



CLIENT PROJECT REPORT CPR1351

Future Managed Motorways Concept Development

Task 2: Design Assurance Simulator Study

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Executive Summary

This report describes the findings of a driving simulator trial conducted by TRL for the Highways Agency entitled *Future Managed Motorways Concept Task 2: Design Assurance Simulator Study*. It is the second of two simulator trials conducted to support the design advice provided in IAN161/12 *Managed Motorways Requirements – All Lanes Running*. These trials aim to provide intelligence regarding the safety and legality of the generic Managed Motorways (MM) All Lanes Running (ALR) design and concept of operations by investigating driving behaviour in a simulated environment.

Task 1 and the work carried out in the TRL's previous programme of work, have looked at different design elements of the future MM concept in isolation (e.g. the spacing of information update points and the comprehensibility of MS4 messages). Task 2 takes all of these elements together and presents a 'full' MM-ALR environment for study.

The MM-ALR environment differs from a standard motorway environment in that it has four permanent lanes with no hard shoulder, it has emergency refuge areas (ERAs), variable mandatory speed limits and supporting messages displayed on a combination of gantry mounted indicators and verge-mounted variable message signs. The purpose of Task 2 was to provide assurance that this environment is acceptable to road users and that adequate guidance is provided. To do this it was necessary to investigate what effect the approach had on driver perception, experience and behaviour.

This was achieved by conducting a driving simulator study to enable participants to drive in simulated future MM conditions, as well as 'control' routes for comparison. The study analysed a sample the general driving population which consisted of 96 participants, evenly split between males and females with a broad distribution of age ranges (mean = 40.9, range = 17 to 68). Each participant completed three drives in the simulator which encompassed driving in a range of MM environments.

In previous studies, the traffic situation has been designed to allow participants to choose their preferred speed and lane to see how they are affected by the infrastructure without the influence of other traffic. In Task 2, participants experienced busy traffic conditions that are more representative of those that may be experienced on a MM during peak hours.

Driver experience and perception were investigated through situational awareness questions asked to participants during each simulator drive and through questionnaires completed after each drive. Driver behaviour was investigated using the recorded data from each simulator drive and by observing the actions taken by the participants in the context of the motorway environment presented.

The results of the study indicate that:

- Participants were aware of the speed limit in the MM-ALR environment and awareness is increased if the speed limit is repeated.
- Participants were aware that there were four lanes available for traffic to drive in, i.e. that Lane 1 is not a hard shoulder.
- Participants were aware of the destination of the next junction after passing the 1 mile ADS sign in the MM-ALR environment irrespective of the design option.
- Participants in an MM-ALR environment were more likely to consider an ERA as the location to stop in the event of breakdown than any other option.

- Subjectively, participants found the verge-mounted signs to be clearer than the overhead signs but that both provide sufficient information. However, verge-mounted signs caused more stress due to possible obscuration than overhead signs.
- Participants experienced similar feelings of safety, comfort, stress and confidence when comparing MM-ALR with a 'standard' 3-lane + hard shoulder configuration.
- Participants reported believing that they would be more likely to be caught if speeding in an MM-ALR environment than in the typical motorway environment, believed to be due primarily to the presence of gantries in the MM-ALR environment and a perception that these are associated with enforcement.
- There were only two (out of 97) minor occurrences of hard shoulder non-compliance, both due merge-overflow in the MM-DHS section following the MM-ALR section. All participants undertaking the situational awareness assessment correctly identified that there were only three lanes available in the sections following the MM-ALR section.
- Participants rated a text-based (Stop Road Closed) sign as clearest, followed by a wicket, followed by a red X for signalling a full motorway closure using an MS4 matrix display.

These findings help to provide assurance that, in general, the information provided within a scheme designed to the specification provided in IAN161/12 will be appropriate for road users to understand how they are expected to behave under normal operation in busy traffic conditions.

1 Introduction

1.1 Background

Over the past two years, the Highways Agency (HA) have been investigating where additional savings can be made to the Spending Review 2010 programme, whilst continuing to meet the Agency's safety objective. This has resulted in a new approach to the design of Managed Motorways (MM) schemes known as 'Managed Motorways – All Lanes Running' (MM-ALR). This approach has received approval from the Secretary of State to proceed with development work and implementation, and in March 2012 the HA issued new design guidance for MM schemes in the form of *Interim Advice Note 161/12 Managed Motorways Requirements – All Lanes Running* (IAN161/12). The MM-ALR Concept of Operations document (an accompanying document to IAN161/12) presents the following case for evolving the MM design:

Evaluation of the M42 pilot demonstrated that managed motorways are able to deliver clear benefits in terms of: improved journey time reliability through reduced congestion; at lower cost and with less environmental impact than conventional widening programmes; and without negatively impacting the safety performance. The subsequent programme to roll-out managed motorways with dynamic hard shoulders designed to IAN 111/09 has delivered similar benefits to conventional road widening programmes, but at significantly lower cost. Experience from these schemes suggests that there is scope to further reduce both the capital and operating costs, whilst continuing to meet the congestion and safety objectives.¹

TRL have supported the HA in the development of the MM-ALR concept initially through a series of six tasks conducted between November 2010 and March 2011 which investigated several of the design features to be included in the proposed future MM design.² Two of these tasks made use of TRL's driving simulator, a tool which has been used extensively to support the development of MM design and operation for several years.

In December 2011 TRL were commissioned to carry out three further tasks to provide intelligence regarding the safety and legality of the generic design and concept of operations by investigating driving behaviour in a simulated MM-ALR environment. The *Design Assurance Simulator Study* is the second of these tasks.

1.2 Task 2: Design Assurance Simulator Study

Task 2 of the Future MM Concept Development project is to conduct a study using TRL's driving simulator to provide assurance of the MM-ALR design approach laid out in IAN161/12.

Task 1 and the work carried out in the TRL's previous programme of work, have looked at different design elements of the future MM concept in isolation (e.g. the spacing of

¹ http://www.dft.gov.uk/ha/standards/tech_info/files/MM-ALR_Concept_of_Operations_v1_0.pdf

² CPR1602 TRL MM2 Tasks 2, 3, 4 and 5 Key Findings Report

³ CPR1335 TRL Future MM Concept Task 1 Final Report

⁴ Diels, Robbins and Reed (in press) Behavioural validation of the TRL driving simulator DigiCar: Phase 1 – Speed Choice, in *Proceedings of the International Conference on Driver Behaviour and Training*. 29-30
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information update points and the comprehensibility of MS4 messages). Task 2 takes all of these elements together and presents a 'full' MM-ALR environment for study.

The MM-ALR environment differs from a standard motorway environment in that it has four permanent lanes with no hard shoulder, it has emergency refuge areas (ERAs), variable mandatory speed limits and supporting messages displayed on a combination of gantry mounted indicators and verge-mounted variable message signs. The purpose of Task 2 was to provide assurance that this environment is acceptable to road users and that adequate guidance is provided. To do this it was necessary to investigate what effect the approach had on driver perception, experience and behaviour.

This was achieved by conducting a driving simulator study to enable participants to drive in simulated future MM conditions, as well as 'control' routes for comparison.

In previous studies, the traffic situation has been designed to allow participants to choose their preferred speed and lane to see how they are affected by the infrastructure without the influence of other traffic. In Task 2, participants experienced busy traffic conditions that are more representative of those that may be experienced on a MM during peak hours.

Driver experience and perception were investigated through situational awareness questions asked to participants during each simulator drive and through questionnaires completed after each drive. Driver behaviour was investigated using the recorded data from each simulator drive and by observing the actions taken by the participants in the context of the motorway environment presented.

2 Task objectives

The objective of this task was to help answer the following questions in relation to the MM-ALR design:

1. Is the guidance provided adequate for drivers to be aware of the relevant information?
2. Is the guidance provided adequate for drivers to respond to the information in the desired manner?
3. Is the driving experience comfortable and intuitive, and perceived as safe?
4. Does the MM-ALR environment affect behaviour in subsequent environments?

Regarding questions 1 and 2, the information of which drivers must be aware and to which they must respond can be defined as:

- *The speed limit* – In MM schemes, variable mandatory speed limits can be set manually for incidents and roadworks as well as automatically for congestion management or queue protection. Task 1 of this project investigated driver response to manually set signals³. Task 2 focused on speed limits set automatically.
- *The lanes that are open/closed to traffic* – The technology within a MM environment allows operators to dynamically open and close lanes. Driver response to lane closures was investigated in Task 1. Task 2 focused on lane availability under normal operation, particularly concerning driver awareness and response to Lane 1.
- *Where and how to stop in the event of a breakdown* – Task 1 investigated participants' response to a simulated breakdown on the approach to an ERA in a MM-ALR environment. Task 2 focused on drivers understanding of emergency stopping provision at different points in an MM-ALR environment, and their response to a simulated breakdown on the approach to a junction.
- *Where the next diverge (off-slip) is and where it is for* – IAN161/12 suggests two options for providing Advanced Direction Signs (ADS), either verge-mounted or gantry- and cantilever-mounted. Task 2 investigates driver response to both of these options.

In addition to the above, questions were also asked of participants' preference for how a full motorway closure should be presented on an MS4, and to determine the usefulness of a leaflet produced to help educate drivers on how to respond in an emergency breakdown scenario in an MM-ALR environment. These therefore provide two further objectives:

- Determine which of three designs for a full-closure MS4 sign is preferred
- Identify if participants correctly understand the instructional leaflet, and report back on potential improvements.

³ CPR1335 TRL Future MM Concept Task 1 Final Report

3 TRL's Driving Simulator

TRL's car driving simulator, DigiCar (see Figure 1), provides an immersive user experience and enables assessment of driver behaviour through a range of simulated experiences and events. Drivers are required to travel through a route representing a stretch of motorway on the network, including junctions and links. DigiCar drivers experience a wraparound forward field of view and fully functional rear view mirrors. Not only is the external environment modelled to the highest detail, the internal vehicle cabin is also as realistic as possible, consisting of a complete Honda Civic, with all controls exactly as those you would find on a road going vehicle. DigiCar utilises a three axis motion system (heave, pitch and roll) to provide drivers with representative forces of vehicle acceleration, braking and turning. Validation studies comparing driver performance in DigiCar and on real roads have shown acceleration and braking performance in the two driving environments to be nearly identical (see Diels, Reed and Robbins, 2011⁴).



Figure 1 - TRL Driving Simulator, DigiCar

TRL has a comprehensive database of more than 1,500 trial participants from the local area. Previous work has investigated numerous issues for the Highways Agency in relation to network management. This includes a series of trials for the Support to Managed Motorways project, which investigated driver behaviour in response to changes to the network brought about through dynamic use of the hard shoulder and through-junction running. Simulator trials were also run to investigate the use of Emergency Refuge Areas and dedicated lane schemes. This research contributed to an understanding of the levels of safety and intuitiveness of proposed designs for MM schemes.

The driving simulator requires the development of visual environment databases and traffic scenarios. Sub-contractors are utilised to support the creation of these environments.

⁴ Diels, Robbins and Reed (in press) Behavioural validation of the TRL driving simulator DigiCar: Phase 1 – Speed Choice, in *Proceedings of the International Conference on Driver Behaviour and Training*. 29-30 November, 2011, Paris,

4 Methodology

Members of the driving public completed three drives in the TRL simulator, with the aim of analysing participant driving behaviour and subjective perceptions in response to the drives. Participants drove three of the four routes described in Section 4.2.

4.1 Participant Sample

A sample of 96 participants, selected from the TRL participant database was used for this trial, with equal numbers of males and females. In some instances, TRL staff not involved with the design of the trial or of any similar trials, were used. Participants selected had not participated in the Task 1: Design Comparison trial. Participant experience of MM or CM schemes was not considered as a recruitment criterion due to the increasing prevalence of schemes and proximity of the M25 CM scheme to TRL, making such a filtering as impractical.

4.1.1 Age

Participants were assigned to one of three age groups for this study. The younger driver group was defined as those aged 17-24 years; the middle driver group was defined as those aged 25-64 years, and the older driver group defined as those aged 65+ years. Previous simulator studies have shown that younger drivers tend to make better use of and show a better understanding of MM schemes, but are also more likely to disregard traffic regulations.. The numbers of participants recruited from each age group were roughly representative of the general driving population (see Table 1).

Table 1: Number of participants by age and gender

Age group	Gender	Number of participants
Older (65+)	Male	8
	Female	2
Middle (25-64years)	Male	28
	Female	34
Younger (17-24years)	Male	12
	Female	11

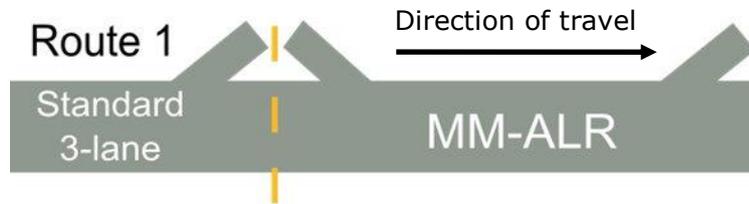
4.2 Route Design

The study utilised four different simulated routes:

- Route 1 – Managed Motorway-All Lanes Running (MM-ALR)
- Route 2 – Standard 3-lane Motorway
- Route 3 – MM-ALR to Managed Motorway-Dynamic Hard Shoulder (MM-DHS)
- Route 4 – MM-ALR to 3-lane Controlled Motorways (CM)

These routes are described below. Appendix B contains a full design specification for each of the routes.

Route 1 – MM-ALR



Route 1 was a 10km stretch of motorway with two junctions. It consisted of a 2km 'lead-in' section followed by an 8km MM-ALR section.

The lead-in section was a standard 3-lane motorway. See the description of Route 2 for further details.

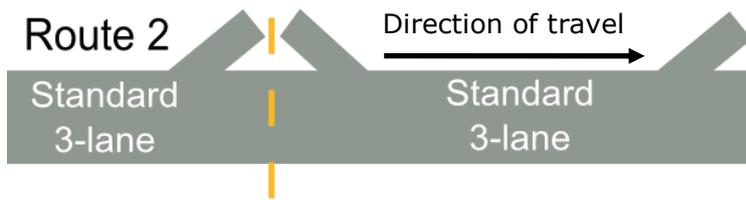
The MM-ALR section reflected the generic MM-ALR design specified in IAN161/12, i.e:

- Four permanent running lanes and no hard shoulder;
- Three ERAs. There was a maximum distance of 2.5km between 'refuges', whether that be an ERA or an off-slip;
- Two 'gateway' gantries situated at the start of the link and the mid-point of the link;
- Verge-mounted MS4s situated at regular intervals between gantries. The spacing of these was at the maximum distance permissible given the forward visibility requirements specified in IAN161/12. The information displayed on the technology throughout the route was representative of what it would be under busy traffic conditions, with 60 and 50mph signals set due to high traffic flows and queue protection 40mph signals set responding to stop-start traffic. Accompanying messages and pictograms were also displayed;
- Enforcement camera signs at all gantries and MS4s;
- Fixed, blue 'variable speed limit' signs located within the first junction and at the top of the first merging slip road;
- Either verge-mounted or gantry- and cantilever-mounted ADS (see table 2). IAN161/12 present two options for displaying ADS in MM-ALR schemes. Hence, two Route 1 designs were used, presenting each of the two ADS options illustrated in Table 1. Half of the participants drove Route 1 Option 1 and the other half drove Route 1 Option 2.

Table 2: ADS Options in Route 1

	Option 1	Option 2
1 mile to junction		
1/2 mile to junction		
Final ADS		

Route 2 – Standard 3-lane Motorway

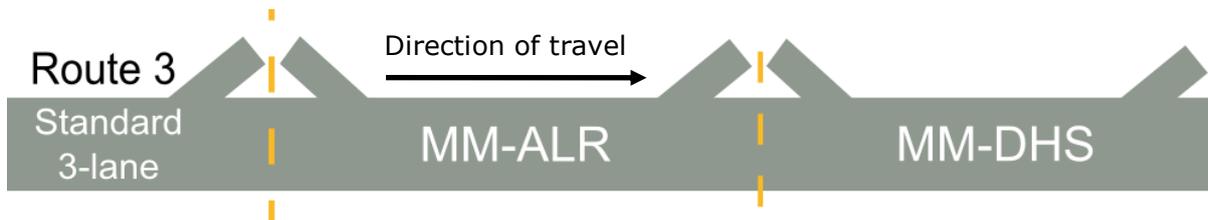


Route 2 was a 10km stretch of motorway with two junctions. It consisted of a 2km 'lead-in' section identical to that of Route 1 followed by an 8km section used to observe driving behaviours in on a 'standard' motorway link to support the assessment measures used in Route 1.

Both sections of Route 2 reflected a standard 3-lane motorway environment, i.e:

- Three permanent running lanes and a permanently closed hard shoulder;
- No technology gantries, MS4s or enforcement equipment.
- No emergency refuge areas;
- Emergency telephone signs situated in between gantry spacings, with one roughly every other gantry.
- Verge-mounted ADS.

Route 3 – MM-ALR to MM-Dynamic Hard Shoulder



Route 3 was a 20km stretch of motorway with three junctions. It consisted of a lead-in section and an MM-ALR section identical to that of Route 1 (except for the ADS illustrated in Table 3), followed by a MM-Dynamic Hard Shoulder (MM-DHS) section.

The MM-DHS section reflected the generic MM-DHS design specified in IAN111/09, i.e:

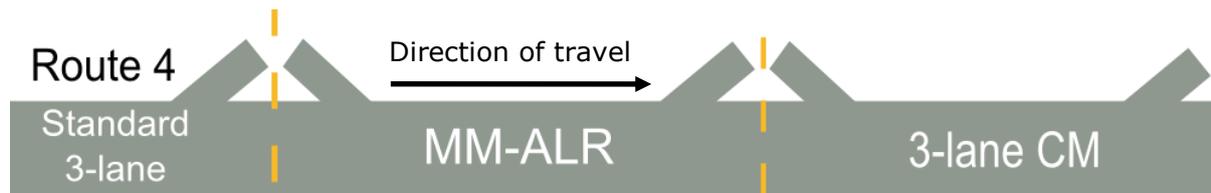
- Three permanent running lanes and a dynamic hard shoulder (closed to traffic for the whole link);
- Technology gantries fully equipped with four AMIs and an MS4 situated at 800m intervals. Each gantry displayed a 60mph speed limit with a Red X over the hard shoulder;
- Emergency refuge areas situated after every second or third gantry;
- Enforcement camera signs at all gantries;
- Verge-mounted ADS.

As with Route 1, two options for Route 3 were used in the MM-ALR section, presenting each of the two ADS options illustrated in Table 3. Because the junction following the MM-ALR section was a lane-drop junction, a different style of ADS is required than in Route 1 where four lanes continued through the junction. Half of the participants driving Route 3 drove Route 3 Option 1 and the other half drove Route 3 Option 2 (see table 3).

Table 3: ADS options in Routes 3 and 4

	Option 1	Option 2
1 mile to junction		
1/2 mile to junction		
Final ADS		

Route 4 – MM-ALR to Controlled Motorways



Route 4 was a 20km stretch of motorway with three junctions. It consisted of a lead-in section and an MM-ALR section identical to that of Route1 (except for the ADS illustrated in Table 2), followed by a Controlled Motorways (CM) section in 'all-off' mode.

The CM section reflected a typical CM environment, i.e:

- Three permanent running lanes and a permanently closed hard shoulder;
- No emergency refuge areas;
- Emergency telephone signs situated in between gantry spacings, with one roughly every other gantry.
- Verge-mounted ADS.
- Technology gantries fully equipped with three AMIs and an MS4 situated at 1000m intervals. All of the AMIs and MS4s were blank;
- Enforcement camera signs at all gantries;

The MM-ALR section in Route 4 was identical to that of Route 3 and, hence, the same two ADS options were presented as in Table 3. Half of the participants driving Route 4 drove Route 4 Option 1 and the other half drove Route 4 Option 2.

4.2.1 Lane designation

As just described, the MM-ALR sections within the routes had four permanent running lanes while all the other sections had three running lanes and a hard shoulder. Within this report the lanes on all sections will be referred to as Lanes 1 to 4, where Lane 4 is nearest to the central reserve and Lane 1 is nearest to the verge. Lane 1 will be a running lane in the MM-ALR sections and hard shoulder in all other environments.

All the lanes were 3.65m wide in all of the routes.

4.3 Simulated Traffic and Scenarios

The purpose of this trial was to examine driver experience and perception of the generic MM-ALR environment under 'normal' peak hour conditions. This would be the period in which variable mandatory speed limits will be regularly utilised and in which the majority of users would be using the scheme. Therefore, simulated traffic on all routes was designed to replicate peak hour driving conditions on a busy section of the motorway network.

To allow comparison between routes the traffic conditions were generally the same on all routes, although a slightly different speed profile was used for simulated traffic in Routes 1 and 2 than was used in Routes 3 and 4. Traffic conditions in all routes could be described as follows:

- When participants passed the first junction traffic became dense. This was still relatively free-flowing but lane changing would not be easy. Average speed was around 55mph with slightly slower vehicle speeds in Lanes 1 and 2 than in Lanes 3 and 4.
- Around the middle of the link, the traffic was programmed to simulate flow breakdown caused by the density of the traffic. This twice caused participants to have to come to a stop then start again. There was generally a short distance of less dense traffic following the flow breakdown area.
- Following this area, the traffic returned to dense but relatively free-flowing conditions. Routes 1 and 2 then came to an end at the next junction. In MM-DHS link of Route 3 the traffic remained dense to provide an incentive to exhibit non-compliance in regards to the hard shoulder. For the Controlled Motorway link in Route 4, traffic was of a medium density to be consistent with the conditions that would be expected in 'all-off' mode.

Table 4 provides a summary of the traffic conditions throughout the drives.

Table 4: Traffic conditions on Routes 1 to 4

	Approximate distance from the start of the drive					
	0-2km	2-5km	5-8km	8-10km	10-20km	
					Route 3	Route 4
Traffic conditions	Free flowing	Dense	Stop-Start	Dense	Dense	Medium density
Approximate average speed	70mph	55mph	30mph	40mph	55mph	55mph

The first 10km of Routes 1, 3 and 4 were the same. The speeds and density were the same in Route 2 but as only three lanes were available then a lower number of simulated vehicles were present overall.

The vehicle mix on all routes consisted of a relatively high proportion (20-25%) of HGVs located in Lanes 1 and 2 to increase the risk of obscuration.

4.3.1.1 Emergency Breakdown Scenario

Half of the participants (48), as they approached the end of the MM-ALR section in either Route 3 or Route 4, were informed that a fault had occurred with their vehicle and they should bring the vehicle to a halt. This was to provide an indication as to how drivers may react in a future MM environment in the event of a breakdown when no hard shoulder is provided and an off-slip is nearby. This was not the junction for the participants’ target destination. These 48 participants were also asked to complete an additional questionnaire related to their experiences of the breakdown scenario.

4.4 Experimental Groups

Each participant completed three drives in the simulator: Route 1, Route 2 and one of Route 3 or 4.

The design of the trial required that different sub-groups of the participant sample drove in different variations of the routes. These variables were as follows:

- Whether the participant drove in Route 3 or Route 4 on their 3rd drive;
- Whether the ADS in the MM-ALR sections was displayed in line with Option 1 or Option 2 (see Table 2 and Table 3);
- Whether or not the in-car situational awareness was carried out (see Section 4.5.3.1);
- Whether or not the participant experienced a vehicle breakdown during their 3rd drive (see Section 4.3.1.1).

As such the participant sample was split into 16 groups of six, as shown in Table 5. Within each group of six, a place was assigned to a participant from each of the six demographic categories (male/female, young/middle/old).

Table 5 - Trial participant groupings and associated experimental conditions

Group	Number of participants (total 96)	Drive 3	ADS option	Breakdown	In-car situational awareness
1	6	Route 3	1	Yes	Yes
2	6	Route 4			
3	6	Route 3	2		
4	6	Route 4			
5	6	Route 3	1	No	
6	6	Route 4			
7	6	Route 3	2		
8	6	Route 4			
9	6	Route 3	1	Yes	No
10	6	Route 4			
11	6	Route 3	2		
12	6	Route 4			
13	6	Route 3	1	No	
14	6	Route 4			
15	6	Route 3	2		
16	6	Route 4			

Ordering effects for Route 1 and Route 2 were balanced as far as possible, however the need to keep group size to a minimum of six prevented full counterbalancing; this resulted in those participants experiencing a breakdown scenario undertaking Route 2 first, and those not experiencing a breakdown undertaking Route 1 first. Order effects between Routes 1 & 2 and Routes 3 & 4 were not considered to be an issue as they were not to be directly compared, and so all participants undertook either Route 3 or route 4 in their third drive. Table 5 presents the participant allocation by group.

4.5 Study Protocol

4.5.1 Participant Recruitment

Participants were selected from from the TRL database of around 1,500 volunteers comprising members of the public who had (at least) previously attended a familiarisation session in the simulator and so were comfortable with its operation and driving in a simulated environment. A small number of TRL staff also took part in the trial. As described in Section 4.1, participants recruited for this trial had not previously participated in trials relating to MM.

Participants were contacted over the phone and, if they were willing and able to participate in the trial, were sent an information pack including a confirmation letter. Participants were given a brief description of the study but were not provided with details regarding the research objectives to ensure that their behaviour was not influenced by such information when undertaking the trial.

Of the 96 participants recruited to take part in the trail, 95 successfully did so and their data were included in analyses.

Only one participant excluded from all analyses due to driving at extremely high speed, nearly always in Lane 1, regardless of other traffic, and often passed though modelled traffic. This participant exhibited grossly atypical driving behaviour when compared to other participants, including those in other studies, therefore their data was removed.

Participant age, experience, gender, and vehicle types driven were recorded and are displayed in Table 6. One driver had only just passed their driving test, and one participant reported driving 0 miles each year. Most drivers had a good deal of experience (22.3 years licence held) and drove around 9000 miles per annum.

Table 6: Description of participant demographics

	Age	Years licence held	Annual Mileage
Minimum	17	0	0
Maximum	68	50	25000
Mean	40.9	22.3	9073.9
Standard Dev.	17.9	17.2	5230.3

From these data we can draw a picture of our sample as being broadly similar to the general population, lending weight to any generalisations of following results to drivers in general.

The participants were scheduled to optimise efficient utilisation of the driving simulator, allowing four to six participants to be trialled per day.

Appendix A provides an overview of TRL’s policy relating to ethical integrity and data protection for research projects involving members of the public.

4.5.2 Trial Procedure

Table 7 provides an overview of the trial procedure for each participant.

Table 7: Overview of the trial procedure

Task	Approximate time taken
Initial Briefing	5 mins
Familiarisation Drive	10 mins
Route 1 or Route 2	10-15 mins
Post-Drive Questionnaire	10 mins
Route 1 or Route 2	10-15 mins
Post-Drive Questionnaire	10 mins
Route 3 or Route 4	15-20 mins
Post-Drive Questionnaire	20-25 mins

On the trial day, after an initial briefing, participants were asked to drive a short stretch of motorway in the simulator which allowed them to re-familiarise with the controls of the vehicle and to settle down to normal behaviour in the simulated environment. This took approximately 10 minutes.

The experimental design required each participant to drive on three test routes. Routes 1 and 2 lasted around 15 minutes each; Routes 3 and 4 took 25-30 minutes each. Participants were asked to complete some short supporting assessment tasks between drives (see Section 4.5.3). Each participant session lasted approximately 2 hours, including introduction, familiarisation and debriefing.

Before the start of each drive, all participants were instructed from beside the car to drive as they normally would. They were told that they should not drive as if they were on their driving test nor as if they were playing a computer game. They would not be judged so they should not feel anxious as TRL needed them to drive as they normally would in the real world. They were additionally instructed to “drive as if late for an important meeting.” Previous TRL studies have shown that this instruction is effective at motivating participants to make good progress.

At the start of each drive, participants were also asked to leave the motorway at the junction for Greenhill. The location of the Greenhill junction depending on whether the participant was driving in Routes 1 and 2 or Routes 3 and 4, as shown in Table 8.

Table 8: Junction destinations

	1 st Junction	2 nd Junction	3 rd Junction
Route 1	J12, Millwood	J11, Greenhill	n/a
Route 2	J12, Millwood	J11, Greenhill	n/a
Route 3	J13, Millwood	J12, Rookmaine	J11, Greenhill
Route 4	J13, Millwood	J12, Rookmaine	J11, Greenhill

Upon leaving at the junction, the participant was asked to stop the vehicle and the drive came to an end. If the participant did not leave at the allocated junction they were asked to pull on to a hard shoulder situated within the junction.

4.5.3 Supporting Assessment

4.5.3.1 Situational Awareness Assessment

For participants in Groups 1-8, an in-car situational awareness assessment was conducted in all of their drives. From the control room, the researcher asked a total of seven questions about the driving situation at prescribed locations within the test route. These questions related to features of which the driver should have been aware in fulfilling the driving task (e.g. How many lanes are open? What is the speed limit? Where would be a safe place to stop in a vehicle emergency?) It was anticipated that this would give a strong set of data about the participants’ understanding and awareness of guidance as they drive the route.

Before commencing the trial, it was anticipated that the in-car situational awareness assessment could affect driver behaviour and, hence, it was only used with half of the participants so that the two groups could be analysed separately if needed. After the trial, analysis was carried out on the differences in behaviour between the two groups, including speed profiles, compliance with junction information, utilisation of Lane 1 and response to the emergency breakdown scenario. From this analysis, we found no evidence to suggest that the situational awareness assessment had caused any significant effects on driver behaviour such that the two groups should be analysed separately.

4.5.3.2 Post-drive Questionnaire: Drives 1 and 2

Following the completion of Drive 1 and again of Drive 2, all participants were asked to complete a questionnaire to measure their experience and perception of the preceding drive. This included questions to assess their perceived level of risk, safety, difficulty and confidence whilst driving the route, and questions to investigate their subjective

response to the drive and their awareness and perception of information provision within the drive.

4.5.3.3 Post-drive Questionnaire: Drive 3

Following the completion of Drive 3, participants were required to fill out a questionnaire that investigated their experience of the transition between the two different motorway environments, as well as general attitudes towards on-road driver information provision in a future MM environment. Additional questions were also included relating to participant preference for signs informing of approaching junctions, and further questions relating to participant preference for signs indicating a full-motorway closure.

4.5.3.4 Emergency Breakdown Scenario

The 48 participants who experienced a breakdown were also asked to complete an additional questionnaire related to their experiences of the breakdown scenario.

4.6 Data Analysis

Data was collected were analysed using tests of statistical significance. For all statistical tests an alpha level of .05 was selected as the threshold for statistical significance (in other words, only results in which we could be at least 95% confident were accepted as significant). Where possible, parametric tests were performed, however, most data were not normally distributed; for all such data appropriate non-parametric tests were performed.

5 Key findings

This section presents the key findings of the study in relation to the four questions posed in Section 2. Specifically:

- Section 5.1 presents findings which aim to help answer - is the guidance provided in MM-ALR schemes adequate for drivers to be aware of the relevant information?
- Section 5.2 presents findings which aim to help answer - is the guidance provided in MM-ALR schemes adequate for drivers to respond to the information in the desired manner?
- Section 5.3 presents findings which aim to help answer - is the driving experience in MM-ALR schemes comfortable and intuitive, and perceived as safe?
- Section 5.4 presents findings which aim to help answer - does the MM-ALR environment affect behaviour in subsequent environments?
- Section 5.5 presents findings which support the two additional objectives listed in Section .

5.1 Awareness of information

The findings of this section address the task objective to answer the following question relating to an MM-ALR environment:

Is the guidance provided adequate for drivers to be aware of the relevant information?

The guidance provided is split into four categories:

- The speed limit;
- The lanes that are open to traffic;
- Distance to the next exit and the location it is for
- Where and how to stop in the event of a breakdown;

In this section, each of these types of information is explored in turn in and assessed against the key question above.

Schematic 'snapshots' of the simulated routes are presented in this section to provide context. For the full route specifications see Appendix B.

5.1.1 Awareness of speed limits

Participants' awareness of the speed limit within an MM-ALR environment was measured through the situational awareness assessment (described in Section 4.5.3.1) in which they were asked the following question just after passing a verge-mounted MS4 displaying a speed limit:

"What is the speed limit?"

This was asked both in Route 1, the MM-ALR section, and in the MM-ALR sections of Routes 3 and 4, approximately 300m after passing an MS4 displaying a speed limit. Figure 2 illustrates the location on each of these routes that the question was asked.

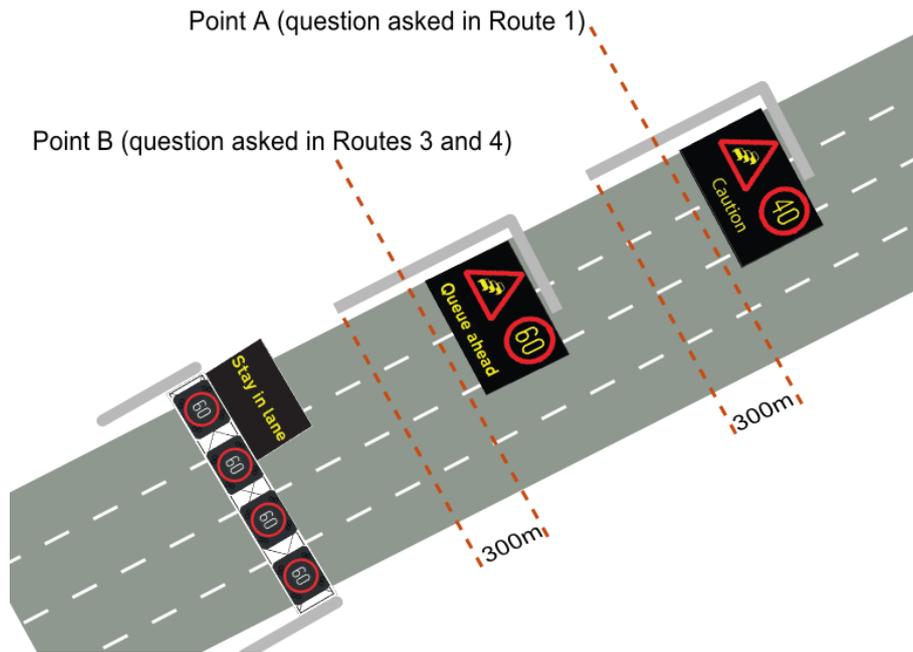


Figure 2: Locations in MM-ALR sections where the speed limit question was asked

Table 9 summarises the responses given by participants at Point A and Point B. Also provided is a summary of responses to the same question asked in the MM-DHS section of Route 3 (Point C). When asked, participants in the MM-DHS section would have passed three consecutive gantries at closer spacing than MM-ALR, approximately 800m apart, all displaying 60mph speed limits. Participants are also asked how confident they were of their answer on a scale of 1-10.

Table 9: Response to question regarding the speed limit

	No. of participants	Correct response	Percentage correct	Mean confidence in answer	Most frequent incorrect response
Point A	48	40mph	75%	9.0	60mph (19%, 7.7 confidence)
Point B	46	60mph	91%	8.8	50mph (6%, 5.0 confidence)
Point C	23	60mph	87%	9.2	50mph (13%, 9.3 confidence)

The majority of participants answered this question correctly, with a high degree of confidence in their answer. Fewer participants answered correctly at Point A, when they had only passed the 40mph speed limit once, than Point B when they had passed three consecutive 60mph speed limits.

The following characteristics were observed of the group that incorrectly answered at Point A:

- The average speed of these participants at Point A was 50.1mph, 2.5mph higher than the average for all participants at this point (47.6mph).
- Half (six) of these participants were driving in Lane 2 at Point A, five were in Lane 3 and one was in Lane 4.
- The mean response to the post-drive question regarding the sufficiency of speed limit information was 7.5. The overall mean was 8.8.

The three participants who incorrectly answered at Point C suggests that some participants were not aware of the speed limits in the MM-DHS link despite the greater frequency of speed limits and that speed limits were all gantry-mounted. In the post-drive questionnaire, two of these participants stated that the speed limit had been 60mph throughout this section, while one claimed to not have been aware of any variable speed limits present on the section.

Additional to the situational awareness assessment, some participants made comments relating to awareness of speed limits when given the opportunity to provide general comments following Route 1. These are presented in Table 10.

Table 10: General comments relating to awareness of the speed limit

Comment
"Hard to keep track of variable speed limit because it kept changing."
"Much better signs. Speed cameras are always a good deterrent for speeding. Average speed check are even better."
"Everything really clearly displayed."
"Would like to have been reminded that it was still 40 at more regular intervals."
"I felt a lot happier knowing what the speed limit was and when other drivers were likely to slow down/speed up."
"No lines for cameras so pretty unlikely to get caught speeding."

The findings suggest that most participants were aware of the speed limit in the MM-ALR environment and awareness is increased if the speed limit is repeated. The fact that, even in an MM-DHS environment, a small number of participants were unable to correctly identify the speed limit suggests that any lack of awareness is not necessarily associated with the particulars of the MM-ALR design.

5.1.2 Awareness of available lanes

Participants’ awareness of how many lanes were available to traffic in an MM-ALR environment was measured through the situational awareness assessment in which they were asked the following question:

"How many lanes are open to traffic?"

This was asked both in Route 1 and in the MM-ALR section of Routes 3 and 4. Figure 3 illustrates the location on each of these routes that the question was asked.

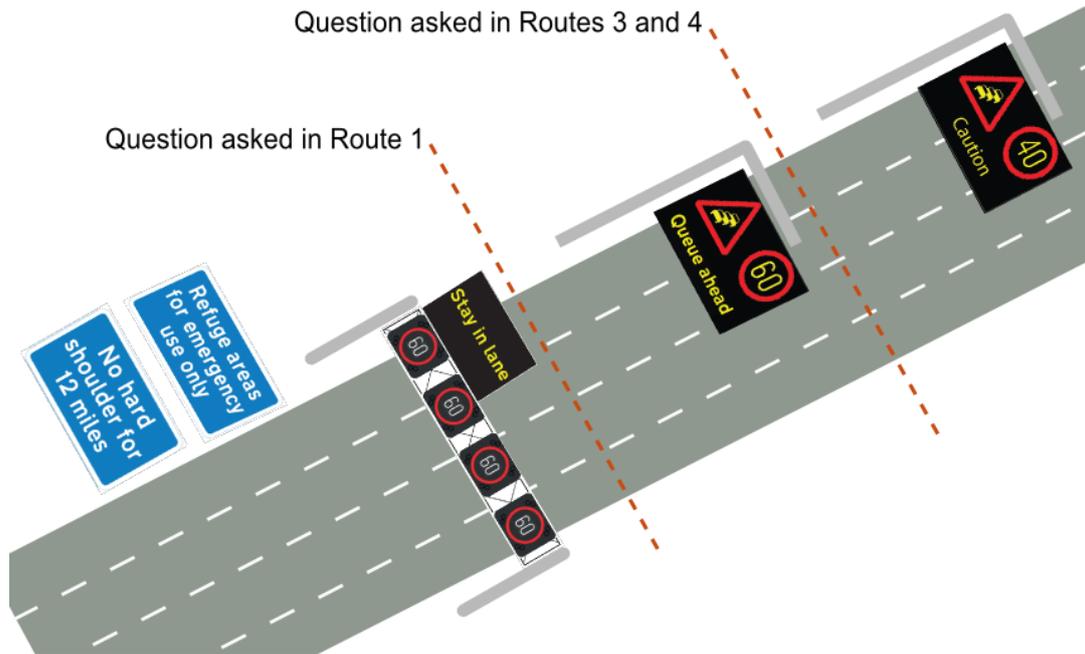


Figure 3: Location in MM-ALR sections where the question regarding available lanes was asked

Table 11 summarises the responses given by participants in Route 1 and Routes 3 and 4. Also included is a summary of the response given to the same question asked approximately half way through Route 2.

Table 11: Response to question regarding available lanes

	Correct response	Percentage correct	Mean confidence in answer	Most frequent incorrect response
Route 1	4	94%	9.0	3 (6%, 7.3 confidence)
Route 2	3	100%	9.6	-
Route 3/4	4	100%	9.2	-

Table 11 shows that the vast majority of participants answered this question correctly, including all participants in Routes 2, 3 and 4. A small number of participants (three) in Route 1 responded that there were only 3 lanes available. Of these three participants:

- All moved into Lane 1 successfully to leave at the Greenhill junction as instructed;
- One participant drove in Lane 1 for a substantial part of the route prior to the ADS becoming invisible;
- All participants correctly answered when asked again in Route 3 or 4.

These findings suggest that the vast majority of participants were aware that there were four lanes available for traffic to drive in, i.e. that Lane 1 is not a hard shoulder. When asked for the second time, all participants answered correctly.

5.1.3 Awareness of junction information

Participants' awareness of information relating to the next junction was measured through the situational awareness assessment, in which they were asked the following questions:

"The next junction is signposted for what destination?" – asked in Route 1, MM-ALR

"How far is the next junction?" – asked in the MM-ALR section of Routes 3 and 4

In Route 1 and the MM-ALR section in Routes 3 and 4, ADS signs were presented in one of two design options:

- Option 1 – Standard ADS signs located in the verge;
- Option 2 – 1 mile and ½ mile ADS shown on cantilever-mounted signs over Lane 1, and the final ADS displayed on a gantry.

Figure 4 illustrates the locations on Route 1 and Routes 3 and 4 that the questions regarding destination of the next junction was asked. It shows Option 1 ADS only.

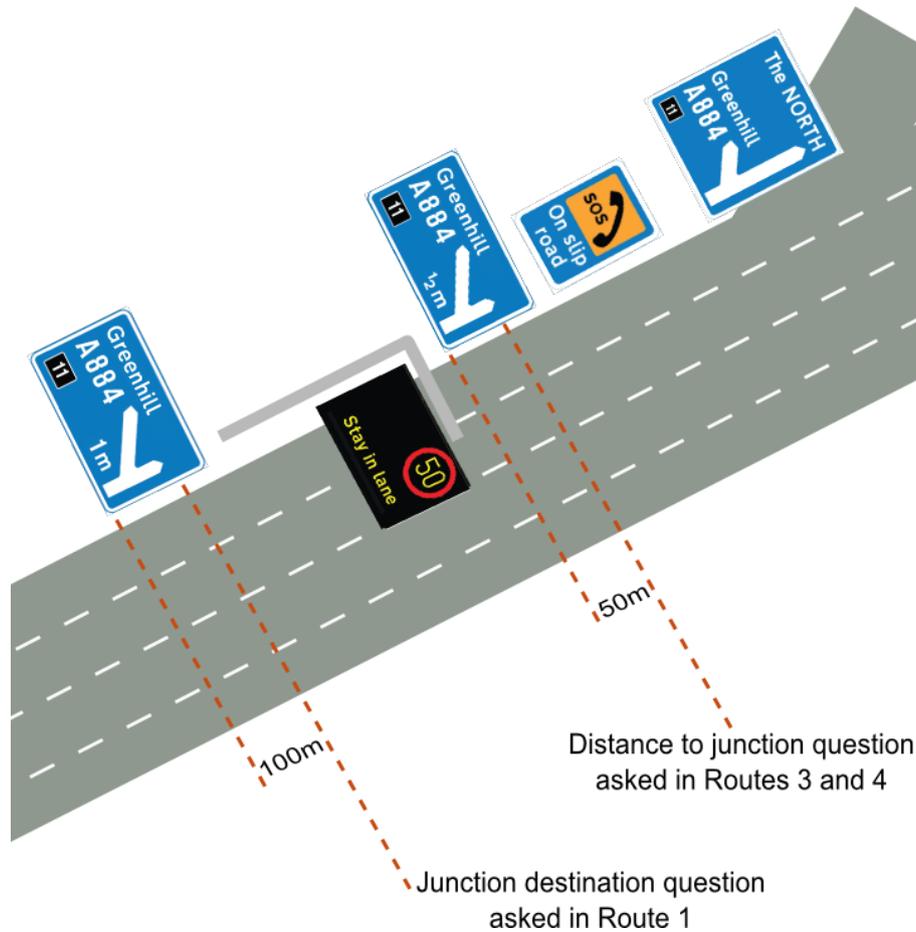


Figure 4: Location in MM-ALR sections where the questions regarding junction info were asked

Table 12 summarises the responses to the junction destination question given by participants in Route 1 for each ADS design option. Also included is a summary of the responses given to the same question asked at the same location in the 3 lane standard motorway route, Route 2.

Table 12: Response to question regarding the destination of the next junction

	No. of participants	Percentage correct	Mean confidence in answer
Route 1 Option 1	24	100%	9.7
Route 1 Option 2	24	92%	9.6
Route 2	46	96%	9.3

The vast majority of participants correctly answered this question regardless of the approach used for ADS. One participant driving in Route 1 with Option 1 ADS responded "Green Lane" (only slightly different from the correct answer "Greenhill") and one participant didn't know. In Route 2 there were two participants that didn't know.

Table 13 summarises the responses to the 'distance to junction' question given by participants in Routes 3 and 4 for each ADS design option.

Table 13: Response to question regarding the distance to the next junction

	No of participants	½ mile		1 mile	
		Percentage	Confidence	Percentage	Confidence
Route 3/4 Option 1	12	42%	8.0	33%	4.0
Route 3/4 Option 2	11	91%	6.4	9%	3.0

Many fewer participants answered this question, and a smaller proportion answered this question correctly. The majority of the participants answering incorrectly when asked in the route with Option 1 (standard motorway) ADS.

Three participants gave neither '½ mile' or '1 mile' as their answer: one participant said '2 miles', one said '100m' and the other did not know.

Although, the majority of participants answered this incorrectly it should be noted that the high awareness of the destination information (Table 12) suggests that participants would already be aware that this was not a junction they were to use. Therefore, the distance to the junction becomes much less relevant to them and not a piece of information they would be trying to make themselves aware of.

Additional to the situational awareness assessment, some participants made comments relating to awareness of junction information when given the opportunity to provide general comments following Route 1 or Route 2. These are presented in Table 14.

Table 14: General comments relating to awareness of junction information

Comment	Route just driven
"Not enough overhead signs, more on side of road."	1 Option 2
"I would not have seen the 1/2 mile notice if was not running parallel to a bus on the nearside lane. The sign was much larger than average I thought but not high enough in such congested traffic with HGVs on near side. All other gantry signing was very clear and informative."	1 Option 1
"Because the nearside lane was full of lorries the[re were] signs I missed when watching the traffic."	1 Option 2
"The signs for junctions were blocked when big truck and coaches were beside you. Could there not be signs overhead to deal with this problem?"	1 Option 1
"Everything really clearly displayed."	1 Option 1
"Large lorries can obscure the view of signs, but I think I did manage to see them all."	1 Option 2
"High-sided vehicles made me nervous about missing signs for junction."	2
"Slight difficulty to read junction signs in advance with heavy traffic in Lane 1."	2
"Didn't see the signs for the junction until the last one."	2
"Junction signs can be obscured by high-sided vehicles in Lane 1."	2

These findings suggest that participants were aware of the destination of the next junction after passing the 1 mile ADS sign in the MM-ALR environment irrespective of the design option. They also suggest that participants driving a route with standard ADS signs located in the verge were less aware of the distance to the next junction. This was possibly due to obscuration by high-sided vehicles, which participant comments suggest occurred in Route 2 as well as in the MM-ALR sections.

5.1.4 Awareness of how to respond in the event of a breakdown

Participants’ awareness of how they should respond in the event of a breakdown was measured through the situational awareness assessment in which they were asked the following question:

"In an emergency, if you needed to stop your vehicle, where would be a safe place to do so?"

This was asked both in Route 1, MM-ALR and in the MM-ALR section of Routes 3 and 4. Figure 5 and Figure 6 illustrate where the question was asked in Route 1 and Route 3/4 respectively.

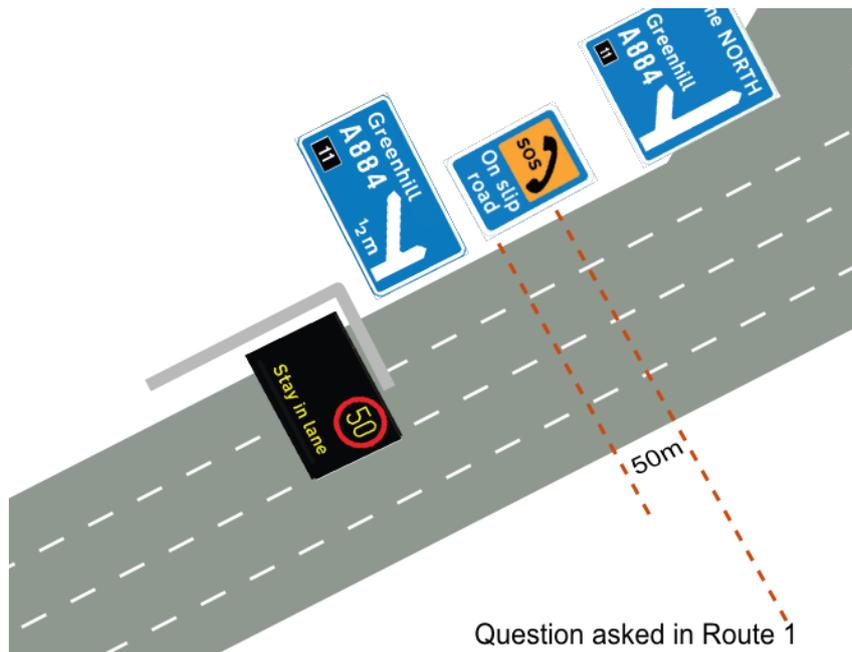


Figure 5: Location in Route 1 where the breakdown question was asked

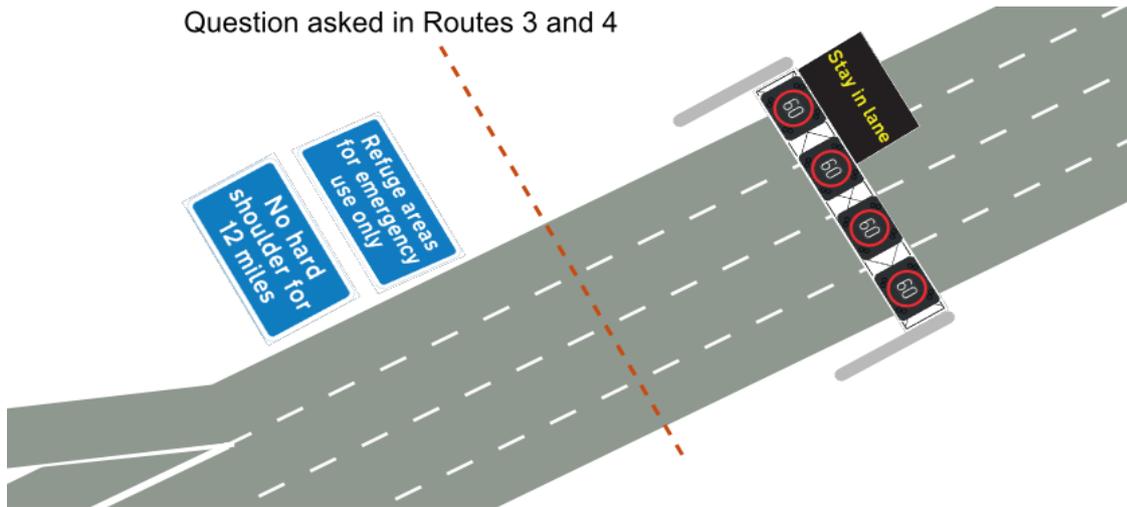


Figure 6: Location in MM-ALR section of Routes 3 and 4 where the breakdown question was asked

Figure 7 presents participants' responses to the question. Some participants provide two responses (e.g. "ERA or verge"). These responses have been counted in both of the relevant categories. Table 15 presents the mean confidence level for each of the categories. These values do not include the confidence levels stated by participants who gave more than one answer.

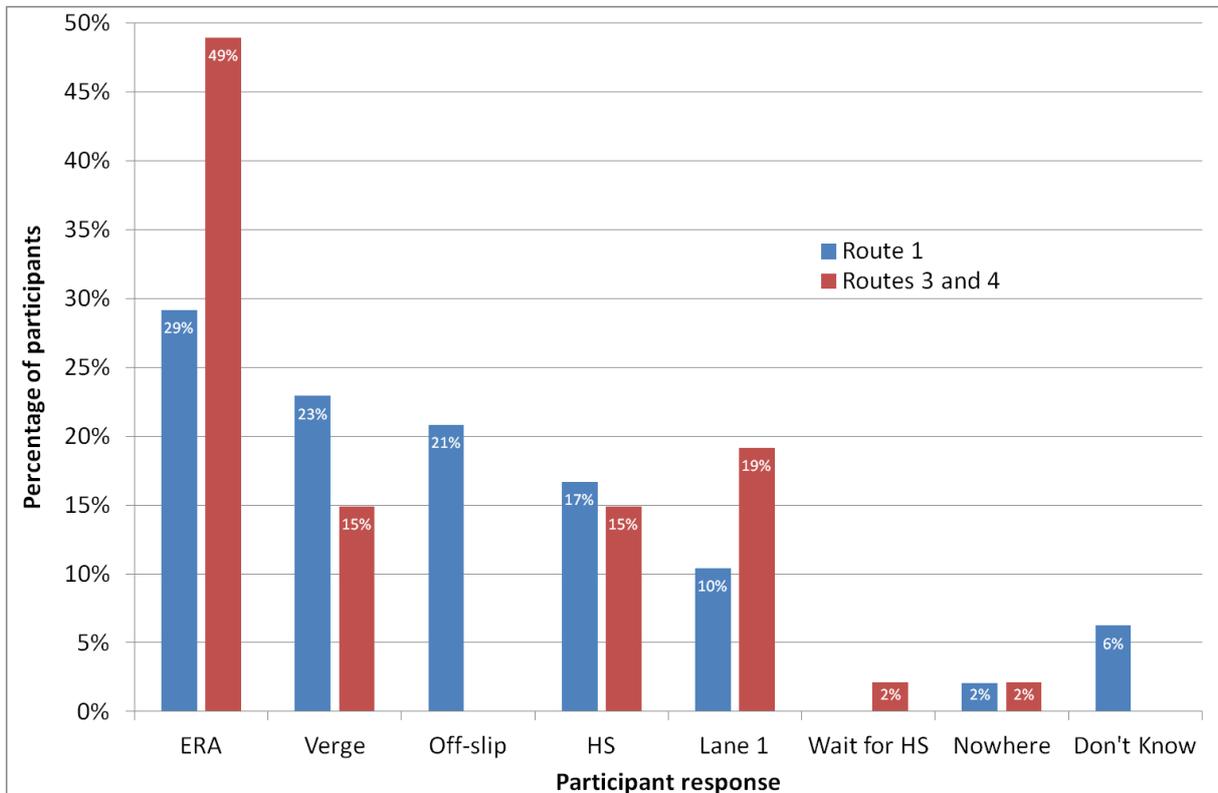


Figure 7: Responses to the question regarding breakdown in an MM-ALR environment

Table 15: Mean confidence scores for the response to the breakdown question

	ERA	Verge	Off-slip	HS	Lane 1	Wait for HS
Route 1	8.6	8.0	7.4	9.1	7.3	-
Route 3 and 4	9.0	7.9	-	9.0	6.2	7.0

Participants provided a range of responses to this question and are likely to have been affected by their interpretation of the question. For example, how severe they assumed the breakdown to be would have an impact on how quickly they would have to come to a stop.

While three participants in Route 1 responded that they did not know where they would stop, no-one responded that they would stop in a lane other than Lane 1.

As can be seen, the responses given by participants varied depending on the location at which they were asked. Participants in Route 1 were approaching a junction and, therefore, around an fifth of the participants responded that they would leave the carriageway and move onto the upcoming slip road. Participants in Routes 3 and 4 had just entered the MM-ALR section. Some participants later experienced a situation such as this within driving simulator. Section 5.2.4 describes their response.

ERA was the most common response regardless of when the question was asked. When asked in Route 1 participants would not have actually passed an ERA, suggesting an awareness provided by the "Refuge areas for emergency use only" sign.

Also considered was whether or not the drive order had an effect on participant responses. Figure 8 presents the percentage of participants driving Route 1 divided in to those who drove Route 1 first and those who drove Route 2 then Route 1. This figure suggests that having driven in Route 2 first appears to increase the likelihood of participants responding "hard shoulder", despite driving on a section of carriageway without one. Participants who drove Route 1 first were instead more likely to suggest the verge or the off-slip as a location for stopping.

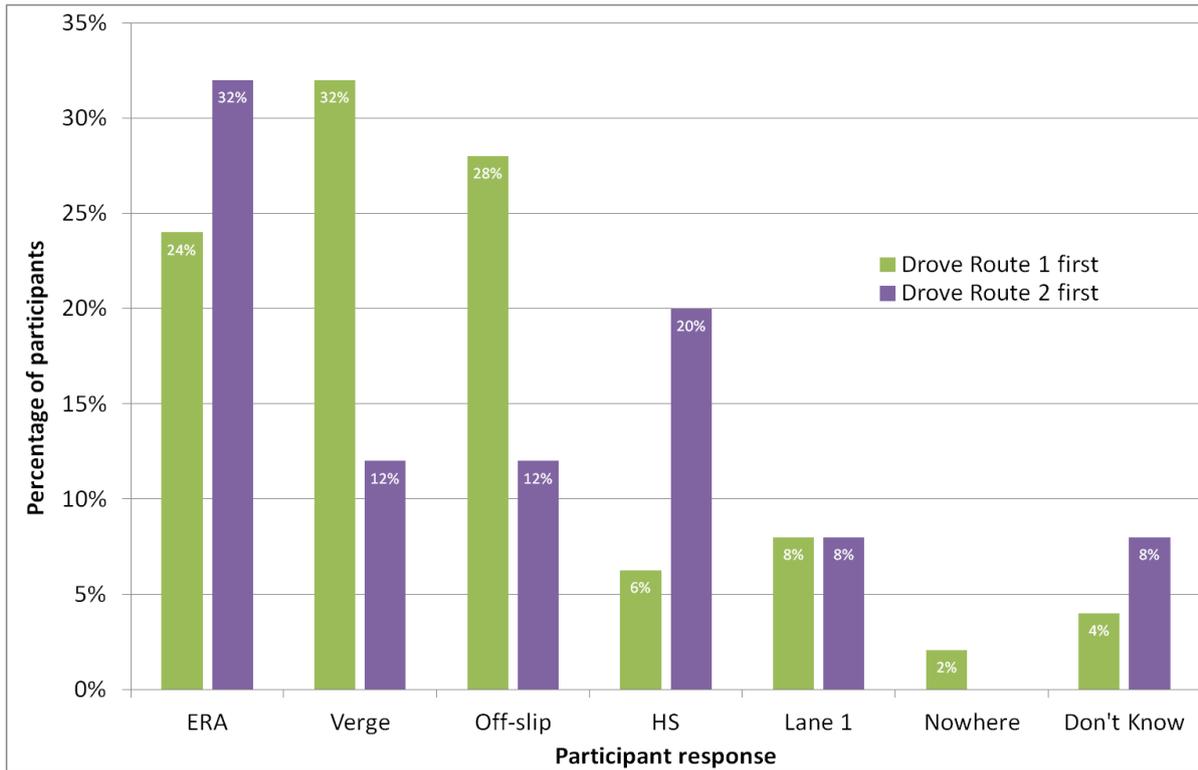


Figure 8: Responses to Responses to the question regarding breakdown in Route 1, grouped by drive order

The same question was asked at three other points to allow comparison with the following motorway environments:

- A standard 3-lane motorway environment (Route 2, at the same location as in Route 1);
- A MM-DHS environment with 60mph variable speed limits and a Red X (the third link of Route 3, around half way through the link);
- A 3-lane Controlled Motorway environment with no speed limits shown (the third link of Route 4, around half way through the link).

Table 16 summarises the responses to the breakdown question given by participants in Route 2, the MM-DHS section of Route 3 and the CM section of Route 4.

Table 16 – Response to question regarding breakdown in other motorway environments

	No of participants	Hard Shoulder		ERA		Other
		Percentage	Confidence	Percentage	Confidence	Percentage
Route 2	46	96%	9.4	0%	-	4%
Route 3	23	57%	9.2	52%	8.1	4%
Route 4	24	100%	9.5	0	-	-

In these environments where a hard shoulder is present, the vast majority of participants responded that the hard shoulder should be used in an emergency. For

participants driving in the MM-DHS section of Route 3, the responses were split between participants who said the hard shoulder should be used and those said ERAs should be used. Two participants said "ERA or hard shoulder".

The other responses are made up of the following:

- In Route 2, one participant said they would use the off-slip and one participant said that they didn't know as they had "not seen any signs" informing them.
- In Route 3, one participant said that they would stop in the verge as well as saying that they would use an ERA.

Additional to the situational awareness assessment, some participants made comments relating to awareness of breakdown information when given the opportunity to provide general comments following Route 1. These are presented in Table 17.

Table 17: General comments relating to awareness of breakdown information

Comment
"I saw signs for emergency phones but when asked I was unclear whether I would be able to make it to the phone and also I couldn't remember how far the next phone was likely to be."
"Too much breakdown info. Not keen on refuge bays rather than hard shoulder. Too many signs along motorway."
"Much more information signage... Was not familiar with ERAs when hard shoulder in use before this simulation."
"Could see SOS phone signs but no place to stop."
"I didn't notice any info about what to do in case of a breakdown.; I'll look harder in the next drive."
"I saw no info about what to do in a breakdown, only an area so signed."

These findings suggest that participants in an MM-ALR environment were more likely to consider an ERA as the location to stop in the event of breakdown than any other option. Participants' understanding of where to stop was dependent on where they are in the route and recent driving experience.

No participants understood any lane other than Lane 1 as a place that they would stop in an emergency.

5.2 Driver Behavioural Response to information

The findings of this section address the task objective to answer the following question relating to an MM-ALR environment:

Is the guidance provided adequate for drivers to respond to the information in the desired manner?

The guidance provided is split into four categories:

- The speed limit;
- The lanes that are open to traffic;
- Distance to the next exit and the location it is for
- Where and how to stop in the event of a breakdown;

In this section, each of these types of information is explored in turn in and assessed against the key question above.

5.2.1 Response to speed limits

Participants' response to the variable speed limits displayed in the MM-ALR environment (Route 1) was assessed by observing their mean speeds and time spent travelling above the speed limit. These were both compared by those observed in the standard 3-lane environment (Route 2) with the same traffic conditions but no reduced speed limits.

Figure 9 presents the Route 1 and Route 2 speed profiles for the whole of the routes averaged across all participants. As can be seen, there is very little difference between the two profiles. This is because of the density of the traffic in both environments causing participants' speed choice to be greatly influenced by the speed of the surrounding simulated traffic.

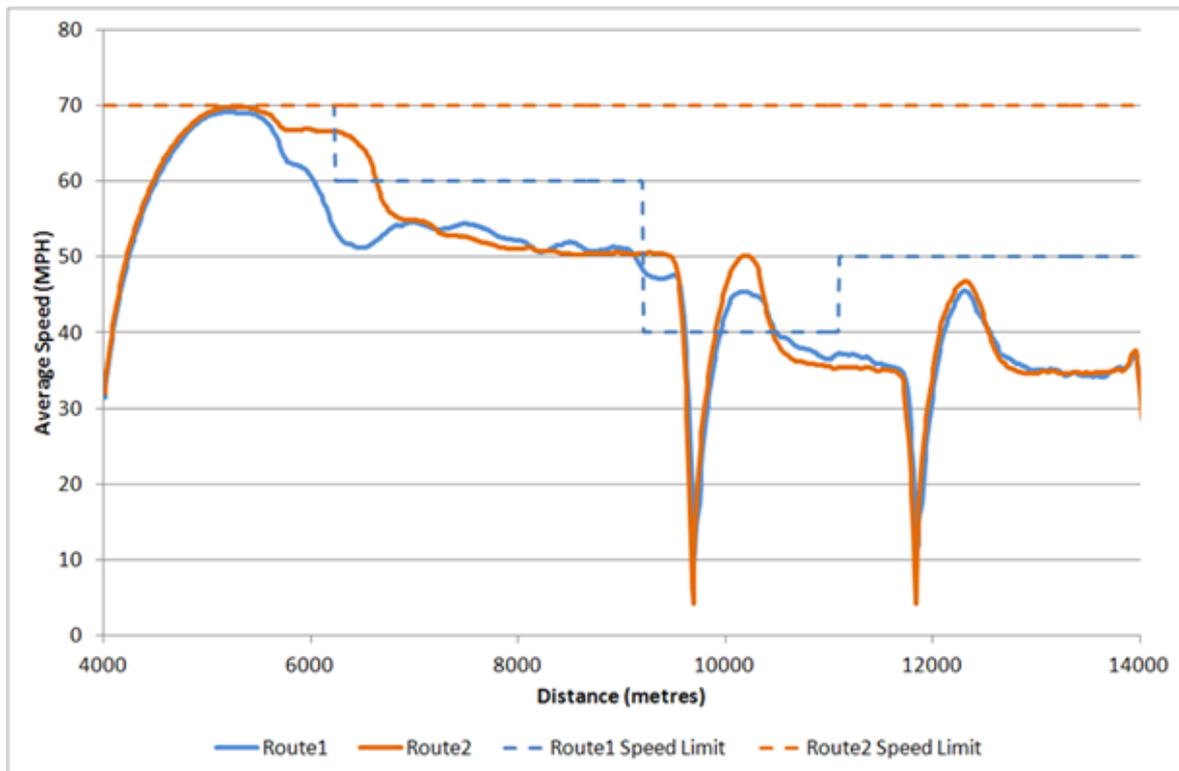


Figure 9: Mean speed profiles for Route 1 and Route 2

5.2.1.1 Mean speeds

The data were then examined for statistically significant differences. Differences in mean speeds across the entire route were compared between Route 1 and Route 2, as well as differences in mean speeds in response to each variable speed limit.

The differences in mean speed across the entire route was not found to be significant ($U = 504941.0, p = .81$).

5.2.1.2 Time spent above the speed limit

The amount of time all drivers spent exceeding the speed limit in the MM-ALR environment was also calculated to give a fuller description of drivers speed behaviour. No comparison with Route 2 was carried out as no variable speed limits were shown on this route.

Figure 10 presents the percentage of time participants spent above the speed limit. The entire bars (combined lighter and darker sections) represent the total percentage of time spent above the displayed speed limit. The darker portion represents the percentage of time that participants spent travelling between the speed limit and 10% above the speed limit (e.g. 61 – 66mph). The paler portion represents the percentage of time that participants spent travelling at speeds greater than the 10% above the speed limit (e.g. greater than 67mph).

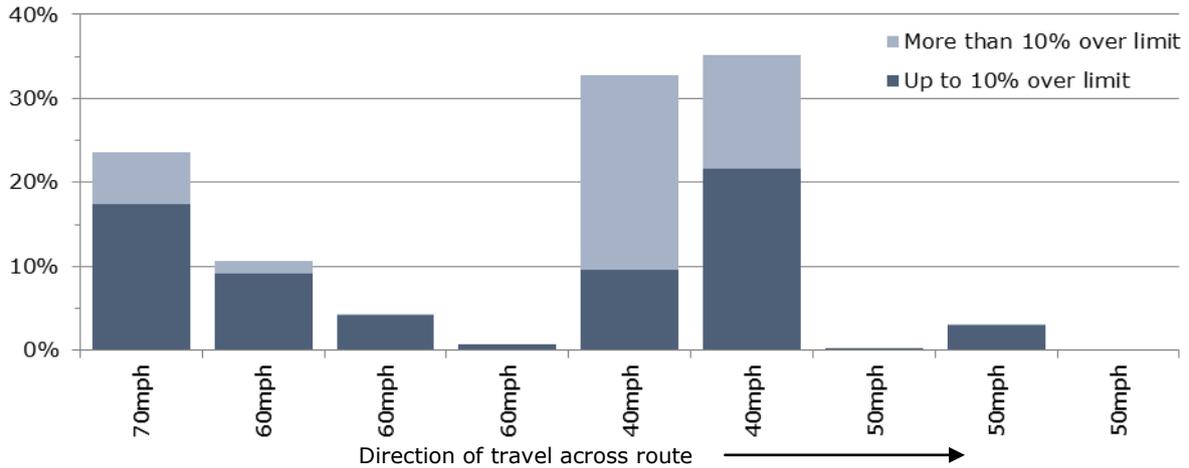


Figure 10: Percentage of driving time across all participants spent above the speed limit for Route 1

From Figure 10 we can see that drivers spent the greatest proportion of time above the speed limit when subjected to a 40mph limit, followed by when subjected to a 70mph limit. As discussed earlier, the speed of the simulated traffic was the greatest influence on the speed participants drove at. Much of the traffic was travelling at speeds above the 40mph limit when it was able to (i.e. before reaching the stop/start traffic) and, therefore, the speed of the participants was similarly non-compliant.

The speed which participants drove at in the MM-ALR environment was greatly influenced by the speed of the simulated traffic. As a result, there was very little difference in speeds between those in the MM-ALR environment and in the standard 3-lane environment with the same traffic conditions. Also when the simulated traffic was largely non-compliant with the speed limits, the greatest amount of non-compliance by the participants was observed.

5.2.2 Response to information regarding available lanes

Participants’ response to information regarding the available lanes in an MM-ALR environment was assessed by observing the proportion of each Route 1 and the MM-ALR sections of Route 3 and 4 were that was spent in each of the four lanes. This was compared with lane utilisation in Route 2, the MM-DHS section of Route 3 and the CM section of Route 4.

There were no lane closures in any of the routes. Therefore, the participant response of interest is whether or not they use all of the available lanes in the MM-ALR environment, particularly Lane 1. As participants were required to leave at a particular junction in each of their drives, they would need to move into Lane 1 to do so.

This section of the report is concerned with lane utilisation more generally, therefore only the section of each link up to the point where the first ADS sign becomes visible was included in this analysis. Lane utilisation beyond that point is investigated in Section 5.2.3.

The percentage of each participant’s drive spent in each lane was averaged and is shown in Figure 11. Note, Lane 1 was only open to traffic in the MM-ALR condition, hence when comparing MM-ALR with the other conditions we are comparing a four lane motorway environment with three lane motorway environments.

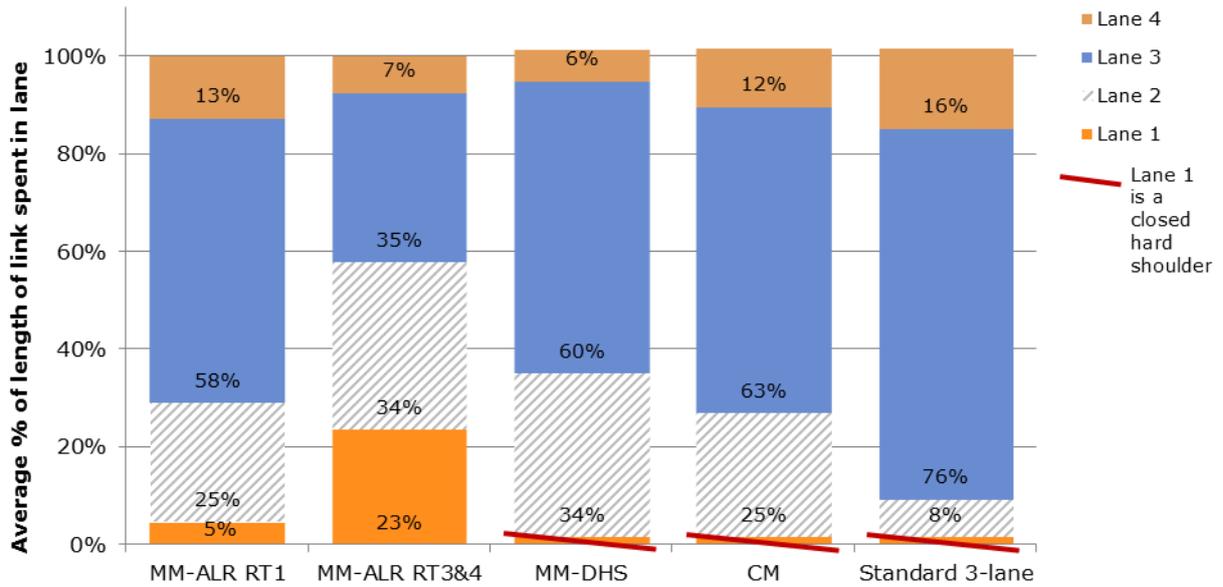


Figure 11: Mean percentage of time spent in each motorway environment

In Route 1 13% of participants drove in Lane 1 at some point before the “1 mile to junction sign”. As can be seen in Figure 11, this equates to 5% of the average lane utilisation of all participants.

Participants were much more likely to drive in Lane 1 when passing through the MM-ALR environment for the second time in routes 3 and 4 (24%) compared to when they passed through for the first time (5%). This may be due to participants having an expectation of leaving the motorway once they entered the MM-ALR section again. They also spent more time in Lane 4 when passing through the MM-ALR environment for the first time (Route 1 = 13%, routes 3&4 = 8%).

Patterns of lane choice also differed between the three lane environments (MM-DHS, CM and standard 3-lane). Participants spent much less time in Lane 1 when in the standard 3-lane environment (8%) compared to either the MM-DHS environment (34%) or the CM environment (25%).

Due to the complexity of the routes and differences in number of lanes available to traffic, it was not practical to subject these data to statistical analysis.

5.2.3 Response to junction information

Participants’ response to the junction information displayed in the MM-ALR environment was assessed by telling them to leave at a particular junction before their drive (Greenhill) and observing if and how they did so. Behaviour was compared with that observed in the standard 3-lane environment.

In Route 1 with verge-mounted ADS, 45 (out of 47) participants left at the correct junction. In Route 1 with cantilever- and gantry-mounted ADS, 45 (out of 48) participants left at the correct junction. In Route 2 (standard 3-lane with verge-mounted ADS) 91 (out of 95) participants left at the correct junction. Appendix C presents some further data relating to these participants.

Three participants failed to leave the junction on either their Route 1 or their Route 2 drive. It is likely that they misunderstood the command given at the start of the drives.

No participants left at an incorrect junction on any of the routes, unless experiencing a simulated vehicle breakdown (see Section 5.2.4).

5.2.3.1 Lane choice on approach to junction exit

Participant lane choice on approach to the Greenhill junction was examined, with particular reference to how driver behaviour changed in response to junction information. Figure 12 shows the number of participants that were in each lane on approach to the Greenhill junction within Route 1 Option 1 (verge-mounted ADS), Route 1 Option 2 (cantilever/gantry-mounted ADS) and Route 2.

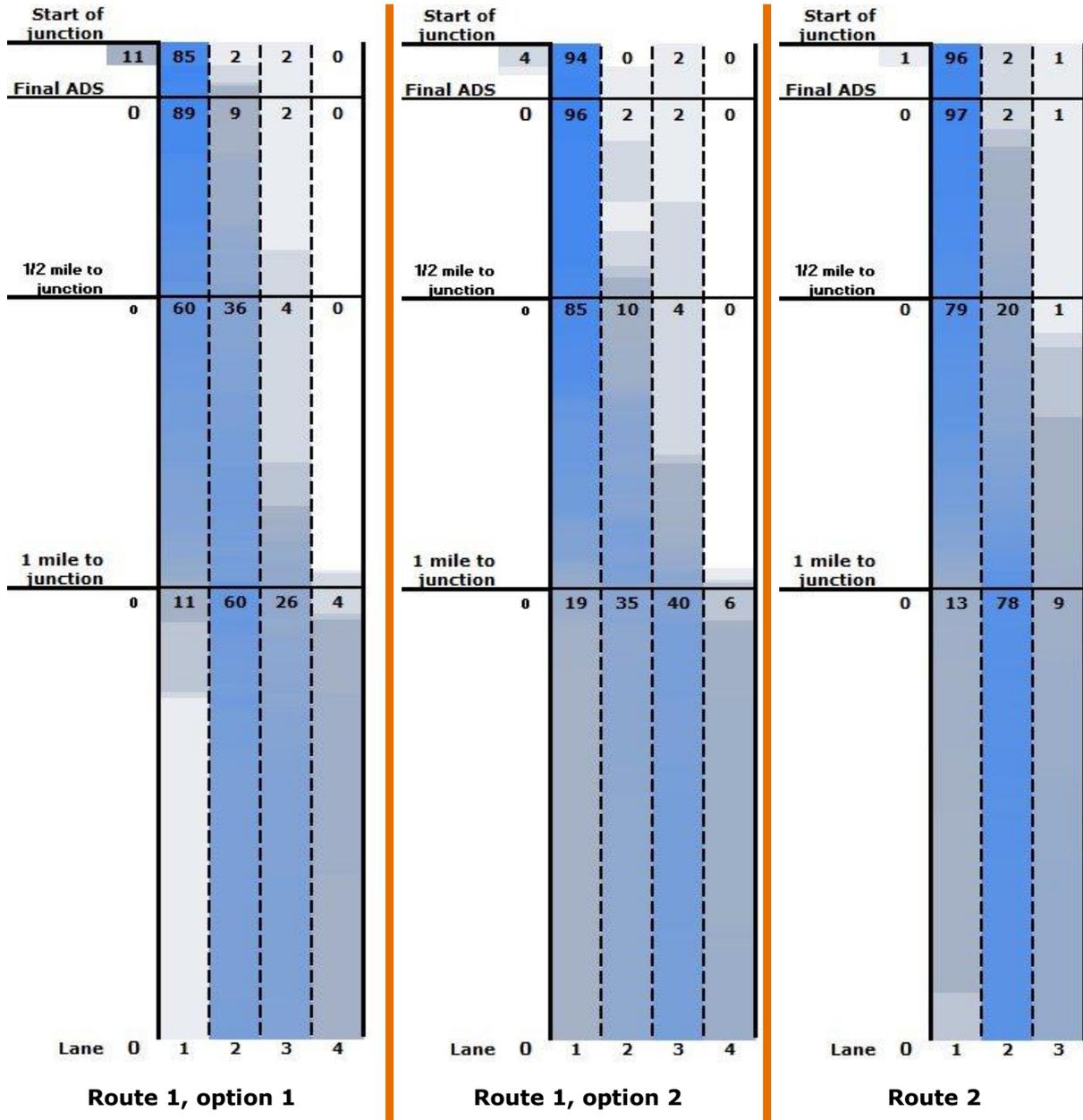


Figure 12: Participant lane position count on approach to Greenhill junction (blue represents higher numbers of participants)

As can be seen from Figure 12, the proportion of participants that moved into Lane 1 before the '1/2 mile to junction' sign in the MM-ALR section with verge-mounted ADS was less than in the same environment with cantilever/gantry-mounted ADS (60% for Option 1 compared with 85% in Option 2).

Similarly, the proportion of participants that had moved into Lane 1 before the ‘½ mile to junction’ sign in the MM-ALR section with verge-mounted ADS was less than in the standard 3-lane environment with verge-mounted ADS (60% for Route Option 1 compared with 79% in Route 2).

As there was one fewer lane available in Route 2 than in Route 1, statistical comparison of lane choice behaviour between Route 1 and Route 2 was impractical, therefore, analysis concentrated on the last position where a vehicle entered Lane 1. This metric was selected as Lane 1 was equal in all routes and therefore, these data are the best representation of where participants made their final decisions to position themselves appropriately to exit the motorway.

Figure 13 shows position where each participant moved into Lane 1 to leave at the junction. Only the final movement into Lane 1/2 has been plotted. Any other lane movements to and from this lane have been disregarded

Statistical comparison of the mean location of movement (represented by the solid red lines in Figure 13) was carried out between the two signing option conditions (verge mounted and gantry mounted) and the 3 lane motorway (control) condition. None of the comparisons produced a significant result, suggesting the position where participants chose to enter Lane 1 in advance of the diverge was independent of signing condition (see Table 18 for statistical results).

Comparison	U or Z	P
Verge mounted (RT1, option1) and gantry mounted (RT1, option 2)	U = 753	.14
Verge mounted (RT1, option1) and Route 2	Z = -1.52	.13
gantry mounted (RT1, option 2) and Route 2	Z = -0.62	.54

Table 18: Statistical results of comparisons between motorway environment conditions

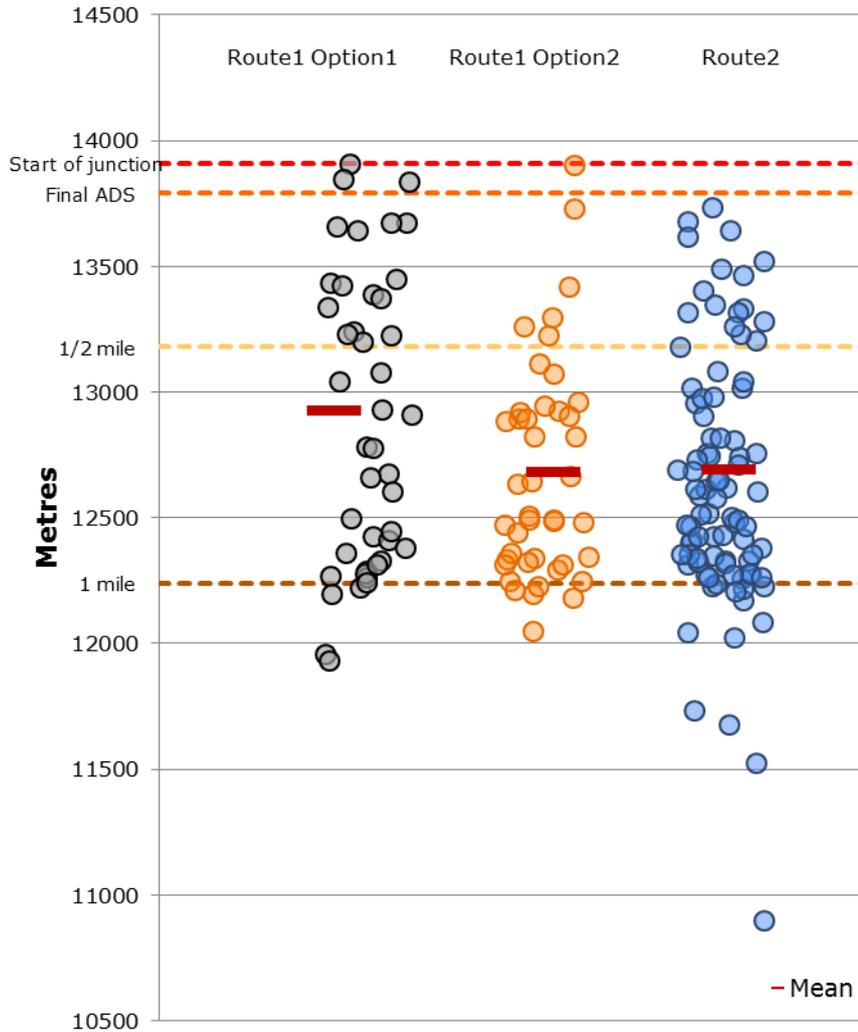


Figure 13: Latest position where participants entered Lane 1 on approach to Greenhill junction

A large majority of drivers recognised the approach of the Greenhill junction and moved into lane 1 accordingly. Most drivers had entered lane 1 by the time of their encounter with the ½ mile to junction sign. There were no differences in the average point where drivers moved into Lane 1 neither between route 1: verge mounted and route 2; nor between route 1: gantry mounted and route 2.

5.2.3.2 Lane choice on approach to junction continuation

In Routes 3 and 4 participants drove through an MM-ALR section before moving into either an MM-DHS or CM environment. The junction after the MM-ALR section was for Rookmaine rather than Greenhill and therefore participants were required to drive through. After the Rookmaine off-slip, the hard shoulder was reintroduced. How participants behaved on the approach to this junction was examined.

Figure 14 shows the number of participants that were in each lane on approach to the Rookmaine junction within Routes 3 and 4 for participants who did not experience the breakdown scenario. This figure shows that all participants moved into one of Lanes 2, 3

or 4 before the off-slip and almost all (94%) before the '½ mile to junction' sign. The latest participant exited Lane 1 approximately 500m before the final ADS.

No participants drove in Lane 1 (the hard shoulder) within the junction.

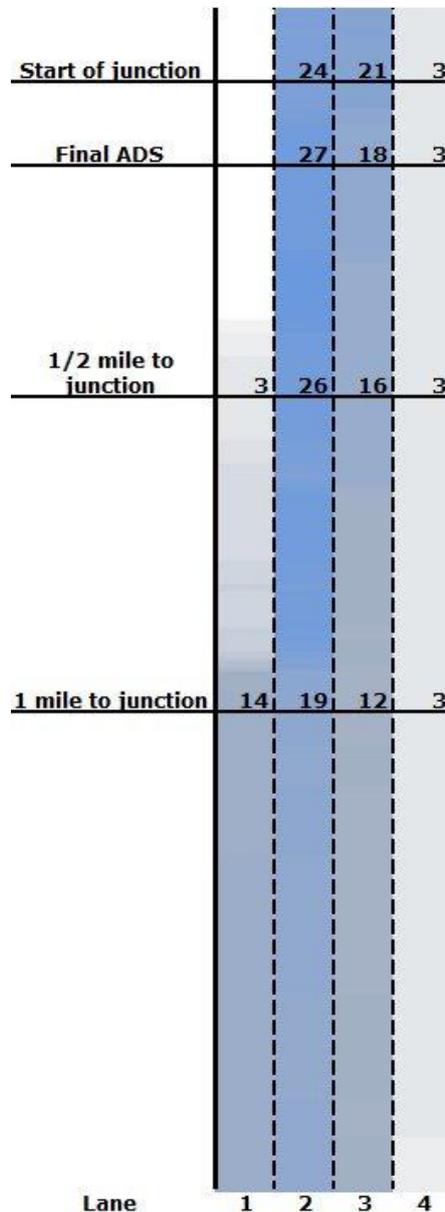


Figure 14: Participant lane position count on approach to the Rookmaine junction in Routes 3 and 4 (blue represents higher numbers of participants)

Participants did not enter the hard shoulder within the junction. Furthermore, participants who were using Lane 1 exited it well in advance of the junction, with the latest departure being roughly 500m before the final ADS.

5.2.3.3 Subjective driver ratings of sign options

Following their third drive in the simulator (i.e. either Route 3 or Route 4) participants answered a questionnaire about their experiences. A section within this questionnaire asked participants to rate the clarity of different ADS signage options. Four different ADS scenarios were presented:

1. A 1-mile advance warning of a junction where all four lanes continue through
2. At-junction signing of a junction where all four lanes continue through
3. A 1-mile advance warning of a junction where one of the four lanes is dropped to form the exit slip road for the junction
4. At-junction signing of a junction where one of the four lanes is dropped to form the exit slip road for the junction

For each of these four scenarios participants were shown either a verge-mounted or an overhead-mounted sign configuration. Thus the following signs were evaluated (Figure 15 to Figure 22), with each participant seeing four of them (either all overhead or all verge-mounted):



Figure 15: Junction Scenario 1 – verge mounted ADS



Figure 16: Junction Scenario 1 – overhead ADS



Figure 17: Junction Scenario 2 – verge mounted ADS



Figure 18: Junction Scenario 2 – overhead ADS



Figure 19: Junction Scenario 3 – verge mounted ADS



Figure 20: Junction Scenario 3 – overhead ADS



Figure 21: Junction Scenario 4 – verge mounted ADS



Figure 22: Junction Scenario 4 – overhead ADS

For each sign configuration that participants saw, they were asked to rate from 1 to 10 the clarity of sign in conveying information about the junction number, adjoining road and destination (route information); and separately to rate from 1 to 10 the clarity of the sign in conveying information about which lanes should be used by traffic wishing to continue through the junction (lane-availability). The scores for the overhead and verge-mounted configurations were compared for each of the four ADS scenarios with regard to both elements of the signing information (i.e. route information and lane-availability information). Thus eight comparison tests were performed. For each comparison the data are presented in frequency tables of participants' ratings of sign clarity.

Table 19: Lane-continuation advance sign (Figures 15 and 16) – Route information

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Verge				1	2	1	2	9	8	24	8.9
Overhead			2	1	4	6	9	5	9	12	7.7

Table 20: Lane-continuation advance sign (Figures 15 and 16) – Lane availability information

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Verge	3	1	1		1	1	2	12	11	15	8.0
Overhead	7	1	6	2	5	4	5	6	5	6	5.8

Table 21: Lane-continuation at-junction sign (Figures 17 and 18) - Route information

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Verge				1	1		3	7	11	24	9.0
Overhead	1	2		1	5	1	1	10	11	15	8.0

Table 22: Lane-continuation at-junction sign (Figures 17 and 18) – Lane availability information

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Verge	1	1		1	3		2	9	14	16	8.4
Overhead	1	3		2	7	1	4	6	8	15	7.5

Table 23: Lane-drop advance sign (Figures 19 and 20) - Route information

	Answer rating										
Condition	1	2	3	4	5	6	7	8	9	10	Mean score
Verge					1	1	2	5	8	29	9.3
Overhead		3	3	8	2	2	7	6	8	7	6.7

Table 24: Lane-drop advance sign (Figures 19 and 20) – Lane availability information

	Answer rating										
Condition	1	2	3	4	5	6	7	8	9	10	Mean score
Verge		1				1	1	2	11	30	9.3
Overhead	3	6	6	5	3	3	7	4	4	5	5.5

Table 25: Lane-drop at-junction sign (Figures 21 and 22) - Route information

	Answer rating										
Condition	1	2	3	4	5	6	7	8	9	10	Mean score
Verge					1	1	3	7	7	28	9.2
Overhead			1	1	1		4	10	10	20	8.7

Table 26: Lane-drop at-junction sign (Figures 21 and 22) – Lane availability information

	Answer rating										
Condition	1	2	3	4	5	6	7	8	9	10	Mean score
Verge						2	2	3	10	30	9.4
Overhead			1				4	8	11	23	9.0

For the data shown in each of the tables above (Table 19 to Table 26) the participant ratings for the verge and overhead configurations were compared using Wilcoxon Signed Rank tests. Table 27 shows the outcome of these tests.

Table 27: Results of significant difference tests between overhead and verge-mounted sign configurations

Junction type	location	Information category	Higher-rated sign configuration	Statistically significant?
Lane-continuation	1-mile advance	Route	Verge	Yes
		Lane-availability	Verge	Yes
	At-junction	Route	Verge	Yes
		Lane-availability	Verge	No
Lane-drop	1-mile advance	Route	Verge	Yes
		Lane-availability	Verge	Yes
	At-junction	Route	Verge	No
		Lane-availability	Verge	No

Table 27 shows that the verge configuration was rated as being clearer than the overhead configuration in all four scenarios and with regard to both the junction information and lane-availability information aspects. However, it is also clear that whilst this effect was shown to be significant for the advanced signs, it was not found to be significant for all but one of the at-junction scenarios (although the lane-continuation at-junction sign came close to significance with regards to lane availability [$p=0.080$]).

Based on feedback from participants in the questionnaires it appears that the main reason why the overhead signs were rated so poorly in the 1-mile advance scenario is that the sign was mounted only over Lane 1 and not over each lane as would be the case in a gantry format. Participants frequently reported that this meant it was less clear in conveying both elements of information. Some examples of typical participant comments are as follows:

"The overhead sign implies to me that only Rookmaine lies ahead, i.e. the motorway ends and is replaced by the A886."

"The information on the overhead sign is less obvious and presented in an unfamiliar way."

"Gaps within the overhead sign suggest that the elements are separate and it is not clear that Rookmaine is the next junction"

"The overhead sign merely indicates the turning for Greenhill, it gives no visual indication about continuing ahead."

"The overhead sign doesn't show any other lanes in the picture, so doesn't look like you need to get in a particular lane."

In contrast, in the at-junction scenarios, participants reported that they felt much more comfortable about what was happening as all four lanes had a marker to show where it would take them. There was also a general impression that the overhead gantry sign made better use of the space and presented information in a more coherent manner than the cantilevered overhead signs.

These findings suggest that participants found the verge-mounted signs to be clearer than the overhead signs. Of the overhead signs, the gantry (all lane) configuration was felt to be clearer than the cantilevered (single lane) configuration. It is interesting that the preference for verge signs prevailed despite large numbers of participants reporting that they would be concerned about the verge signs being obscured by high-sided vehicles.

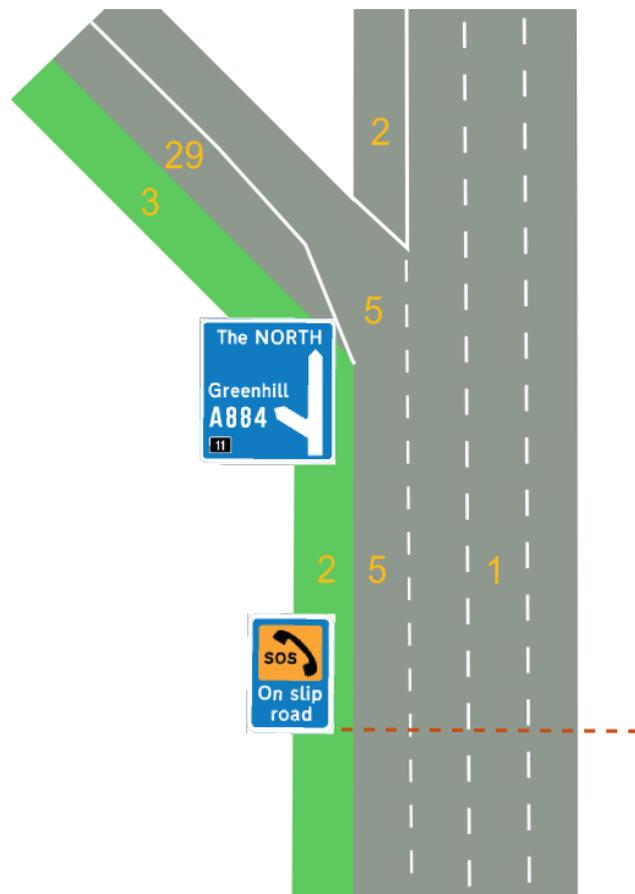
5.2.4 Response to an emergency breakdown scenario

Participants’ behaviour in an emergency breakdown scenario was assessed by simulating a breakdown using the methodology described in 4.3.1.1. Half of the participants experienced a simulated breakdown on the approach to the junction at the end of the the MM-ALR section in Routes 3 and 4. The locations where participants chose to stop their vehicles were analysed.

The positions where drivers stopped their vehicle were categorised into seven locations: hard shoulder on slip; verge on slip; hard shoulder after slip; main carriageway at mouth of slip; verge before slip; Lane 1 on approach to slip; and main carriageway before slip. Table 28 lists the frequency of stopping positions for these locations. Given the effects of signing option were independent of the emergency breakdown task this analysis combined results for both options. Participants were unable to stop on the running lane of the slip due to a queue of traffic that had formed there.

Table 28: Frequency of breakdown stopping positions by location

Location	Frequency count
Hard shoulder on slip	29
Verge on slip	3
Main carriageway at mouth of slip	5
Hard shoulder after slip	2
Verge before slip	2
Lane 1 on approach to slip	5
Main carriageway before slip	1



The most popular stopping location across the two options was the hard shoulder on slip (29). An additional three participants stopped on the verge off the slip. Five more participants stopped on the main carriageway at the mouth of the slip, suggesting they intended to leave at the junction, but were unable to do so due to the queue of traffic on the slip. This represents a total of 37 out of 47 participants (79%) who either stopped after exiting the main carriageway, or indicated that they were attempting to do so.

Two participants passed the slip and came to a halt on the hard shoulder within the junction. No participants passed the slip and stopped on the main carriageway.

Finally, five participants stopped in Lane 1 in advance of the slip, and a further two stopped on the verge before the slip. Only one participant stopped on the main carriageway in advance of the slip.

Just over two thirds of participants (32 of 47) stopped on the slip, with a further five indicating they attempted to do so by stopping in the mouth of the junction when encountering a queue of traffic blocking the slip.

A minority of drivers chose locations which were less appropriate, with a total of seven participants either stopped on Lane 1 before the slip (5), or drew onto the grass verge (2). Two participants drove past the junction and stopped on the hard shoulder. Only one participant halted their vehicle on the main carriage way, most likely as a consequence of misunderstanding the vehicle fault as a technical fault with the simulator.

5.3 Driver subjective experience of trial environments

The findings of this section address the task objective to answer the following question relating to an MM-ALR environment:

Is the driving experience comfortable and intuitive, and perceived as safe?

5.3.1 Participants’ experiential perceptions of Routes 1 and 2

After completion of each of their first two drives in the simulator (undertaking Routes 1 and 2) participants were asked to fill out a short questionnaire asking them, among other things, to rate their experience of the drive according to various criteria. For each question participants were asked to rate their experience on a scale of 1 to 10. All participants answered an identical set of questions relating to both Route 1 and Route 2, thus enabling a comparison of scores between the two routes to be made. Note that in some of the tables within this section the counts do not add up to the full set of 96 participants. In these cases it is due to one or more participants failing to answer the relevant question within the questionnaire.

5.3.1.1 Perception of personal safety

Participants were asked to rate how ‘safe’ they felt during the preceding drive on a scale of 1 to 10. Table 29 is a frequency table displaying the range of scores given by participants.

Table 29 - Participants perceptions of safety during Routes 1 and 2

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Route 1				2	7	3	16	30	11	27	8.1
Route 2				2	7	4	15	26	25	15	8.1

It can be seen from the table that the scores across both Routes were similar; indeed the overall mean scores for both groups were the same. The data were analysed using a Wilcoxon Signed Rank test to check for a statistical difference in scoring between the two routes. The test returned a non-significant result, therefore we can conclude from the data that there was no significant difference in participants’ perceptions of safety between the current standard motorway and the MM-ALR environments.

5.3.1.2 Perception of personal comfort

Participants were asked to rate how ‘comfortable’ they felt during the preceding drive on a scale of 1 to 10. Table 30 is a frequency table displaying the range of scores given by participants.

Table 30 - Participants perceptions of comfort during Routes 1 and 2

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Route 1				2	5	10	16	30	17	16	7.9
Route 2	1		1	3	4	11	15	29	22	9	7.7

Once again, the table shows that scoring was similar. A Wilcoxon Signed Rank test showed no significant between scores between Routes 1 and 2, thus we can conclude from the data that there was no significant difference in participants’ perceptions of comfort between the current standard motorway and the MM-ALR environments.

5.3.1.3 Perception of personal stress

Participants were asked to rate how ‘stressed’ they felt during the preceding drive on a scale of 1 to 10. Table 31 is a frequency table displaying the range of scores given by participants. Note that this scale was in the reverse to the other questions, i.e. 1 = Not stressed at all and 10 = Very stressed.

Table 31 - Participants perceptions of stress during Routes 1 and 2

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Route 1	11	9	17	16	4	10	23	2	4		4.6
Route 2	7	17	16	8	8	11	14	11	3		4.6

A Wilcoxon Signed Rank test showed no significant difference between route 1 and Route 2 scores. The data therefore indicate that there is no significant difference in participants’ perceptions of stress between the current standard motorway and the MM-ALR environments.

5.3.1.4 Perception of personal confidence

Participants were asked to rate how ‘confident’ they felt during the preceding drive on a scale of 1 to 10. Table 32 is a frequency table displaying the range of scores given by participants.

Table 32 - Participants perceptions of confidence during Routes 1 and 2

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Route 1			1	2	9	12	22	23	15	12	7.5
Route 2			2	3	4	10	19	33	17	7	7.6

A Wilcoxon Signed Rank test showed no significant difference between scores for the two Routes. The data therefore show no significant difference in participants’ perceptions of confidence between the current standard motorway and the MM-ALR environments.

5.3.1.5 Perception of the likelihood of being caught speeding

Participants were asked to imagine that they were driving down a stretch of motorway in the real world, configured according to the environment they had just experienced, and to imagine that they were breaking the posted speed limit. They were asked to rate (from 1 to 10) the likelihood that they would be caught for their speeding in such a scenario. Table 14 is a frequency table displaying the range of scores given by participants.

Table 33 - Participants perceptions of the likelihood of being caught speeding within Routes 1 and 2

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Route 1	3	5	10	11	9	6	16	19	7	9	6.2
Route 2	8	14	19	7	21	5	6	7	6		4.4

In this case the frequency table indicates that scores between the two routes were dissimilar, with a difference of 1.8 in the mean scores. A Wilcoxon Signed Rank test revealed that this difference was statistically significant ($p < 0.001$). We can therefore conclude that participant, on average, felt it more likely that they would be caught if speeding in an MM-ALR environment than in a standard motorway environment. This finding is perhaps as would be expected, given that there are a greater number of speed camera warning signs in this environment, and the regularly-spaced gantries provide perceived opportunities for such cameras to be mounted.

Based on the findings from Section 5.3.1 we can conclude the following:

Participants experienced similar feelings of safety, comfort, stress and confidence during their undertaking of Routes 1 and 2 in the simulator, indicating that these feelings do not significantly differ between an MM-ALR environment and a typical motorway environment during busy traffic periods.

Participants reported believing that they would be more likely to be caught if speeding in an MM-ALR environment than in the typical motorway environment.

5.3.2 Participants’ perceptions of sufficiency of information

5.3.2.1 Perception of the sufficiency of visually-presented junction information

Participants were asked to rate the sufficiency of information relating to junction information. Given that, within Route 1, half of the participants experienced verge-mounted and half overhead ADS, in this case we are interested in whether there was a difference in ratings between groups, within Route 1. The ratings given by participants are shown in Table 34. The data appear to suggest a slight favouring of the overhead

ADS condition, but a Mann-Whitney test shows this result to be non-significant ($p=0.158$).

Table 34: Frequency distribution of participant ratings of the sufficiency of junction information in Route 1

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Verge				1		3	10	15	11	7	8.1
Overhead				3	3	1	7	7	11	17	8.3

5.3.2.2 Perception of the sufficiency of visually-presented information about what to do in the event of a breakdown

Participants were also asked to rate the sufficiency of information about what to do in the event of a breakdown. Here we are interested in comparing Route 1 with Route 2 to evaluate the effect of having either a hard shoulder (HS) with regularly-spaced emergency telephones, or a running lane 1 with ERAs provided. Table 35 shows a frequency distribution of the responses. The data appear to show a strong favouring of Route 1, which is borne out by a Wilcoxon Signed Rank test ($p<0.001$). This finding is perhaps surprising and it is recommended the finding be treated with caution as it is felt that the results may have been corrupted by participants answering the question in a manner different from that intended. Specifically it is believed that participants may not have regarded the emergency telephone signs as ‘information about what to do in the event of a breakdown’.

Table 35: Frequency distribution of participant ratings of the sufficiency of breakdown information in Routes 1 and 2.

Condition	Answer rating										Mean score
	1	2	3	4	5	6	7	8	9	10	
Route 1 (ERAs)	4	11	6	10	9	7	12	11	13	12	6.1
Route 2 (HS)	29	18	14	5	7	4	6	3	4	3	3.4

Participants rated the sufficiency of junction information similarly between the verge-mounted and overhead conditions.

Participants seemingly reported that information about what to do in the event of a breakdown was less sufficient in Route 2 (hard shoulder) than in route 1 (ERAs), but the findings is not necessarily believed to be reliable due to potential participant confusion.

5.3.3 Participant feedback on information presented within the drives

5.3.3.1 Legibility of information

Following their undertaking of both Route 1 and Route 2, participants were asked if there were any signs that they could not read. Both routes received 13 responses out of 96 of participants being unable to read a sign. Six of the responses for Route 1 related to participants stating that signs were obscured by high-sided vehicles, and nine of the comments for Route 2 related to this. Given that participants undertaking Route 1 were split into two groups, with some experiencing verge-mounted ADS and some Gantry-mounted, it might be expected that the possibility of signs being obscured by high-sided vehicles might alter drivers' perceptions of Route 1 depending on which group they were in (although Table 34 seemingly shows that this isn't the case). The data in Section 5.3.1 were re-analyzed to compare responses between participants in the verge and gantry groups in the Route 1 drive; i.e. their perceptions of safety, comfort, stress and confidence. The data showed that participants experiencing the verge-mounted ADS felt less safe, comfortable and confident and felt more stressed. However, only one of these (stress) proved to be a statistically significant difference (in this case the statistical test used was a Mann-Whitney test as the samples between groups were unrelated). However, the results indicate that, in an MM-ALR environment during high traffic-flow conditions, participants felt more stressed when ADS were verge mounted than when gantry mounted. This result is seemingly contradictory to the finding from Section 5.2.3.3 that participants felt the verge-mounted signs were clearer. The difference is likely to be at least partly due to the fact that in that Section the participants were rating the signs based on a static image containing no other vehicles. Participant ratings of stress were based on their experience driving on a route containing many cars and with a high percentage of high-sided vehicles in Lane 1.

5.3.3.2 Comprehensibility of information

Participants were also asked if there was any information that they saw but didn't understand. There were no positive responses to this question for Route 2 but there were three from Route 1 that related to elements within the interests of the trial:

- One participant reported that he didn't know if the variable speed limit signs on the gantries were advisory or compulsory.
- One participant stated that there was an overhead symbol that she didn't recognize, although she couldn't say which one.
- Another participant stated that she wasn't familiar with the symbol for the 'emergency stopping layby'; however it would seem that the overall message was understood, given her ability to explain the context of it.

Other than these cases it therefore appears that misunderstanding of the information is not widespread.

Participants experiencing verge-mounted ADS reported feeling more stressed in the drive than those experiencing overhead ADS.

Drivers reported that they found the information in verge signs more clearly presented but seemingly were worried about signs being obscured by high-sided vehicles.

Missing visual information due to obscuration may be perceived to be an issue but, provided it is seen, misunderstanding the information is not a widespread problem.

5.4 Behaviour in subsequent motorway sections

The findings of this section address the task objective to answer the following question relating to an MM-ALR environment:

Does the future MM environment affect behaviour in subsequent environments?

5.4.1 Time spent in hard shoulder when not permitted

To assess whether driving from an MM-ALR environment would affect hard shoulder compliance, the lane utilisation of participants in the last section of Routes 3 and 4 was observed. In Route 3 this was a MM-DHS section with the hard shoulder closed and in Route 4 this was 3-lane CM section (see section 4.2).

In Route 3, two out of 47 participants were found to use the hard shoulder despite it being closed to traffic.

One of these participants was rejoining the main carriageway from the on-slip and merged late, approximately 150m after the end of the merge taper and the first gantry displaying a Red X. Following the drive, the participant reported awareness of using the hard shoulder and stated:

"I was not allowed to join the flowing traffic to the right. The move right came without warning."

The other participant was also rejoining the main carriageway from the on-slip. They successfully merged into Lane 2 but then shortly afterwards moved into the hard shoulder for a brief period. They moved into the hard shoulder around 150m after the first Red X gantry then moved back out another 150m later. Following the drive, the participant reported awareness of using the hard shoulder and stated:

"The lane was moving quicker and I was in a rush to get to work."

There was no evidence to suggest that the non-compliance exhibited by these two participants was the result of just leaving an MM-ALR section.

In Route 4, none of the 48 participants were found to use the hard shoulder.

5.4.2 Participant awareness of a change in hard shoulder provision

Participants’ awareness of how many lanes were available to traffic in a section following an MM-ALR environment was measured through the situational awareness assessment in which they were asked the following question:

"How many lanes are open to traffic?"

This was asked both in Routes 3 and 4 300m after the first gantry of the link. Table 36 summarises the responses given by participants.

Table 36: Response to question regarding available lanes

	No of participants	Percentage correct	Mean confidence in answer
Route 3	22	100%	9.4
Route 4	24	100%	9.4

This finding suggests that all participants were aware of the reintroduction of the hard shoulder shortly after moving into the section following an MM-ALR section. This is further supported by the findings presented in Table 16 in Section 5.1.4.

Also, following their final drive, all participants were asked:

"Are you aware that it is illegal to drive in a marked hard shoulder unless in an emergency situation or prompted to do so by overhead signing?"

Only one of the 96 participants responded that they were not aware of this.

5.4.3 Time spent exceeding speed limit

Drivers speed choice before and after the transition from the MM-ALR environment to the MM-DHS/CM environment was examined. Figure 23 presents the percentage of time across all participants that was spent above the speed limit for each section of the two routes. The height of each whole bars represent the total time spent above the displayed speed limit. The darker portion represents the percentage of time that participants spent travelling between the speed limit and 10% above the speed limit (e.g. 61 – 66mph). The paler portion represents the percentage of time that participants spent travelling at speeds greater than the 10% above the speed limit (e.g. greater than 67mph). The dashed green line in Figure 23 represents the transition points between the MM-ALR environment to the MM-DHS/CM environments.

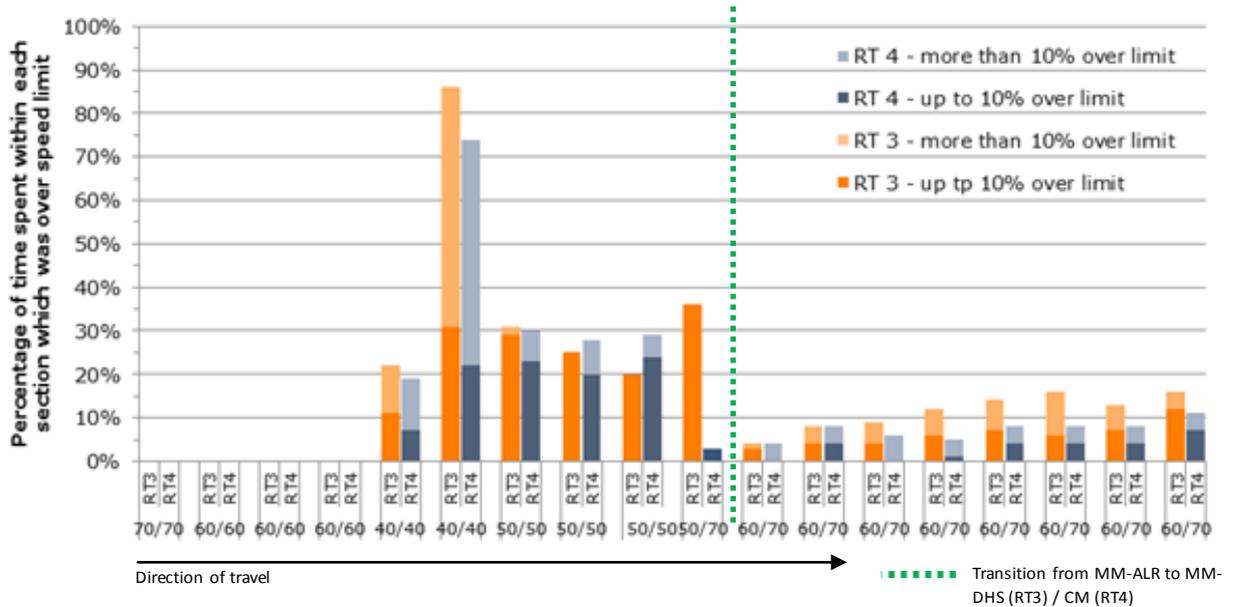


Figure 23: Time spent over speed limit for routes 3 and 4

As described in Section 4.3, the speed profile of simulated traffic in the MM-ALR environment in Route 2 was different to that in the same environment in Routes 3 and 4. Comparing the first half of Figure 23 with the equivalent chart relating to compliance in Route 2 (Figure 10), shows the effect of the different speed profiles have on participant compliance.

Similarly, compliance with the speed limit in MM-DHS and CM links would have been greatly influenced by the speed of the surrounding traffic. Unsurprisingly, non-compliance was greater in the MM-DHS environment with a 60mph speed limit displayed than in the CM environment with all signals set as blank.

The differences between routes 3 and 4 were not significant for neither the over limit data ($U = 139.5, p = .48$), nor for the 10%+ over limit data ($U = 131.5, p = .34$).

There were only two minor occurrences of hard shoulder non-compliance, both in the MM-DHS section following the MM-ALR section.

All participants undertaking the situational awareness assessment correctly identified that there were only three lanes available in the sections following the MM-ALR section.

There was a moderate amount of non-compliance with the speed limit in both the MM-DHS section and the CM section, although participants chosen speeds are likely to have been greatly influenced by the speed of the surrounding traffic.

5.5 Additional Research Questions

The findings of this section address the additional task objective to answer the following questions:

Do participants display a preference with regards to MS4 signs indicating a full road closure?

Do participants understand the informational storyboard regarding how to behave in a future MM concept environment?

Also included are some findings relating to participants' awareness of the text messages presented on MS4s in the MM-ALR environment.

5.5.1 Do participants display a preference with regards to MS4 signs indicating a full road closure?

Upon completion of their third drive (i.e. either Route 3 or Route 4) participants completed a questionnaire on their experiences. A section of this questionnaire was intended to examine participants' preference for a method for displaying a full road closure on a verge-mounted MS4 sign. Three options were presented to participants and they were asked to rate (from 1 to 10) how clear they thought the sign was at conveying a full road closure. The three options are shown below in Figure 24 to Figure 26.



Figure 24: Full road closure - Sign 1

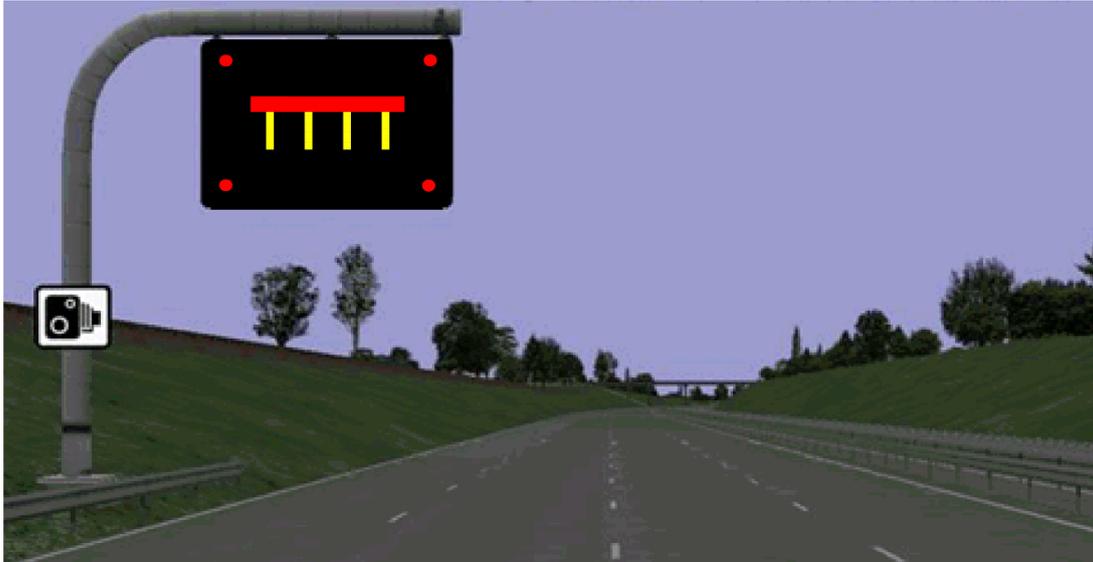


Figure 25: Full road closure - Sign 2



Figure 26: Full road closure - Sign 3

All participants saw all three options of the sign, however a secondary evaluation was also conducted to determine if the presence or absence of 'lanterns' on the sign had any influence on participant ratings. Half of the participants were therefore presented signs showing lanterns and half saw signs with the lanterns absent (the figures above all show lanterns). Table 37 shows a frequency table for the data.

Table 37: Frequency table of ratings of sign clarity

Condition	Answer rating										Mean score	
	1	2	3	4	5	6	7	8	9	10		
Sign 1 – lanterns	9	9	8	9		2	1		5	4	4.1	3.8
Sign 1 – no lanterns	14	7	7	5	3	5	2	1	1	2	3.5	
Sign 2 – lanterns	8	5	3	4	1	6	4	5	7	4	5.4	5.6
Sign 2 – no lanterns	6	2	6	4	3	1	9	8	3	5	5.7	
Sign 3 – lanterns		1		1	3		3	1	8	30	9.0	9.0
Sign 3 – no lanterns		1	1		1	1	1	3	9	30	9.1	

It is clear from the table that participants found Sign 3 to be the clearest of the three, and a suggestion that Sign 2 was similarly perceived to be better than Sign 1.

Statistical tests were performed on the data in order to provide a reliable indication of differences between the conditions. Due to the fact that not all sign configurations were seen by all participants, different tests needed to be performed to answer different questions. The following is a summary of the tests performed and their outcomes:

Test 1: Determine if there is an effect of lantern presence on score.

- The data for each sign option were looked at in isolation to see if there are differences in participant ratings between the two groups of those who saw signs with lanterns shown and those who saw signs without lanterns shown.
- Three independent-sample comparisons were therefore performed, using Mann-Whitney tests:
 - Sign 1 – lantern vs. no-lantern
 - Sign 2 – lantern vs. no-lantern
 - Sign 3 – lantern vs. no-lantern
- All three tests came back negative, showing that no significant difference in scores, based on the presence or absence of lanterns, could be determined.

Test 2: Determine if there are significant differences between the sign options, irrespective of whether there are lanterns present.

- The lantern and no-lantern data were combined such that each participant provided a rating score against each of the three sign designs.
- Paired-sample comparisons were conducted between each of the sign designs using Wilcoxon Signed Rank tests, thus the following tests were performed:
 - Sign 1 vs. Sign 2
 - Sign 1 vs. Sign 3
 - Sign 2 vs. Sign 3

- The tests showed that all three designs scored significantly differently from each other. Sign 3 scored highest, Sign 2 second and Sign 1 the lowest.

No significant effect of the presence or absence of lanterns on participant ratings of sign clarity could be identified.

Overall, participants rated Sign 3 as being the clearest, followed by Sign 2 and then Sign 1 as the least clear.

In addition to providing a rating of sign clarity, participants were also asked to report any reasons they may have had for believing any of the three options to be particularly unclear. Sign 1 was frequently criticised for the fact that there was only a single X displayed, and that it was presented directly over Lane 1. As such participants felt that it would be easy to interpret the sign to be a closure of Lane 1 only. Sign 2 was criticised principally because some participants found the symbol itself to be confusing. Some seemingly understood the symbol but felt that others might not, whilst other participants reported that they had no idea how the symbol was supposed to relate to a road closure. Despite the 'wicket' symbol being relatively common on the motorway network, it appears that in the four-lane-closure version the representation becomes more abstract to users. Sign 3 was criticised by some over the possibility that non-native English speakers would not understand it, although this was not enough to prevent it being voted overwhelmingly as the clearest of the three. All three signs were criticised in part for the lack of any specific information on where they would be expected to stop. For example some stated that they would possibly keep going until the next junction or until they saw an indication of the road being physically blocked. Some suggested a change of wording to "STOP NOW, ROAD CLOSED" (or similar) to offer some mitigation of this potential ambiguity.

In addition to being asked about the clarity of the three signs, participants were also asked to state their perceived likelihood of stopping if they encountered these signs in the real world. The results were the same, with participants overall stating they felt they were most likely to stop in response to Sign 3 and least likely to stop in response to Sign 1. Although not directly assessed in this study, it is possible that a sign formed from a combination of Signs 2 and 3 might prove to be a suitable option.

5.5.2 Do participants understand the informational storyboard regarding how to behave in an emergency breakdown situation?

A subset of 33 participant were presented with an informational storyboard intended to provide members of the public with information and instructions on how to behave in an MM-ALR environment, and what to do in the event of a breakdown. Having read through the storyboard participants were then asked to complete a very short questionnaire about their understanding of it. The participants who took part in this assessment were not chosen against any particular criteria, simply those who completed the trial quicker than anticipated and thus had some spare time within the allocated trial period, but the distribution of participants within the six age and sex categories was fairly even. The only deviation of note was a slight skew in to demographics of the female participants towards those in the 'old' category.

Within the questionnaire, participants were first asked to state, with a simple yes or no response, whether or not they understood the storyboard and, if not, what it was they

didn't understand. All 33 participants stated that they did understand the storyboard, although a few went on to provide feedback on a few elements:

- One participant stated that he *"would put the 'What do you do in a breakdown?' heading above the story board rather than at the top of the orange sidebar"*.
- Another stated that *"it would be good to provide very clear differences in a grid format - as you have to read and interpret and compare whole paragraphs; making the difference hard to spot."*
- A third participant reported feeling some clarification was needed over the instruction to park against the central barrier and leave by the passenger door, as this would require stepping out into traffic.

On the whole therefore, participant acceptance of the storyboard appears to be high.

Participants were also asked to rate how much they felt their understanding of what to do in MM-ALR environments had improved due to seeing the storyboard. Participants were given three response options: 'Not at all', 'slightly' and 'very much'. Figure 27 and Figure 28 show the frequency of participant responses to these three options based on age and gender respectively. The figures suggest that 'young' people found the storyboard to be more helpful than 'old' people, and that males found it more helpful than females, however it is not possible to verify these findings statistically due to the sample of female participants being skewed towards an over-representation of those in the 'old' category. This means that if either one of 'age' or 'sex' has a genuine effect on participant score, it will confound the result of the other one. The over-riding result is that all participants found the storyboard helpful in as much as it improved their understanding of what to do.

Figure 27: Participants' improvement in storyboard understanding, by age

	Answer		
Age group	Not at all	Slightly	Very much
Young	0	3	7
Middle	0	11	4
Old	0	6	2

Figure 28: Participants' improvement in storyboard understanding, by sex

	Answer		
Age group	Not at all	Slightly	Very much
Male	0	9	9
Female	0	11	4

5.5.3 Awareness of text messages

Participants’ awareness of the text messages presented on MS4s within an MM-ALR environment was measured through the situational awareness assessment (described in Section 4.5.3.1) in which they were asked one of the following questions just after passing a verge-mounted MS4:

"Did the last variable message sign say 'Stay in lane' or 'Queue ahead'?" - asked in Route 1, MM-ALR

"Did the last variable message sign say 'Stay in lane' or 'Caution'?" - asked in the MM-ALR section of Routes 3 and 4

Figure 2 illustrates the location on each of these routes that the question was asked.

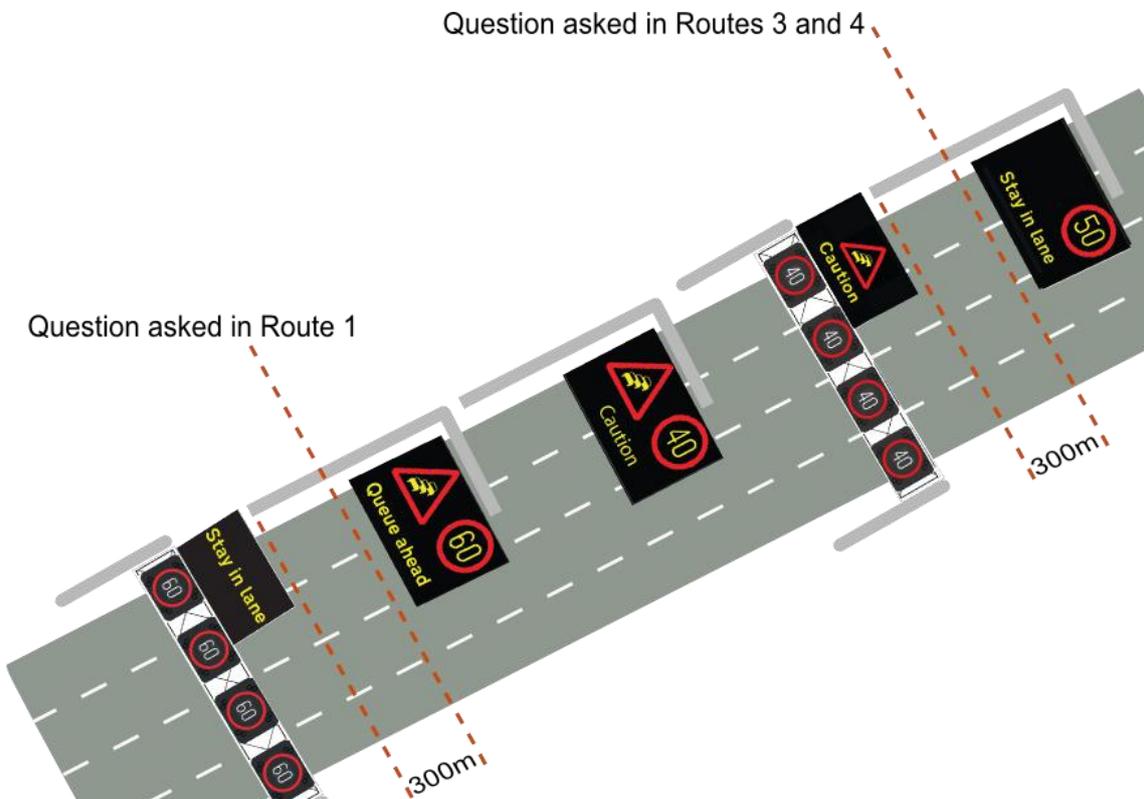


Figure 29: Locations in MM-ALR sections where the text message question was asked

Table 38 summarises the responses given by participants at the two locations. Participants are also asked how confident they were of their answer on a scale of 1-10.

Table 38: Response to question regarding the VMS text

	No.of participants	Correct response	Percentage correct	Mean confidence in answer	Most frequent incorrect response
Route 1	48	Queue ahead	35%	7.5	Stay in lane (60%, 8.2 confidence)
Route 3/4	47	Stay in lane	81%	8.3	Caution (17%, 6.3 confidence)

As can be seen from Table 38, the majority when having just passed a 'Stay in lane' message correctly identified the message. However, when having just passed a 'Queue ahead' message most participants answered incorrectly. A likely explanation is that 'Stay in lane' is an instructive message requiring the participant to perhaps take appropriate action, where 'Queue ahead' is informative message only.

6 Conclusions

In summary, the following conclusions can be drawn from this study in response to the four questions making up the task objective:

Is the guidance provided in an MM-ALR environment adequate for drivers to be aware of the relevant information?

The findings of the situational awareness assessment found that, regarding the MM-ALR environment:

- Most participants were aware of the speed limit and awareness is increased if the speed limit is repeated. The small number of participants who were unable to correctly identify the speed limit after seeing it for the first time was comparable with the proportion of participants who were unable to do so in an MM-DHS environment. This suggests that any lack of awareness is not necessarily associated with the particulars of the MM-ALR design.
- The vast majority of participants were aware that there were four lanes available for traffic to drive in, i.e. that Lane 1 is not a hard shoulder. When asked for the second time, all participants answered correctly.
- Participants were aware of the destination of the next junction after passing the 1 mile ADS sign irrespective of the design option. They also suggest that participants driving a route with standard ADS signs located in the verge were less aware of the distance to the next junction.
- Participants were more likely to consider an ERA as the location to stop in the event of a breakdown than any other option. Participants' understanding of where to stop was dependent on where they are in the route and recent driving experience. No participants understood any lane other than Lane 1 as a place that they would stop in an emergency.

Is the guidance provided in an MM-ALR environment adequate for drivers to respond to the information in the desired manner?

Analysis of the data from the driving simulator found that, regarding the MM-ALR environment:

- The speed which participants drove at was greatly influenced by the speed of the simulated traffic. As a result, there was very little difference in speeds between those in the MM-ALR environment and in the standard 3-lane environment with the same traffic conditions. Also when the simulated traffic was largely non-compliant with the speed limits, the greatest amount of non-compliance by the participants was observed.
- Lane 1 was not well used by participants when they first drove the MM-ALR environment, although this was a similar degree to which the nearside lane was used in the standard 3-lane environment. This utilisation of Lane 1 significantly increased when participants drove it for the second time.
- A large majority of drivers recognised the approach of the Greenhill junction and moved into Lane 1 accordingly. Most drivers had entered Lane 1 by the time of their encounter with the ½ mile to junction sign. There were no differences in the mean position where drivers moved into Lane 1 between all three route conditions examined.

- Just over two thirds of participants (32 of 47) in the emergency breakdown scenario stopped on the slip, with a further five indicating they attempted to do so by stopping in the mouth of the junction when encountering a queue of traffic blocking the slip. A minority of drivers chose locations which were less appropriate, with a total of seven participant's either stopped on Lane 1 before the slip (5), or drew onto the grass verge (2). Two participants drove past the junction and stopped on the hard shoulder. Only one participant halted their vehicle on the main carriageway, most likely as a consequence of misunderstanding the vehicle fault as a technical fault with the simulator.

Is the driving experience comfortable and intuitive, and perceived as safe?

Analysis of the questionnaire data found that:

- Participants experienced similar feelings of safety, comfort, stress and confidence during their undertaking of the MM-ALR route and the standard 3-lane route in the simulator, indicating that these feelings do not significantly differ between an MM-ALR environment and a typical motorway environment during busy traffic periods.
- Participants rated the sufficiency of junction information similarly between the verge-mounted and overhead conditions.
- Drivers reported that they found the information in verge signs more clearly presented but seemingly were worried about signs being obscured by high-sided vehicles.
- Missing visual information due to obscuration may be perceived to be an issue but, provided it is seen, misunderstanding the information is uncommon.

Does the MM-ALR environment affect behaviour in subsequent environments?

- There were only two (out of 97) minor occurrences of hard shoulder non-compliance, both due merge-override in the MM-DHS section following the MM-ALR section. All participants undertaking the situational awareness assessment correctly identified that there were only three lanes available in the sections following the MM-ALR section.
- All participants undertaking the situational awareness assessment correctly identified that there were only three lanes available in the sections following the MM-ALR section.
- There was a moderate amount of non-compliance with the speed limit in both the MM-DHS section and the CM section, although participants' chosen speeds are likely to have been greatly influenced by the speed of the surrounding traffic.

Additional research questions:

- Overall, participants rated the text only sign as being the clearest, followed by the Wicket aspect and then the Red X aspect as the least clear.
- No significant effect of the presence or absence of lanterns on participant ratings of sign clarity could be identified.
- All participants suggested that reading an informational leaflet about how to respond in an MM-ALR environment in the event of a breakdown improved their understanding of what they should do.

These findings help to provide assurance that, in general, the information provided within a scheme designed to the specification provided in IAN161/12 will be appropriate for road users to understand how they are expected to behave under normal operation in busy traffic conditions.

Appendix A Ethics and data protection

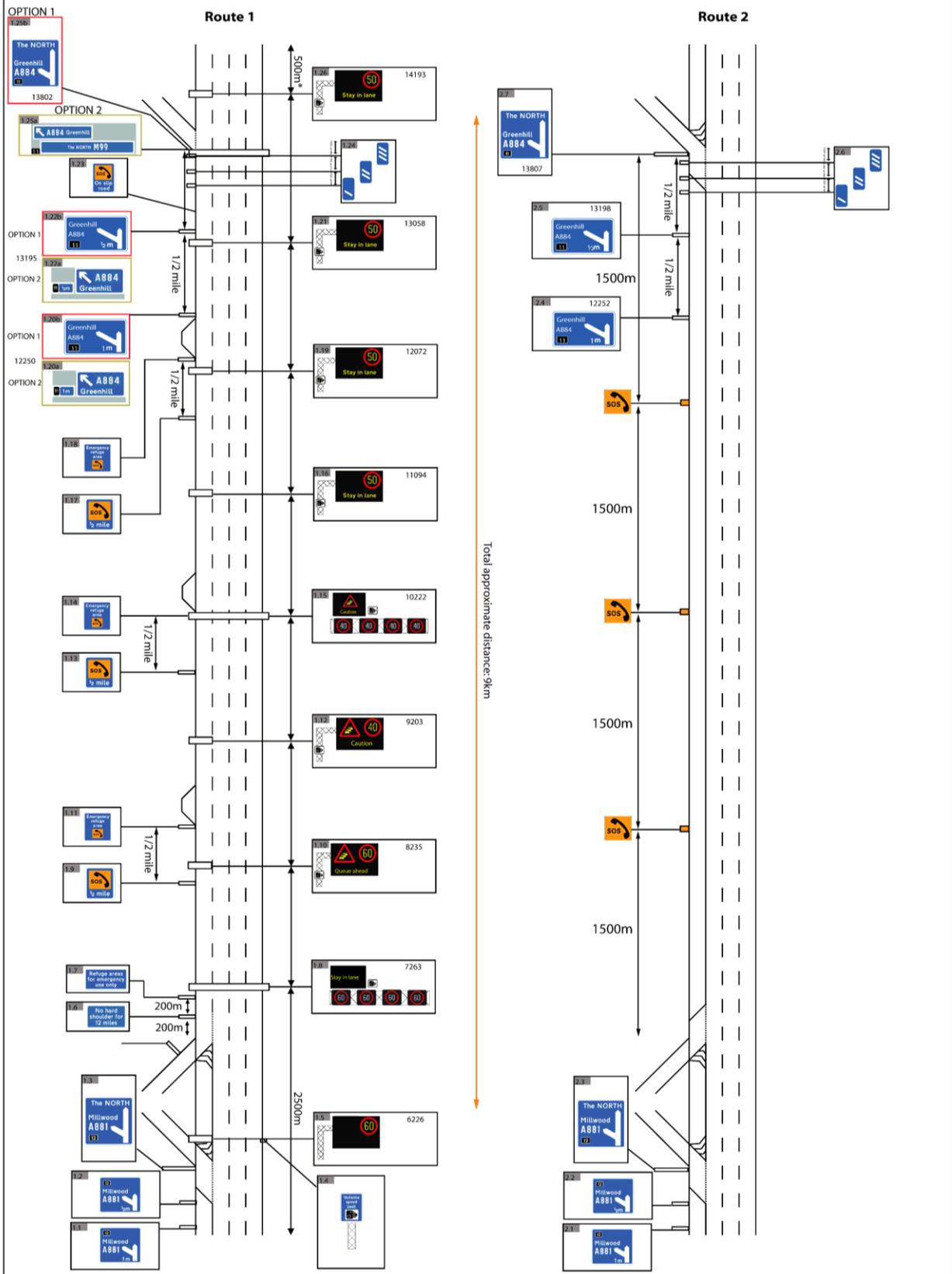
Research at TRL is designed and executed to the highest scientific and ethical standards of professional integrity. TRL operates a quality management system as part of its Integrated Management System (IMS).

All project outputs are subject to TRL's Project Technical Review Procedure, whereby scientific reports are reviewed by the project Technical Referee before leaving TRL. In addition, TRL projects involving human participants are required to complete a TRL Ethical approval Checklist and Application Form, which is submitted for assessment by a specialist Ethics Panel to ensure that all study designs follow recognised ethical principles. During the trial, strict ethical procedures for participant handling are undertaken by trained TRL staff.

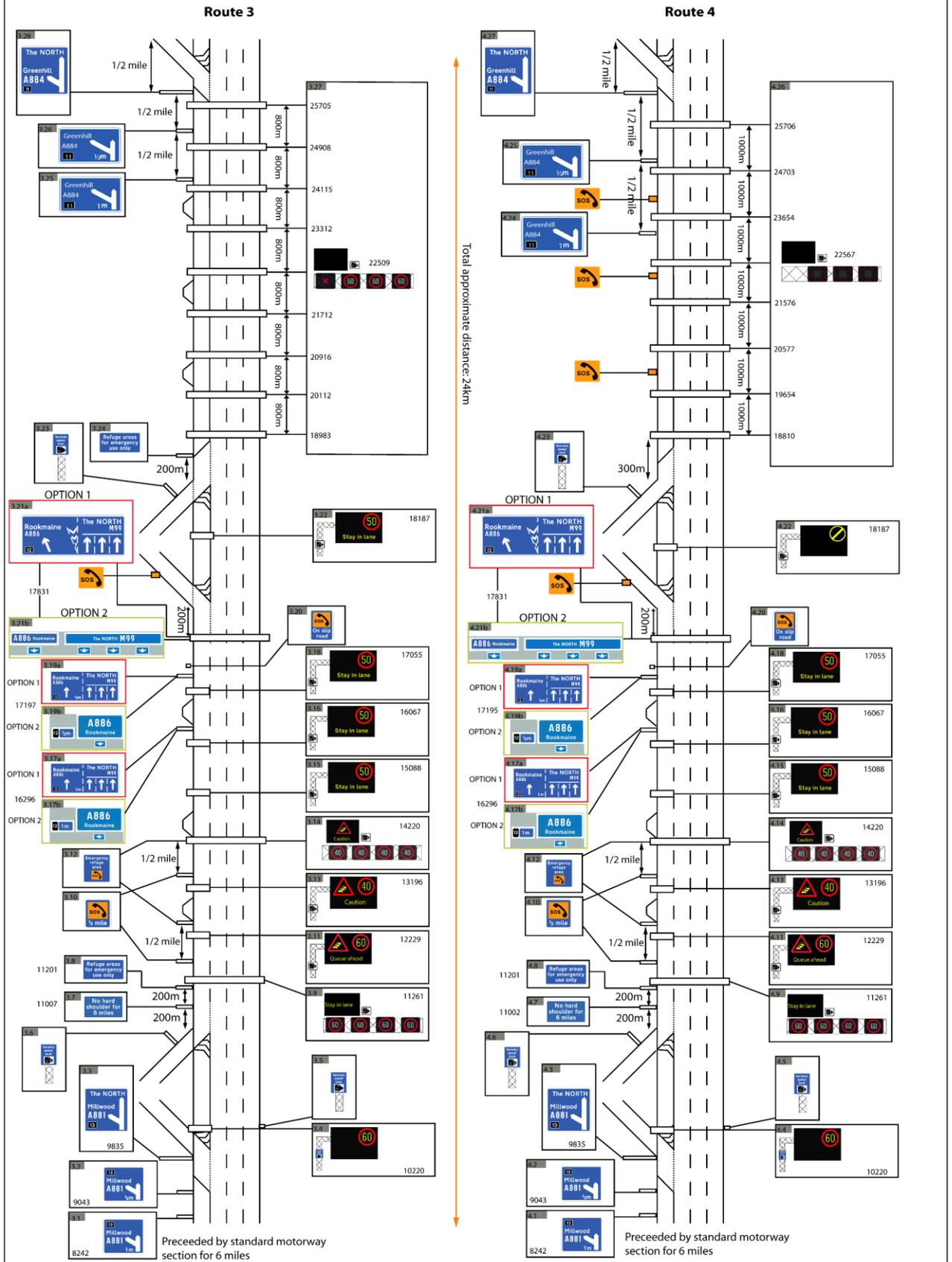
Standard operating procedures for secure data management, back-up and archiving implemented to ensure data confidentiality, intellectual property and human rights are maintained at all times. In line with the requirements of the Data Protection Act 1988, TRL operates a policy for non-disclosure of the identity of research participants and as all data outputs and reports will be kept anonymous. Participants are required to complete a Privacy Statement prior to partaking in a trial.

Appendix B Trial route specifications

future Managed Motorways concept - Task 2 Route Specification - Version 7 (page 1 of 2)



future Managed Motorways concept - Task 2 Route Specification - Version 7 (page 2 of 2)



Appendix C Additional data tables

Table 39 provides some further information about the participants who failed to leave at correct junction on both Route 1 and Route 2.

Table 39: Participants who failed to leave at the correct junction on both Route 1 and Route 2

Participant Number	Age	Sex	No. of years holding licence	Annual mileage
19	27	F	10	5000
23	22	F	4	4000
30	21	M	4	7000

Table 40 **Error! Reference source not found.** presents the same information for the three participants who failed to leave at the correct junction on of either Route 1 or 2.

Table 40: Participants who failed to leave at the correct junction on either Route 1 or Route 2

Route	Participant Number	Age	Sex	No. of years holding licence	Annual mileage
1 Option 2	61	61	F	44	6000
1 Option 2	91	68	F	43	9000
2	78	22	M	1	4000