

Managed Motorways - All Lanes Running (MM-ALR) Provision of Adequate Guidance Review Issue B

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Executive Summary

The concept design of Managed Motorways - All lanes running (MM-ALR) has a reduced level of signalling and variable message signing compared to MM Hard Shoulder Running (HSR) schemes designed to Interim Advice Note (IAN) 111/09 [1]. In addition, MM-ALR signalling, variable message signing and fixed signing will be predominantly verge mounted unlike the requirement in IAN 111/09 for overhead mounted signalling and signing on portal gantries.

This adequacy assessment will only indicate a level of confidence. A residual risk will remain that adequate guidance is not provided until the MM-ALR concept is operationally proven. Gathering and assessing relevant and robust evidence is essential to help maximise the level of confidence and effectively assess this risk prior to going live.

The majority of the 'Strong Evidence' contained within this assessment has been obtained through the Future MM Concept Development Simulator Trial. Although this evidence has provided a good indication as to how drivers are likely to behave in an MM-ALR environment it needs to be recognised that the MM Concept Development Trial is based upon a driver simulator and responses to questionnaires. Whilst this does provide the best evidence available at this time, it is not until a MM-ALR scheme is constructed and commences operation it will be truly known just how drivers will react and behave in an MM-ALR environment.

The information presented in this report demonstrates the below key points.

- Compliance with speed limits is likely to be achieved:
 - Speed compliance on existing MM-HSR (IAN 111/09) schemes with portal gantries is very good.
Strong evidence identified
 - Variable speed limits on MM-ALR are expected to provide adequate guidance and deliver acceptable levels of compliance
Strong simulator evidence identified, supported by off-road trials
 - It will be possible to enforce speed limits on MM-ALR at gateway and intermediate portal gantries
Strong evidence identified
- Lane Information provided is likely to achieve the required driver behaviour
 - Verge direction signing on MM-ALR is expected to provide adequate guidance
Strong simulator evidence identified that the performance of cantilever mounted ADS will be acceptable; mixed evidence for post mounted
 - Cantilever mounted VMS lane closure information on MM-ALR is expected to provide adequate guidance to drivers
Strong simulator evidence identified, supported by off-road trials.
- Suitable headways are likely to be achieved
 - Advance warning of queues is likely to be provided

Strong evidence identified

- Congestion is likely to be managed
Strong evidence identified

It should be noted that the evidence that exists on enforceability of mandatory speed limits is substantially associated with AMI signals located over each lane on portal gantries. Whilst evidence has been identified that MS4 signalling will provide adequate guidance to the driver it is our view that work still needs to be done before it could confidently be demonstrated that these signals are legally enforceable. The potential enforcement from MS4s is currently in development and this could be trialled on an early MM-ALR scheme.

This report has shown that strong evidence has been confirmed for a number of goals to demonstrate that adequate guidance and adequate information is likely to be provided to the road user so that he/she understands how he/she is expected to behave on an MM-ALR scheme.

It is also worth noting that the Future Managed Motorways Concept Development – Task 3 June 2012 [14] report provides the following summary:

“In summary the work conducted to examine behavioural issues related to MM-ALR has identified minor areas of concern with regard to participants perception of how MM-ALR schemes operate and what behaviours they are expected to adopt, but has not identified any compelling evidence to suggest that an MM-ALR scheme of the design tested in the simulator does not provide sufficient information to understand and exhibit the required driving behaviour to a level comparable to existing Managed Motorway schemes.”

Summary

This adequacy assessment has indicated a level of confidence and provided strong evidence in a number of key areas to demonstrate that adequate guidance and information is likely to be provided to the motorist. A number of the assumptions and associated conclusions on the likely driver behaviour are based on simulator derived evidence and a residual risk will remain that adequate guidance is not provided until the MM-ALR concept is operationally proven. Accordingly, it is recommended that due consideration is given to the capture of before and after monitoring data in order to effectively validate those assumptions.

1 Introduction

1.1 Objective of this paper

The concept design of Managed Motorways - All lanes running (MM-ALR) has a reduced level of signalling and variable message signing compared to MM Hard Shoulder Running (HSR) schemes designed to Interim Advice Note (IAN) 111/09 [1]. In addition, MM-ALR signalling, variable message signing and fixed signing will be predominantly verge mounted unlike the requirement in IAN 111/09 for overhead mounted signalling and signing on portal gantries.

The objective of this paper is to review whether the concept design of MM-ALR is likely to provide adequate guidance and adequate information to the road user so that they understand how they are expected to behave within the new MM-ALR environment. As part of this assessment the paper will consider whether it will be possible to undertake enforcement in an MM-ALR environment.

This adequacy assessment will only indicate a level of confidence. A residual risk will remain that adequate guidance is not provided until the MM-ALR concept is operationally proven. Gathering and assessing relevant and robust evidence is essential to help maximise the level of confidence and effectively assess this risk prior to going live.

1.2 Background

1.2.1 Managed Motorways Development

The MM pilot project on the M42 between Junctions 3A and 7 commenced operation in September 2006 and became the first motorway in the UK to dynamically use the hard shoulder as a running lane. The pilot project led the way in new approaches to address the issue of congestion and provided effective and innovative technology solutions. The concept was further developed through the delivery of the Birmingham Box Managed Motorways Phase 1 and 2 (BBMM12) schemes and through IAN111/09 Hard Shoulder Running Design guidance [1]. IAN 111/09 reduced the level of infrastructure when compared to the initial pilot – for example gantries were installed at nominal 800m distances compared to nominal 500m on the pilot.

Highways Agency objectives to continue the development of the Managed Motorways concept together with increased pressure on HA budgets has provided the stimulus for the development of a revised concept for MM, known as All lanes running (MM-ALR) which incorporates the permanent conversion of the hard shoulder into a running lane and reduces the level of infrastructure compared to an IAN 111/09 scheme. IAN 161/12 Managed Motorway All lanes running [36] is expected to contribute to Agency business aims by reducing the capital and operating costs of managed motorway schemes, whilst meeting congestion and safety objectives.

Appendix A provides an overview of the MM-ALR concept design.

1.2.2 Legislation Framework

An overview of the key legislation framework is as follows:

Section 85 (1) of the Road Traffic Regulation Act 1984 (RTRA) [2] provides that:

*“For the purpose of securing that **adequate guidance** is given to drivers of motor vehicle as to whether any, and if so what, limit of speed is to be observed on any road, it shall be the duty of the Secretary of State, in the case of a road for which he is the traffic authority to erect and maintain traffic signs in such positions as may be requisite for that purpose”.*

A MM-ALR scheme must demonstrate that ‘adequate guidance’ has been provided to make sure that drivers are aware of the speed limits and other instruction/information being displayed.

With regards to the Traffic Signs Regulations and General Directions 2002 (TSRGD) [3], Department for Transport (DfT) legal have advised that although the Secretary of State (SoS) is required to follow the Traffic Sign Regulations (describes the types of signing that should be used), the General Directions (which set out the circumstances and conditions under which certain traffic signs may be placed on or near roads) do not apply to the SoS. The minutes [4] from the DfT meeting where the legislative requirements were discussed are shown at Appendix B.

This is the approach that has been followed for all Controlled Motorways and MM schemes to date. In using lane specific gantry mounted Advanced Motorway Indicators (AMIs) there is a robust case for stating that the Highways Agency satisfies the Secretary of States’ duty to provide ‘adequate guidance’. Unlike an IAN 111/09 scheme, the MM-ALR design uses verge mounted information (e.g. cantilever Message Signs Mark 4 (MS4s) and verge mounted Advance Direction Signs (ADS)) and therefore the Highways Agency needs to determine that the concept design will provide ‘adequate guidance’ to road users.

Other relevant documentation includes the Highway Code [5] and Traffic Signs Manual [6]. Road users are expected to comply with the requirements of the Highway Code but their levels of compliance will be dependent on whether an MM-ALR scheme provides appropriate and relevant information at optimum locations. The Traffic Signs Manual, Design Manual for Roads and Bridges (DMRB) and Interim Advice Notes (IANs) set out the requirements for use of signs, signals and road markings and this enables the designer to ensure that information is provided to the required standard.

1.3 Defining what is ‘adequate’

Adequate can be defined as ‘*enough or good enough for a particular purpose*’¹. The Highways Agency will be required to demonstrate that the provision of signalling and signing to inform drivers of the speed limit and other information is sufficient to meet its purpose. One key indicator of providing information through the use of signs and signals to satisfy the legal requirement for adequate guidance is to obtain ‘compliant

¹ Definition of adequate [adjective] from the Cambridge Business English Dictionary.

driver behaviour'. A further requirement for the provision of a controlled environment is to enable speed enforcement to be undertaken. Obtaining compliant driver behaviour will result in a scheme which is safe and provides considerable congestion benefits. In order to meet its purpose, drivers need to understand what is expected from them and behave in accordance with the information/instructions being provided. Should appropriate and relevant information not be provided then drivers may not comply and less of the congestion and safety benefits of MM-ALR will be achieved.

Within an MM-ALR scheme display of information/instruction is required for a number of different reasons. A review of each piece of display information is important to establish whether a scheme provides adequate guidance. Table 1-1 below shows the type of information and also the purpose and impact of providing that information.

Table 1-1: Display Information - Purpose and Impact

Information	Purpose	Impact on driver behaviour and why important
Speed	To provide adequate guidance to road users of the speed limit on the carriageway	At low flow times the national speed limit will apply. During heavier traffic flows, and after incidents, variable speed limits will be set. Good levels of compliance with signal settings including speed are assumed as part of the MM-ALR safety assessment. In particular compliance with reduced speed limits during incident management and when setting out temporary traffic management (TTM) protects vulnerable road users (if outside their vehicles during incidents), Traffic Officers, Maintainers, the Emergency Services, and staff from recovery organisations. Lower levels of compliance may result in schemes failing to meet their safety and operational performance targets.
Destination	To provide information on the next junction exit. Also enable drivers to position themselves in the most appropriate lane.	Enables driver to position themselves in the appropriate lane - clear information will reduce amount of weaving and late lane changes (swooping).
Incident Management (Collisions)	To provide relevant and appropriate information so that drivers are aware of incidents	Safety and operational benefits including management of changes in number of lanes available to traffic and provision of information.
Road works (i.e. Lane closures)	Lanes closed and information provided on MS4s as necessary to close lanes while TTM is being set out/removed	Directs traffic out of lanes that are about to be closed for maintenance, protecting roadworkers.
Queue Protection	To provide relevant and appropriate information to drivers to warn them of queues and reduce speeds accordingly	This is important to protect queuing traffic and will help prevent secondary incidents from occurring. Drivers will be aware of congestion/incident and react accordingly.

Congestion management	To smooth traffic flow, reduce the occurrence of flow breakdown and improve capacity during periods of heavy traffic; and to reduce the number of congestion related collisions	This is one of the key reasons why MM provides considerable congestion benefits ² . Speeds are reduced resulting in smoother traffic flows.
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Considering Table 1-1 the question on adequate guidance can be rephrased to,

“Will an adequate level of information/guidance be provided to the road user so that they understand how they are expected to ‘behave’ within the motorway environment of MM-ALR?”

Where ‘behave’ means **compliance with speed** (rows highlighted in yellow in Table 1-1), **correct lane** (white rows in Table 1-1, **and a suitable headway** (rows highlighted in blue in Table 1-1).

A comprehensive behaviour assessment should also include whether road users will use refuge areas and ERTs as intended by the design.

1.4 Goal-Structured Notation (GSN)

Answering a question such as what is adequate guidance is difficult, even when rephrased as above. Therefore it is useful to break the question down into a number of parts that answered together address the overarching questioning. This creates a number of arguments that can be individually considered.

Goal-Structured Notation (GSN) has been used to structure the arguments in a graphical manner. A GSN diagram shows how goals are broken down into sub-goals and eventually supported by evidence, whilst making clear the strategies adopted to meet the goals and the context in which goals are stated. These four entities are depicted by the following shapes.

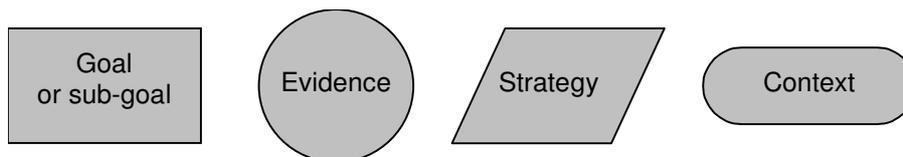


Figure 1-1: Four entities of GSN

The GSN diagram for this report is supplied at Appendix C of this document. Colour is used to denote progress with goals as shown in Figure 1-2.

² The main impact of MM is to provide additional capacity in the form of an additional lane.

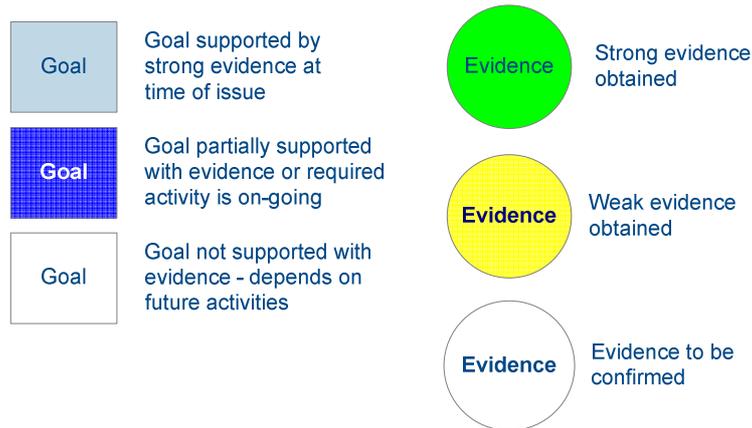


Figure 1-2: Key to progress with GSN goals

The GSN diagram shows how the question of providing adequate guidance has been addressed.

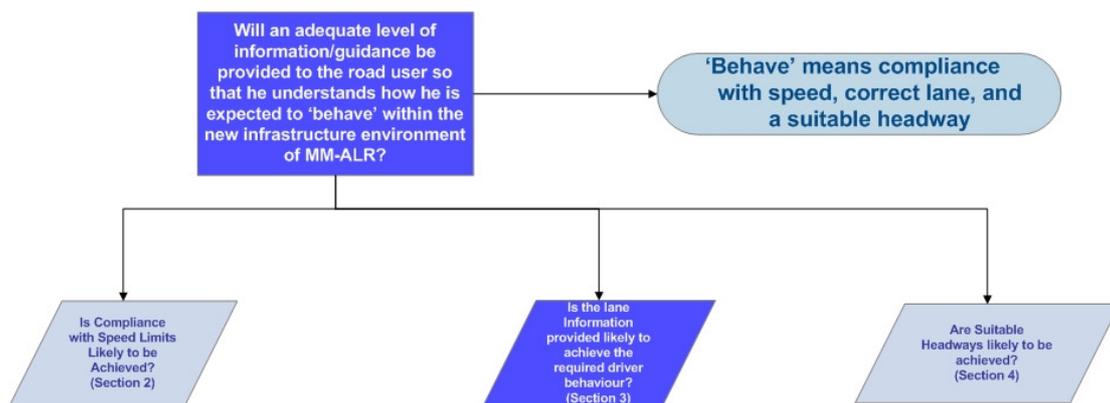


Figure 1-3: Three strategies to demonstrate that an adequate level of information / guidance will be provided to road users

1.5 Document Structure

The remaining sections of this report are therefore structured as follows:

Section 2 considers whether "Compliance with speed limits is likely to be achieved?"

Section 3 considers whether, "Lane Information provided is likely to achieve the required driver behaviour?"

Section 4 considers whether, "Suitable headways are likely to be achieved?"

Section 5 provides the conclusions.

1.6 Evidence

Within each section evidence is provided to support the goals (see Appendix C). Some of the evidence is strong in that studies have been completed and empirical

Safe roads, reliable journeys, informed travellers

data is available to support the goal. However in some cases the evidence is weaker or still to be gathered. Therefore following receipt of further stronger evidence this report may need to be updated to reassess the level of confidence that 'adequate guidance' will be provided.

1.7 Status Boxes

Where an element of the evidence is not yet confirmed a 'Status' box is provided to explain what remains to be completed; an example is provided below.

Example Status: Before implementation of MM-ALR the signals are to be checked on signals test bed and FAT.

2 Is Compliance with Speed Limits Likely to be Achieved?

This section demonstrates that:

- Speed compliance on existing MM-HSR (IAN 111/09) schemes with portal gantries is very good
- Variable speed limits on MM-ALR are likely to provide adequate guidance and deliver acceptable levels of compliance
- It will be possible to enforce speed limits on MM-ALR

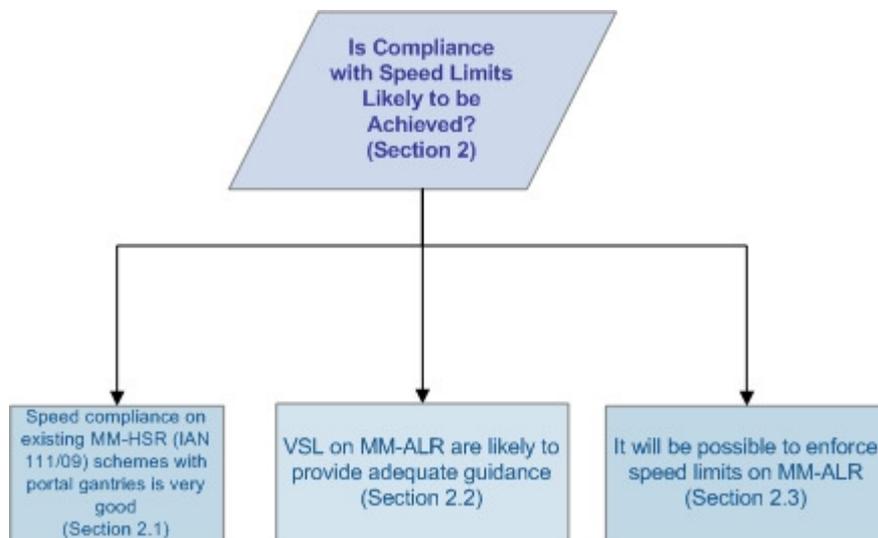


Figure 2-1: Extract of GSN showing how it is demonstrated that compliance with speed limits is likely to be achieved

2.1 *Speed compliance on existing MM-HSR (IAN 111/09) schemes with portal gantries is very good*

This section demonstrates that:

- Evidence from existing MM schemes (M42 MM and BBMM12) shows a high level of compliance.
- Existing MM schemes provide more reliable journeys encouraging compliance.
- Evidence from existing MM schemes (M42 MM and BBMM12) shows MM creates a controlled environment.

2.1.1 Evidence from existing MM schemes shows a high level of compliance

Strong Evidence:

a) The ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report [7] [M42 MM]:

“When considering the Association of Chief Police Officers (ACPO) threshold of enforcement (speed limit +10% +2 mph), compliance on the main carriageway was on average 94% or better at the 70 mph, 60 mph, 50 mph speed limits and 84% or better at the 40 mph speed limit between January 2006 and September 2007.”

b) M42 ATM Monitoring Compliance with VMSL [Variable Mandatory Speed Limits], Lane Closures & Hard Shoulder Operation January – February 2009 [8]

“When considering the ACPO threshold of enforcement (speed limit + 10% + 2 mph), compliance on the main carriageway has, on average, been 95% or better at 70 mph, 60 mph and 50mph speed limits and 77% or better at the 40 mph speed limit from February 2008 to February 2009.”

c) Managed Motorway Monitoring and Evaluation of Through Junction Running and Safety BBMM1 Compliance with VMSL & Hard Shoulder Operation October 2010 [9]

“When considering the ACPO threshold of enforcement, compliance on the main carriageway has, on average, remained consistent over the three month period at the 50mph (90%), 60mph (96%) and 70mph (94%) speed limits. Compliance with the 40mph speed limit has been 77% or better.”

Discussion:

The level of speed compliance on the M42 MM and Birmingham Box Managed Motorways Phase 1 (BBMM1) schemes has significantly supported the safe and successful operation of the MM concept. Controlling the speed and behaviour of traffic has enabled the realisation of traffic benefits. In order to achieve a similar level of compliance on an MM-ALR scheme adequate signal provision alongside a suitable compliance strategy and education campaign will need to be in place so that drivers understand the reasons why they should comply with the information provided and also so that if drivers do exceed the speed limit then they risk prosecution. **If the majority of road users travel at the speed limits then it limits the ability of other road users to speed.** Without an appropriate compliance strategy or education campaign it is unlikely that a similar level of compliance would be achieved.

2.1.2 Existing MM schemes provide more reliable journeys encouraging compliance

Strong Evidence:

a) The ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report [7]:

“4L-VMSL demonstrated that on average over all weekdays the variability of journey times has been reduced by 22% and 32% when compared to No-VSL [Variable Speed Limits] and 3L-VMSL respectively. Drivers are therefore more able to predict their overall journey times as the difference between the worst and best cases is greatly reduced”

“On average, over all weekday types, the variability of journey times has been reduced by 21% and 22%, with respect to the northbound and southbound directions”.

Discussion

The introduction of more reliable journeys is a key consideration for road users as surveys have indicated that ‘not knowing’ the time a journey is going to take is a major frustration. Therefore making Journey Times reliable day in, day out is a key benefit that the existing MM schemes (i.e. M42 MM Pilot) has delivered to the road user. Customer surveys have shown that the significant increase in Journey Time reliability was seen as key in giving a relaxing journey.

MM-ALR will introduce a reduced level of infrastructure when compared to an IAN 111/09 scheme. Through their design the existing MM (IAN 111/09) schemes have encouraged compliance. Through the introduction of additional capacity on an MM-ALR designed scheme there will be a higher probability of freeflow driving conditions than previously and therefore there is likely to be less inclination for a road user to change lanes or speed to recover lost time or gain an advantage over other traffic – this will result in drivers being encouraged to comply.

2.1.3 Evidence from existing MM schemes (M42 MM and BBMM12) shows MM creates a controlled environment

Strong Evidence:

a) The ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report [7]:

“The outcome of implementing a controlled environment is as follows: “The analysis demonstrates that 4L-VMSL has been successful in reducing congestion, improving the predictability of journey times and increasing motorway capacity.”

Weak Evidence:

b) Interim Advice Note (IAN) 111/09 Managed Motorways implementation guidance – Hard shoulder running [1]

“Managed Motorways is a ‘tool-box’ which facilitates the dynamic control of traffic for congestion and incident management. The tools allow the road space to be managed in different ways for varying conditions to maximise capacity whilst providing a safe and informed environment for the travelling public and on-road resources. The safety assessment must take account of the general reduction in safety risk which has been experienced from the M42 ATM Pilot between Junction 3A and 7 and is likely to result from the ‘controlled environment’”. [Note this is weak evidence as it does not provide outcomes – this is provided by the strong evidence above.]

Discussion

The concept of a controlled environment is to some extent related to the amount of infrastructure and technology introduced through the existing MM (IAN 111/09) [1] schemes. This will be reduced with an MM-ALR scheme with no fixed hard shoulder cameras and fewer opportunities to provide information. However there will still be comprehensive CCTV coverage and information will be located at spacing which optimises the amount of time that a driver cannot see the next signal/variable message sign within the signal spacing design parameters.

MM-ALR will increase the spacing of signalling, and a significant amount of it will be cantilever mounted in the verge (the MS4s) rather than overhead for all lanes. Signalling will be regularly spaced and the design of the MM-ALR schemes will result in good forward visibility before the next signal. The location of signs and signals will need to meet a number of design criteria to ensure appropriate provision of information. This siting criteria is detailed in IAN 161/12 [36].

2.2 VSL on MM-ALR are likely to provide adequate guidance

This section demonstrates that:

- The number of pieces of information is likely to be acceptable to road users
- VSL displayed in the verge will lead to acceptable levels of speed compliance
- Obscuration of VSL by HGVs is not expected to prevent acceptable levels of compliance being achieved.
- The distance between information is likely to be acceptable for compliant driver behaviour
- Impact of equipment failure should not materially affect operation.

2.2.1 Number of pieces of information is likely to be acceptable to road users

Strong Evidence:

a) Future MM Concept Development Simulator Trial Task 1 (May 2012) [12]

“Overall, the results suggested that in the mixed route (i.e. the general design approach outlined in IAN161/12) participants understood the information presented to them and exhibited appropriate driving behaviour”.

“Participants reported a high degree of certainty of what the speed limit was across all three routes [gantry mounted AMI only, verge mounted MS4 only, and mixed] although participants were slightly less sure in the mixed route than the gantry route”.

b) Future MM Concept Development Simulator Trial Task 2 (June 2012) [13]

“These findings help to provide reassurance that, in general, the information provided within a scheme designed to the specification provided in IAN 161/12 will be appropriate for road users to understand how they are expected to behave under normal operation in busy traffic conditions”.

Following situational awareness assessment *“The findings suggest that most participants [average 83%] 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”.*

c) Managed Motorways Concept Development Tasks 2, 3 4 and 5 March 2011 [11]

"In summary, the results for both the static and dynamic versions suggested that participants' accuracy and speed of comprehension of information presented on a single verge-mounted MS4 was greater than or equal to the same information displayed on gantry-mounted signals and an MS4".

"For both the static and dynamic versions, there was no occasion where an individual gantry-mounted option was responded to significantly faster than an equivalent individual verge-mounted option for any of the statement categories. On the contrary, several verge-mounted options outperformed gantry-mounted options and indicate that driver information can be equally or better relayed via verge-mounted MS4 options than via gantry-mounted options".

"There was no evidence to suggest that the addition of supplementary information adversely affected the response times to verge-mounted options compared with gantry-mounted options; there was only one occasion when a gantry-mounted option was responded to significantly faster than a verge-mounted option, where the verge option included an additional supplementary element. However, it does appear that the addition of supplementary information can affect response times for both verge-mounted and gantry-mounted options"

d) MS4 Signalling Development Display Trial Findings Report [16]

"The trial was attended by some 21 stakeholders, who achieved a broad consensus that the display technology used on the MS4 provides all the necessary optical performance for potential use of verge mounted displays for managed motorways.

e) Highways Agency policy for the use of Variable Signs and Signals (VSS) [23]

"A risk based approach has been taken to ensure that all legends and guiding principles found within this policy document are appropriate for use. Research carried out in 2010 by Nottingham University on behalf of the Highways Agency has proven that it is appropriate to display legends on fixed VMS which contain a maximum of 7 pieces of information, using an absolute maximum of 10 words, although best practice is that legends should be restricted to a maximum of 8 words."

"Portable VMS are located on a verge, and not above a carriageway. Due to this all legends shown on portable VMS shall not contain more than 4 units of information as the verge location limits the amount of time drivers have to read and absorb the information displayed."

f) VMS Customer Research (GRIPS), Process to support VMS approval [24]

The Nottingham University research underlying the VSS policy states that "The message should not contain more than seven pieces of information but traffic speed (if low) may allow more to be displayed."

Discussion:

On an existing MM HSR (IAN 111/09 [1]) designed scheme drivers will pass gantries containing AMIs above each lane which display a speed aspect and an MS4 will be positioned on the gantry and will display an appropriate message with regard to the status of the hard shoulder (during HSR). Also at some locations there could be a fixed ADS located above the gantry boom alongside a speed enforcement camera sign. At these locations a driver could be faced with several different pieces of information that he needs to acknowledge. The monitoring results from the initial MM schemes have shown that drivers generally understand what is expected from them and therefore the majority comply with the speed limits on display.

On a D3M scheme there could be MS4s located at 1500m intervals and these have the capability of displaying many of the same messages (e.g. pictogram, speed aspect and text) as would be displayed on a MM-ALR scheme with the exception that on a D3M scheme the MS4s will only display advisory speeds and would not display wicket and speed information concurrently. During incident management appropriate messages would be displayed to close lanes.

An example of the typical information that could be displayed on an MS4 on a MM-ALR scheme is shown below in Figure 2-2.



Figure 2-2: Example of an MM-ALR MS4 showing speed and queue protection information

There are three areas of the MS4 where drivers would be required to see the information. The speed will be located on the right of the MS4 with pictogram/wicket on the left and a text message towards the bottom of the MS4. It should be noted that this information will be in the same place (i.e. on the MS4) and not over each lane (i.e. individual lane signals) and evidence from the Managed Motorways Concept Development Tasks 2, 3 4 and 5 March 2011 [11] concludes that the speed of comprehension of information presented on a single verge-mounted MS4 was greater than or equal to the same information displayed on gantry-mounted signals and an MS4.

Generally ADS will not be co-located and is likely to be verge mounted. The results from the simulator trial (Tasks 1 and 2 June 2012 [12] [13]) have provided further evidence as to whether the number of pieces of information is acceptable to road users. The outcome from the simulator trial is that in general the MM-ALR scheme is likely to provide sufficient information for road users to understand how they are expected to behave.

It is likely that, as shown from the Highways Agency policy for the use of Variable Signs and Signals (VSS)[20] report a maximum of seven pieces of information should be acceptable. The policy also suggests that on a Portable VMS located on the verge that no more than four units of information should be displayed. The MS4 display on an MM-ALR scheme is shown to have no more than four units of information with the speed aspect, text message and pictogram potentially shown at the same time. Also the MS4 will be located at a significantly higher height than a Portable VMS and therefore visibility is likely to be much clearer. Finally the research underlying the VSS policy states that more information can be understood at low speeds, which will occur when an incident causes traffic to slow.

2.2.2 VSL displayed in the verge will lead to acceptable levels of speed compliance

Strong Evidence:

a) Future MM Concept Development Simulator Trial Task 1 (May 2012) [12].

"We can conclude that in Test Area 1, there was no difference between mean speeds in the mixed condition [an IAN 161/12 design] and the gantry condition. Drivers in the MS4 condition drove faster than in the other two conditions. Although this was statistically significant, the difference was slight in both cases (roughly 1mph)".

"In test Area 2 only a very small (around 1mph), difference in mean speeds was observed. Mean speeds in the mixed condition were slower than the MS4 condition but faster than the gantry condition".

"The results demonstrate that there was no statistically significant difference in surfing behaviour between the three signing configurations [gantry mounted AMI only, verge at any of the sections analysed within the two test areas".

These results indicate that the mixed condition did not produce statistically significant different spot speeds than the other two conditions".

"Participants in the mixed condition spent 69% of the time exceeding the speed limit, which was not statistically different from the other two conditions. Participants spent significantly more time exceeding the speed limit in the MS4 configuration (71%) than the gantry configuration (66%) across all test sections. Results suggest that there was no statistical difference in the percentage of time spent more than 10% above the speed limit between any of the three signing configuration conditions"

Questionnaires: "Participants reported a high degree of certainty of what the speed limit was across all three routes, although participants were slightly less sure in the mixed route than in the gantry route".

Questionnaires: "An equally high number of participants (45 out of 48) understood compliance with a variable speed limit to be either mandatory or compulsory on gantries and MS4s".

"The questionnaire suggested that there was a statistically significant difference in the report certainty of the speed limit between Mixed and Gantry routes. However, both results were high and the actual simulator speed data suggests that any uncertainty that participants had, had little or no discernable effect on driver behaviour."

b) Future Managed Motorways Concept Development –Task 2 June 2012 [13]

"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".

c) Future Managed Motorways Concept Development –Task 3 June 2012 [14]

"The evidence from the Design Assurance trial suggests that in busy traffic conditions the speed of traffic of an individual driver will be greatly influenced by the speed of surrounding traffic".

"However while the actual driver behaviour effects of VMSL remain unclear, the evidence from the relevant simulator studies suggests that there would be no major differences that could be attributable to the particular design features of the MM-ALR scheme tested. Behaviour in both the Verge vs Gantry and Design Comparisons trials suggest that speed choice is not significantly affected by whether the speed limit is shown on an MS4 or on a gantry mounted signal. The main differences were observed immediately following a speed limit; compliance in the vicinity of gantries was found to be higher than for equivalent MS4 sites. However, the effect of this on road users who exhibited 'surfing' behaviour appears to be a reduction in the magnitude of surfing, resulting in a smoother speed profile following speed limits displayed on MS4s".

“Although some findings suggest that some road users will not be aware of the prevailing variable speed limit in busy traffic conditions, no findings suggest that this is specific to speed limits displayed on MS4s and it is difficult to see how this could be improved by more or clearer on road information.”

d) MS4 Signalling Development Display Trial Findings Report [16]

“The trial was attended by some 21 stakeholders, who achieved a broad consensus that the display technology used on the MS4 provides all the necessary optical performance for potential use of verge mounted displays for managed motorways.”

“In summary:

- At 100m and 200m distances majority of scores are between 4 and 5 showing that the displays are clear or very clear at that distance regardless of the pictogram or aspect display size.*
- The 350m distance provides a good indication of how the Pictogram/Aspect size affects legibility. As the Pictogram/Aspect size is increased the legibility improves averaging a score of 3 at 1200mm and 4 at 1500mm.*
- 500m the displays become illegible or they can be seen but it is not clear what information is being displayed.*

These results are consistent with the minimum (350m) and desirable (500m) viewing distances for an EMI advised in the DMRB TA 74/05 Annex A4. This also correlates with the delegates’ opinions summarised in section 3.3 which suggests a preference for the largest element size of 1500mm”.

e) Managed Motorways Concept Development Tasks 2, 3 4 and 5 March 2011 [11]

“The findings suggest that only a small proportion of traffic would have its view of a signal on an MS4 obscured; for an expected MM2 [now known as MM-ALR] environment with typical peak-hour traffic, the proportion obscured is estimated to be 8% using a 2 second viewing criterion, which reduces to 2.3% if drivers are only required to see the signal for 0.5 seconds.”

Weak Evidence:

f) Perceptions of Variable Message Sign Accuracy Report 2009 (from VMS KPI research report Highways Agency March 2010) [18]

“The ‘Perceptions of Variable Message Sign Accuracy reports (2006-2009) examine a breadth of different areas relating to VMS. The evidence from the literature review demonstrates that as a whole and over the 3 year period the public perception of VMS seems to have stabilised and maintained a common trend. The results appear to paint a fairly positive picture for customer perception for VMS accuracy and VMS as a whole. For example only 13% of respondents thought speed restrictions and warning messages were inaccurate, where only 8% found information and advanced warning messages inaccurate. This is a consistently low number similar to the preceding 3 years. With 86% of respondents in 2009 from 73% in 2008 believing that the information they saw on a VMS to be correct, this is also another positive report. However results from the past 3 years highlight that safety and campaign messages have always formed divisive opinions between respondents. It could be suggested that it maybe beneficial to conduct further investigation into this area. However as forementioned, this study was implemented throughout the ‘Midlands Box’ area where there are successful and well-received projects like the Active Traffic Management (ATM) project. Therefore attitudes towards VMS may well be more positive in these areas than elsewhere around the country and so it could be argued that these findings do not provide ‘representative’ data”.

Areas of Concern:

g) Future Managed Motorways Concept Development –Task 3 June 2012 [14]

“Some findings suggest that a minority of road users will show poor compliance with both speed limits and lane closure information in an MM-ALR environment. However, this would not be expected to be specific to particulars of the MM-ALR design, i.e. speed and lane choice is not significantly affected by whether the information is shown on an MS4 or on a gantry mounted signal.”

A concern that should be noted is that the high levels of compliance on an HSR scheme designed to IAN 111/09 may be partially due to the fixed CCTV being perceived as enforcement by the road user. Without fixed CCTV on an MM-ALR scheme there is a risk that compliance could be adversely affected.

Discussion:

On an MM-ALR scheme speed information will be provided to drivers predominantly through verge mounted MS4 cantilevers (the information will be over lane 1). There will be gateway gantries with AMIs and there could be some intermediate gantries on longer links (also with AMIs). The key difference between the MM-ALR design and the existing MM HSR (IAN 111/09 [1]) design is that the majority of mandatory speed information is displayed from the verge compared to individual lane signals above each lane on an IAN 111/09 scheme. Gateway and intermediate gantries on MM-ALR will continue to show mandatory speeds over individual lanes and positively contribute towards the objective of adequate speed compliance as discussed in section 2.1.

Providing the information is relevant and suitable to the traffic conditions drivers are likely to understand the information and will behave accordingly.

It should also be recognised that the relative position of the MS4 on a D3M scheme and on MM-ALR will be broadly similar with the MS4 part way over Lane 1 on MM-ALR or over the hard shoulder on a D3M scheme. A comparison between a D3M scheme with MS4 cantilevers and an MM-ALR scheme is shown at Appendix D.

Although the concern over the absence of fixed CCTV on an MM-ALR scheme is recognised, the MM Concept Development Simulator Trials have demonstrated that compliance with the speed limits on display is unlikely to be significantly affected whether the speed is displayed on an overhead gantry or on a cantilever MS4.

An education campaign that includes information on the benefits of a Controlled Environment and considers how drivers should behave will help to ensure that compliant driver behaviour is achieved. A clear and consistent education strategy for MM-ALR will need to be developed in order to achieve an acceptable level of compliance.

2.2.3 Obscuration of VSL by HGVs is not expected to prevent acceptable levels of compliance being achieved

Strong Evidence:

a) Future MM Concept development Simulator Trial Task 2 (June 2012) [13]

“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”.

It should be noted that for the assessment the vehicle mix on all routes consisted of a high proportion (20-25%) of HGVs located in Lanes 1 and 2 however flow levels are described in qualitative terms (dense) in the report but are not quantified so it is difficult to determine how representative the conditions are of a typical MM-ALR scheme during peak flows.

b) Managed Motorways Concept Development Tasks 2, 3 4 and 5 March 2011 [11]

“The findings suggest that only a small proportion of traffic would have its view of a signal on an MS4 obscured; for an expected MM2 [now known as MM-ALR] environment with typical peak-hour traffic, the proportion obscured is estimated to be 8% using a 2 second viewing criterion, which reduces to 2.3% if drivers are only required to see the signal for 0.5 seconds. As would be expected, obscuration rates are greatly influenced by the number and spread of HGVs. With a 5% HGV proportion only 0.9% of traffic is obscured using a 0.5 second viewing time. With a 25% HGV proportion the percentage of traffic with their view obscured was 2.7%, using the same viewing time [based on flows of 6000 veh/hour]. This investigation has found that drivers have three realistic options available to them to avoid obscuration: change lanes, decelerate to increase their field of view. These actions can significantly reduce both lateral and longitudinal obscuration rates. If the correct mitigating action is taken by a driver at the correct time it is conceivable that all instances of obscuration can be removed.

Although it is unlikely in reality that all drivers will take the correct action at the correct time, this investigation has shown that in practice obscuration rates are likely to be smaller than those indicated in the simulation model.”

c) MS4 Signalling Development Display Trial Findings Report [16]

“In summary:

- At 100m and 200m distances majority of scores are between 4 and 5 showing that the displays are clear or very clear at that distance regardless of the pictogram or aspect display size.*
- The 350m distance provides a good indication of how the Pictogram/Aspect size affects legibility. As the Pictogram/Aspect size is increased the legibility improves averaging a score of 3 at 1200mm and 4 at 1500mm.*
- 500m the displays become illegible or they can be seen but it is not clear what information is being displayed.*

These results are consistent with the minimum (350m) and desirable (500m) viewing distances for an EMI advised in the DMRB TA 74/05 Annex A4. This also correlates with the delegates’ opinions summarised in section 3.3 which suggests a preference for the largest element size of 1500mm”.

Areas of Concern:

d) Future Managed Motorways Concept Development – Task 1 May 2012 [12]

Questionnaire: “Overall the gantry signs were regarded as being more visible than the verge signs (19 participants rated the gantry as more visible, 3 the verge signs more visible and 26 rated them equally). It is likely that this relates in part to a feeling amongst some participants that the verge signs could be obscured by large vehicles. Despite this the mean score for both conditions remains high.”

e) Future MM Concept Development Simulator Trial Task 2 (June 2012) [13].

Driver subjective experience: "Drivers reported that they found the information on verge signs more clearly presented but seemingly were worried about signs being obscured by high-sided vehicles."

Discussion:

MS4s located over the verge have been operating on the network for a number of years in broadly the same capacity as they would in an MM-ALR scheme (noting exception that MM-ALR will operate with mandatory and not advisory speeds). On an MM-ALR scheme for the majority of the time it is expected that drivers should generally be able to see the speed limit and other information displayed on a cantilever MS4 (see TRL trial evidence March 2011 [11]). There will however be occasions when the view of an MS4 will be obscured by an HGV in a nearside lane - this could happen anywhere on the network where reduced fixed mandatory speed limits are in place, or in locations where advisory speed limits are being displayed on MS4s. On an MM-ALR scheme although the view of an MS4 could theoretically be obscured by an HGV at anytime, the majority of occurrences will be when traffic flows are high. It should be noted that in that scenario most road users will be able to see the MS4, and the overall 'population' of vehicles will therefore affectively influence the behaviour of individual drivers who may be obscured. As shown from the MS4 trial, a distance of 350m provides good visibility of the information on the MS4. Further upstream of this point drivers will be aware that information is being provided and that they will need to position themselves in an appropriate position to be able to read the information.

Should the motorway be heavily congested then speeds will have been reduced and therefore drivers will be constrained by the traffic around them, such that there is little opportunity for them not to comply. It is recognised that due to the higher density of vehicles resulting in reduced headway that there is the potential for increased obscuration, however with reduced speeds it is likely that this could be at least partially mitigated because drivers will have more opportunity to see the information on display on a cantilever MS4 due to the additional time it will take to reach the MS4 and to some degree drivers are likely to anticipate the location of the next signal site downstream and take appropriate action to reduce the potential for obscuration.

A distance of 350m from an MS4 provides good advance visibility of the MS4 (subject to HGV obscuration). After passing the upstream signal drivers should be able to manoeuvre themselves in order to be able to see the information displayed on the next downstream MS4. Anecdotal evidence from the existing MM schemes (M42 MM Pilot and BBMM12) has shown that the regular spacing of information will encourage compliance as drivers will be expecting information and will therefore position themselves as necessary to be able to acknowledge and understand the information.

The MM Concept Development trials have provided confidence that the potential obscuration of MS4s is unlikely to have a significant affect on the levels of compliance. However, the concerns raised by participants in the trial needs to be recognised as it is likely that some drivers view of a speed limit on the MS4 could be obstructed by a high sided vehicle.

2.2.4 Distance between information is likely to be acceptable for compliant driver behaviour

Strong Evidence:

a) Future Managed Motorways Concept Development – Task 1 (May 2012) [12]

“The spacing of driver information update points – gantries/MS4s were presented at 1500m intervals.... Overall the results suggested that in the mixed route (i.e. the general design approach outlined in IAN 161/12) participants understood the information presented to them and exhibited appropriate driving behaviour”.

“Of all of the assessment measures used to study behaviour within the simulated environment, there was found no practical significant difference in behaviour between participants driving in the all gantry route and the mixed route, with the following exception: in the 70mph then 60mph sections following the second lane closure mean speeds were found to be higher on the Mixed route than on the Gantry route. However although achieving statistical significance, this only relates to a difference of 1mph so may represent little practical significance”.

“The results demonstrate that there was no statistically significant difference in surfing behaviour between the three signing configurations at any of the sections analysed within the two test areas”.

b) Future MM Concept Development Simulator Trial Task 2 (June 2012) [13].

“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”.

It should be noted that for the assessment the vehicle mix on all routes consisted of a high proportion (20-25%) of HGVs located in Lanes 1 and 2 however flow levels are described in qualitative terms (dense) in the report but are not quantified so it is difficult to determine how representative the conditions are of a typical MM-ALR scheme during peak flows.

Situational awareness: “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.”

Questionnaire: “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.”

c) TRL Managed Motorways Concept Development Tasks 2, 3 4 and 5 March 2011 [11]

“Surfing magnitude was found to be significantly greater with 3000m spacing than all spacings lower than 2000m spacing in either the 40 or 50mph sections (between 6.3 to 11.4mph difference depending on the comparison), and the 2000m spacing was significantly greater than the 500m spacing (7.2mph and 8.1mph for 40mph and 50mph sections respectively). No other statistically significant relationships were found for these speed limit sections.

In the 60mph section, 2000m was found to have a significantly greater surfing magnitude than all the spacings less than 1500m (as much as 8.2mph greater

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compared with 500m), and the 1500m spacing was found to have significantly greater surfing magnitude than the two shortest spacings (4.0mph and 5.8mph greater for 800m and 500m respectively)”.

“Figure 10 represent the average percentage of participants’ time spent travelling above the displayed speed limit and the speed limit plus 10% (i.e. 44mph, 55mph and 66mph) within the test areas under each gantry spacing layout. With a few exceptions, both the time above the speed limit and the time above the speed limit plus 10% increases with gantry spacing but remains largely constant after 2000m”.

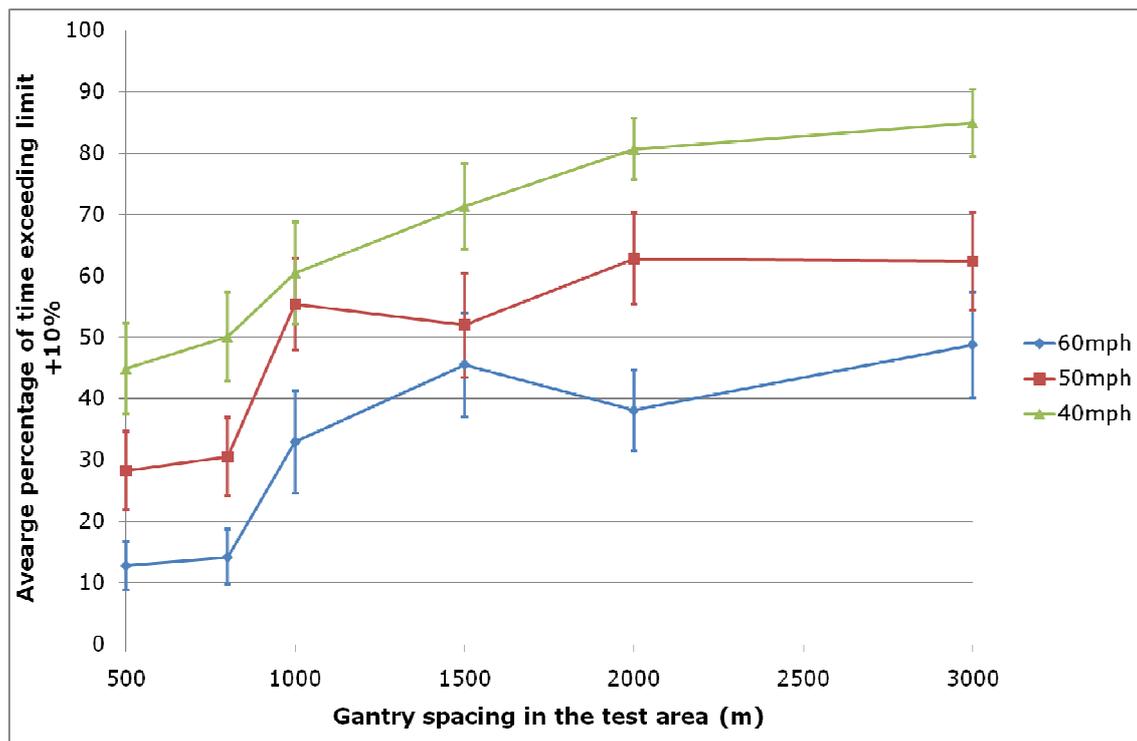


Figure 2-3: Average percentage of time spent travelling at speeds above the displayed speed limit plus 10% as a function of gantry spacing layout for each limit (\pm SEM) [Source: [11]]

d) M25 CM Surfing - TRL Research [32]

“On M25 J15-16 gantries are typically spaced every 1.2km, with intervisibility at around 800m (i.e. drivers travel for 400m without being able to see the next gantry). After monitoring there was no evidence of drivers either speeding up between gantries, or of them slowing down due to uncertainty about the speed limit in force.”

Weak Evidence:

e) M42 Managed Motorway Monitoring and Evaluation of TJR and Safety “Speed Surfing” on M42 MM and M6 BBMM January 2011 [19][9]

“When comparing the average differential in speed upon passing under the gantry to the speed mid-gantry (speed surfing), there is no real correlation between increasing gantry spacing and increasing speed differentials for both the M42 and M6”.

f) Birmingham Box Managed Motorways Phases 1 & 2 Assessment of Inter-visibility of BBMM Phase 1 28th May 2010 – Issue A

“Output from Safety Review

A Safety and Operational review of BB MM Phase 1 has been undertaken to consider the impact should future MM schemes not meet the ‘operational inter-

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visibility requirements' described in IAN 111 and 112. The safety review has determined the change in risk that may occur on a section of motorway where a road user cannot see the next signal gantry.

The review concluded that, based on a reasonably cautious estimate, there will be of the order of a 6% increase in risk (KSI) on the section on which the next gantry cannot be seen when compared to a section on which the next gantry can be seen."

Areas of Concern:

g) Future MM Concept Development Simulator Trial Task 3 (June 2012) [14].

"The evidence from the Gantry Spacing, Verge vs Gantry and Design Comparison trial suggests that a proportion of drivers, if unrestricted by the presence of other traffic, will exhibit surfing behaviour in response to the variable speed limits in an MM-ALR environment."

Discussion:

As indicated above there is expected to be a greater spacing between information on an MM-ALR scheme when compared to an existing MM HSR scheme designed to IAN 111/09 [1]. On an MM-ALR scheme information is likely to be located at average spacing of around 1,000m compared to a nominal spacing of 800m on an IAN 111/09 scheme (spacing could range from minimum of 600m up to maximum 1,500m on straight sections of road with little or no overbridges to restrict forward visibility between signals on MM-ALR compared to 600m to 1000m for MM HSR). In order to obtain compliant driver behaviour MM-ALR will look to optimise the time period when the next downstream signal cannot be seen (within the signal location design parameters) – this will remind drivers that they are in a controlled environment. The early monitoring results from the BBMM1 scheme has shown that a high level of compliance has been obtained despite there being a spacing of 1,000m between information in some locations [34].

As discussed previously good visibility of an MS4 is achievable at 350m. As demonstrated by the Future MM Concept Development Simulator Trial Task 2 situational awareness assessment, when drivers pass one set of information they are likely to be able to retain that information for a period of time before they will start to expect the next piece of information. Should the next set of information not be seen for a period of time the driver is likely to be positioning himself to be able to see the next information. In this gap between information a road user will be expected to drive in accordance with the Highway Code and behave accordingly. Future MM Concept Development Simulator Trial Task 2 also provides evidence of the degree to which a driver's speed is likely to be influence by other drivers some of whom are likely to be able to see the next set of information and will be reacting accordingly, however it should be noted that flow levels are described in qualitative terms (dense) in the report but are not quantified so it is difficult to determine how representative the conditions are of a typical MM-ALR scheme during peak flows.

The monitoring report 'M42 Managed Motorway Monitoring and Evaluation of TJR and Safety "Speed Surfing" on M42 MM and M6 BBMM' (January 2011 Highways Consultancy Group - Highways Research Group) analysed whether an increase in gantry spacing leads to increased speed surfing. The report compared the typical 800m spacing between gantries on BBMM 1 with the typical 500m spacing on the M42 MM section. It had been previously thought that an increase in gantry spacing could potentially lead to an increase in speed surfing. The report concluded that an increase in gantry spacing did not lead to any increase in speed surfing. However it needs to be recognised that the TRL trial undertaken in 2011 did show that spacing

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of 1,500m did lead to increased surfing when compared to distances of 500m and 800m spacing. Finally, it should be noted that the M25 CM J15-16 review found that surfing was not an issue at 1200m spacing, with typically 800m of visibility of the downstream gantry.

The outcome of the MM Concept Development trial has shown that although there may be some surfing if traffic is unrestricted due to low traffic flows, this is shown to be very similar whether the scheme was designed with gantries only or a IAN 161/12 scheme with a mix of gantries and cantilever MS4s. Overall the trial indicated that a good level of compliance could be achieved with the spacing of information proposed for MM-ALR.

2.2.5 Impact of equipment failure should not materially affect operation

Strong Evidence:

a) The ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report [7] (M42 MM):

“When considering the Association of Chief Police Officers (ACPO) threshold of enforcement (speed limit +10% +2 mph), compliance on the main carriageway was on average 94% or better at the 70 mph [when no signals were set] ... January 2006 and September 2007.”

b) The design for MM-ALR has a signal gantry with MS4 at the start of a link, and intermediate signal gantries typically after every four MS4s (if the link is long enough).

It is unlikely that all four AMIs and the MS4 will fail at the same time (power failures or failures affecting all AMIs and the MS4 on a gantry are rare) so for the majority of the time there will be information at the start of each link, and on intermediate gantries where present. Therefore it is only the failure of MS4s located on cantilevers that leaves a complete lack of signalling in one location which could potentially result in a gap of up to 3km as a result of failure of one MS4 or up to a maximum of 5km without information in the unlikely event of a number of consecutive MS4s (typically 4) being non-operational.

c) Highway Code [5]

Drivers will be expected to behave in accordance with the Highway Code and drive in accordance with the traffic conditions.

Weak Evidence:

d) Remote Integration - Some faults will be addressed through remote interrogation. *This is a new approach and is discussed below.*

e) M42 ATM Pilot Monitoring Results [7] - Additional capacity will reduce congestion
“The operation of 4L-VMSL on the M42-ATM section has increased the observed capacity of the motorway by an average of 7% (compared to NO-VSL) and 9% (compared to 3L-VMSL).” *“The introduction of 4L-VMSL has successfully reduced congestion, improved journey time reliability and increased the available capacity of the M42-ATM section.”*

Discussion

Should there be an equipment failure then drivers will miss information displayed at a certain location. This is different to when a driver misses information due to an HGV obscuring the view to the speed aspect/information on the verge. In the scenario whereby a driver misses information due to obscuration by an HGV, the driver will follow the vehicle in front and will therefore to some extent be forced to comply as a result of the driver in front complying. Alternatively the driver may overtake the HGV and remove the obscuration and be able to read the MS4. During an equipment failure the information will not be available to any driver at that location and therefore it needs to be considered whether this affects scheme performance and whether the risk is acceptable for drivers. There are a number of key points to consider should an equipment failure occur:

- The majority of faults that occur should be investigated through remote interrogation³ and some of the faults could be rectified relatively quickly.

A number of faults that occur on an MM-ALR scheme in relation to AMIs or MS4s could be addressed through remote interrogation. (Watchdog reset of roadside controller and all connected devices should be sufficient to clear lockups in 95% of the situations). Although a number of faults cannot be rectified through remote interrogation as they are signal failures the process of remote interrogation will help to identify the cause of the fault. Therefore if a fault occurs, assuming it is detected quickly, some faults may only impact on drivers for a short period of time.

Should an MS4 be expected to be out of operation for a longer period of time appropriate mitigation may need to be considered as some drivers will be expecting information to be displayed. Mitigation could include putting a 'signal not in use' sign on the MS4 (this would mitigate against road users assuming any speed or lane restriction had been cleared due to the blank panel). Another potential option if an MS4 were to be out of use for some time would be to introduce a portable VMS although it is noted this may not display VMSS and may only be able to display text messages – some work would be required to ensure that appropriate messages are displayed at the right time.

As noted in evidence b) the impact of a signal equipment failure on a signal gantry is not so significant due to the presence of the remaining operational equipment.

- Messages and information will generally be displayed on multiple pieces of signalling so the loss of one piece of information will be compensated by the others.

Should a fault occur on an MS4 at one specific location and a queue is forming upstream then MIDAS will also be displaying appropriate information on the upstream gantry/MS4 from the MS4 which has a fault. Drivers will therefore be aware of a potential queue/incident downstream. There is a risk that should a driver then pass a blank MS4 he may assume the incident has passed. However, during congested periods this risk is mitigated as speeds

³ Remote Interrogation is an initiative underway for TTD to develop a remote interrogation capability which will allow investigation and it is assumed this will be provided for all MM-ALR roadside equipment.

are likely to have been reduced and the driver will be inclined to follow the vehicle in front and drive in accordance with the traffic conditions.

- In congested conditions, should a queue form then the information displayed at that specific location will be most important for a limited time only as a shockwave will move the queue upstream to a previous MS4/gantry where appropriate information can be displayed. As the shockwave moves upstream the provision of information at other locations becomes more important.
- If there is a significant failure of signalling then drivers will be expected to behave in accordance with the Highway Code and drive in accordance with the traffic conditions.

During a sub-system failure, or a major power supply failure there will be no electronic messages/speeds displayed on significant stretches of motorway and therefore the motorway will operate as a standard four lane motorway with no hard shoulder. Road users will be expected to drive and behave in accordance with the Highway Code and the prevailing conditions. In such circumstances it may be important for the RCC to undertake more proactive CCTV monitoring and/or despatch on-road resources to the affected location in case of an incident.

2.3 It will be possible to enforce speed limits on MM-ALR

This section demonstrates that:

- Effective automatic speed enforcement can be provided at the gateway and intermediate portal gantries
- Police could enforce portal signals using traditional enforcement methods, if required
- Future enforcement development is being considered

2.3.1 Effective automatic speed enforcement can be provided at the gateway and intermediate portal gantries

Strong Evidence:

a) IAN 111/09 Hard Shoulder Running Guidance [4]

“Good compliance to the VMSL is supported by the use of an appropriate enforcement system (in the case of the M42 Pilot the Highways Agency Digital Enforcement Camera System (HADECS) is used).”

b) The ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report [7] [M42 MM]:

“When considering the Association of Chief Police Officers (ACPO) threshold of enforcement (speed limit +10% +2 mph), compliance on the main carriageway was

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on average 94% or better at the 70 mph, 60 mph, 50 mph speed limits and 84% or better at the 40 mph speed limit between January 2006 and September 2007.”

“4L-VMSL has resulted in a smaller proportion of points with higher speed at free flow conditions compared to NO-VSL. This is likely to be due to the impact of the ATM infrastructure (many gantries, signs and unfamiliar layout) and speed enforcement⁴ on driver behaviour.”]

Discussion:

Automatic speed enforcement is carried out on existing MM HSR schemes (IAN 111/09 [1]) scheme through the location of the cameras on overhead gantries (e.g. M42 MM and BBMM1&2). Evidence from the M42 Pilot has shown that the perceived enforcement encourages a high level of compliance. Since the automatic speed enforcement became operational on the M42 Pilot there have been no successful challenges to issued Notices of Intended Prosecution.

Overhead gantries will continue to exist on an MM-ALR scheme and therefore it would be possible to locate a camera on a gateway gantry or intermediate gantry.

The location of a camera on an intermediate gantry would be the preferred location as the gantry is unlikely to be located in sections where there is a high level of weaving traffic as the gantry is not located on an approach to a junction. The gateway gantry can however be used for enforcement, except for the first link within a scheme. MM-ALR will result in a four lane motorway and the gateway gantry will be located downstream of the merge. Traffic in lane 4 is unlikely to have merged from the junction or will have been affected by weaving manoeuvres and therefore enforcement from this gantry should be considered. It is recognised that this approach to the provision of enforcement will need to be discussed and agreed with the appropriate enforcement authority to agree on the level of enforcement and number of offences required in order to obtain an acceptable level of compliance.

As noted in Section 2.2.2 there is a concern that the absence of fixed CCTV in an MM-ALR scheme may adversely impact on the level of compliance. The development of a clear and consistent education campaign will help to achieve an acceptable level of compliance. Following the commencement of scheme operations it will be necessary to undertake post implementation monitoring and if an acceptable level of compliance cannot be achieved it may be necessary to consider additional mitigation measures, such as an increase in the level of education and encouragement or a greater level of enforcement.

2.3.2 Police could enforce portal signals using traditional enforcement methods, if required

Strong Evidence:

a) Guide For The Operational Use Of Speed And Red-Light Offence Detection Technology [20]

“Speed Detection Using A Speedometer Fitted To A Patrol Vehicle

⁴ Noted that enforcement during initial 12 months was perceived automatic enforcement.

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This type of check, commonly known as the 'follow check,' has been used by police forces for a number of years and is readily accepted by the courts and motoring public alike."

Radar Speedmeters (Hand-Held)

Radar speedmeters will typically acquire, quality check, calculate and display the speed of a target vehicle in one to three seconds, with the operator being required to track and maintain a steady indicated speed for more than one measurement cycle of the radar speedmeter."

b) The ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report [7]:

"When considering the Association of Chief Police Officers (ACPO) threshold of enforcement (speed limit +10% +2 mph), compliance on the main carriageway was on average 94% or better at the 70 mph, 60 mph, 50 mph speed limits and 84% or better at the 40 mph speed limit between January 2006 and September 2007."
[When no automatic speed enforcement was operating.]

Discussion:

The Police are able to enforce the speed limit using existing operational enforcement methods, such as using a speedometer fitted to a patrol vehicle, or with a hand-held radar speedmeter, as they would be able to do on any other section of motorway on the network.

In terms of speed compliance through the M42 MM section, the scheme operated for the first 13 months without an automated enforcement system, with the police carrying out only operational enforcement as experienced everywhere else on the motorway network. The HADECS system has now been operating for a number of years and monitoring of the scheme has shown that there has been little change to the high levels of compliance achieved in the first 13 months when the system was non operational [7][8]. The level of compliance at 50, 60 and 70mph has remained high (over 95%) following the introduction of HADECS.

2.3.3 Future enforcement development is being considered

Evidence to be confirmed:

a) Enforcement from MS4s

Status: Potential for enforcement through HADECS 3 to be undertaken from MS4s – system in development

b) Potential TRL Simulator Spot Speed v Average speed enforcement

Status: Potential trial to be undertaken to review Spot Speed v Average Speed enforcement.

The Highways Agency is continuing to look at enforcement of MM-ALR schemes and other approaches to enforcement could be considered. The potential enforcement from MS4s is currently in development and this could be trialled on an early MM-ALR scheme. In order to enable enforcement from an MS4 it must be considered that the

provision of enforcement is being fair to the motorist. Therefore there is likely to be a need to prove that the driver had sufficient opportunity to view the MS4 and that his view and acknowledgment of the speed displayed on the MS4 would not have been obscured by an HGV or other vehicle (this would need to be considered as part of the type approval of the system).

The implementation of an average speed enforcement system within a MM-ALR scheme may be a consideration in the future. However, as outlined above in Section 2.3.1 enforcement from gateway/intermediate gantries can be undertaken.

3 Is the Lane Information provided likely to achieve the required driver behaviour?

This section demonstrates that:

- Verge direction signing on MM-ALR is expected to provide adequate guidance
- Verge VMS lane closure information on MM-ALR is expected to provide adequate guidance to drivers

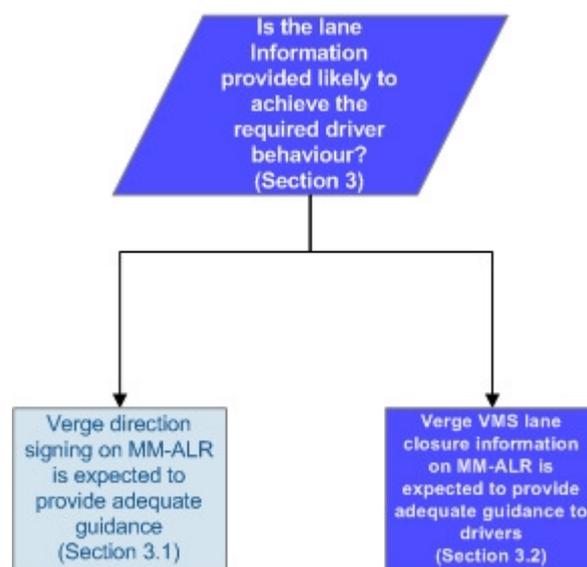


Figure 3-1: Extract of GSN showing how it is demonstrated that correct lane information is likely to be achieved

3.1 *Verge direction signing on MM-ALR is expected to provide adequate guidance*

This section demonstrates that:

- Verge ADS is expected to be sufficiently clear to road users
- An acceptable number of drivers' view of the ADS will be obscured by HGVs
- Managed speeds, reduced start/stop conditions and additional capacity should provide greater opportunity for a driver to safely exit
- Availability of satellite navigation for infrequent users mitigates the requirement for ADS

3.1.1 Verge ADS is expected to be sufficiently clear to road users

Strong Evidence:

a) Future Managed Motorways Concept Development –Task 2 June 2012 [13]

“The findings of the situational awareness assessment found that, regarding the MM-ALR environment.... 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 [although it should be noted that the associated exit destination was not one participants had been asked to leave the motorway at and this may have influenced their retention of this information as unimportant].”

Questionnaire: *“Subjectively, participants found the verge-mounted signs to be clearer than the overhead signs [i.e. 1m and ½ mile cantilever mounted ADS and final ADS displayed on a portal gantry] but that both provide sufficient information. However, verge-mounted signs caused more stress due to possible obscuration than overhead signs”.*

Weak Evidence:

b) TD 22 – Layout of Grade Separated Junctions [21]

On D3M motorways with a hard shoulder ADS are normally located on verge and drivers can see the ADS from lane 3.

“The provision and layout of traffic signs and road markings is an integral part of the junction design process and must be considered at an early stage. Advance direction and warning signs must be provided. Positioning of signs within the junction must be carefully considered so that they do not interfere with drivers’ visibility. It is essential that there is no over-provision of signing.

For grade separated junctions two or three advance direction signs must be provided. These are to be located at the start of the diverging lane ½ mile (1/3 mile in difficult circumstances) from the junction and additionally for motorways and some all-purpose roads 1 mile (2/3 mile in difficult circumstances) from the junction. On motorways either a confirmatory gantry sign or a route number confirmatory sign (TSRGD diagram 2910), located at the back of the nose, must be provided.”

Discussion:

On an MM-ALR scheme the ADS could be located in the verge (noted that ADS could be positioned on an overhead gantry if appropriate for the junction layout or an existing gantry is present in an appropriate location for MM-ALR). The MM concept development trial has shown that participants showed a preference for verge signing as opposed to overhead signing [i.e. 1m and 1/2m cantilever mounted ADS and final ADS displayed on a portal gantry] as they felt that verge signing was clearer.

It is noted that TD22 states verge VMS can be used for a D3M motorway, which in width terms is equivalent to MM-ALR (the hard shoulder has been converted to a running lane). When TD22 states that gantry ADS are required for a D4M this is wider than MM-ALR with four lanes as D4M has four running lanes and a hard shoulder. However the traffic flows on MM-ALR and D4M are likely to be similar.

3.1.2 An acceptable number of drivers' view of the ADS will be obscured by HGVs

Strong Evidence:

a) Future Managed Motorways Concept Development – Additional Task (June 2012) [15]

"This task has estimated that, using the default parameters described [in particular 6000 veh/hour with 15% HGV] and a 1 second viewing criterion, 18% of traffic in a MM-ALR environment would have their view of a destination shown in an ADS obscured, i.e. 18% of drivers would have to make an adjustment to their driving to be able to see the destination name for at least 1 second. The equivalent rate of the same point in a 3-lane standard motorway environment was estimated as 15%".

b) Future Managed Motorways Concept Development –Task 2 June 2012 [13]

Driving simulator: "A large majority of drivers recognised the approach of the junction [they had been instructed to exit at] 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".

c) Future Managed Motorways Concept Development –Task 3 June 2012 [14]

The ADS obscuration assessment estimated that some drivers would have to make an adjustment to their driving or range of view to be able to see the ADS for long enough to extract destination information. However, it should be noted that the highest obscuration rate was estimated to be in Lane 4 where drivers are less likely to be considered leaving at the next junction. The situational awareness assessment provided evidence that suggests, despite being in an environment with a high proportion of HGVs, participants were almost all able to identify the junction destination correctly after passing the '1 mile to junction' sign.

d) Obscuration from HGVs on D3M – TD 22 Layout of Grade Separated Junctions [21]

On a D3M section of motorway it is accepted that some drivers may miss a sign due to the volume of HGVs travelling in the nearside lanes.

Areas of Concern:

e) Future Managed Motorways Concept Development –Task 2 June 2012 [13]

"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".

Discussion:

As discussed previously (Section 2.2.3) where drivers may miss information on an MS4, there is also the possibility that an HGV will obscure a driver's view of the ADS sign.

During off peak (low flow) periods there should not be an issue with drivers seeing verge mounted ADS. During congestion it is likely that the drivers will be able to see the ADS in the verge through gaps in traffic as they would on any D3M scheme with verge mounted signing. Speeds will be reduced and therefore there is more opportunity to see the sign although it is noted that due to reduced headways there is

the possibility of obscuration of the sign. There is an additional lane of traffic but on both the D3M and MM-ALR sections of the network there is the possibility that a driver could miss an ADS.

Some road users on a section of road will be regular users and therefore will be unlikely to rely on the ADS. On a D3M section of motorway it is accepted that some drivers may miss the sign due to the volume of HGVs travelling in the nearside lanes. The same applies to an MM-ALR scheme and appropriate mitigations, such as the ½ mile ADS are in place. With heavily congested links (or links with a high percentage of HGVs) on the approach to junctions the possibility of a driver missing the ADS may mean that it is appropriate to consider additional signing (for example on a gantry) to provide better provision of information to the motorist (in such cases there may already be ADS mounted on gantries).

The MM Concept Development trial has recognised that there is an increase in the likelihood of a driver having his view of an ADS obscured by a high sided vehicle, however it should be noted that the 18% figure identified, whilst not necessarily the worse case scenario, was based on relatively high flows (6000 veh/hour) and proportion HGV (15%) and does not take into account the impact of multiple ADS (e.g. 1 mile, ½ mile) and the potential for the driver to take mitigating action in order to improve their opportunity to see the ADS. It should also be noted that the trial has demonstrated participants were equally aware of the next destination in all design scenarios.

3.1.3 Managed speeds, reduced start/stop conditions and additional capacity should provide greater opportunity for a driver to safely exit

Strong Evidence

a) Future Managed Motorways Concept Development –Task 2 June 2012 [13]

“A large majority of drivers recognised the approach of the Greenhill junction and moved into Lane 1 accordingly. Most drivers entered lane 1 by the time of their encounter with the ½ mile to junction sign”.

b) Future Managed Motorways Concept Development –Task 3 June 2012 [14]

“The position at which participants moved into Lane 1 to leave the motorway was examined.... Although the participants awareness of the junction destination following the ‘1 mile junction’ sign indicated that obscuration may not adversely affect their awareness of the junction destination, one explanation of participant behaviour in the Design Assurance trial may suggest otherwise; participants generally took longer to move into Lane 1 to leave the motorway if presented with a verge-mounted ADS than if presented with cantilever-mounted ADS”.

“However, unless any of the these factors (i.e. environmental) are found to present a serious issue then evidence suggests that despite some obscuration of individual signs, either verge mounted and cantilever/gantry mounted ADS should be sufficient for drivers to exhibit the required behaviour in an MM-ALR environment”.

Weak Evidence:

c) M42 MM Monitoring and Evaluation Three Year Safety Review January 2011 [10]

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“The total number of PIAs during the first 36 months of 4L VMSL operation has decreased compared to the equivalent time periods during 3L VMSL and No VSL operation. During the first 36 months of 4L VMSL operation a total of 81 PIAs were recorded compared to a prorated number of 114 and 183 PIAs in the 3L VMSL and No VSL cases respectively. This is equivalent to 2.25 accidents per month compared to 3.17 and 5.08 in the 3L VMSL and No VSL cases respectively; this represents a 55.7% reduction between No VSL and 4L VMSL”.

d) Synopsis of Design and Safety work carried out in support of Future Managed Motorways Concept (MM-ALR) [now known as MM-ALR] [22]

There has been a substantial decrease in both the frequency and severity of accidents in the 3 year ‘after’ monitoring period of the M42 Managed Motorway Pilot (2006 – 2009).

There are various ways of measuring this decrease taking into account the improvement in severity as well. Some useful headlines are as follows:

- *PIA Rate per Month - 5.08 (before) to 2.25 (after)*
- *PIA rate (taking traffic flow into account) - 115.92 (before) to 47.98 (after)*
- *PIA rate per Month x Severity ratio - 0.81 (before) to 0.18 (after)*
- *Weighted rate (Fatal 10, Severe 3 and Slight 1) 7.533 (before) to 2.583 (after)*

MM-ALR (with the introduction of control through technology and with MIDAS) is expected to have a level of safety that is comparable with a D3M with MIDAS. This is evidenced by:

- *Research into the results of the benefits of MIDAS, suggests that D3M*
- *With MIDAS have 10% less KSI accidents than the baseline of D3M without MIDAS [25].*
- *M42 MM links (which have control through technology) are considerably safer than the baseline.*

Discussion:

Should a driver miss the 1 mile ADS during peak periods then drivers are likely to be travelling at a reduced speed and the additional capacity of MM will enable more space to enable drivers to change lane in order to exit. It is recognised that some drivers will need to cross an extra lane to exit although MM-ALR will look to create a controlled environment which will encourage compliant driver behaviour and therefore drivers should be able to exit safely. The introduction of additional capacity with the provision of signs and signals should result in a higher probability of free driving conditions. The Controlled Motorways environment is expected to reduce headways but with drivers travelling at generally the same speed across all four lanes drivers should be able to exit the scheme safely.

The MM Concept Development trial has shown that there is likely to be an increase in obscuration of the ADS and MS4s. It was also noted that drivers did generally move into lane 1 later with a verge mounted ADS. Despite this, the trial has provided confidence that drivers should be able to exit the scheme safely.

3.1.4 Availability of satellite navigation for infrequent users mitigates the requirement for ADS

Strong Evidence:

a) AA website - Racing the satnav - Majority of younger drivers try to beat estimated journey time 23rd September 2011 [35]

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“The AA/Populus research (17-24 August, 11,361 respondents) shows that nearly three-quarters of 18-24 year olds have a satnav, and of those with a satnav 55% of them say that there are occasions when they put estimated journey times to the test. The lure of out-smarting the technology also persists among the 60% of 25-34 year olds who own a satnav with more than one third saying that they put the satnav’s times to the test.

Younger drivers are more likely to own a satnav and ownership declines with age. However satnav ownership remains above 50% even for drivers aged 65 years or more, although the urge to race the estimated time drops to 15% in late middle age and reaches 7% among pensioners. Drivers in Scotland, Northern Ireland and the West Country are least likely to own a satnav.”

Discussion:

An ADS must be visible, clear and present information at the right time so that road users are able to make safe manoeuvres at key decision points on the Motorway. Motorists that undertake a regular journey such as a commute are unlikely to rely on ADS signs as much as infrequent user. A high percentage of road users that infrequently use a junction could be expected to have a satellite navigation facility which if enabled would provide adequate information to facilitate a safe exit.

3.2 Verge VMS lane closure information on MM-ALR is expected to provide adequate guidance to drivers

This section demonstrates that:

- MM-ALR signal sequences are expected to provide a safer driving and operating environment than the baseline
- Information on MS4s is expected to be understood by road users

3.2.1 MM-ALR signal sequences are expected to provide a safer driving and operating environment than the baseline

Evidence to be confirmed:

a) MM-ALR signals checked on test bed

Status: Before implementation of MM-ALR the signals are to be checked on signals test bed and Factory Acceptance Test (FAT).

Strong Evidence:

b) Future Managed Motorways Concept Development –Task 1 May 2012 [12]

Driving simulator: *“There was no statistical difference across route configurations in the point where participants moved out of the lane subject to closure on the approach to the first obstruction. It was observed that the majority of participants moved out of lane 1 upon or shortly after, encountering the first warning of a lane closure ahead on all routes”.*

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Questionnaires: "When presented with a layout of each of the signing options, participants reported the mixed route to be clearer in communicating that Lane 1 was open to traffic following a closure".

c) Future Managed Motorways Concept Development –Task 2 June 2012 [13]

"The Sign Comprehension Study demonstrated that the speed of comprehension of information presented on verge mounted MS4's was greater or equal to that of comparable gantry mounted signals, and that the Hooked Arrow aspects appeared to give clearer instruction of the end for traffic to move out of lane than other aspects that were trialled".

d) Safety risk assessment of the Closer Spaced Signalling Rules [26]

The report reviews the closer spaced signalling rules used on Managed Motorways Hard Shoulder Running (MM-HSR) schemes to determine suitable closer spaced signalling (less than 900m spacing) rules for Managed Motorways – All Lane Running (MM-ALR). Development of closer spaced signalling rules will also support the development of signalling rules for spacings greater than 900m.

Weak Evidence:

e) Signal Sequences on M42 MM Pilot and BBMM12 schemes

The signals settings on the early MM schemes were tested before implementation to ensure that when they became operational the signals would be appropriate and relevant to the traffic conditions. This is a key reason which has resulted in the success of the early MM schemes.

Areas of Concern:

f) Future Managed Motorways Concept Development –Task 3 June 2012 [14]

"Some findings suggest that awareness of certain areas of information could be considered as ambiguous, such as the use of Wicket aspects to communicate lane closures and how road users would be expected to respond in the event of an emergency breakdown. Clarifying these areas may be beyond the influence of on-road information provision alone and therefore the role of road user education could be considered".

Discussion:

Should an incident occur drivers will be provided with appropriate information in order to react and behave accordingly. The signal sequences are currently being developed but are likely to be broadly similar to the existing MM HSR⁵ (IAN 111/09 [1]) designed scheme where appropriate information is provided upstream of the incident in order to marshal vehicles into the correct lane, close lanes and protect the incident. An example of a lane 1 and 2 lane closure is shown at Appendix E and this is compared to signals on an existing MM scheme (IAN 111/09). As outlined above there may be occasions when a driver will miss the information displayed on one MS4. However the signalling patterns will be for a minimum of three items of signalling equipment, which is likely to include one portal gantry, so there will be other opportunities for drivers to find out which lanes are closed. This is further mitigated through the introduction of the controlled environment which will manage

⁵ Although broadly similar, there will be differences between an MM-ALR and IAN 111/09 signalling. The IAN 111/09 signalling is predominantly carriageway signals and signals are more widely spaced.

speeds whilst road users are required to change lanes. The display of appropriate information is greater than a D3M section of motorway due to the ability to control speeds, provide supporting information and display lane diverts and this will provide considerable benefits with the management of incidents or when protecting roadworkers setting out/removing TTM.

The signal sequences used in the MM Concept Development trial were similar to those used on an existing MM scheme (note there are some differences due to the use of wickets during lane closures). The behaviour of drivers was generally similar for an MM-ALR design compared to the behaviour of drivers on an IAN 111/09 scheme. The concerns through the MM Concept Development trial with regard to how drivers would respond in the event of an emergency breakdown have been noted and it is likely to be essential that a suitable education campaign is undertaken through the delivery of an MM-ALR scheme.

3.2.2 Information on MS4s is expected to be understood by road users

Strong Evidence:

a) Future Managed Motorways Concept Development –Task 1 May 2012 [12]

“There was no statistical difference across route configurations in the point where participants moved out of the lane subject to closure on the approach to the first obstruction. It was observed that the majority of participants moved out of lane 1 upon or shortly after, encountering the first warning of a lane closure ahead on all routes”.

Questionnaires: “Participants reported an equally high degree of certainty about which lanes were open or closed across all three routes.”

b) Future Managed Motorways Concept Development –Task 3 June 2012 [14]

“The Verge vs Gantry simulator study suggested that compliance with a lane closure communicated via verge-mounted MS4s will be generally comparable with closures communicated via gantry-mounted Red X indicators. The Design Comparison trial suggested that compliance with lane status instruction in an MM-ALR environment combining gantries and MS4s, will also be comparable.

Compliance with the Red X is technically different to compliance with a Wicket symbol. While the difference is reflected in people’s understanding, there is no evidence to suggest that this will have a significant impact on behaviour.

Slightly lower levels of compliance were observed for offside lane closures but the post drive questionnaire suggested that non compliance was not as a result of poor comprehension. More likely this was due to the dense traffic present in this scenario and the requirement to find a suitable space to move out of the closed lane”.

c) MM2 [now MM-ALR] Concept Development Trial TRL Tasks 2, 3, 4 and 5 March 2011[11]

The trial “demonstrated that the speed limit and lane closure information displayed on a verge-mounted MS4 could be comprehended successfully even for the most complex configuration of MS4 message” Configurations ranged in complexity from the simplest configuration where one speed limit was displayed, up to the most complex configuration where a speed limit aspect, lane closure aspect and one/two lines of text was displayed. “For speed limit instructions, it appeared that

comprehension was equally good for all MS4 message configurations. Response times were higher for the MS4 message configurations when lane closure as opposed to speed limit instruction was being communicated.

d) MS4 Signalling Development Display Trial Findings Report [16]

"The trial was attended by some 21 stakeholders, who achieved a broad consensus that the display technology used on the MS4 provides all the necessary optical performance for potential use of verge mounted displays for managed motorways."

"In summary:

- At 100m and 200m distances majority of scores are between 4 and 5 showing that the displays are clear or very clear at that distance regardless of the pictogram or aspect display size.*
- The 350m distance provides a good indication of how the Pictogram/Aspect size affects legibility. As the Pictogram/Aspect size is increased the legibility improves averaging a score of 3 at 1200mm and 4 at 1500mm.*
- 500m the displays become illegible or they can be seen but it is not clear what information is being displayed.*

These results are consistent with the minimum (350m) and desirable (500m) viewing distances for an EMI advised in the DMRB TA 74/05 Annex A4. This also correlates with the delegates' opinions summarised in section 3.3 which suggests a preference for the largest element size of 1500mm".

e) Highways Agency policy for the use of Variable Signs and Signals (VSS) December 2011 [23]

"This document defines the policy relating to the Highways Agency operation of electronic Variable Message Signs (VMS) and electronic light emitting Matrix signals – known together as Variable Signs and Signals (VSS). VSS provide the capability to display a wide range of warning messages and other traffic information.

"A risk based approach has been taken to ensure that all legends and guiding principles found within this policy document are appropriate for use. Research carried out in 2010 by Nottingham University on behalf of the Highways Agency has proven that it is appropriate to display legends on fixed VMS which contain a maximum of 7 pieces of information, using an absolute maximum of 10 words, although best practice is that legends should be restricted to a maximum of 8 words."

f) Perceptions of Variable Message Sign Accuracy Report 2009 (from VMS KPI research report Highways Agency March 2010) [18]

"The 'Perceptions of Variable Message Sign Accuracy reports (2006-2009) examine a breadth of different areas relating to VMS. The evidence from the literature review demonstrates that as a whole and over the 3 year period the public perception of VMS seems to have stabilised and maintained a common trend. The results appear to paint a fairly positive picture for customer perception for VMS accuracy and VMS as a whole."

Areas of Concern:

g) Future Managed Motorways Concept Development –Task 3 June 2012 [14]

"Some findings suggest that awareness of certain areas of information could be considered as ambiguous, such as the use of Wicket aspects to communicate lane closures and how road users would be expected to respond in the event of an emergency breakdown. Clarifying these areas may be beyond the influence of on-road information provision alone and therefore the role of road user education could be considered".

Discussion:

During incident management appropriate messages would be displayed on MS4s to close lanes. These are generally standard wicket aspects and messages and standard speed aspects. The lane closure wicket legends used in the lane closure signal sequences will generally be replicating signs from TSRGD, and hence should be understood by road users. Furthermore, as the wicket legends will be 'representing' what is displayed on lane specific signalling it should become apparent to regular users what is intended. Appendix E shows some of the proposed legends during an incident.

Evidence from the VSS policy shows that the number of pieces of information displayed on the MS4 is unlikely to be too much for road users to absorb and understand. The policy suggested that on a Portable VMS (which is a lower height than a MM-ALR MS4 Cantilever) located on the verge that no more than four units of information should be displayed. The MS4 display on an MM-ALR scheme is shown to have no more than four units of information with the speed aspect, text message and pictogram potentially shown at the same time.

To support the development of MM-ALR, MS4 displays being considered were demonstrated to stakeholders from HA, DfT, ACPO and CAST in November 2011. The attendees' were asked to complete a checklist rating the displays for visibility, legibility and whether clear information was provided by the displays which included VMSL in combinations with, VMSL Aspect only, VMSL Aspect & Text, VMSL & pictogram/wicket and VMSL Aspect with Text & Pictogram. The trial was attended by some 21 stakeholders. A broad consensus was that the display technology used on the MS4 provides all the necessary optical performance for potential use of verge mounted displays for MM-ALR.

The MM Concept Development trial has shown that drivers should understand how they are expected to behave in an MM-ALR environment. Although the trial did suggest some areas of ambiguity with regard to the Wicket aspects used to communicate lane closures the findings indicate that compliance with a lane closure communicated through cantilever MS4s will be comparable with closures through gantry mounted signals displaying the Red X signal.

4 Are Suitable Headways likely to be achieved?

This section demonstrates that:

- Advance warning of queues is likely to be provided
- Congestion is likely to be managed

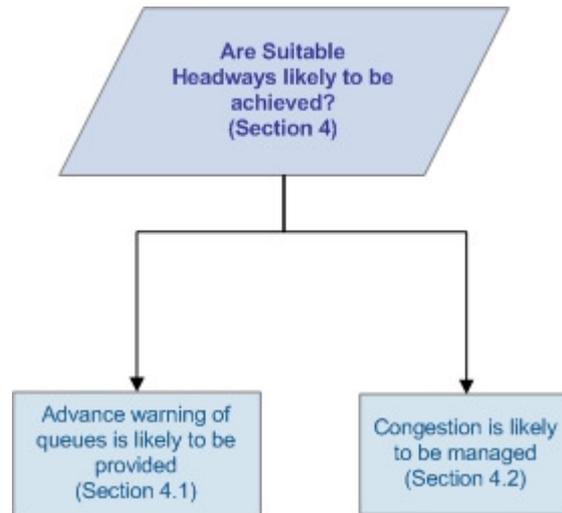


Figure 4-1: Extract of GSN showing how it is demonstrated that suitable headways are likely to be achieved

4.1 Advance Warning of Queues is likely to be provided

This section demonstrates that:

- The queue protection algorithm is expected to be effective
- Loop spacing is appropriate
- Pictograms and speed limits are likely to provide sufficient warning of queues

4.1.1 The queue protection algorithm is expected to be effective

Strong Evidence:

a) Evaluating the benefits of MIDAS automatic queue protection Highways Agency October 2006 [25].

"This paper reports on a study of the operation of MIDAS (Motorway Incident Detection and Automatic Signalling) over a ten year period and covering a route 602 kilometres in length. This study of 10 years of operations has shown a safety improvement of 13% and significant congestion relief benefits. The study has estimated that, on average, the safety benefit of MIDAS automatic queue protection had a value of £49,000 per km per year of motorway route. The associated

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congestion relief benefit had a value of £11,000 per km per year at the time when the study was conducted. The corresponding value of accident savings on the 800 km on which MIDAS was then operated was £39 million per year and the associated delay savings were £9 million per year”.

b) HD 20/05 Detector Loops for Motorways. [27]

HA Standards uses induction loops spaced at 500 metre intervals in the road to detect slow moving, queuing or stationary traffic arising from an accident, incident or other cause. Benefits proven at 500m loop spacing (MM-ALR is nominally 500m spacing).

c) M42 MM Monitoring and Evaluation Three Year Safety Review January 2011 [10]
Queue Protection on the early MM schemes has resulted in significant safety benefits:

“The total number of PIAs during the first 36 months of 4L VMSL operation has decreased compared to the equivalent time periods during 3L VMSL and No VSL operation. During the first 36 months of 4L VMSL operation a total of 81 PIAs were recorded compared to a prorated number of 114 and 183 PIAs in the 3L VMSL and No VSL cases respectively. This is equivalent to 2.25 accidents per month compared to 3.17 and 5.08 in the 3L VMSL and No VSL cases respectively; this represents a 55.7% reduction between No VSL and 4L VMSL.”

d) Implementation of HIOCC 2

HIOCC 2 algorithms is to be installed for MM-ALR. This will enable an enhanced queue protection system to be in place and benefits include enabling a reduced number of false triggers.

Discussion:

It has been estimated that MIDAS automatic queue protection reduces accidents by 13%. The queue protection algorithms are the software that uses the information from the MIDAS loops located under the surface of the road. The algorithms are tried and tested before becoming operational and then following initial operation the algorithms continue to be monitored to ensure maximum performance. The same process will be required for MM-ALR as it will be essential that information is provided at the optimum time.

4.1.2 Loop spacing is appropriate

Strong Evidence:

a) Standards and Factors Affecting the Spacing of MIDAS Loops and Signals on a Motorway [34]

“The spacing of MIDAS loops should conform with HD20/05. Congestion management is not sensitive to loop spacing and there is no compelling argument to reduce the spacing for incident management, and increasing the spacing would adversely affect the time to detect in particular during lower flow levels. Thus the spacings should be 500m (+/- 20%).

“The spacing of signals should conform with the guidance provided in TD46/05 relating to cantilever mounted signals. Recent advances in signalling technology (MS4) providing an increase in the distance at which the signal is visible combined with the use of mandatory aspects enhances the likelihood of compliance and thus the ability to create a controlled environment. The potential to introduce enforcement will increase this ability.”

Safe roads, reliable journeys, informed travellers

b) HD 20/05 Detector Loops for Motorways. [27]

HD 20/05 states:

“3.11 Loop sites shall be spaced at intervals of 500m plus or minus 20%. The overall average loop site spacing for a scheme shall be 500m plus or minus 10%.

3.12 Where signals are sited at spacings between 600m and 1km an intermediate loop site shall be provided equidistant between the signal sites to maintain the 500m average spacing. Where signals are positioned at intervals below 600m an intermediate loop site will not be required.”

Discussion

A D3M scheme with MIDAS provides queue protection through loop spacing at 500m and VMS at 1500m spacing and this achieves an accident reduction of 13%. It is proposed that queue protection for an MM-ALR scheme, likely to be implemented through the use of MIDAS loops, will be at 500m in line with a D3M scheme.

Information on an MM-ALR scheme will be provided at a slightly greater spacing than an existing MM (IAN 111/09) scheme (on average 1000m compared with nominal 800m respectively).

Also loops at 400m on an existing MM (IAN 111/09) scheme will not make a significant impact on the display of appropriate queue protection messages. The spacing at 500m is expected to be sufficient to enable appropriate information to be displayed on MM-ALR infrastructure. As shown from the evidence above [34] there is no compelling argument to reduce the spacing for incident management, and increasing the spacing would adversely affect the time to detect in particular during lower flow levels.

4.1.3 Pictograms and Speed Limits are likely to provide sufficient warning of queues

Strong Evidence:

a) Future Managed Motorways Concept Development –Task 2 June 2012 [14]

Driving simulator: 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. No issues with driver behaviour associated with this are identified in the report and the post trial questionnaire identified *“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”*.

b) Future Managed Motorways Concept Development –Task 3 June 2012 [14]

“The findings of the work referenced in this report suggest the hypothesis that an MM-ALR scheme will, in general, provide sufficient information for road users to understand how they are expected to behave”.

c) MS4 Signalling Development Display Trial Findings Report [16]

“The trial was attended by some 21 stakeholders, who achieved a broad consensus that the display technology used on the MS4 provides all the necessary optical performance for potential use of verge mounted displays for managed motorways”.

d) HA MM-ALR [now MM-ALR] Concept Development Trial Tasks 2, 3, 4 and 5 March 2011 [11]

The trial “demonstrated that the speed limit and lane closure information displayed on a verge-mounted MS4 could be comprehended successfully even for the most complex configuration of MS4 message. For speed limit instructions, it appeared that comprehension was equally good for all MS4 message configurations. Response times were higher for the MS4 message configurations when lane closure as opposed to speed limit instruction was being communicated.”

Weak Evidence:

e) VMS KPI Research Report [29]

“Findings from the literature review indicate that overall, the public are fairly positive about VMS and that roughly 70% of respondents found VMS to be reasonably accurate and across reports roughly 30% felt that accuracy of VMS had improved over the past year. However the public view improvement of information on VMS and accuracy of information as key issues. So whilst the research indicates that the public have a fairly positive perception of VMS, they would like to see demonstrable improvements in the future”.

f) IAN 109/08 – Advice Regarding the Motorway Signal Mark 4 (MS4) [30]

“The design and reliability of electrical / electronic components has progressed since the introduction of the MS2 in the early 1990s and the MS3 in the late 1990s. Advances have been made in Light Emitting Diode (LED) technology that enables a wider viewing angle and a higher resolution display with two colours. These developments have been incorporated in to a new generation of motorway signal, known as the Motorway Signal Mark 4”.

g) Highways Agency policy for the use of Variable Signs and Signals (VSS) [23]

This document defines the policy relating to the Highways Agency operation of electronic Variable Message Signs (VMS) and electronic light emitting Matrix signals – known together as Variable Signs and Signals (VSS).

Discussion:

The MS4s will be capable of displaying a wide range of legends / pictograms that will be accompanied by speed aspects and text where appropriate. As demonstrated within this report information should be provided at intervals which optimise the time period where a driver cannot see the next information and the information should be provided at optimum locations to ensure that suitable and relevant information is displayed to road users [7] [34]. The existing MM HSR (IAN 111/09) schemes have shown that a controlled environment which provides information at the optimum time provides a safe and controlled environment.

The MS4 trial has tested the display on MS4s [16] [11], and the Future MM Concept Development Simulator Trial has provided some evidence that sufficient information is likely to be provided for road users to understand how they are expected to behave.

It is noted that the original ‘Triple Package’ was based upon MIDAS loops and advisory signalling at 1500m spacing. MM-ALR queue protection is likely to be at a closer spacing of 1000m-1200m, with mandatory speed limits, hence it would be expected to perform at least as well as Triple Package for protecting queues.

4.2 Congestion is likely to be managed

This section demonstrates that:

- The congestion management algorithms are expected to be effective
- The additional lane will create extra capacity to enable congestion to be managed
- Loop spacing is appropriate
- Pictograms and speed limits are likely to enable congestion to be managed
- Evidence from other MM schemes has demonstrated that congestion is reduced through increased capacity, smoother traffic flows and a reduced number of incidents.

4.2.1 The congestion management algorithms are expected to be effective

Strong Evidence:

a) The ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report [1]:

"The introduction of 4L-VMSL has successfully reduced congestion, improved journey time reliability and increased the available capacity of the M42-ATM section. 4L-VMSL has reduced the occurrence of severe congestion. During 4L-VMSL, traffic congestion and the speed differential between lanes are reduced and there is a higher occurrence of free driving conditions (i.e. headways > 5 seconds). This indicates that 4L-VMSL leads to a lower workload for drivers."

"The operation of 4L-VMSL on the M42-ATM section has increased the observed capacity of the motorway by an average of 7% (compared to NO-VSL) and 9% (compared to 3L-VMSL). In general across the defined peak periods, analysis shows that there is spare capacity during 4L-VMSL operation".

b) BBMM 1&2 Year 3, BBMM1 Summary Report [31]

The analysis carried out showed that BBMM1 has reduced average journey times, improved journey time reliability and smoothed traffic flows, with an overall agreement that roads had improved with the introduction of BBMM1.

c) Safety Benefits of the M25 Controlled Motorway: 1990 to 2006 Data (TRL) [28]

The analysis indicated that the best estimate of the additional effect of the Controlled Motorway on collisions (over and above that which HIOCC automatic queue protection provides) was a reduction of 15%. However, it is inevitable that there is uncertainty in this estimate. The 95 % confidence interval was from a 31% reduction in collisions to a 6% increase.

Discussion:

Evidence suggests that the implementation of 4L VMSL will provide significant congestion benefits. The additional capacity and smoothing of traffic flows will

improve journey time reliability. In order to ensure that drivers comply with the information displayed through a scheme it is essential that the information is appropriate and relevant. Therefore the speed displayed needs to be appropriate for the driving conditions at that time. The Controlled Motorways algorithm thresholds need to be put in place so that they enable speeds to be changed at the optimum time to maximise congestion and safety benefits. The CM thresholds cannot be set to reduce speeds too early as there will be a risk that drivers will not comply. Alternatively, if the thresholds are set too high then speeds will not be reduced and there will be a risk of flow breakdown occurring.

On the existing MM HSR (IAN 111/09 [1]) schemes thresholds to enable congestion management are finely tuned so that they provide congestion information and reduce speeds at the optimum time. The algorithms are tried and tested before becoming operational and then following initial operation the algorithms continue to be monitored to ensure maximum performance. The same process will be required for MM-ALR as it will be essential that information is provided at the optimum time.

4.2.2 The additional lane will create extra capacity to enable congestion to be managed

Strong Evidence:

a) The ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report [1]:

“The operation of 4L-VMSL on the M42-ATM section has increased the observed capacity of the motorway by an average of 7% (compared to NO-VSL) and 9% (compared to 3L-VMSL). In general across the defined peak periods, analysis shows that there is spare capacity during 4L-VMSL operation”.

b) Synopsis of Design and Safety work carried out in support of Future Managed Motorways Concept (MM2) [now referred to as MM-ALR] [22]

“For MM2 initially it would be expected that in most cases no speed control signals will be displayed for the majority of the day in the interpeak period. This is because with the additional capacity provided by the additional permanent running lane, speed control will only be required when demand is sufficiently great that there is a risk of flow breakdown (on four lanes). This is different to Dynamic Hard Shoulder running when speed control would be activated when there is a risk of flow breakdown on three lanes.”

Discussion:

The evidence from the early MM schemes suggests that the implementation of 4L VMSL will provide significant congestion benefits. The additional capacity through the use of an additional lane will smooth traffic flows and improve journey time reliability. The introduction of additional capacity with the provision of signs and signals should result in a higher probability of free driving conditions.

4.2.3 Loop spacing is appropriate

Strong Evidence:

a) Standards and Factors Affecting the Spacing of MIDAS Loops and Signals on a Motorway [34]

“The spacing of MIDAS loops should conform with HD20/05. Congestion management is not sensitive to loop spacing and there is no compelling argument to

reduce the spacing for incident management, and increasing the spacing would adversely affect the time to detect in particular during lower flow levels. Thus the spacings should be 500m (+/- 20%).

“The spacing of signals should conform with the guidance provided in TD46/05 relating to cantilever mounted signals. Recent advances in signalling technology (MS4) providing an increase in the distance at which the signal is visible combined with the use of mandatory aspects enhances the likelihood of compliance and thus the ability to create a controlled environment. The potential to introduce enforcement will increase this ability.”

b) HD 20/05 Detector Loops for Motorways. [27]

HD 20/05 states:

“3.11 Loop sites shall be spaced at intervals of 500m plus or minus 20%. The overall average loop site spacing for a scheme shall be 500m plus or minus 10%.

3.12 Where signals are sited at spacings between 600m and 1km an intermediate loop site shall be provided equidistant between the signal sites to maintain the 500m average spacing. Where signals are positioned at intervals below 600m an intermediate loop site will not be required.”

Discussion:

It is proposed that congestion management for an MM-ALR scheme, likely to be implemented through the use of MIDAS loops, will be at 500m in line with a D3M scheme.

Information on an MM-ALR scheme will be provided at a slightly greater spacing than the existing MM (IAN 111/09) scheme and therefore compared to spacing of loops at 400m on an existing MM (IAN 111/09) scheme, loop spacing at 500m will not make a significant impact on the effectiveness of managing congestion, as shown from the evidence above [34].

The spacing at 500m is expected to be sufficient to enable appropriate information to be displayed on MM-ALR infrastructure.

4.2.4 Pictograms and Speed Limits are likely to enable congestion to be managed

Strong Evidence:

a) Future Managed Motorways Concept Development –Task 3 June 2012 [14]

“The findings of the work referenced in this report suggest the hypothesis that an MM-ALR scheme will, in general, provide sufficient information for road users to understand how they are expected to behave”.

b) MS4 Signalling Development Display Trial Findings Report [16]

The trial was attended by some 21 stakeholders, who achieved a broad consensus that the display technology used on the MS4 provides all the necessary optical performance for potential use of verge mounted displays for managed motorways.

c) HA MM-ALR [now MM-ALR] Concept Development Trial Tasks 2, 3, 4 and 5 March 2011 [11]

The trial “demonstrated that the speed limit and lane closure information displayed on a verge-mounted MS4 could be comprehended successfully even for the most

complex configuration of MS4 message. For speed limit instructions, it appeared that comprehension was equally good for all MS4 message configurations. Response times were higher for the MS4 message configurations when lane closure as opposed to speed limit instruction was being communicated.”

Discussion:

The MS4s will be capable of displaying a wide range of legends / pictograms that will be accompanied by speed aspects and text where appropriate. Congestion messages e.g. ‘Congestion stay in lane’ will be displayed on the MS4 as necessary. As demonstrated within this report information should be provided at intervals which minimise the time period where a driver cannot see the next information and the information should be provided at optimum locations to ensure that suitable and relevant information is displayed to road users. The existing MM HSR (IAN 111/09) schemes have shown that a controlled environment which provides information at the optimum time provides a safe and controlled environment.

The MS4 trial has tested the display on MS4s [16], [11] and the Future MM Concept Development Trial has also provided evidence that sufficient information is likely to be provided so that a driver understands how he is expected to behave. The compliant driver behaviour which is likely to be achieved through the design of an MM-ALR scheme is therefore expected to be sufficient to manage congestion.

4.2.5 Evidence from other MM schemes has demonstrated that congestion is reduced through increased capacity, smoother traffic flows and a reduced number of incidents

Strong Evidence

a) The ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report [1]:

The introduction of 4L-VMSL has successfully reduced congestion, improved journey time reliability and increased the available capacity of the M42-ATM section. 4L-VMSL has reduced the occurrence of severe congestion. During 4L-VMSL, traffic congestion and the speed differential between lanes are reduced and there is a higher occurrence of free driving conditions (i.e. headways > 5 seconds). This indicates that 4L-VMSL leads to a lower workload for drivers.

b) BBMM 1&2 Year 3, BBMM1 Summary Report [31]

The analysis carried out showed that BBMM1 has reduced average journey times improved journey time reliability and smoothed traffic flows, with an overall agreement that roads had improved with the introduction of BBMM1.

Discussion:

The M42 Pilot achieved significant and impressive levels of behavioural compliance which have underpinned the success of the scheme. The number of accidents has decreased from an average of 5.1 to 2.2 a month (after 36 months operation) and drivers ability to predict their weekday journey times improved by 22% (after 12 months operation); A high level of compliant driver behaviour has been obtained where compliance with 40mph, 50mph, 60mph and 70mph speed limits is 94% or better. The BBMM1 scheme on the M6 has been shown to have similar levels of compliance. The additional effect of a Controlled Motorway on collisions (over and

above that which HIOCC automatic queue protection provides) was a reduction of 15%. It is considered that MM-ALR could achieve most of the benefits that the existing MM (IAN 111/09) schemes provide. The provision of additional capacity and the provision of signalling mitigates against the removal of the hard shoulder that has been converted to a full time running (lane 1).

5 Conclusions

5.1 Findings

The objective of this paper is to review whether the concept design of MM-ALR is likely to provide adequate guidance and adequate information to the road user so that they understand how they are expected to behave within the new MM-ALR environment.

This adequacy assessment will only indicate a level of confidence. A residual risk will remain that adequate guidance is not provided until the MM-ALR concept is operationally proven.

The majority of the 'Strong Evidence' contained within this assessment has been obtained through the Future MM Concept Development Simulator Trial. Although this evidence has provided a good indication as to how drivers are likely to behave in an MM-ALR environment it needs to be recognised that the MM Concept Development Trial is based upon a driver simulator and responses to questionnaires. Whilst this does provide the best evidence available at this time, it is not until the MM-ALR scheme is constructed and commences operation it will be truly known just how drivers will react and behave in an MM-ALR environment.

The information presented in this report demonstrates the below key points.

- Compliance with speed limits is likely to be achieved:
 - Speed compliance on existing MM-HSR (IAN 111/09) schemes with portal gantries is very good.
Strong Evidence identified
 - Variable speed limits on MM-ALR are expected to provide adequate guidance and deliver acceptable levels of compliance
Strong simulator evidence identified, supported by off-road trials
 - It will be possible to enforce speed limits on MM-ALR at gateway and intermediate portal gantries
Strong evidence identified
- Lane Information provided is likely to achieve the required driver behaviour
 - Verge direction signing on MM-ALR is expected to provide adequate guidance
Strong simulator evidence identified that the performance of cantilever mounted ADS will be acceptable; mixed evidence for post mounted
 - Cantilever mounted VMS lane closure information on MM-ALR is expected to provide adequate guidance to drivers
Strong simulator evidence identified, supported by off-road trials.
- Suitable headways are likely to be achieved
 - Advance warning of queues is likely to be provided
Strong evidence identified

Safe roads, reliable journeys, informed travellers

- Congestion is likely to be managed
Strong evidence identified

5.2 Areas of Concern

This report has shown that strong evidence has been confirmed for a number of goals to demonstrate that adequate guidance and adequate information is likely to be provided to the road user so that he/she understands how he/she is expected to behave within the new infrastructure environment of MM-ALR. Although strong evidence has been obtained there are some minor areas of concern within a number of goals.

It is recognised that some further mitigation may need to be considered to maximise the level of confidence to demonstrate that adequate information and adequate guidance is likely to be provided.

Minor areas of concern identified with potential mitigations are as follows:

1) Surfing Behaviour - There is likely to be some 'surfing behaviour' observed within an MM-ALR scheme

Mitigation: A comprehensive education campaign should be undertaken through the media. Positive messages about the effect of compliance will improve the safety and performance of the scheme and may help to reduce the level of surfing. The education of motorists is likely to be essential in obtaining compliant driver behaviour.

Post implementation monitoring should be undertaken following the commencement of operations to confirm the conclusions made with regard to the impact of surfing and the level of compliance.

2) Obscuration of MS4s - There is likely to be an increase in the obscuration of information displayed on MS4s (when compared with lane specific signalling) which may affect the level of compliant driver behaviour.

Mitigation: An education campaign that includes information on the benefits of a Controlled Environment and considers how drivers should behave will help to ensure that compliant driver behaviour is achieved. The setting of signs and signals that are suitable and relevant to the road conditions will help encourage compliance from drivers thereby constraining other drivers around them such that there will be little opportunity for them drivers not to comply.

Post implementation monitoring should be undertaken to consider whether there are any issues with the potential obscuration of information displayed on an MS4.

3) Obscuration of ADS - There is likely to be an increase in obscuration of ADS which may impact on some drivers reaching their destination

Mitigation: The impact on the use of verge mounted ADS will need to be considered for each individual scheme. At some locations (e.g motorway to motorway interchanges) the use of overhead signs is more appropriate.

Post implementation monitoring should be undertaken to consider whether there are any issues with the potential obscuration of information displayed on a verge mounted ADS.

4) Lane closure Information displayed on an MS4 - Although the use of cantilever MS4s to display lane information is not generally expected to result in any significant driver behaviour issues the reaction to the use of wickets on the MS4 is a minor concern.

Mitigation: A comprehensive education campaign should be undertaken to ensure that motorists understand the legends used on an MM-ALR scheme. The education of motorists is likely to be essential in obtaining compliant driver behaviour. It is noted that the legends to be displayed within an MM-ALR scheme will be the same as currently shown on fixed plate signs within roadworks on the network and therefore drivers will be already familiar with the display of lane information in this format.

Post implementation monitoring should be undertaken to consider whether there are any issues in relation to the level of compliance with lane closure information.

5.3 Summary:

The Future Managed Motorways Concept Development –Task 3 June 2012 [14] report provides the following summary:

“In summary the work conducted to examine behavioural issues related to MM-ALR has identified minor areas of concern with regard to participants perception of how MM-ALR schemes operate and what behaviours they are expected to adopt, but has not identified any compelling evidence to suggest that an MM-ALR scheme of the design tested in the simulator does not provide sufficient information to understand and exhibit the required driving behaviour to a level of comparable to existing Managed Motorway schemes.”

This adequacy assessment has indicated a level of confidence and provided strong evidence in a number of key areas to demonstrate that adequate guidance and information is likely to be provided to the motorist. A number of the assumptions and associated conclusions on the likely driver behaviour are based on simulator derived evidence and a residual risk will remain that adequate guidance is not provided until the MM-ALR concept is operationally proven. Accordingly, it is recommended that due consideration is given to the capture of before and after monitoring data in order to effectively validate those assumptions.

6 References

[1]	Interim Advice Note 111/09, Managed Motorway Implementation Guidance, Hard Shoulder Running
[2]	Road Traffic Regulation Act 1984, UK
[3]	Traffic Signs Regulations and General Directions 2002, UK
[4]	HA and DfT meeting Minutes - Managed Motorways 2 Legislative Amendments Monday 23 May 2011
[5]	Highway Code (http://www.direct.gov.uk/en/TravelAndTransport/Highwaycode/index.htm)
[6]	Traffic Signs Manual, DfT (http://www.dft.gov.uk/publications/traffic-signs-manual/)
[7]	ATM Monitoring and Evaluation 4-Lane Variable Mandatory Speed Limits 12 Month Report (Primary and Secondary Indicators) June 2008
[8]	M42 ATM Monitoring Compliance with VMSL, Lane Closures & Hard Shoulder Operation January – February 2009
[9]	Managed Motorway Monitoring and Evaluation of Through Junction Running and Safety BBMM1 Compliance with VMSL & Hard Shoulder Operation October 2010
[10]	M42 MM Monitoring and Evaluation, Three Year Safety Review, HCG, January 2011
[11]	Managed Motorways Concept Development Tasks 2, 3, 4 and 5 March 2011, TRL
[12]	Future Managed Motorways Concept Development Task 1: Design Comparison Simulator Study - May 2012
[13]	Future Managed Motorways Concept Development Task 2: Design Assurance Simulator Study - June 2012
[14]	Future Managed Motorways Concept Development Task 3: Synthesis of Evidence – June 2012
[15]	Future Managed Motorways Concept Development Additional Task: Obscuration of Advanced Direction Signs in an MM-ALR Environment – June 2012
[16]	MMFD-MS4-037, MS4 Signalling Development Display Trial Findings Report, Issue 2 December 2011
[17]	A review of anti-swooping trials, TRL Report 491
[18]	Perceptions of Variable Message Sign Accuracy Report 2009 (from VMS KPI research report Highways Agency March 2010)
[19]	M42 Managed Motorway Monitoring and Evaluation of TJR and Safety “Speed Surfing” on M42 MM and M6 BBMM January 2011
[20]	Guide For The Operational Use Of Speed And Red-Light Offence Detection Technology, Version 1, December 2011, ACPO
[21]	TD 22- Layout of Grade Separated Junctions
[22]	Synopsis of Design and Safety work carried out in support of Future Managed Motorways Concept (MM2) [now known as MM-ALR]

[23]	Highways Agency policy for the use of Variable Signs and Signals (VSS) December 2011
[24]	VMS Customer Research (GRIPS), Process to support VMS approval, October 2010
[25]	Evaluating the benefits of MIDAS automatic queue protection Highways Agency 2006
[26]	1039092-CSS-041, Safety risk assessment of the Closer Spaced Signalling Rules, MM-ALR
[27]	HD 20/05 Detector Loops for Motorways
[28]	Safety Benefits of the M25 Controlled Motorway: 1990 to 2006 Data TRL 2007
[29]	VMS KPI Research Report – Highways Agency
[30]	IAN 109/08 – Advice Regarding the Motorway Signal Mark 4 (MS4)
[31]	BBMM 1&2 Year 3, BBMM1 Summary Report, March 2011, Highways Agency
[32]	Email from TRL to Highways Agency July 2010
[33]	Birmingham Box Managed Motorways Phases 1 & 2 Assessment of Inter-visibility of BBMM Phase 1 - 28th May 2010 – Issue A
[34]	Standards and Factors Affecting the Spacing of MIDAS Loops and Signals on a Motorway - Highways Consultancy Group - Highways Research Group January 2011
[35]	AA website (http://www.theaa.com/motoring_advice/news/racing-the-satnav.html) - Racing the satnav - Majority of younger drivers try to beat estimated journey time. 23rd September 2011
[36]	IAN 161/12 – Managed Motorways All Lane Running

Appendix A: The MM-ALR Design

The outline design for MM-ALR is shown overleaf. Key features include:

- a. The hard shoulder on the main line must be permanently converted to a controlled running lane. This includes the main line intra-junction subject to the assessment set out in paragraph 2.5.
- b. Refuge areas provided at a maximum of 2500m intervals. Refuge areas may either be bespoke facilities (an emergency refuge area (ERA)) or converted from an existing facility, for example a wide load bay, a motorway service area (MSA), the hard shoulder on an exit slip/link road or hard shoulder intra-junction.
- c. VMSL
- d. Lane specific signalling only provided at the 'gateway signals and VMS' location and where necessary at intermediate locations. At all other signal locations, verge mounted carriageway signalling must be provided, with the exception of locations with 5 or more running lanes, where lane signalling must be required.
- e. Driver information, including mandatory speed limits, must be provided at intervals not less than 600m and not exceeding 1500m.
- f. Queue protection system
- g. Comprehensive low-light pan-tilt-zoom (PTZ) CCTV coverage
- h. Emergency roadside telephones (ERTs) must be provided in all dedicated refuge areas (except MSAs), e.g. ERAs, intra-junction (where TJR is not required and a suitable hard shoulder is present)
- i. No non-essential infrastructure or technology.
- j. Avoid wherever practicable the positioning of infrastructure in the central reserve

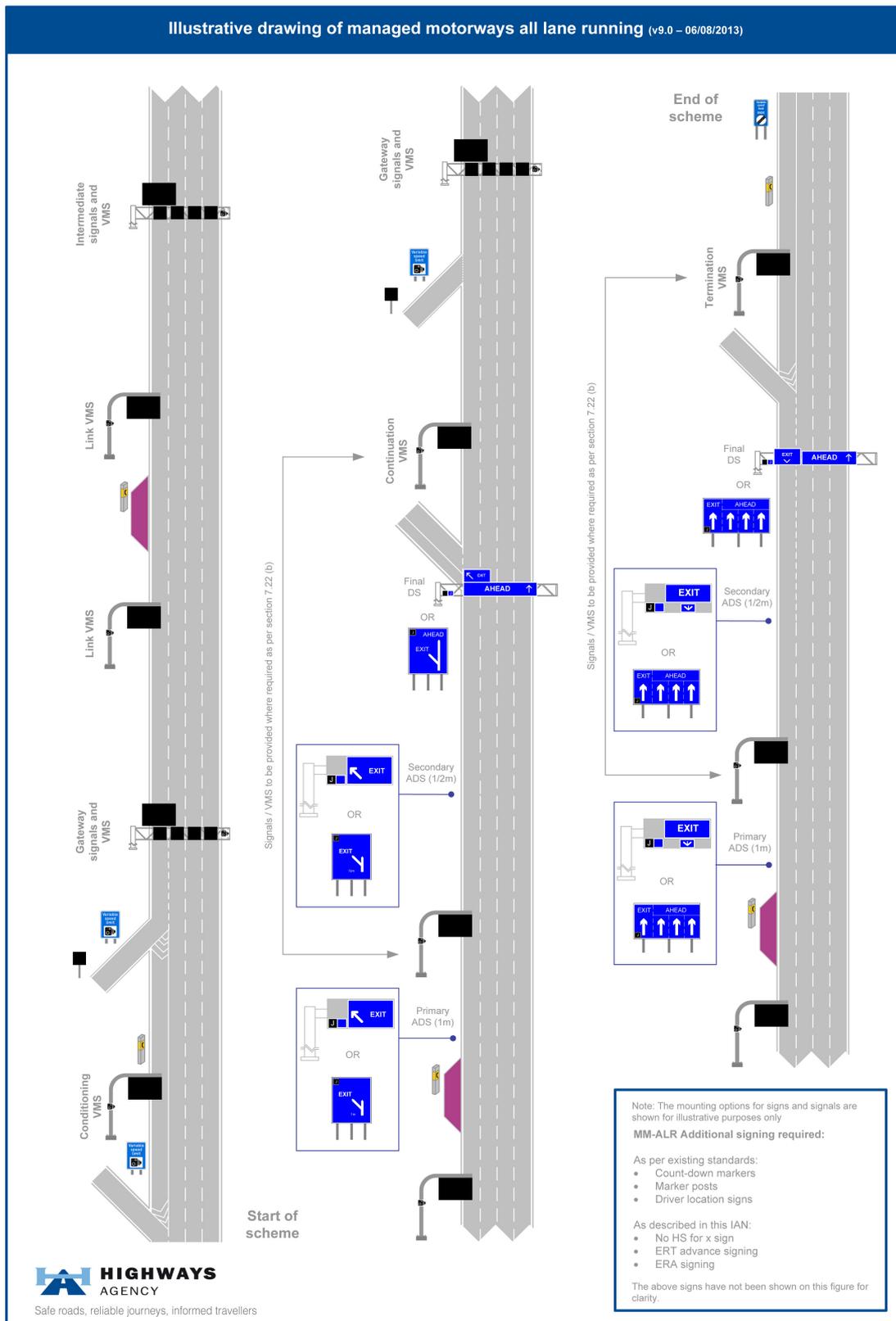


Figure A1: MM-ALR concept drawing

Appendix B: HA and DfT meeting Minutes - Managed Motorways 2 Legislative Amendments Monday 23 May 2011

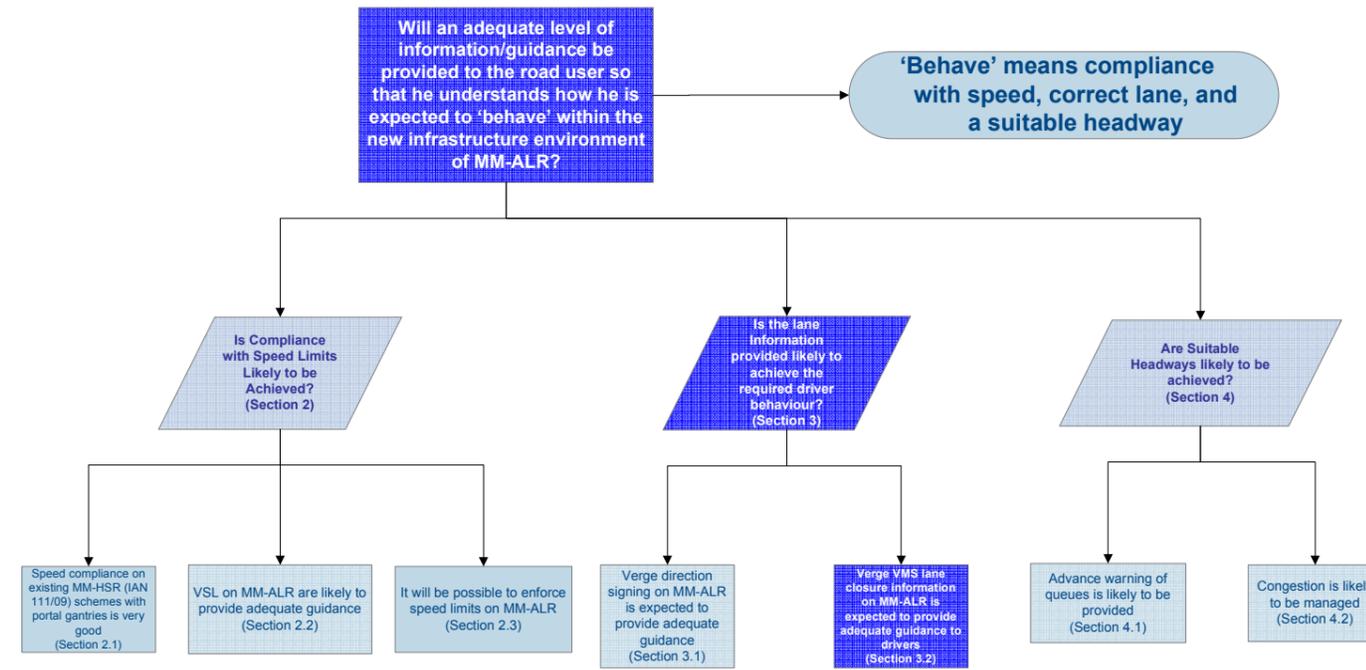
Managed Motorways 2 Legislative Amendments

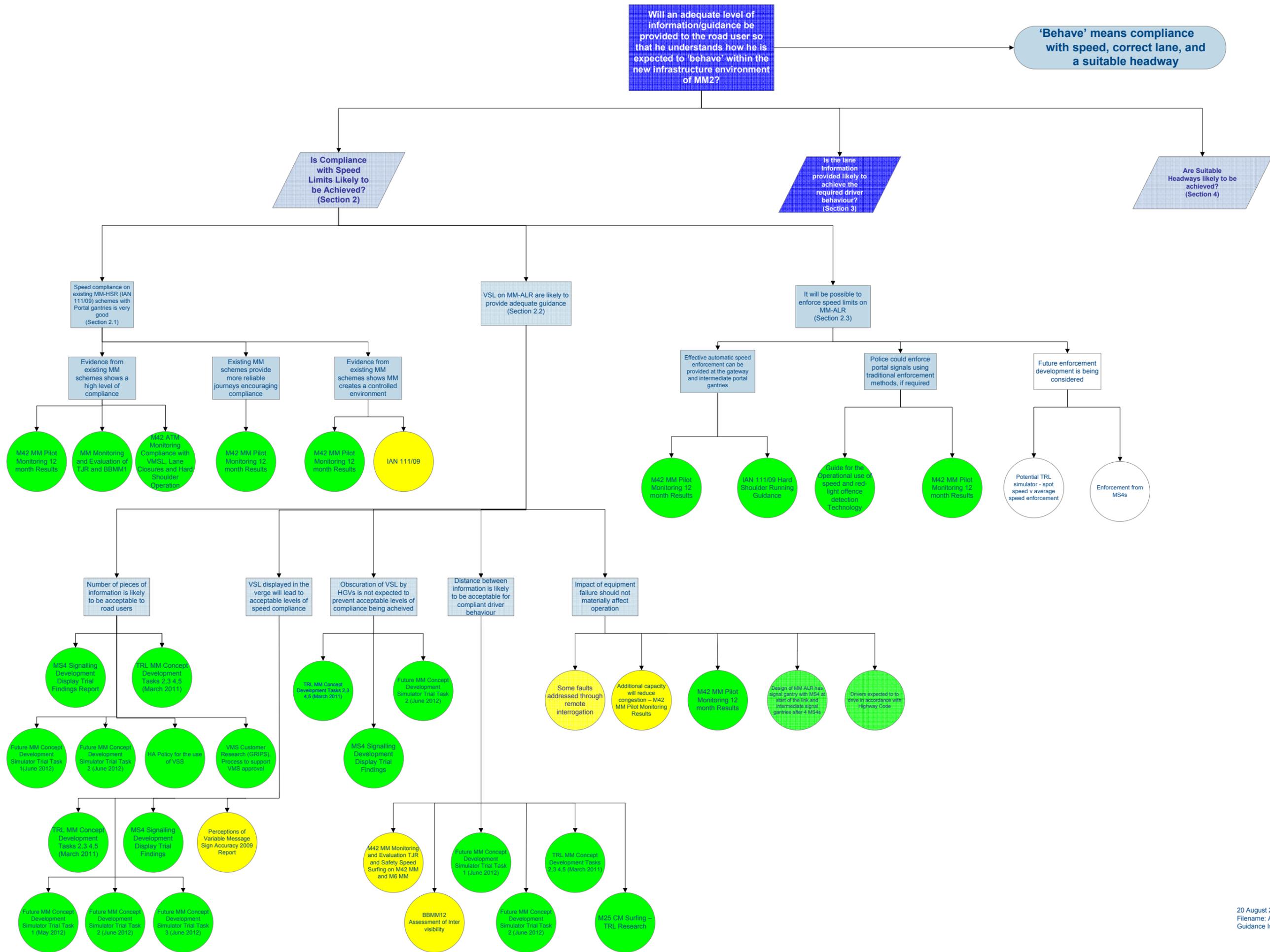
Date:	Monday 23 May 2011, 13:00 – 15:00
Location:	Great Minster House, London
Attendees:	Tim Reardon (TR), Farah Japanwalla (JR), Muriel Killin (MK), Andrew Page-Dove (APD), Sarah Garland (SG), Richard Metcalf (RM)

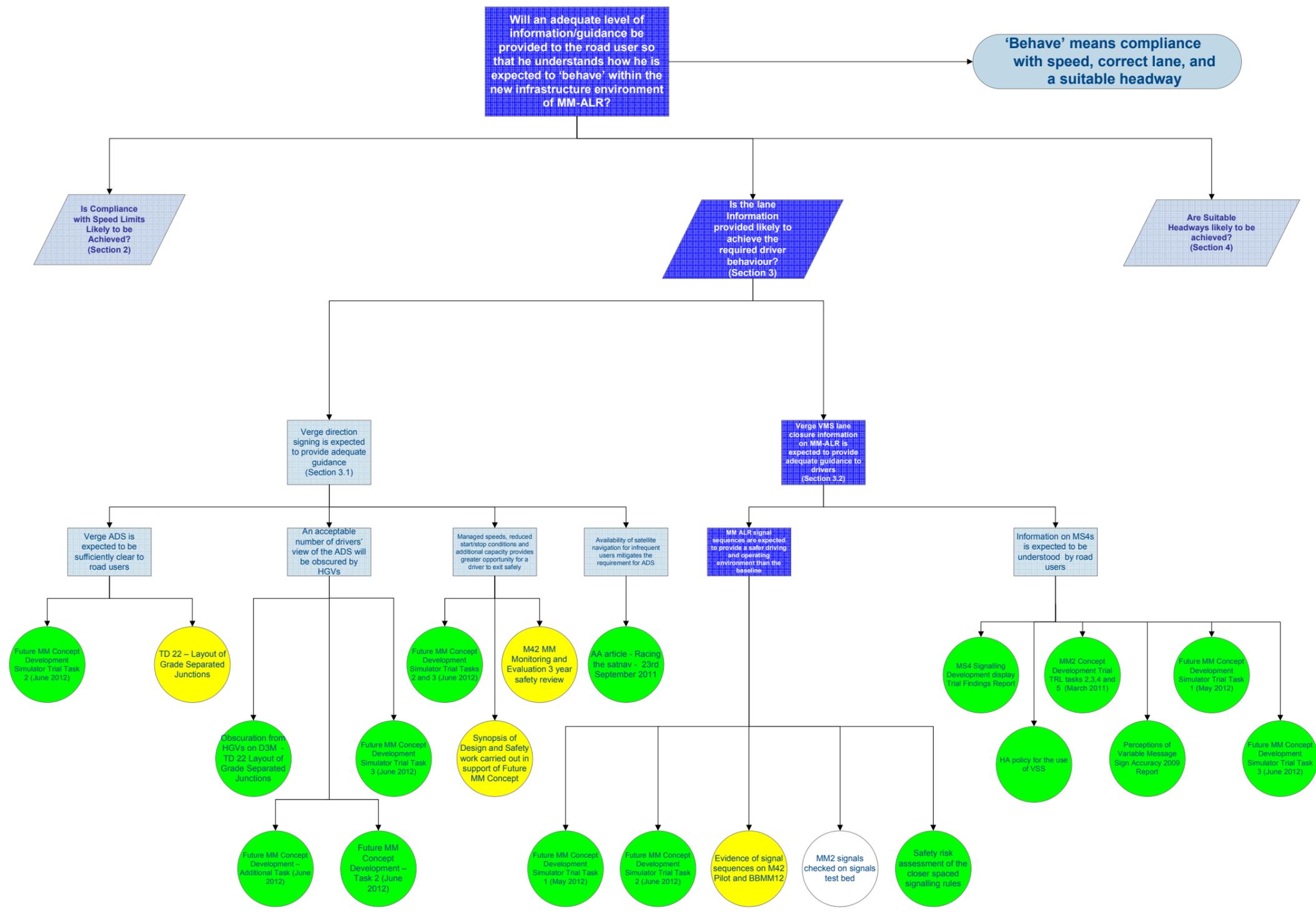
Item	Description	Action Owner
1	<p>Future Managed Motorways concept (referred to as MM2) overview</p> <p>APD gave an overview of the MM2 design concept assumptions and current of the status of the programme. The key design assumptions are;</p> <ul style="list-style-type: none"> • Hard shoulder permanently converted to a running lane • No provision for stopping (no emergency refuge areas as in the current Managed Motorways design or lay-bys) • Variable mandatory speed limits • No lane specific signalling • Spacing of driver information at maximum of 1500m • Queue protection system • Full CCTV coverage • No emergency roadside telephones (ERTs) <p>FJ queried whether corporate manslaughter had been considered as part of the design and the potential liability of the Agency if a road user was killed due to operation of the network. Action: design work to assess any potential liabilities.</p> <p>A simulator study has been undertaken independently to provide assurance on the proposed design concept. This tested how driver behaviour would impact the controlled environment if the design was changed to reflect the assumptions above. Areas tested were the increased spacing of driver information, verge-mounted vs. gantry sign comprehension and obscuration. It also simulated the MM2 environment with no hard shoulder. This work has provided a level of confidence that the MM2 preferred design can deliver its safety objective.</p>	APD/BB
2	<p>TSRGD and General Directions</p> <p>FJ explained that the Secretary of State (SoS) has a duty under the Roads Traffic Regulation Act to erect and maintain such speed limit signs as are necessary for roads which he is the traffic authority. Section 85 (1) describes the duty of the SoS to provide “adequate” guidance to drivers of the applicable speed limit. We need to be confident that we can satisfy this duty when the MM2 design concept is finalised. The decision of whether the duty is satisfied can be made internally within DfT. Ultimately ‘adequacy’ will only be tested the first time a case is taken</p>	

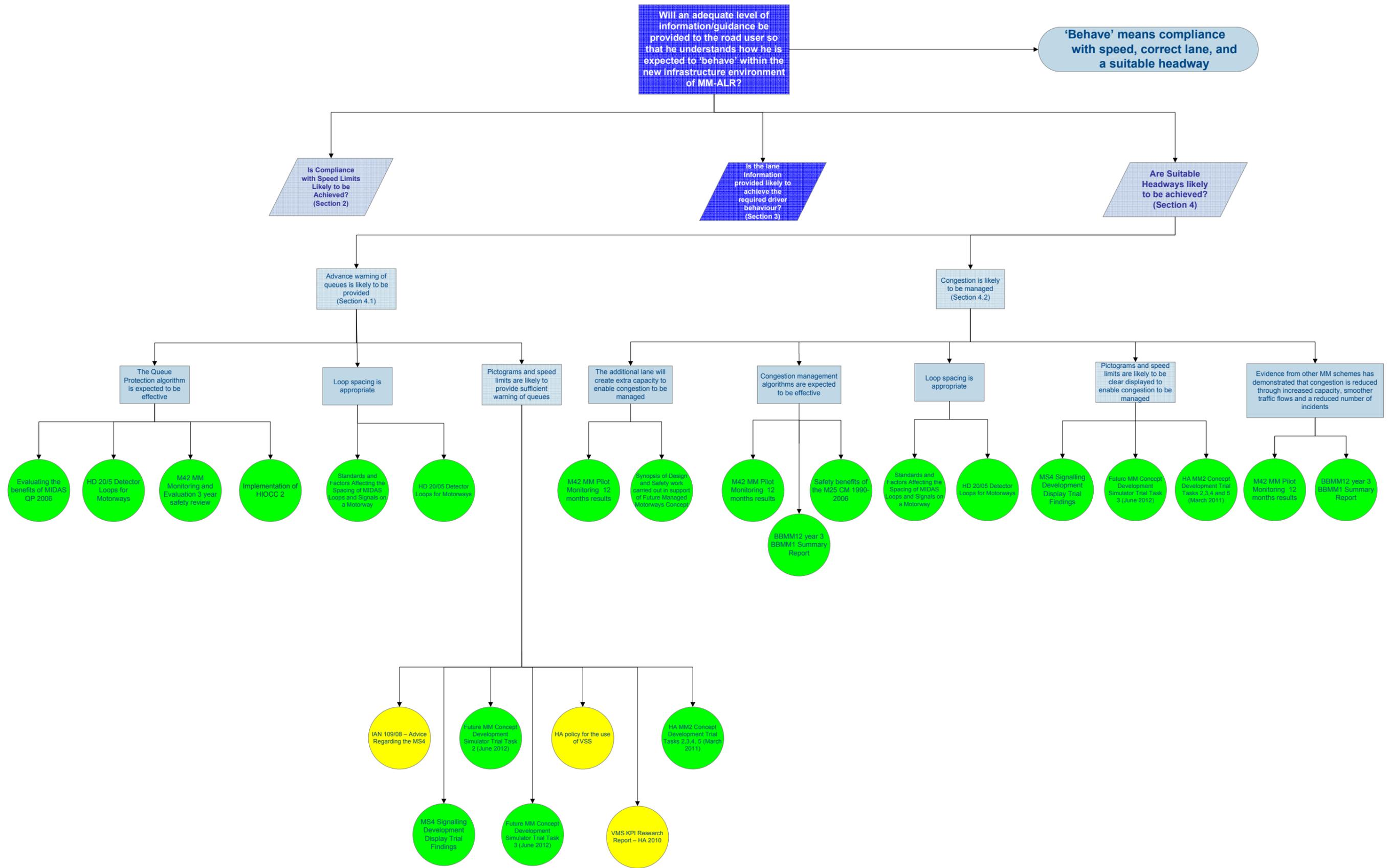
Item	Description	Action Owner
	restriction sign co-located underneath as a reminder. RM to give the HA scheme designers a reminder that this sign should be used and not sign 671 on its own.	RM
5	<p>Entry Slip Signals</p> <p>DfT Legal advised that there was no legal requirement to provide variable mandatory speed limit signs on the entry slip roads. The minimum requirement is the use of signs 2901 and 2931 for entry and exit slips respectively. Where the speed limit on the adjoining road is lower than the national speed limit, then a fixed plate sign displaying both sign 2931 and 670 is deemed appropriate. The SI for some MM schemes does include the slip roads however there is a hard sign informing drivers that they are entering variable mandatory speed limit section which negates the need for advisory speeds. For exit slip roads the end of motorway regulations (diag 2931), which covers section 17, then informs drivers that VMSL has ended.</p>	

Appendix C: Goal-Structured Notation (GSN) Diagram

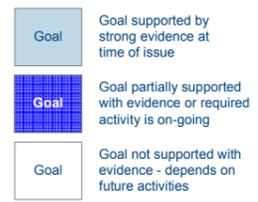
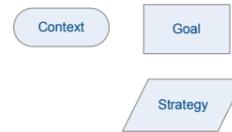








Legend



Goal supported by strong evidence at time of issue

Goal partially supported with evidence or required activity is on-going

Goal not supported with evidence - depends on future activities



Strong evidence obtained

Weak evidence obtained

Evidence to be confirmed

Appendix D: Comparison between D3M scheme with Cantilever MS4s and an MM-ALR scheme

In order to ensure that the design of a MM-ALR scheme obtains an acceptable level of compliant driver behaviour a comparison between the information provided on a MM-ALR scheme and the information provided on other sections of the network has been undertaken. A comparison has been made below in Table 5A between an MM-ALR designed scheme and a standard D3M Motorway with MIDAS and MS4 cantilevers (capable of advisory speeds).

The key is as follows:

- Red – Less benefit
- Amber – Same level of benefit
- Green – More benefit

	D3M	MM-ALR
Infrastructure and Technology		
Distance from speed aspect (MS4) to outside lane	Same	Same
Mandatory Speed aspects	No	Yes
Spacing of information	1500m	Maximum 1500m (likely be around 1000m)
Enforcement	Manual only	Could be spot speed and manual
Queue protection	Not in the baseline (would be advisory if implemented and with 1500m signalling)	Yes (loops at 500m), but with closer spaced signalling and mandatory speed limits
Areas of refuge	Hard Shoulder	ERAs at 2.5km
Congestion Management	No	Yes
Gantry	No (note may be some locations with advisory speeds on gantries)	Gateway and intermediate gantries to provide further control
ADS Verge Mounted	Yes	Yes
MS4 on gantries	No (possibly 2x12)	Yes
MS4 Cantilevers	Yes	Yes
CCTV - Comprehensive PTZ	Some PTZ coverage but not necessarily comprehensive	Yes

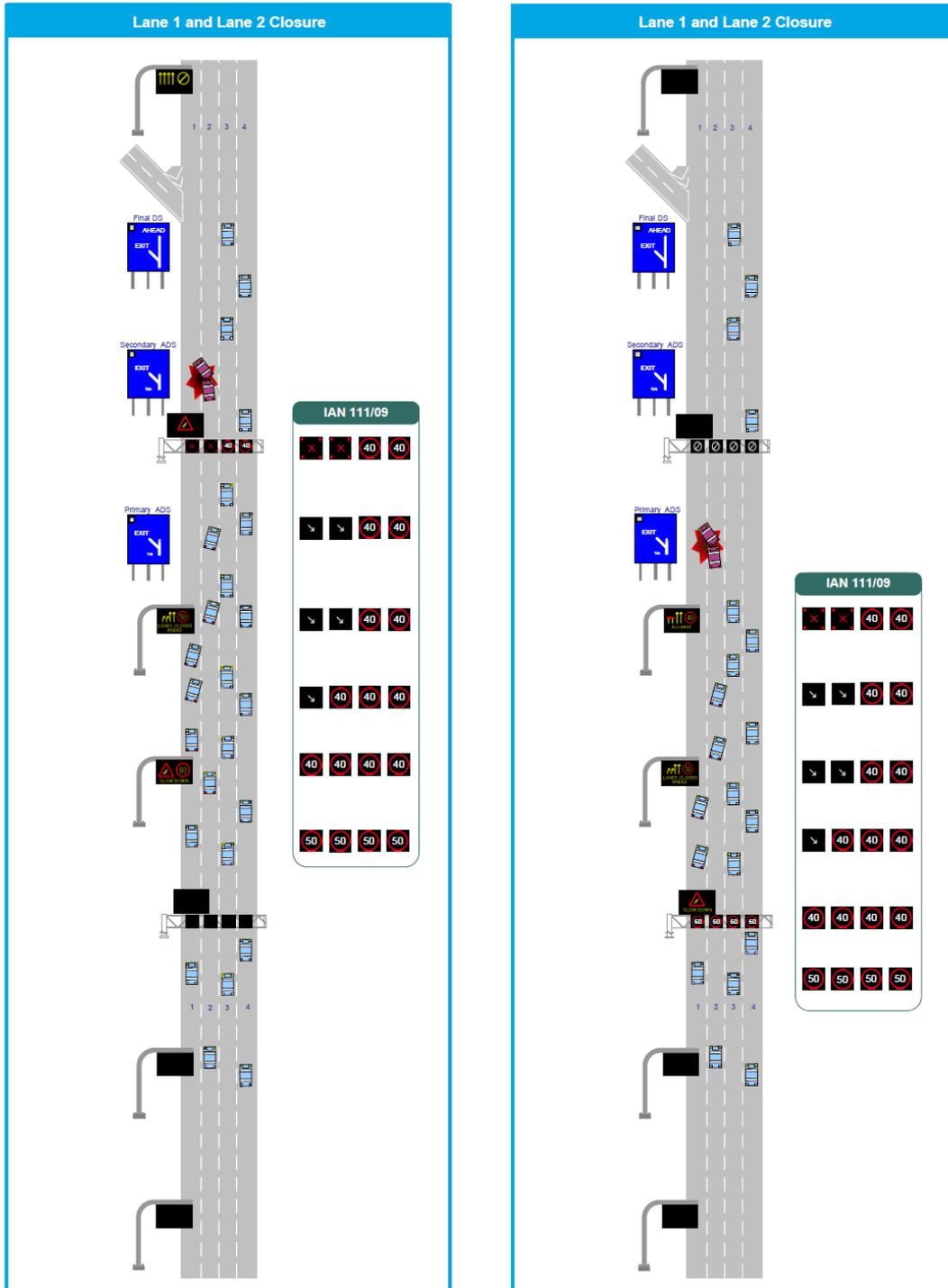
Driver Behaviour and Operation		
Controlled Environment	No	Yes
Obscuration of information	Yes but over three lanes only	Yes over four lanes but gateway and intermediate gantries provide additional signalling and VMS information
No of pieces of information	Acceptable number	Acceptable number
Incident Management (stopping in Lane 1 / hard shoulder)	Hard shoulder available in event of incidents	Signals will protect incidents but MM-ALR not as safe D3M with cantilever MS4s.
Compliance	No	Yes (due to mandatory signals, enforcement and controlled environment)
Driver understanding	Yes	Yes

Table 5A: MM-ALR compared to a D3M scheme with Cantilever MS4s

Compared to a D3M scheme with MS4 cantilevers there is a greater level of technology and infrastructure on MM-ALR to provide information and obtain compliant driver behaviour. There is an additional lane of traffic within an MM-ALR scheme and no hard shoulder to stop on in an emergency but it should be noted that the additional lane is not expected to result in a significant increase in the likelihood of obscuration. Also during emergencies there are ERAs at a maximum of 2.5km and appropriate signs and signals can be set to protect incidents.

Appendix E: Lane 1 and 2 closure compared to an IAN 111/09 signalling

Noted that schematics are based upon maximum spacing (1,500m) allowed by MM-ALR and typical spacing (800m) for MM-HSR.



Appendix F – Glossary of terms and abbreviations

Acronym	Description
ACPO	Association of Chief Police Officers
ALR	All Lane Running
BBMM1	Birmingham Box Managed Motorways Phase 1
DfT	Department for Transport
ERA	Emergency Refuge Area
HSR	Hard Shoulder Running
IAN	Interim Advice Note
LBS	Lane Below Signal
MIDAS	Motorway Incident Detection and Automatic Signalling
MM	Managed Motorways
MS4	Motorway Signal Mark 4
RCC	Regional Control Centre
TTM	Temporary traffic management
VMSL	Variable Mandatory Speed Limits
VSL	Variable Speed Limits