. You may also have the impression that the steering is over-sensitive and tend to over-steer at first. Use the normal "self-centring" of the steering wheel to help keep the car straight. You may find that it is easier to straighten the simulator after a curve by letting the steering wheel slip through your hands. Apply only small inputs to the steering wheel.

For a small percentage of people, the initial "odd" or "unsteady" feelings do not subside and they begin to feel a little unwell. This usually manifests itself in the form of a feeling of motion sickness. If you do feel unwell or nauseous, please do not be embarrassed to withdraw from the study. We would rather this than make you feel ill! Simply inform the researcher that are not feeling well and we will stop the simulation. The researcher will take you back to the briefing area.

**Your task**

The study is investigating motorway driving. All that we ask is that you drive the simulator as you would if it were a real vehicle. We would like you to imagine that you are driving to a meeting during the morning peak traffic.

We will ask you to drive twelve short roads of approximately 7 minutes each. You will be told to drive in either Lane 1 (left lane) or Lane 2 (middle lane) and you should drive until you reach this sign (displayed on the hard shoulder):



After each drive we will ask you to complete a short questionnaire whilst sat in the car. After each block of four of these drives, we will bring you back to the handling area for a short break, otherwise please remain seated in the vehicle.

We will be recording your eye movements using remote cameras. This is not at all intrusive.

**Ethics, safety and confidentiality**

It is important that you understand that we are **not** looking at your individual driving style or judging your ability as a driver. We are solely interested in the behaviour of a group of drivers to draw conclusions about drivers in general.

As with all our research, this study is subject to the strict ethical guidelines of the British Psychological Society and the requirements of the Data Protection Act. In particular please note that:

- At no time now, nor in the future, will any information you provide be published that allows you as an individual to be identified.
- You are free to withdraw from the study at any time without having to give any reason for your decision.
- Video footage, which may include images of your face, may be used during the dissemination of this research project to the scientific community and research sponsors only. We will **not** make such footage available to other organisations, such as the broadcast media.

**Prior knowledge**

In order to achieve meaningful results from this study, it is **extremely** important to us that you have no prior knowledge of the study itself. If anyone, whom you know, has taken part in this study and has since discussed the details of study with you, please let the researcher know.

**Other details**

Should you need the toilets, they are located through the double doors along the corridor from the simulator offices.

**Contacts**

If you have any questions on this research project please feel free to speak to Samantha Jamson at the University of Leeds (0113 343 6606).

Finally, thank you very much for expressing an interest in this work and we hope that you enjoy your time at the simulator. Your contribution towards the science of road safety is appreciated.

## Annex 7. Sign Comprehension Quiz

Prior to the simulator trial, participants were presented with a 24 question multiple-choice quiz testing their comprehension. A copy of the quiz is shown below.

Participant no. \_\_\_\_\_

**Improving road signs**

The driving simulator trial you have taken part in today, aims to provide policy makers with advice on how signing in road works can be improved. We also know that some of the signs we encounter in our everyday driving can sometimes be misunderstood or not recognised.

The following multiple choice questionnaire asks you to consider the meaning of some well-known (and not so well-known) signs. Just do your best (we will give you the answers at the end).

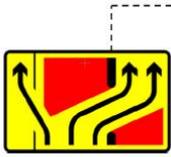
**What do the following signs mean? Tick one box only**

1		<input type="checkbox"/> Trams only <input type="checkbox"/> Oncoming trams <input type="checkbox"/> No trams ahead <input type="checkbox"/> Trams crossing ahead
2		<input type="checkbox"/> Parking allowed at certain times <input type="checkbox"/> Loading allowed at certain times <input type="checkbox"/> No loading at any time <input type="checkbox"/> No parking at any time
3		<input type="checkbox"/> Cyclists and pedestrians in the road ahead <input type="checkbox"/> Segregated pedal cycle and pedestrian route <input type="checkbox"/> Cycle route ahead <input type="checkbox"/> No entry to cyclists and pedestrians
4		<input type="checkbox"/> Keep in single file <input type="checkbox"/> Queues likely <input type="checkbox"/> Keep your distance <input type="checkbox"/> Car park
5		<input type="checkbox"/> Low-flying aircraft or sudden noise <input type="checkbox"/> Stop on the hard shoulder <input type="checkbox"/> Use the nearside lane <input type="checkbox"/> Leave the motorway at the next exit

6			<ul style="list-style-type: none"> <li>⌞ Broken down lorry</li> <li>⌞ Adverse camber</li> <li>⌞ Uneven road</li> <li>⌞ Risk of grounding</li> </ul>
7			<ul style="list-style-type: none"> <li>⌞ Parking for military vehicles</li> <li>⌞ Oncoming military vehicles</li> <li>⌞ Slow moving military vehicles ahead</li> <li>⌞ Tanks only</li> </ul>
8			<ul style="list-style-type: none"> <li>⌞ Road noise</li> <li>⌞ Airport ahead</li> <li>⌞ Crosswinds</li> <li>⌞ Adverse camber</li> </ul>
9			<ul style="list-style-type: none"> <li>⌞ Minimum speed limit</li> <li>⌞ No stopping</li> <li>⌞ End of 20 mph zone</li> <li>⌞ Entry to 20 mph zone</li> </ul>
10			<ul style="list-style-type: none"> <li>⌞ Low bridge ahead</li> <li>⌞ railway tunnel ahead</li> <li>⌞ tunnel ahead</li> <li>⌞ accident spot ahead</li> </ul>
11			<ul style="list-style-type: none"> <li>⌞ Pedestrians in the road ahead</li> <li>⌞ Children crossing ahead</li> <li>⌞ School crossing ahead</li> <li>⌞ Pedestrian crossing ahead</li> </ul>
12			<ul style="list-style-type: none"> <li>⌞ No double parking</li> <li>⌞ No stopping</li> <li>⌞ No-overtaking</li> <li>⌞ One-way street</li> </ul>
13			<ul style="list-style-type: none"> <li>⌞ Uneven road</li> <li>⌞ Soft verges</li> <li>⌞ Humps</li> <li>⌞ Tunnel</li> </ul>

14		<input type="checkbox"/> Service area ahead <input type="checkbox"/> Road Noise <input type="checkbox"/> Slippery Road Ahead <input type="checkbox"/> Danger Ahead
15		<input type="checkbox"/> Swing bridge ahead <input type="checkbox"/> Quayside or river bank <input type="checkbox"/> Soft verges <input type="checkbox"/> Slippery road
16		<input type="checkbox"/> Mini roundabout <input type="checkbox"/> Circular route <input type="checkbox"/> Ring Road <input type="checkbox"/> Link road
17		<input type="checkbox"/> Lay-by 30 miles ahead <input type="checkbox"/> Minimum speed 30 mph <input type="checkbox"/> Maximum speed 30 mph <input type="checkbox"/> Service area 30 miles ahead
<b>Where would you see the following signs? Tick one box only</b>		
18		<input type="checkbox"/> On a Ring road <input type="checkbox"/> On a Motorway <input type="checkbox"/> Approaching a Roundabout <input type="checkbox"/> In a Car Park
19		<input type="checkbox"/> At a Level crossing with no barrier <input type="checkbox"/> On a roundabout <input type="checkbox"/> On an overhanging load <input type="checkbox"/> At the end of the motorway
20		<input type="checkbox"/> On a slip road on a motorway <input type="checkbox"/> In a motorway service area <input type="checkbox"/> On the motorway hard shoulder <input type="checkbox"/> Under a motorway bridge

And finally.....

21	 <p>Which type of vehicle does this sign apply to?</p>	<input type="checkbox"/> Long vehicles <input type="checkbox"/> High vehicles <input type="checkbox"/> Heavy vehicles <input type="checkbox"/> Wide vehicles
22	<p>Usually, on a motorway, how far from the exit is the first sign showing the junction number?</p>	<input type="checkbox"/> Half a mile <input type="checkbox"/> One mile <input type="checkbox"/> Two miles <input type="checkbox"/> Three miles
23	<p>What shape is a <i>STOP</i> sign?</p>	<input type="checkbox"/> Circular <input type="checkbox"/> Triangular <input type="checkbox"/> Inverted triangle <input type="checkbox"/> Octagonal
24	 <p>What does the thick black line denote?</p>	<input type="checkbox"/> Lane markings <input type="checkbox"/> The central reservation <input type="checkbox"/> Line of cones <input type="checkbox"/> Temporary safety barrier

## Annex 8. Sign Comprehension Quiz Results

The summary results of the sign comprehension quiz are presented in the table below.

Driving Experience	Quiz Score	
	Mean (SD)	Range
Low	16.25 (2.81)	8-20
High	17.85 (3.59)	7-23

High experience drivers scored higher than low experience drivers on average. This is likely to be because the quiz contained signs may be considered to be less common, and therefore greater driving experience will increase the likelihood of coming into contact with these signs.

The table below shows the number of correct responses for each sign. It is interesting to note that Question 24, which asked about the meaning of the black line denoting the central reserve, was one of the five signs where less than half knew the correct answer.

Question	Correct Responses
1	22
2	15
3	36
4	34
5	27
6	28
7	29
8	35
9	39
10	33
11	15
12	36
13	33
14	38
15	39
16	37
17	27
18	18
19	23
20	27
21	35
22	18
23	19
24	19

## Annex 9. Full Trial Results

The tables on the following pages present the full results from the simulator trial. To aid interpretation the abbreviations used within the full results are presented here for reference:

Key	
Ch8	Existing Chapter 8 Signs
Rev	Revised Signs
Low	Low Experience/Traffic Flow
High	High Experience/Traffic Flow
L1	Lane 1
L2	Lane 2

Variable Names		Units
msp	Mean Speed	Mph
spvar	Speed Variance	Mph
prc	Percent Road Centre	%
pri	Percent Road Left	%
prr	Percent Road Right	%

Contraflow Results: Mean Speed

Sign Ref.	Statistic	Main effects				Interactions				Lane x Experience	
		Sign	Experience	Traffic Flow	Lane	Sign x Experience	Sign x Traffic Flow	Sign x Lane	Traffic Flow x		Traffic Flow x Lane
7230 (200yds)	p-value	0.714	0.177	0.001	<.001	0.123	0.750	0.478	0.626	0.433	0.053
	Means	48.1 Ch8	48.4 Low	48.8 Low	47.1 L1	48.8 Ch8 - Low 47.5 Ch8 - High 48.1 Rev - Low 47.9 Rev - High	48.9 Ch8 - Low 47.3 Ch8 - High 48.7 Rev - Low 47.3 Rev - High	47.1 Ch8 - L1 49.2 Ch8 - L2 47.2 Rev - L1 48.8 Rev - L2	49.1 Low - Low 48.6 Low - High 47.8 High - Low 46.9 High - High	48.0 Low - L1 49.6 Low - L2 46.2 High - L1 48.4 High - L2	47.1 L1 - Low 47.2 L1 - High 49.8 L2 - Low 48.3 L2 - High
7230	p-value	0.964	0.227	<.001	<.001	0.326	0.520	0.022	0.998	0.986	0.098
	Means	47.4 Ch8	47.7 Low	48.2 Low	46.1 L1	47.4 Ch8 - Low 47.3 Ch8 - High 47.9 Rev - Low 46.9 Rev - High	48.3 Ch8 - Low 46.4 Ch8 - High 48.1 Rev - Low 46.7 Rev - High	45.6 Ch8 - L1 49.1 Ch8 - L2 46.6 Rev - L1 48.2 Rev - L2	48.5 Low - Low 47.9 Low - High 46.8 High - Low 46.3 High - High	47.0 Low - L1 49.5 Low - L2 45.3 High - L1 47.8 High - L2	46.0 L1 - Low 46.2 L1 - High 49.3 L2 - Low 48.0 L2 - High
7212 (200yds)	p-value	0.186	0.109	<.001	<.001	0.029	0.752	0.301	0.830	0.777	0.161
	Means	47.4 Ch8	47.6 Low	47.9 Low	46.0 L1	47.4 Ch8 - Low 47.4 Ch8 - High 47.7 Rev - Low 46.4 Rev - High	48.1 Ch8 - Low 46.7 Ch8 - High 47.7 Rev - Low 46.4 Rev - High	46.0 Ch8 - L1 48.9 Ch8 - L2 45.9 Rev - L1 48.2 Rev - L2	48.2 Low - Low 47.5 Low - High 46.9 High - Low 46.3 High - High	46.6 Low - L1 49.2 Low - L2 45.4 High - L1 47.8 High - L2	46.0 L1 - Low 45.9 L1 - High 49.1 L2 - Low 47.9 L2 - High
7212	p-value	0.845	0.023	<.001	<.001	0.457	0.723	0.855	0.904	0.132	0.502
	Means	47.6 Ch8	48.1 Low	48.3 Low	46.1 L1	48.0 Ch8 - Low 47.3 Ch8 - High 48.2 Rev - Low 46.9 Rev - High	48.3 Ch8 - Low 47.0 Ch8 - High 48.4 Rev - Low 46.8 Rev - High	46.1 Ch8 - L1 49.2 Ch8 - L2 46.1 Rev - L1 49.0 Rev - L2	48.8 Low - Low 47.8 Low - High 47.3 High - Low 46.4 High - High	47.2 Low - L1 49.5 Low - L2 45.1 High - L1 48.7 High - L2	46.4 L1 - Low 45.8 L1 - High 49.7 L2 - Low 48.5 L2 - High
7210	p-value	0.903	0.071	<.001	<.001	0.953	0.971	0.709	0.844	0.001	0.319
	Means	47.6 Ch8	47.9 Low	48.4 Low	45.9 L1	48.0 Ch8 - Low 47.2 Ch8 - High 47.9 Rev - Low 47.2 Rev - High	48.4 Ch8 - Low 46.8 Ch8 - High 48.4 Rev - Low 46.8 Rev - High	45.8 Ch8 - L1 49.4 Ch8 - L2 45.9 Rev - L1 49.2 Rev - L2	48.8 Low - Low 48.0 Low - High 47.1 High - Low 46.4 High - High	47.3 Low - L1 49.5 Low - L2 44.5 High - L1 49.1 High - L2	46.0 L1 - Low 45.7 L1 - High 49.8 L2 - Low 48.8 L2 - High
7231 (200yds)	p-value	0.814	0.148	<.001	<.001	0.973	0.820	0.515	0.647	0.001	0.212
	Means	47.1 Ch8	47.5 Low	48.0 Low	45.5 L1	47.4 Ch8 - Low 46.8 Ch8 - High 47.5 Rev - Low 46.9 Rev - High	48.0 Ch8 - Low 46.2 Ch8 - High 48.0 Rev - Low 46.4 Rev - High	45.3 Ch8 - L1 48.9 Ch8 - L2 45.7 Rev - L1 48.7 Rev - L2	48.4 Low - Low 47.6 Low - High 46.6 High - Low 46.1 High - High	46.9 Low - L1 49.0 Low - L2 44.0 High - L1 48.6 High - L2	45.6 L1 - Low 45.4 L1 - High 49.4 L2 - Low 48.3 L2 - High
7231	p-value	0.626	0.573	<.001	<.001	0.967	0.737	0.426	0.182	0.001	0.026
	Means	46.8 Ch8	47.0 Low	47.6 Low	45.4 L1	46.9 Ch8 - Low 46.7 Ch8 - High 47.1 Rev - Low 46.8 Rev - High	47.5 Ch8 - Low 46.1 Ch8 - High 47.8 Rev - Low 46.1 Rev - High	45.2 Ch8 - L1 48.4 Ch8 - L2 45.6 Rev - L1 48.3 Rev - L2	48.0 Low - Low 47.3 Low - High 46.0 High - Low 46.2 High - High	46.8 Low - L1 48.5 Low - L2 44.0 High - L1 48.2 High - L2	45.1 L1 - Low 45.7 L1 - High 48.8 L2 - Low 47.8 L2 - High
7237	p-value	0.568	0.296	0.144	<.001	0.377	0.902	0.319	0.576	0.419	0.012
	Means	48.1 Ch8	48.0 Low	48.3 Low	46.3 L1	47.9 Ch8 - Low 48.3 Ch8 - High 48.0 Rev - Low 48.1 Rev - High	48.3 Ch8 - Low 48.0 Ch8 - High 48.2 Rev - Low 47.8 Rev - High	46.3 Ch8 - L1 50.0 Ch8 - L2 46.4 Rev - L1 49.7 Rev - L2	48.1 Low - Low 48.5 Low - High 47.9 High - Low 48.0 High - High	46.6 Low - L1 50.0 Low - L2 46.1 High - L1 49.7 High - L2	46.6 L1 - Low 46.1 L1 - High 49.4 L2 - Low 50.3 L2 - High
7216 (200yds)	p-value	0.015	0.678	0.282	<.001	0.283	0.782	0.459	0.413	0.796	0.007
	Means	48.0 Ch8	47.9 Low	48.1 Low	46.1 L1	47.9 Ch8 - Low 48.2 Ch8 - High 48.0 Rev - Low 47.8 Rev - High	48.1 Ch8 - Low 47.9 Ch8 - High 48.0 Rev - Low 47.8 Rev - High	46.1 Ch8 - L1 50.0 Ch8 - L2 46.1 Rev - L1 49.7 Rev - L2	48.0 Low - Low 48.2 Low - High 47.9 High - Low 47.8 High - High	46.3 Low - L1 49.9 Low - L2 46.0 High - L1 49.7 High - L2	46.4 L1 - Low 45.9 L1 - High 49.5 L2 - Low 50.2 L2 - High
7216 (200yds)	p-value	0.347	0.727	0.642	<.001	0.853	0.328	0.474	0.529	0.617	0.201
	Means	49.0 Ch8	49.1 Low	49.1 Low	48.0 L1	49.0 Ch8 - Low 48.9 Ch8 - High 49.2 Rev - Low 49.1 Rev - High	48.9 Ch8 - Low 49.0 Ch8 - High 49.3 Rev - Low 49.0 Rev - High	47.8 Ch8 - L1 50.1 Ch8 - L2 48.1 Rev - L1 50.2 Rev - L2	49.2 Low - Low 49.0 Low - High 49.0 High - Low 49.0 High - High	48.0 Low - L1 50.2 Low - L2 47.9 High - L1 50.2 High - L2	48.2 L1 - Low 47.8 L1 - High 50.1 L2 - Low 50.3 L2 - High
7216	p-value	0.950	0.722	0.936	0.001	0.291	0.730	0.847	0.465	0.182	0.414
	Means	49.4 Ch8	49.4 Low	49.4 Low	49.0 L1	49.3 Ch8 - Low 49.6 Ch8 - High 49.5 Rev - Low 49.4 Rev - High	49.4 Ch8 - Low 49.5 Ch8 - High 49.4 Rev - Low 49.4 Rev - High	49.0 Ch8 - L1 49.9 Ch8 - L2 49.0 Rev - L1 50.2 Rev - L2	49.3 Low - Low 49.5 Low - High 49.4 High - Low 49.4 High - High	49.1 Low - L1 49.7 Low - L2 48.8 High - L1 50.2 High - L2	49.0 L1 - Low 48.9 L1 - High 49.7 L2 - Low 50.0 L2 - High

Contraflow: Speed Variance

Sign Ref.	Statistic	Main effects				Interactions				Lane x Experience
		Sign	Experience	Traffic Flow	Lane	Sign x Traffic Flow	Sign x Lane	Traffic Flow x	Traffic Flow x Lane	
7230 (200yds)	p-value	0.600	0.866	0.001	0.433	0.166	0.438	0.498	0.602	0.384
	Means	0.49 Ch8	0.46 Low	0.14 Low	0.52 L1	0.38 Ch8 - Low	0.12 Ch8 - Low	0.21 Low - Low	0.16 Low - L1	0.61 L1 - Low
7230	p-value	0.190	0.814	<.001	0.946	0.290	0.216	0.645	0.955	0.505
	Means	0.40 Rev	0.43 High	0.75 High	0.38 L2	0.26 Rev - High	0.63 Rev - High	0.79 High - High	0.63 High - L2	0.44 L2 - High
7212 (200yds)	p-value	0.60	0.364	0.001	0.017	0.222	0.792	0.982	0.037	0.889
	Means	0.24 Ch8	0.3 Low	0.12 Low	0.37 L1	0.33 Ch8 - Low	0.10 Ch8 - Low	0.15 Low - Low	0.13 Low - L1	0.42 L1 - Low
7212	p-value	0.614	0.851	0.004	0.113	0.851	0.621	0.453	0.134	0.123
	Means	0.27 Ch8	0.24 Low	0.10 Low	0.33 L1	0.25 Ch8 - Low	0.09 Ch8 - Low	0.12 Low - Low	0.10 Low - L1	0.24 L1 - Low
7210	p-value	0.683	0.350	<.001	0.001	0.985	0.456	0.907	0.003	0.440
	Means	0.40 Ch8	0.43 Low	0.12 Low	0.57 L1	0.46 Ch8 - Low	0.10 Ch8 - Low	0.18 Low - Low	0.12 Low - L1	0.59 L1 - Low
7231 (200yds)	p-value	0.965	0.259	<.001	0.019	0.460	0.791	0.716	0.011	0.431
	Means	0.35 Ch8	0.42 Low	0.12 Low	0.49 L1	0.38 Ch8 - Low	0.11 Ch8 - Low	0.17 Low - Low	0.11 Low - L1	0.51 L1 - Low
7231	p-value	0.902	0.097	<.001	0.001	0.390	0.959	0.171	<.001	0.347
	Means	0.31 Ch8	0.38 Low	0.09 Low	0.47 L1	0.34 Ch8 - Low	0.09 Ch8 - Low	0.10 Low - Low	0.07 Low - L1	0.6 L1 - Low
7237 (200yds)	p-value	0.714	0.211	0.970	0.062	0.039	0.665	0.153	0.507	0.097
	Means	0.09 Ch8	0.11 Low	0.09 Low	0.11 L1	0.13 Ch8 - Low	0.10 Ch8 - Low	0.12 Low - Low	0.10 Low - L1	0.11 L1 - Low
7237	p-value	0.741	0.065	0.462	0.199	0.186	0.486	0.021	0.314	0.726
	Means	0.08 Ch8	0.11 Low	0.09 Low	0.10 L1	0.12 Ch8 - Low	0.09 Ch8 - Low	0.13 Low - Low	0.09 Low - L1	0.12 L1 - Low
7216 (200yds)	p-value	0.360	0.264	0.519	0.001	0.439	0.656	0.580	0.377	0.997
	Means	0.08 Ch8	0.10 Low	0.08 Low	0.11 L1	0.09 Ch8 - Low	0.08 Ch8 - Low	0.10 Low - Low	0.10 Low - L1	0.12 L1 - Low
7216	p-value	0.324	0.119	0.297	0.228	0.207	0.919	0.028	0.216	0.984
	Means	0.11 Ch8	0.20 Low	0.14 Low	0.12 L1	0.13 Ch8 - Low	0.11 Ch8 - Low	0.21 Low - Low	0.12 Low - L1	0.18 L1 - Low

Contraflow: Percent Road Centre

Sign Ref.	Statistic	Main effects				Interactions				Lane x Experience
		Sign	Experience	Traffic Flow	Lane	Sign x Traffic Flow	Sign x Lane	Traffic Flow x	Traffic Flow x Lane	
7230 (200yds)	p-value	0.126	0.497	0.125	0.479	0.345	0.674	0.889	0.850	0.609
	Means	59.9 Ch8	62.8 Low	59.9 Low	62.1 L1	59.3 Ch8 - Low	60.2 Ch8 - L1	61.1 Low - Low	60.4 Low - L1	63.0 L1 - Low
7230	p-value	0.172	0.421	0.355	0.001	0.094	0.610	0.708	0.597	0.880
	Means	63.0 Rev	60.1 High	63.0 High	60.8 L2	60.5 Rev - Low	61.9 Rev - L2	61.5 High - High	62.2 High - L2	59.0 L2 - High
7212 (200yds)	p-value	0.368	0.686	0.968	<.001	0.637	0.367	0.341	0.237	0.019
	Means	74.3 Ch8	76.0 Low	75.2 Low	79.7 L1	73.9 Ch8 - Low	77.9 Ch8 - L1	76.7 Low - Low	80.7 Low - L1	78.8 L1 - Low
7212	p-value	0.669	0.977	0.669	0.504	0.662	0.127	0.589	0.710	0.239
	Means	66.6 Rev	65.8 High	68.3 High	64.0 L2	66.6 Ch8 - Low	67.7 Ch8 - L1	67.9 Low - Low	66.7 Low - L1	66.1 L1 - Low
7210	p-value	0.110	0.475	0.330	<.001	0.549	0.590	0.484	0.784	0.001
	Means	72.6 Ch8	75.7 Low	73.4 Low	78.7 L1	71.3 Ch8 - Low	77.5 Ch8 - L1	75.4 Low - Low	77.4 Low - L1	77.1 L1 - Low
7231 (200yds)	p-value	0.653	0.977	0.427	<.001	0.720	0.674	0.836	0.837	<.001
	Means	79.0 Rev	78.6 High	79.2 High	76.5 L2	78.5 Rev - Low	80.0 Rev - L1	79.3 High - Low	81.4 High - L1	78.7 L2 - Low
7231	p-value	0.656	0.136	0.595	0.164	0.757	0.911	0.685	0.614	0.045
	Means	80.8 Ch8	82.9 Low	80.7 Low	81.5 L1	80.9 Ch8 - Low	82.0 Ch8 - L1	83.4 Low - Low	82.1 Low - L1	82.4 L1 - Low
7237 (200yds)	p-value	0.601	0.237	0.933	0.001	0.896	0.065	0.088	0.352	0.956
	Means	70.5 Rev	67.9 High	70.1 High	65.9 L2	71.4 Ch8 - Low	75.5 Ch8 - L1	73.5 Low - Low	75.2 Low - L1	76.6 L1 - Low
7237	p-value	0.249	0.339	0.042	0.041	0.669	0.258	0.253	0.102	0.713
	Means	68.4 Ch8	71.0 Low	67.7 Low	71.5 L1	67.2 Ch8 - Low	71.5 Ch8 - L1	70.3 Low - Low	71.6 Low - L1	73.7 L1 - Low
7216 (200yds)	p-value	0.226	0.033	0.722	0.002	0.859	0.932	0.059	0.116	0.186
	Means	66.0 Rev	62.4 High	67.6 High	63.7 L2	68.4 Ch8 - Low	72.1 Ch8 - L1	73.9 Low - Low	72.3 Low - L1	74.4 L1 - Low
7216	p-value	0.240	0.240	0.529	0.024	0.383	0.265	0.265	0.565	0.462
	Means	74.5 Rev	71.0 High	72.9 High	75.7 L2	73.6 Ch8 - Low	69.2 Ch8 - L1	77.8 Low - Low	72.6 Low - L1	73.2 L1 - Low

Contraflow: Percent Road Left

Sign Ref.	Statistic	Main effects				Interactions				Lane x Experience	
		Sign	Experience	Traffic Flow	Lane	Sign x Experience	Sign x Traffic Flow	Sign x Lane	Traffic Flow x		Traffic Flow x Lane
7230 (200yds)	p-value	0.521	0.161	0.609	0.50	0.303	0.523	0.176	0.954	0.527	0.679
	Means	18.1 Ch8	15.8 Low	18.1 Low	18.1 L1	17.1 Ch8 - Low	18.0 Ch8 - Low	19.8 Ch8 - L1	16.3 Low - Low	19.1 Low - L1	19.1 Low - L1
7230	p-value	0.625	0.184	0.064	0.004	0.565	0.377	0.259	0.677	0.294	0.408
	Means	17.1 Rev	19.4 High	17.2 High	17.1 L2	19.7 Rev - High	16.2 Rev - High	17.8 Rev - L2	19.0 High - High	17.1 High - L2	17.1 High - L2
7212 (200yds)	p-value	0.731	0.235	0.206	<.001	0.278	0.735	0.732	0.748	0.736	0.612
	Means	6.2 Ch8	5.3 Low	6.6 Low	4.2 L1	5.0 Ch8 - Low	6.6 Ch8 - Low	4.2 Ch8 - L1	5.7 Low - Low	4.6 Low - L1	4.6 Low - L1
7212	p-value	0.173	0.249	0.845	0.015	0.222	0.116	0.669	0.807	0.344	0.338
	Means	5.9 Rev	6.9 High	5.6 High	8.0 L2	6.2 Rev - High	5.3 Rev - High	7.7 Rev - L2	6.2 High - High	7.3 High - L2	7.3 High - L2
7210	p-value	0.594	0.492	0.066	0.053	0.950	0.150	0.059	0.869	0.894	0.444
	Means	3.7 Ch8	3.3 Low	3.1 Low	3.1 L1	3.4 Ch8 - Low	2.9 Ch8 - Low	2.8 Ch8 - L1	2.8 Low - Low	2.6 Low - L1	2.6 Low - L1
7231	p-value	0.588	0.197	0.417	0.220	0.215	0.243	0.559	0.157	0.674	0.540
	Means	3.0 Ch8	2.5 Low	2.9 Low	2.7 L1	2.7 Ch8 - Low	2.4 Ch8 - Low	2.5 Ch8 - L1	2.7 Low - Low	2.6 Low - L1	2.6 Low - L1
7237 (200yds)	p-value	0.556	0.079	0.548	0.011	0.313	0.172	0.868	0.379	0.394	0.189
	Means	6.0 Rev	7.2 High	6.0 High	7.4 L2	4.1 Rev - High	3.1 Rev - High	3.4 Rev - L2	4.2 High - High	3.7 High - L2	3.7 High - L2
7237	p-value	0.163	0.150	0.060	0.584	0.989	0.938	0.167	0.037	0.141	0.726
	Means	18.3 Ch8	15.5 Low	18.7 Low	17.7 L1	16.4 Ch8 - Low	19.7 Ch8 - Low	17.8 Ch8 - L1	15.4 Low - Low	17.8 Low - L1	17.8 Low - L1
7216 (200yds)	p-value	0.683	0.022	0.639	<.001	0.611	0.951	0.353	0.613	0.352	0.441
	Means	16.2 Rev	19.0 High	15.8 High	16.8 L2	17.9 Rev - High	14.9 Rev - High	14.9 Rev - L2	16.0 High - High	14.1 High - L2	14.1 High - L2
7216	p-value	0.003	0.015	0.623	0.002	0.406	0.498	0.898	0.124	0.459	0.632
	Means	18.0 Ch8	12.1 Low	16.3 Low	12.7 L1	13.6 Ch8 - Low	19.0 Ch8 - Low	14.9 Ch8 - L1	11.2 Low - Low	12.4 Low - L1	12.4 Low - L1
7216	p-value	0.003	0.015	0.623	0.002	0.406	0.498	0.898	0.124	0.459	0.632
	Means	13.8 Rev	19.8 High	15.5 High	19.2 L2	17.2 Rev - High	14.0 Rev - High	17.2 Rev - L2	18.1 High - High	18.0 High - L2	18.0 High - L2

Contraflow: Percent Road Right

Sign Ref.	Statistic	Main effects				Interactions				Lane x Experience	
		Sign	Experience	Traffic Flow	Lane	Sign x Experience	Sign x Traffic Flow	Sign x Lane	Traffic Flow x		Traffic Flow x Lane
7230 (200yds)	p-value	0.292	0.696	0.114	0.092	0.246	0.808	0.290	0.196	0.945	0.903
	Means	11 Ch8	10.9 Low	11.4 Low	9.6 L1	10.9 Ch8 - Low	11.8 Ch8 - Low	9.4 Ch8 - L1	12.6 Low - Low	10.4 Low - Low	10.1 L1 - Low
7230	p-value	0.732	0.735	0.094	0.095	0.614	0.150	0.297	0.819	0.876	0.240
	Means	10 Rev	10.1 High	9.6 High	11.5 L2	11.0 Rev - Low	11.0 Rev - Low	9.7 Rev - L1	9.3 High - Low	8.7 High - L1	11.8 L2 - Low
7212 (200yds)	p-value	0.772	0.934	0.740	<.001	0.927	0.903	0.432	0.693	0.066	0.458
	Means	9.3 Ch8	9.2 Low	8.9 Low	7.0 L1	9.4 Ch8 - Low	9.2 Ch8 - Low	7.7 Ch8 - L1	8.7 Low - Low	5.9 Low - L1	7.5 L1 - Low
7212	p-value	0.869	0.820	0.785	0.256	0.799	0.255	0.232	0.818	0.683	0.106
	Means	19.8 Ch8	19.1 Low	19.9 Low	20.6 L1	19.0 Ch8 - Low	19.1 Ch8 - Low	19.4 Ch8 - L1	19.1 Low - Low	20.6 Low - L1	21.6 L1 - Low
7210	p-value	0.397	0.915	0.143	0.001	0.779	0.624	0.368	0.453	0.895	0.022
	Means	16 Ch8	15.1 Low	16.5 Low	12.5 L1	15.5 Ch8 - Low	17.5 Ch8 - Low	12.4 Ch8 - L1	15.7 Low - Low	13.6 Low - L1	14.2 L1 - Low
7231 (200yds)	p-value	0.414	0.717	0.414	0.116	0.418	0.983	0.334	0.925	0.897	0.013
	Means	10.1 Rev	10.0 High	10.0 High	11.4 L2	9.2 Rev - High	9.6 Rev - High	10.2 Rev - L2	9.4 High - High	10.8 High - L2	12.3 L2 - High
7231	p-value	0.446	0.755	0.899	0.128	0.314	0.936	0.154	0.540	0.128	0.915
	Means	5.9 Ch8	6.0 Low	6.2 Low	6.9 L1	6.0 Ch8 - Low	5.9 Ch8 - Low	5.8 Ch8 - L1	5.8 Low - Low	6.4 Low - L1	6.6 L1 - Low
7237 (200yds)	p-value	0.86	0.766	0.216	0.078	0.262	0.606	0.652	0.721	0.688	0.182
	Means	4.8 Ch8	4.9 Low	4.3 Low	4.0 L1	5.4 Ch8 - Low	4.1 Ch8 - Low	3.9 Ch8 - L1	4.6 Low - Low	3.6 Low - L1	3.6 L1 - Low
7237	p-value	0.665	0.559	0.903	0.025	0.819	0.891	0.636	0.433	0.361	0.163
	Means	4.6 Ch8	5.1 Low	4.8 Low	3.6 L1	5.1 Ch8 - Low	4.6 Ch8 - Low	3.3 Ch8 - L1	5.4 Low - Low	4.0 Low - L1	3.2 L1 - Low
7216 (200yds)	p-value	0.448	0.685	0.626	<.001	0.048	0.906	0.780	0.183	0.836	0.951
	Means	5.2 Ch8	5.2 Low	5.2 Low	6.9 L1	6.1 Ch8 - Low	5.4 Ch8 - Low	7.0 Ch8 - L1	4.8 Low - Low	7.0 Low - L1	7.1 L1 - Low
7216	p-value	0.484	0.728	0.687	<.001	0.490	0.966	0.537	0.815	0.727	0.546
	Means	4.8 Rev	4.9 High	4.9 High	1.8 L2	5.2 Rev - High	4.5 Rev - High	2.7 Rev - L2	3.9 High - High	2.8 High - L2	2.9 L2 - High

**Narrow Lanes: Mean Speeds**

Sign Ref.	Statistic	Main effects						Interactions					
		Sign		Experience		Traffic Flow		Sign x Experience		Sign x Traffic Flow		Traffic Flow x Experience	
7235	p-value	0.276		0.020		0.856		0.954		0.567		0.672	
	Means	48.9	Ch8	49.9	Low	49.2	Low	49.7	Ch8 - Low	49.1	Ch8 - Low	49.8	Low - Low
								48.1	Ch8 - High	48.7	Ch8 - High	48.6	Low - High
		49.4	Rev	48.4	High	49.1	High	50.2	Rev - Low	49.3	Rev - Low	50.0	High - Low
								48.7	Rev - High	49.5	Rev - High	48.2	High - High

**Narrow Lanes: Speed Variance**

Sign Ref.	Statistic	Main effects						Interactions					
		Sign		Experience		Traffic Flow		Sign x Experience		Sign x Traffic Flow		Traffic Flow x Experience	
7235	p-value	0.158		0.422		0.069		0.583		0.233		0.526	
	Means	0.38	Ch8	0.32	Low	0.08	Low	0.50	Ch8 - Low	0.10	Ch8 - Low	0.09	Low - Low
								0.25	Ch8 - High	0.66	Ch8 - High	0.06	Low - High
		0.11	Rev	0.17	High	0.41	High	0.13	Rev - Low	0.05	Rev - Low	0.54	High - Low
								0.09	Rev - High	0.17	Rev - High	0.28	High - High

**Narrow Lanes: Percent Road Centre**

Sign Ref.	Statistic	Main effects						Interactions					
		Sign		Experience		Traffic Flow		Sign x Experience		Sign x Traffic Flow		Traffic Flow x Experience	
7235	p-value	0.263		0.143		0.269		0.857		0.045		0.324	
	Means	57.1	Ch8	61.5	Low	56.8	Low	60.5	Ch8 - Low	58.3	Ch8 - Low	58.4	Low - Low
								53.8	Ch8 - High	56.0	Ch8 - High	55.1	Low - High
		59.7	Rev	55.3	High	60.1	High	62.6	Rev - Low	55.3	Rev - Low	64.7	High - Low
								56.8	Rev - High	64.2	Rev - High	55.5	High - High

**Narrow Lane: Percent Road Left**

Sign Ref.	Statistic	Main effects						Interactions					
		Sign		Experience		Traffic Flow		Sign x Experience		Sign x Traffic Flow		Traffic Flow x Experience	
7235	p-value	0.325		0.054		0.874		0.079		0.458		0.573	
	Means	9.2	Ch8	7.0	Low	8.4	Low	6.5	Ch8 - Low	8.8	Ch8 - Low	7.3	Low - Low
								12.0	Ch8 - High	9.7	Ch8 - High	9.5	Low - High
		7.9	Rev	10.1	High	8.7	High	7.5	Rev - Low	8.1	Rev - Low	6.7	High - Low
								8.3	Rev - High	7.7	Rev - High	10.7	High - High

**Narrow Lane: Percent Road Right**

Sign Ref.	Statistic	Main effects						Interactions					
		Sign		Experience		Traffic Flow		Sign x Experience		Sign x Traffic Flow		Traffic Flow x Experience	
7235	p-value	0.598		0.484		0.112		0.892		0.557		0.670	
	Means	19.2	Ch8	17.4	Low	20.6	Low	17.8	Ch8 - Low	20.5	Ch8 - Low	19.9	Low - Low
								20.5	Ch8 - High	17.8	Ch8 - High	21.2	Low - High
		17.9	Rev	19.7	High	16.5	High	16.9	Rev - Low	20.6	Rev - Low	14.8	High - Low
								18.9	Rev - High	15.2	Rev - High	18.2	High - High

## Annex 10. Driver Workload Questionnaire

Participant no. \_\_\_\_\_ Drive no. \_\_\_\_\_



**Workload**

The next set of questions is designed to gauge your impression of how much workload you experienced when driving. Six factors are known to contribute to the overall level of mental workload that people feel when they perform a task. Below are questions designed to measure these six factors.

For each factor, please indicate, by placing a vertical line at the appropriate point on the scale, the level of workload that you experienced while driving.

**Mental Demand** refers to any mental activity required by performing the driving task. That is how much thinking, deciding, looking, searching etc. was required when you were driving. Was the driving task easy/simple (low) or complex/demanding (high)?

LOW |-----| HIGH

**Physical Demand** refers to any physical activity required when driving. For example, operating accelerator, brake or steering wheel and adjusting stereo settings. Was it easy/restful (low) or strenuous and laborious (high)?

LOW |-----| HIGH

**Time Pressure** refers to how hurried or harassed you felt while driving. Was the pace of driving slow and leisurely (low) or rapid and rushed (high)?

LOW |-----| HIGH

On average, how satisfied were you with your **performance** when driving?

GOOD |-----| POOR

**Effort** refers to how hard you had to work (mentally and physically) to achieve your level of performance when driving. Was little effort (low) or a large amount of effort (high) required?

LOW |-----| HIGH

**Frustration Level** refers to how relaxed or stressed you felt while driving. Did you feel secure, content, relaxed and complacent (low) or insecure, discourage, irritated stressed and annoyed (high)?

LOW |-----| HIGH

## Annex 11. Results from Driver Workload Questionnaire

### Narrow Lanes Scenarios

**Analysis:** Repeated Measures ANOVA

**Between-subjects factors:** Driver experience (Low and High experience groups)

**Within-subjects factors:** Sign (Chapter 8 or Revised), Traffic Flow (High and Low).

Each driver workload subscale score (mental demand, physical demand, temporal demand, overall performance, effort, and frustration) was assessed for the main effect of each of the above factors. The summed score across all subscales (Total Workload) was also considered. Driver workload is considered for an entire drive as it was not deemed possible to collect intermittent workload readings during a drive.

The results of this analysis are shown in the following table:

Sign	Main Effects			Interactions
	Sign (Chapter 8 vs. Revised)	Traffic Flow (High vs. Low)	Experience (High vs. Low)	Sign x Experience
<b>Mental demand</b>	Not Significant	<b>Significant @ <math>\alpha = .05</math></b>	Not Significant	Not Significant
<b>Physical demand</b>	Not Significant	Not Significant	Not Significant	Not Significant
<b>Temporal demand</b>	Not Significant	<b>Significant @ <math>\alpha = .05</math></b>	Not Significant	Not Significant
<b>Overall performance</b>	Not Significant	Not Significant	Not Significant	Not Significant
<b>Effort</b>	Not Significant	Not Significant	Not Significant	Not Significant
<b>Frustration</b>	Not Significant	Not Significant	Not Significant	Not Significant
<b>Total workload</b>	Not Significant	Not Significant	Not Significant	Not Significant

Outcomes:

- There were no effects of Sign or Experience on workload ratings (either total workload, or subscales) during narrow lanes driving.
- The signage revisions do not increase the workload experienced by the driver.
- In all cases, high density traffic increased workload ratings relative to low density traffic. This reached significance for two subscales of the workload metric. This implies that the manipulation of traffic density resulted in a noticeable change in driver workload/difficulty of the driving task.

**Contraflow Scenarios**

**Analysis:** Repeated Measures ANOVA

**Between-subjects factors:** Driver experience (Low and High experience groups)

**Within-subjects factors:** Sign (Chapter 8 or Revised), Traffic Flow (High and Low), Lane (participant instructed to drive in Lane 1 or 2)

Each driver workload subscale score (mental demand, physical demand, temporal demand, overall performance, effort, and frustration) was assessed for the main effect of each of the above factors. The summed score across all subscales (Total Workload) was also considered. Driver workload is considered for an entire drive as it was not deemed possible to collect intermittent workload readings during a drive.

The results of this analysis are shown in the following table:

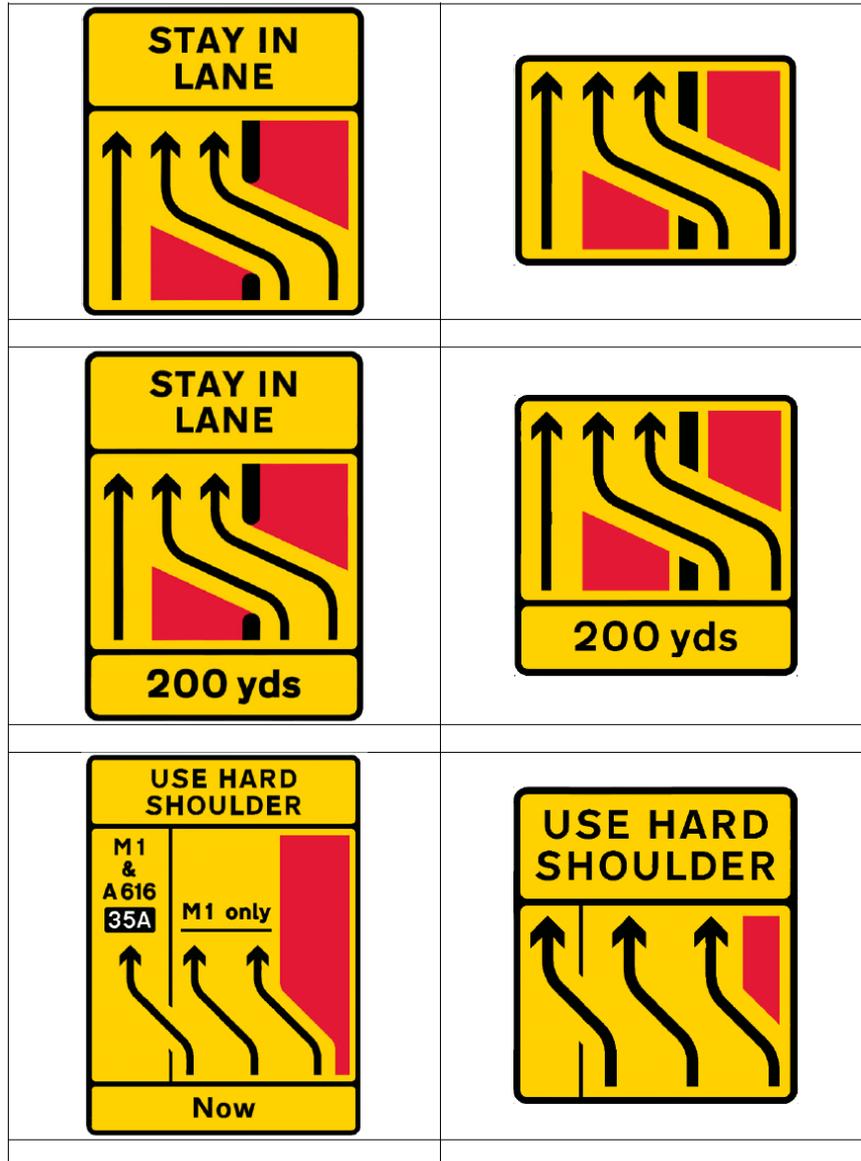
Sign	Main Effects				Interactions
	Sign (Chapter 8 vs. Revised)	Traffic Flow (High vs. Low)	Lane (Lane 1 vs. Lane 2)	Experience (High vs. Low)	Sign x Experience
<b>Mental demand</b>	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant
<b>Physical demand</b>	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant
<b>Temporal demand</b>	Not Significant	<b>Significant @ <math>\alpha = .05</math></b>	Not Significant	Not Significant	Not Significant
<b>Overall performance</b>	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant
<b>Effort</b>	Not Significant	Not Significant	<b>Significant @ <math>\alpha = .05</math></b>	Not Significant	Not Significant
<b>Frustration</b>	Not Significant	Not Significant	<b>Significant @ <math>\alpha = .05</math></b>	Not Significant	Not Significant
<b>Total workload</b>	Not Significant	Not Significant	<b>Significant @ <math>\alpha = .05</math></b>	Not Significant	Not Significant

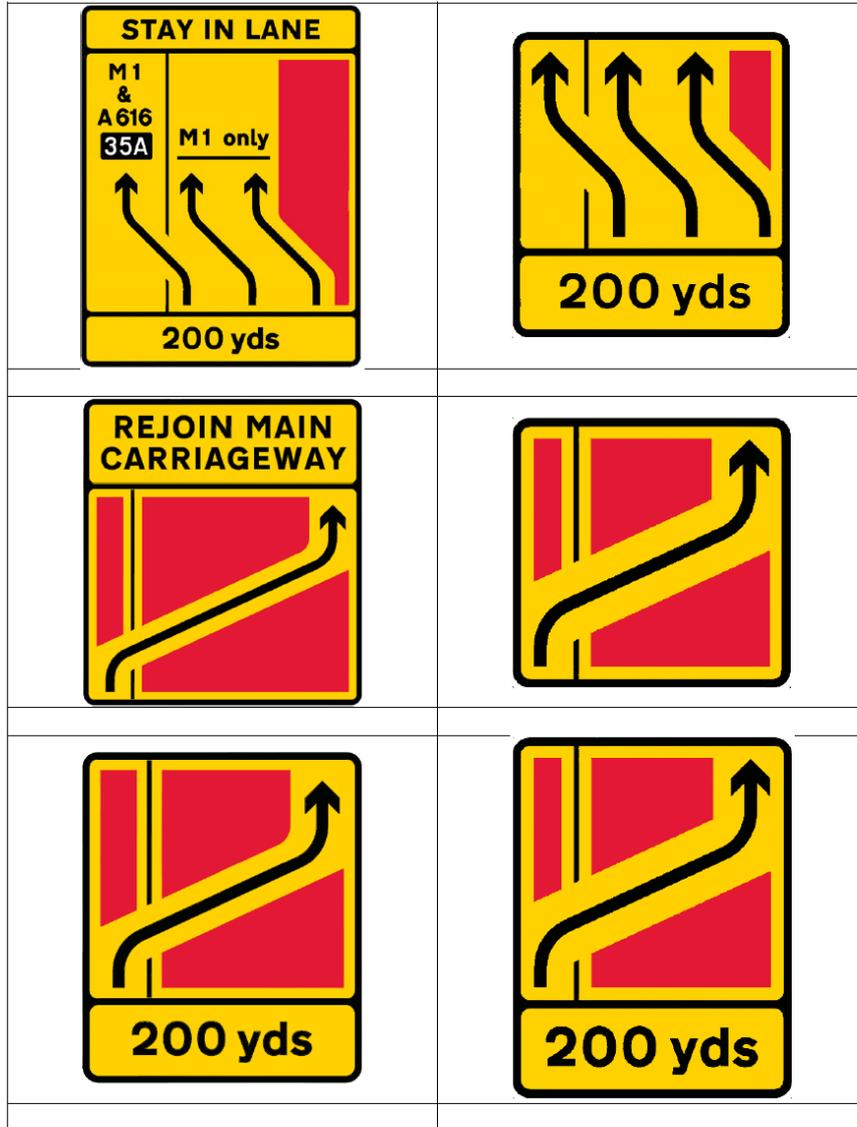
Outcomes:

- There were no effects of Sign or Driving Experience on workload ratings (either total workload, or subscales) during contraflow driving.
- The signage revisions do not increase the workload experienced by the driver.
- Total Workload (and the Effort and Frustration subscales) was judged to be greater when driving in Lane 2 compared to Lane 1.
- There was a near significant effect of Experience on Frustration ratings, with low experience drivers giving high ratings on average, than high experience drivers.
- In all cases, high density traffic increased workload ratings relative to low density traffic. This reached significance for two subscales of the workload metric. This implies that the manipulation of traffic density resulted in a noticeable change in driver workload/difficulty of the driving task.

## Annex 12. Driver Preference Questionnaire

Which sign conveys information most clearly? (CONTRAFLOW) (0 = no diff; 1 = left; 2= right)	





	
 <b>200 yds</b>	 <b>200 yds</b>
<p>Which sign conveys information most clearly? (NARROW LANES) (0 = no diff; 1 = left; 2= right)</p>	
 <b>200 yards</b>	 <b>200 yds</b>

## Annex 13. Results of Driver Preference Questionnaire

Participants were asked to compare pairs of signs (Chapter 8 versus Revised) and rate which sign conveyed information most clearly. This questionnaire was administered after all drives were completed. Drivers were able to choose a preferred sign, or select neither if they had no preference. The following tables show the result of this questionnaire:

### Narrow Lanes

Sign Reference	Prefer Chapter 8 Sign	Neither	Prefer Revised Sign
7235	32	0	4

### Contraflow

Sign Reference	Prefer Chapter 8 Sign	Neither	Prefer Revised Sign
7210	10	7	19
7212	29	0	7
7210 (200yds)	30	0	6
7216	29	0	7
7216 (200yds)	30	0	6
7230	24	1	11
7230 (200yds)	31	0	5
7231	25	0	11
7231 (200yds)	2	15	19
7237	29	0	7
7237 (200yds)	32	0	4

## Annex 14. Statistical Confidence

The statistical significance of the effect of an independent variable (i.e. sign type) on a dependent variable (i.e. mean speed) is typically based on the p-value output from the analysis. The *p-value* is the probability that a difference between two conditions could have arisen by chance rather than a genuine effect, and we consider an effect of a variable to be genuine, when  $p < 0.05$ . However, the p-value can be influenced by both the presence of an *effect* and the *sample size*. For example, to take two extreme cases, a significant effect can occur as a result of a large effect in a small sample, or a small effect in a large sample. The latter case is likely to be more valid given that the outcome is based upon data from a larger representation of the total population. For this reason, it is sensible to consult the *effect size* to assess the reliability of a statistical analysis. The effect size is *a measure of the difference between conditions that is independent of the sample size tested*. Effect size allows us to draw conclusions beyond the simple i.e. whether or not there is a difference between two conditions, and instead informs us in more depth: i.e. about the magnitude of the difference between the two conditions. In this sense, it is often considered as a true measure of significance of a difference. The benefit of considering effect sizes is that they can be used to compare the relative magnitude of effects both across variables and across studies.

A measure of our confidence in the selection of the participant sample size in this study and thus in the output of the statistical analyses and related conclusions can be gained through an assessment of effect sizes. The eta-squared ( $\eta^2$ ) effect size was used in this case. Simply, effect sizes are categorised as 'small' (approximately 0.1-0.3), 'medium' (approximately 0.3-0.5) and 'large' (greater than 0.5). For effect sizes, smaller than 0.1, the effect is typically not considered great enough to warrant further investigation.

For each dependent variable (mean speed, speed variance, percent road centre, percent road left, percent road right) analysed on the approach to a sign that was revised from the existing Chapter 8 version, the effect sizes were considered for each main effect of an independent variable (e.g. sign type, driver experience, traffic flow, lane travelled). The effect sizes are illustrated in the following tables.

To allow us to be confident that our selected sample size was sufficient to demonstrate an effect of the key independent variables (sign type, driver experience), where one existed, we would hope to see few instances of a large effect size with a non-significant main effect. Occurrences of a large effect size with a non-significant main effect would imply that the effect may reach significance with the testing of a larger sample of participants.

Overall, in cases where the main effects were shown to be non-significant (i.e. there was no significant difference between the two sign types, experience levels, traffic flows, or lanes), there were no instances of an effect size greater than 0.1. Importantly, for the principal independent variable under test (sign type; the difference in performance on roads with existing Chapter 8 and revised signs), there were no non-significant effect sizes greater than 0.78. This suggests that with a sample size of 40 participants, there is little evidence of near significant effects that would be shown to be significant with a small increase in sample size. The evidence suggests that the sample size selected based on a pre-study power analysis was sufficient to observe significant differences between conditions where they existed.

Effect sizes for analyses of mean speed (main effects only). Significant main effects are highlighted in green.

Scenario	Sign	Main effect			
		Sign	Experience	Traffic Flow	Lane
Contraflow	P7230 200yds	0.004	0.047	0.253	0.381
	P7230	0.001	0.038	0.339	0.461
	P7212 200yds	0.046	0.066	0.305	0.521
	P7212	0.001	0.128	0.283	0.511
	P7210	0.001	0.083	0.304	0.683
	P7231 200yds	0.001	0.054	0.355	0.684
	P7231	0.006	0.008	0.355	0.672
	P7237 200yds	0.009	0.029	0.055	0.836
	P7237	0.015	0.005	0.030	0.883
	P7216 200yds	0.023	0.003	0.006	0.723
P7216	0.001	0.003	0.001	0.246	
Narrow Lanes	P7235	0.031	0.135	0.001	N/A

Effect sizes for analyses of speed variance (main effects only). Significant main effects are highlighted in green.

Scenario	Sign	Main effect			
		Sign	Experience	Traffic Flow	Lane
Contraflow	P7230 200yds	0.007	0.001	0.269	0.016
	P7230	0.045	0.001	0.297	0.001
	P7212 200yds	0.007	0.022	0.266	0.141
	P7212	0.007	0.001	0.195	0.065
	P7210	0.004	0.023	0.330	0.255
	P7231 200yds	0.001	0.033	0.277	0.136
	P7231	0.001	0.071	0.365	0.261
	P7237 200yds	0.004	0.041	0.001	0.089
	P7237	0.003	0.086	0.014	0.043
	P7216 200yds	0.022	0.033	0.011	0.255
P7216	0.026	0.063	0.029	0.038	
Narrow Lanes	P7235	0.052	0.017	0.085	N/A

Effect sizes for analyses of percent road centre (main effects only). Significant main effects are highlighted in green.

Scenario	Sign	Main effect			
		Sign	Experience	Traffic Flow	Lane
Contraflow	P7230 200yds	0.069	0.014	0.070	0.015
	P7230	0.056	0.020	0.026	0.302
	P7212 200yds	0.025	0.005	0.001	0.577
	P7212	0.006	0.004	0.006	0.014
	P7210	0.078	0.016	0.03	0.486
	P7231 200yds	0.006	0.001	0.019	0.315
	P7231	0.006	0.066	0.009	0.058
	P7237 200yds	0.008	0.042	0.001	0.307
	P7237	0.040	0.028	0.120	0.121
	P7216 200yds	0.044	0.131	0.003	0.258
P7216	0.046	0.046	0.013	0.158	
Narrow Lanes	P7235	0.037	0.062	0.036	N/A

Effect sizes for analyses of percent road left (main effects only). Significant main effects are highlighted in green.

Scenario	Sign	Main effect			
		Sign	Experience	Traffic Flow	Lane
Contraflow	P7230 200yds	0.012	0.055	0.008	0.013
	P7230	0.007	0.050	0.095	0.211
	P7212 200yds	0.003	0.040	0.045	0.465
	P7212	0.052	0.038	0.001	0.157
	P7210	0.008	0.014	0.093	0.103
	P7231 200yds	0.008	0.047	0.019	0.043
	P7231	0.010	0.085	0.010	0.171
	P7237 200yds	0.003	0.044	0.046	0.059
	P7237	0.055	0.058	0.097	0.009
	P7216 200yds	0.005	0.142	0.006	0.412
P7216	0.219	0.158	0.007	0.240	
Narrow Lanes	P7235	0.028	0.102	0.001	N/A

Effect sizes for analyses of percent road right (main effects only). Significant main effects are highlighted in green.

Scenario	Sign	Main effect			
		Sign	Experience	Traffic Flow	Lane
Contraflow	P7230 200yds	0.032	0.004	0.070	0.079
	P7230	0.003	0.003	0.078	0.077
	P7212 200yds	0.004	0.001	0.003	0.304
	P7212	0.001	0.002	0.002	0.037
	P7210	0.021	0.001	0.060	0.258
	P7231 200yds	0.019	0.004	0.019	0.069
	P7231	0.017	0.003	0.001	0.065
	P7237 200yds	0.001	0.003	0.043	0.086
	P7237	0.005	0.010	0.001	0.135
	P7216 200yds	0.017	0.005	0.007	0.353
	P7216	0.014	0.003	0.005	0.599
Narrow Lanes	P7235	0.008	0.014	0.071	N/A

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