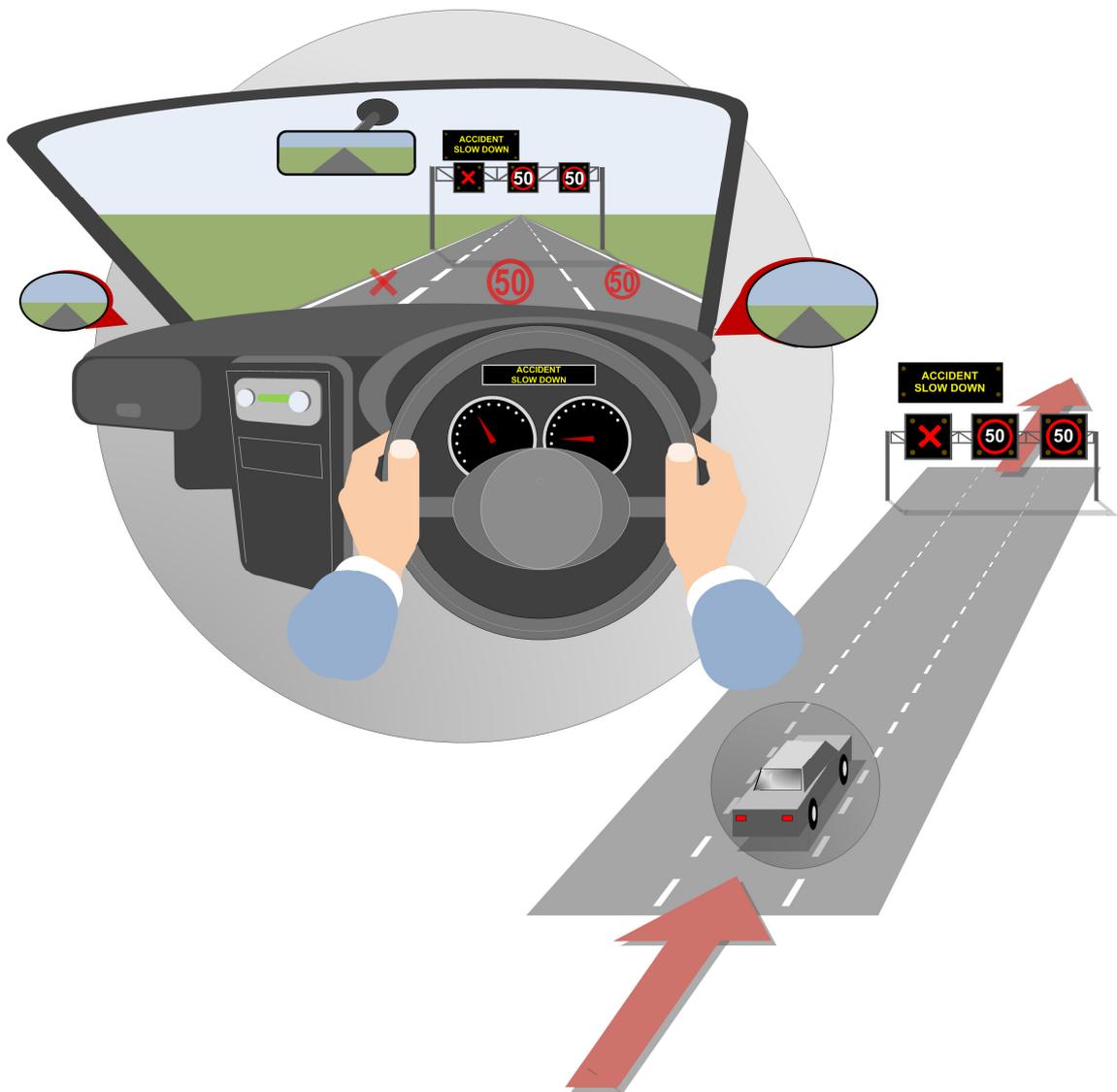


The journey ahead:

Delivering Managed Motorway information
to In-Vehicle devices

Analysis Report



Delivering Managed Motorway information to In-Vehicle devices:

Analysis Report

Revision Schedule

Analysis Report 11.05.2010

Rev	Date	Details	Prepared by	Reviewed by	Approved by
01	25.05.2010	1st issue	Robert Cranston Principal Consultant	Adam Curry Principal Consultant	Ewan Hobbs Associate

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Executive Summary

This document presents an analysis of current objectives for the provision of information to motorists on Managed Motorways. The report investigates the way in which requirements for the Intelligent Transport System (ITS) responsible for this provision of information would vary in order for the same objectives to be fulfilled by means of In-Vehicle devices.

The starting point for the study is a vision of a system that will, by means of in-vehicle devices, provide drivers with the same level of tactical and strategic information that is provided by the current array of roadside technologies. This is in respect not only of messages, but also lane specific speed restrictions and diversions for traffic management, including dynamic use of the Hard Shoulder on Managed Motorways.

Being solely conceptual, the scope of the analysis specifically excludes detailed analysis of technology relating to In-Vehicle devices and the transmission systems that might be deployed. However, the analysis has identified some interesting constraints on the form that a future In-Vehicle system must take.

The analysis derives a number of high level draft requirements for the envisaged system. These relate to broad functional changes that would facilitate a system where roadside technologies and in-vehicle technologies can complement one another and be interchangeable to the extent that, in the future, in-vehicle devices could potentially provide an alternative to roadside devices along sections of the motorway network.

As a by-product of the analysis a number of 'Human Factor' issues have been documented. Primarily, these relate to the way information would be presented on an In-Vehicle Device. For example: should the display be auditory or visual; should the In-Vehicle device represent all lanes at a signal site and indicate the lane the vehicle is travelling in; should In-Vehicle technology replicate roadside signal and message sign flasher functionality? It is beyond the scope of this study to resolve these complex issues, but it is useful to document them here so that they may be framed with reference to the Managed Motorway information prior to future analysis.

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PART 1: INTRODUCTION

1 Introduction

1.1 The purpose of this Document

This document presents the analyses of current objectives for the provision of information to motorists on Managed Motorways and how the requirements for the Intelligent Transport System (ITS)¹ responsible for providing this information would vary in order to order for the same objectives to be fulfilled by means of In-Vehicle devices integrated into the ITS.

1.1 Background

The Highways Agency commissioned Scott Wilson to undertake this study, the starting point for which is a vision of a system that will, by means of in-vehicle devices, provide drivers with the same level of tactical and strategic information that is provided by the current array of roadside technologies. This is in respect not only of messages, but also lane specific speed restrictions and diversions for traffic management, including dynamic use of the Hard Shoulder on Managed Motorways (MM).

Ultimately, the vision is of a system where roadside technologies and in-vehicle technologies can complement one another and be interchangeable to the extent that, in the future, in-vehicle devices could potentially provide an alternative to roadside devices along sections of the motorway network. This challenging vision of the future holds several significant benefits, especially in terms of reducing the visual and environment impact of the system, but also in terms of providing greater resolution of information to drivers and a more dynamic approach to traffic management.

Being solely conceptual, the scope of the analysis specifically excludes detailed analysis of technology relating to In-Vehicle devices and the transmission systems that might be deployed. However, the analysis has identified some interesting constraints on the form that a future In-Vehicle system must take.

1.2 The Aim of the Analysis

The aim of the analysis has been to develop a clear understanding of current objectives relating to the provision of information on Managed Motorways and the constraints these impose on a future system incorporating in-vehicle technologies. An output of this is a set of top level requirements for modifications to the current system and a definition of the data that will be conveyed to In-Vehicle devices (IVDs) that will enable the future system to fulfil these Managed Motorway information objectives.

Accordingly, the analysis has been conducted in two major phases:

¹ ('ITS' is a generic term used to refer to the integrated application of communications, control and information processing technologies to a transport system.

- **Phase 1:** Document and understand the current objectives:
 - Document current objectives and requirements for the provision of information to drivers on Managed Motorways and understand the implications of these for the display of information by means of in-vehicle devices, and
 - Document and understand those aspects of the system architecture that need to be considered if the system is to be extended to allow accessibility of data and use by In-Vehicle devices.

The output from this part of the analysis is a description of current system requirements and architecture relating to information provided to drivers on Managed Motorways. This includes lane specific signalling for traffic management. This output is used subsequently to facilitate the investigation into the way in which current requirements would vary when applied to future In-Vehicle information presentation (see 'Understanding the Current Objectives' below).

The results of this analysis are documented in Appendix C: *Managed Motorway Information Objectives*.

- **Phase 2:** Investigate the way in which requirements of the current system would vary when applied to future in-vehicle information provision of MM information.

The output of this phase is a first draft specification of amendments to the current requirements for system data and any requisite modifications to the system architecture.

At this early juncture in a possible long term initiative to integrate In-Vehicle technologies into the HATMS infrastructure (for the provision of MM information to drivers), it is considered that a low level and detailed set of requirements would not meet the objectives of this project. The reasons for this are as follows:

- Low level detailed specification may have dependencies on Human Factor issues that are beyond the scope of this project to resolve;
- Low level detailed specification may involve extant functionality or architectural features that will change significantly over the course of this initiative as a result of other unrelated modifications to the system; and
- Low level detailed specification will not aid the *understanding* of the way in which the system would vary to integrate In-vehicle technology.

The methodologies applied to the analyses in Phase 1 and Phase 2 are described in Section 2 below.

PART 2: METHODOLOGY

2 Understanding the Current Objectives

2.1 The Method of Analysis

2.1.1 Overview

2.1.1.1 Categorising Objectives & Requirements

The method of analysis is first to identify categories in which system requirements and objectives may be grouped. These are plotted down the vertical axis (column 1) of a table. An example category is Signal Sequencing. Categories of objectives and requirements may be further subdivided in sub-categories for general consideration. These are entered in rows down the second column of the table. An example sub-category is Transverse Sequencing: a sub-category of Signal Sequencing. This categorisation of objectives and requirements is intended to ensure a systematic approach to the analysis: another analyst may find it useful to categorise requirements and objectives differently, but the requirements/objectives would remain the same. This process is refined through the course of the work package.

2.1.1.2 Characterising the System

The next step in the analysis is to *characterise* the current HATMS in ways that will lead to a *useful* understanding in respect of the aim of providing information to drivers by means of In-Vehicle devices. For example, the system may be characterised as a system comprising *static* roadside signal and sign devices. Explicitly characterising the system this way raises challenging questions when the objectives for displaying information are considered in respect of devices that move (In-Vehicle devices). There are various characterisations and they are plotted along the horizontal axis of the table as column headings.

To illustrate the process of *characterising* the current system, consider the objective of preventing motorists from making sudden changes in speed or course when speed restrictions are set on-street. The objective is met by the implementation of Upstream Signal Sequencing Rules that ensure that upstream signals are set with a safe 30 mph speed reduction between them. It is almost a truism to say that the motorist can see the restriction from a point upstream, but consider the significance of this for the display on an In-Vehicle device: if the display on the In-Vehicle device is updated with the same aspect at or around the point that the motorist can see the aspect displayed at the gantry downstream, then how will the In-Vehicle device convey to the driver that the restriction applies from the location of the signal site downstream and not at the vehicle's current location, thus ensuring that the driver does not decelerate abruptly?

Another example of how the current HATMS might be categorised is as a system comprising signal devices that are 'hard wired' into the HATMS infrastructure. Consider the fact that different signal sites may be in very close physical proximity (e.g. two signal sites, one each side of convergence of an entry slip with the main carriageway). Being hardwired into the HATMS infrastructure it is straightforward to targeted specific signal devices with setting data and, therefore, straightforward to target information at a specific set of drivers, namely, those drivers in the proximity of, and travelling towards, the relevant signal site. By virtue of being hard-wired into the system, transmissions to specific signal devices will not be 'received' by drivers on nearby carriageways. In this regard, the objective is really then to target information at drivers on a location by location basis. How will the future Infrastructure to Vehicle 'transmission system' achieve this?

2.1.1.3 Completing the Analysis

Having established initial requirements categories, and having characterised the system in useful ways, populating the table entails analysing each category and sub-category of information objectives/requirements against each of the various system characterisations and recording the results of the analysis in the relevant table cell.

2.1.1.4 Understanding the Terms 'Managed Motorway' and 'HATMS'

Throughout the main document the term 'HATMS' (*'Highways Agency Traffic Management System'*), and not the term 'Managed Motorway', is used when referring to system requirements. The reason for this is that HATMS is the IT system and infrastructure that underpins Managed Motorway initiatives and is the system to which the relevant objectives and requirements apply. The term 'Managed Motorway', by way of contrast, refers to a technology driven approach to the use of motorways controlled by HATMS.

2.1.2 Categories of Information Objectives and Requirements

The resultant categorisation of the system requirements/objectives is as follows:

- **Operational Performance:** Requirements for system performance is a key consideration: Whatever modifications are made to the current system in order to facilitate the integration of In-Vehicle technologies, it is reasonable to expect that these should not degrade system performance or impede future initiatives to improve system performance. 'System performance' refers to both the rate of signal and sign setting throughput and the rates of data transmission between instation and outstation as a result of this. The significance of this for V2I integration is that current and anticipated volumetric rates may place constraints of the type of transmission system that can be deployed for V2I integration. As part of the analysis
- **Transmission:**

- **Latency:** Considerations of Real-Time, Near-Time and Some-Time quality of information. These are significant considerations since it is a prima facie requirement that information provided to the driver via In-Vehicle technologies should not conflict with information provided via roadside technologies. For example, a discernable lag (Hysteresis) between setting of roadside devices and In-Vehicle devices could confuse and undermine confidence in the system.
- **Frequency:** Considerations of the Rate of signal and sign setting updates. For example, what constraints on transmission technologies would there be in relation to the rate and volume of data transactions?
- **Site Data:** The significance of site data is that device data and signal and sign geometry data map to the actual on-street environment: device data defines attributes of devices and geometry data defines sites and the interrelationships between sites. So, for example, if the signal geometry data specifies that lane 1 at a particular site is a hatched lane, and this is used by the Signal Sequencing rules to determine whether a certain aspect should be displayed over a hatched lane or not, then what are the implications of this for an In-Vehicle displays? How would the In-Vehicle device represent the variable running lane configuration as the vehicle approaches and travels past the hatched lane?
- **Operational Regimes:** Operational Regimes are scenarios or plans that the operator or system implements in response to real time traffic conditions. More broadly speaking, they are considered here to be standard responses to day to day traffic conditions. An example of an operational regime that might be considered is a Motorway Diversion. Motorway Diverts (◀ or ▶) are set upstream of a divergence to direct traffic away from one or other of the divergent carriageways. If a vehicle passes under a gantry displaying a Motorway Divert, and if the Motorway Divert display on the In-Vehicle device persists beyond that gantry location and to a point beyond the open divergence downstream, then the In-Vehicle device will misrepresent the actual road configuration at that point downstream.
- **Signal Settings/Aspects:** This category encompasses requirements mainly relating to the appearance of signal settings. The distinction between Mandatory speed aspects and Advisory speed aspects, for example, is explained. What is the significance of Mandatory as opposed to Advisory speed aspects for In-Vehicle displays? What is the significance of amber and red flashers both for signals and signs? How would these be handled In-Vehicle when, for example, roadside message sign flashers are suppressed due to extant signal settings?
- **Signal Sequencing:** An implicit requirement of this project is that the proven through use safety case for the Sequencing Rules should not be compromised through the specification of any modifications to the current HATMS requirements. If, for example, the objective of a particular Upstream Sequencing rule is to condition traffic flow upstream of a speed restriction so that sudden breaking of approaching vehicles is avoided (e.g. by setting '50' upstream of a primary '20'), then the V2I initiative should not compromise this objective.

- **Signal Siting Requirements:** Signal Siting requirements relate to the positioning of signal sites. What are the implications of, for example, gantry spacing for In-Vehicle technologies – what constraints would these requirements impose on an Infrastructure to Vehicle transmission system? What is the significance of siting requirements based on considerations of inter-visibility and parallax for In-Vehicle displays?
- **Variable Message Signs:** The analysis places a heavy emphasis on signals as opposed to message signs. The reason for this is that the provision of information through signalling, enabling lane specific traffic management, is considerably more problematic for V2I integration than the provision of strategic, tactical, driver and campaign information through signing. This is borne out through analysis. Therefore, considerations of the requirements for variable message signing are grouped together in a single category including site data, siting and some of the other categories that are dealt with individually for signalling.
- **Fixed Signage:**
 - *Fixed Text Message Signs:* Fixed Text Message Signs (FTMS) are any type of VMS that display two or more fixed legends. There are currently a number of technologies used in such signs, the more common being active light emitting, flexible roller blind and rotating plank or prism, the latter two normally being electro mechanical. Of these types the rotating plank or prism is most suitable for strategic use. How are these used to display MM information and what is the significance of these for V2I integration?
 - *Marker Posts:* Marker posts are used on Managed Motorways to point to the safest available ERT (Emergency Roadside Telephone). This can be classed as Managed Motorway Information and it is information that *could* be provided via In-Vehicle technologies.
 - *Driver Location Signs:* Driver Location Signs are located within ERAs (Emergency Refuge Areas) and inform drivers, traffic officers and maintenance staff of their precise location and the direction of travel. This is Managed Motorway information and could be provided In-Vehicle. An obvious benefit here would be to mobility impaired drivers, and drivers generally, when, for whatever reason, the hard signage is obscured from view.
- **Cross-Boundary Interworking:** As a category or requirements, Cross-Boundary interworking is significant since the current division of the Highways Agencies motorway network into RCCs (Regional Control Centres), each with a dedicated set of instation control system hardware, means that data is transmitted between the instation and the outstation on a regional basis. What are the implications of this for a transmission system for V2I integration?

2.1.3 Characterisation of the System

The resultant characterisation of the current system is as follows:

- **A System Comprising Various Device and Site Types:** HATMS deploys various different device types that are used to convey Managed Motorway signal and sign information to drivers. Each device type will have specific capabilities, e.g. the ability to display wicket aspects on certain signal devices (post mounted signals) and not others. What is the significance of this for V2I integration? Should, for example, an In-Vehicle device display a wicket aspect when the setting on the roadside device is a wicket, or, should the In-Vehicle device always display lane-by-lane settings: should X-50-50 be displayed when lane 1 on a three lane carriageway is closed irrespective of the 'TII' set on the roadside device?
- **A System Targeting Specific Device and Site Types:** Specific sites or device types may be targeted for specific purposes. For example, MM-schemes are interspersed with MS4 type and MS3 type message signs. On MM-schemes, MS4s are generally mounted over gantry mounted signal AMIs (Advanced Motorway Indicators) over the Hard shoulder and are used primarily to display tactical messages supporting the associated signal settings. The MS3s tend to be used for displaying strategic messages. How does the current system manage this? How would the system 'prioritise' sign settings for In-Vehicle devices to avoid rapidly alternating tactical and strategic message updates as the vehicle travels along the MM-scheme?
- **A System Comprising Devices Hardwired into Infrastructure:** Primarily, the significance here is that by virtue of being hard-wired into the HATMS infrastructure, data transmissions to devices are highly targeted, and, therefore, MM *information* is targeted very precisely at drivers at specific locations at specific times and for specific durations. How will an Infrastructure to Vehicle transmission system achieve this?
- **A System Comprising Static Display Devices:** A clear distinction between roadside technology and In-Vehicle technology is that roadside devices are static whereas In-Vehicle devices are moving. One obvious observation is that when a vehicle passes under a gantry the driver will no longer be able to see the signal setting on display, therefore, two consecutive signal sites, cannot be in conflict. How is this relevant? Consider the following example: If 'End' (appears as either 'End' or 'Ø' depending on the device type) is set on a signalling gantry the driver will understand that the restriction is eased from the point directly below the gantry. There is no need to repeat the 'End' at the next signal site downstream so it will be blank (which it must be according to the Signal Sequencing Rules). Moreover, the signal site downstream may have been blank for some time and therefore will not have received a setting update for that duration. However, the 'End' displayed on the In-Vehicle device needs to be cleared in order to avoid a conflict or disparity with the blank aspect on the downstream device? Given, though, that the vehicle would not receive an update from the blank downstream gantry, how would the system clear the 'End' displayed on the In-Vehicle device? What does this suggest about the structure of setting data that would be transmitted to vehicles?

- **System Comprising Devices Spatially Aligned to Lanes:** At gantry locations signal devices (e.g. Gantry mounted AMIs on MM-schemes) are mounted directly over the lanes that they are intended to represent; there is a direct spatial relationship between signal devices and lanes. However, it is not possible for the In-Vehicle display to stand in such a close one-to-one spatial relationship with actual lanes. What are the Human Factor implications of this? Assuming that In-Vehicle devices will represent all lanes on the carriageway to enable drivers to make informed choices (e.g. choosing not to change into a lane that is closed), would the In-Vehicle device be required to 'highlight' the restriction applying to the particular lane that the vehicle is travelling in so that the driver is able to intuitively associate the In-Vehicle display with the actual lane configuration?

2.1.4 Conclusion

In conducting the analysis it was observed that objectives and requirements relating to the provision of information to drivers on Managed Motorways are not always framed as Objectives for Information as such. Moreover, the specification of requirements is spread over a wide and diverse range of documents, each of which has a different objective and frame of reference. Therefore, in order to record a meaningful statement of the system's capability, the analyst's own experience of the system had to be drawn upon to interpret the requirements. This is quite natural and was anticipated in the original task proposal.

3 Defining the Future System

3.1 Establishing Guiding Principles

3.1.1 The Overall Objective

Looking to the future, any number of systems providing information to drivers on MM could be imagined, however nebulous in conception they may be. It is important to establish, therefore, criteria or principles that will guide the analysis and systematically preclude alternatives that are impracticable or that cannot efficiently be integrated into the existing system.

'Cost Effectiveness' is not explicitly included as a guiding principle since it is assumed to be an overarching consideration, barring, perhaps, for any safety related functions.

In-Vehicle technologies should compliment roadside technologies and, possibly, provide an alternative that will provide drivers with the same level of tactical and strategic information that is provided by the current array of roadside technology (post, cantilever and gantry mounted signals and signs). This is in respect not only of messages, but also lane specific speed restrictions and diversions for traffic management, including dynamic use of the Hard Shoulder on MM.

3.1.2 The Guiding Principles

The following principles are considered to provide a robust basis for the derivation of a new set of requirements:

- Principle 1: Maintain the Safety Case;
- Principle 2: Retain Control of MM Information;
- Principle 3: Strive for Simplicity in System Design;
- Principle 4: Avoid Conflict with Existing Roadside Technologies;
- Principle 5: Settings on Road Side Devices (RSDs) have Primacy;
- Principle 6: Maintain Quality of MM Information; and
- Principle 7: Aim to be Independence of *Particular* Technology Solutions.

Each of these is explained in paragraphs 3.1.2.1 to 3.1.2.7 below.

3.1.2.1 Principle 1: Maintain the Safety Case

HATMS is a *Safety Related* system, therefore any proposed modification to the current requirements should be considered in respect of the existing Safety Case, irrespective of whether the Safety Case is implicit or explicit in any part. Ownership of the Safety Case has not been determined, but it is considered that there is an onus on this study to ensure that, to the best of our knowledge, any proposed modifications will not compromise the system's safety integrity.

3.1.2.2 Principle 2: Retain Control of Managed Motorway Information

For the Safety Case to be maintained, Managed Motorway Information provided to drivers should, ultimately, be under the control of HATMS. Control of information should also ensure conformity of display from one vehicle to the next.

Wherever possible, intelligence for processing data conveying MM Information should be retained within HATMS.

3.1.2.3 Principle 3: Strive for Simplicity in System Design

For example, if it is not necessary that the future system receive satellite positioning data (e.g. via GPS or Galileo) then there is no reason to include those technologies.

Dependencies on a satellite global positioning technology, for example, would effectively incorporate such systems into the traffic management system, increasing reliance on third parties (see Principle 2) and adding a further point of failure and possible cause of hysteresis between settings on RSDs (Roadside Devices) and settings on IVDs (see Principle 4 Below).

3.1.2.4 Principle 4: Avoid Conflict with Roadside Technologies

In-Vehicle displays must not conflict with roadside displays such that disparity between RSD and IVD displays could be distract or confuse drivers, and undermine confidence in the system generally.

3.1.2.5 Principle 5: RSD (Roadside Device) Displays have Primacy

Displays on RSDs have primacy in the sense that IVD settings should achieve parity with RSD settings and not the reverse. This relates somewhat to the principle of maintaining the Safety Case: the current system is proven therefore information presented in-vehicle should conform to that displayed at the roadside.

3.1.2.6 Principle 6: Retain Quality of Managed Motorway Information

- Enable Drivers to make the same degree of Informed Choices
- Replicate Real Time behaviour of the current system

3.1.2.7 Principle 7: Aim to be Independent of Particular Technology Solutions

3.1.2.7.1 *IVD Technology*

For example, no assumption is made as to whether the 'display' of information on IVDs should be auditory and/or visual (the term 'display' is used throughout this document when referring the information presented to derives but it is not used exclusive of auditory information. So, for example, if it is required that for each and every signal site the system transmits the settings for all lanes, irrespective of the particular lane that the vehicle is in, then it is an open question at this stage as to whether the IVD communicates that information to the driver by means of a visual display representing those lanes or whether the lane information is 'voiced' to the driver.

3.1.2.7.2 *Transmission Technology*

No assumption is made as to transmission technology or medium) by means of which data is transmitted.

3.2 Analysing Objectives in Respect of In-Vehicle Devices

Having established a set of principles to guide the investigation, the objectives and requirements for the provision of information to travellers on Managed Motorways documented in the first Phase 1 of the study will be analysed in respect of their implications for In-Vehicle devices and the particular considerations that obtain therein

A top level, draft functional specification for modifications to the current system will be made with respect to:

- Functional requirements relating to IVD (In-Vehicle Device) displays;
- Requirements for change to the current system; and
- Data requirements, including signal and message sign setting data. These are to be developed in a subsequent project as an interface specification for HATMS-IVD interworking

PART 3: DERIVING A NEW SYSTEM

4 Filling the Gap

4.1 Introduction

From the analysis of the current objectives and requirements for Managed Motorway information four broad areas of consideration for the future system have been demarcated. These are:

- **In-Vehicle Displays:** Implications/constraints on IVDs
- **Data Transfer Methods:** Implications for the future Transmission System allowing infrastructure to communicate with In-Vehicle technologies.
- **Architecture:** Implications for the current system Architecture. The system Architecture will depend to some extent on the transmission system and vice versa, but they need to be considered separately.
- **Human Factors:** Human Factor Considerations (HFC) will be documented but are outside the scope of this study to resolve

4.2 Data Dependencies relating to the IVD Display

4.2.1 Introduction to IVD Issues

This section reviews the implications of MM objectives for IVD 'displays'².

All IVD display considerations are more or less HFCs (Human Factor Considerations) since the IVD display is precisely the Human-System interface. However, whilst there are HFCs that may be within the scope of this project to address, others will be beyond its scope. To determine which is which, the approach here is to indentify whether the HFC relates to the *content* of MM information presented to the motorist or, rather, to the *way* it is presented to the motorist. The former being within scope to consider, the latter being within scope to raise as an issue to be resolved outside this project.

As an example, consider a vehicle approaching a signal gantry: by virtue of the fact that the array of signal aspects on display at the gantry represents all lane specific settings at that site drivers can make an informed judgement as to the appropriate lane and speed on their approach. This is undoubtedly an HFC, but it relates to the content of the information that is presented to the driver. In order, then, to provide the driver with the same degree and quality of information by means of an IVD it is reasonable to expect that for any given signal site the system should transmit to the vehicle data pertaining to settings at all lanes at that site. Therefore, in this instance, it is an HFC within the scope of this project to address.

² By 'display' is meant not necessarily a visual display: the presentation of Managed Motorway information could be through auditory means but no assumption either way is made in this analysis.

On the other hand, the way the signal site information is presented drivers (e.g. whether an auditory or a visual representation of the site, perhaps with the current lane the vehicle is travelling in highlighted) is an HFC that is beyond the scope of this project to address.

Certainly, in the example give, a visual representation would overcome issues of language, and it would seem more direct and intuitive than an auditory breakdown of site information, but is beyond the scope of this project to determine which method is more appropriate. It is sufficient for this project to define the data that would *facilitate* either method of presentation.

4.2.2 Achieving Parity with the Point at which Compliance with Restrictions is observed

4.2.2.1 Forewarning the Motorist

Consider that one of most intuitive aspects of RSD displays is that the motorist can see the settings on an RSD from some distance upstream from the device. At the same time, the motorist is cognizant that the restrictions apply from that signal site and not from the point that the he or she is first able to see those settings.

The main consideration here is that since drivers see restrictions on the RSDs from some distance upstream they are able to do one of the following:

- Decelerate (in the case of a speed restriction) in a safe manner,
- Change lane (in the case of a lane or motorway divert) in a safe manner;
- Stop (in the case of a full carriageway closure) in a safe manner; or
- Revert to the national speed limit (in the case of a restriction being eased – END/NR or RE – seen as ‘End’ or ‘Ø’).

Forewarning motorists in this way is one of the primary objectives for the Signal Sequencing Rules (see 4.4.2.2.1 below). To ensure that the motorist adjusts his or her speed or changes of lane in an orderly manner, thus delaying the onset of flow breakdown further upstream, one of the main objectives of the Signal Sequencing Rules is to *condition* traffic flow on the approach to a restriction. For example, the Signal Sequencing rules may typically generate a secondary *lead-in* ‘50’ aspect at the site upstream from a primary ‘20’ aspect. Figure 1 below illustrates a simple Signal Sequencing event.

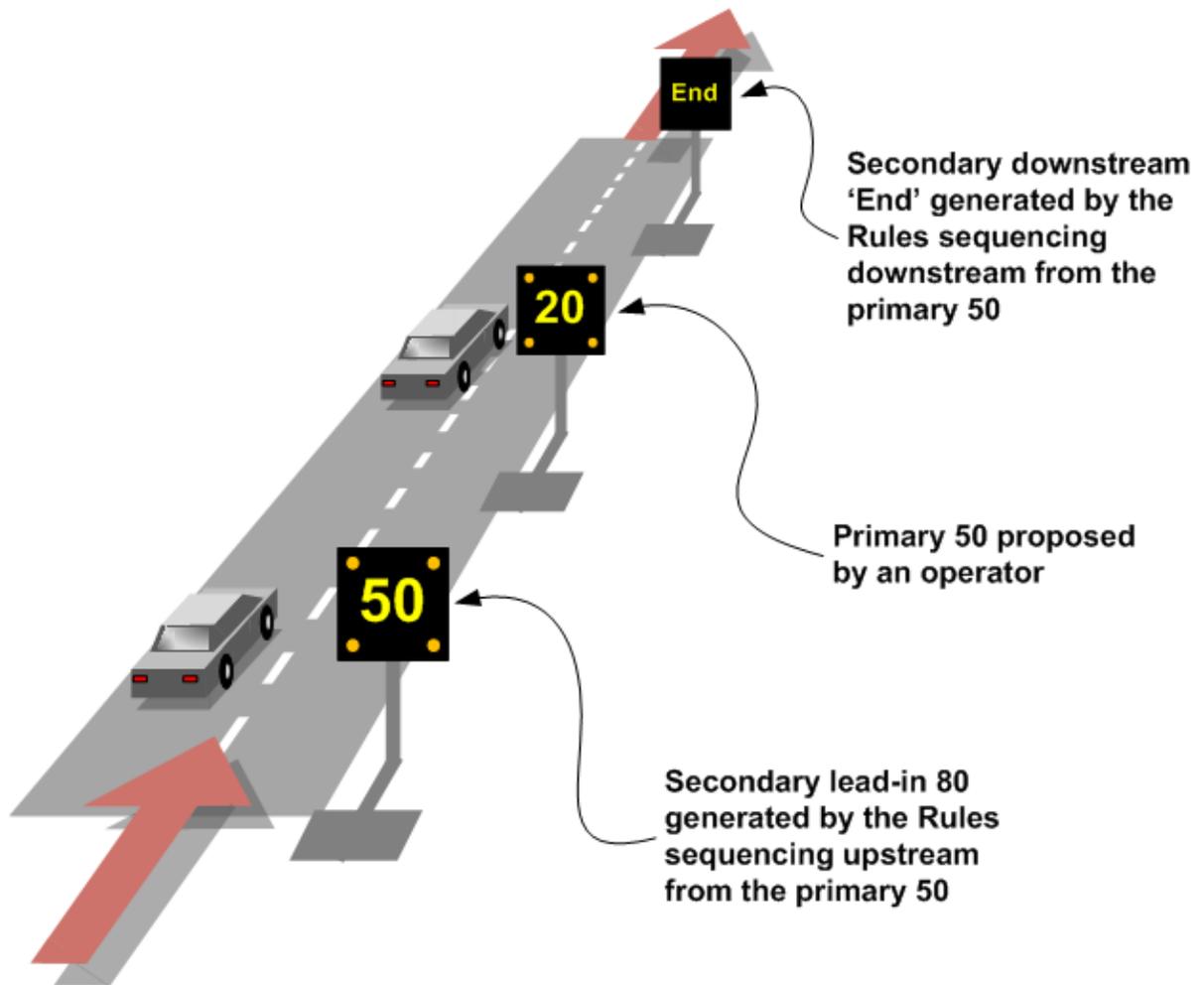


Figure 1: A Simple Signal Sequencing Event

Data transmitted to vehicles should be sufficient in content for the same objective to be fulfilled by means of an IVD display.

The issue for IVD displays is that though this conditioning effect must be maintained in order to fulfil the implicit safety case in the rules, an aspect displayed on an IVD may not have the same intuitive effect as the same aspect displayed on a roadside device and may mislead the driver into believing that the restriction applies from the moment the aspect appears on the IVD. Consequently, the driver may decelerate abruptly presenting a hazard to drivers upstream and possibly be a catalyst for flow breakdown. How can this be resolved?

It is really an HFC to address how to present the information so that it both advises of the restriction downstream but does not cause drivers to react abruptly. However, in order to facilitate this, the IVD would be required to either:

- a) Be pre-configured with sign geometry data so that the IVD could communicate to the driver when/from where the restriction applies.

However, this presupposes that vehicles entering the network deploy up-to-date geometry data, and that its currency is checked on entering the network, or, that the system is somehow able to communicate geometry data as it travels onto and through the network.

Site data is upgraded at regular intervals so if IVDs are to be pre-configured, it is not clear how the activities of updating IVDs and site data upgrades could be coordinated (especially so for vehicles travelling through the network while the site data upgraded takes place).

With respect to geometry data downloads to vehicles entering the network, it should be noted that there is an allowable maximum of 5000 in-boundary signal sites per RCC (there are 7 RCCs, therefore 35,000 sites for the entire network) so it would seem improbable that this amount of data could be transmitted to every vehicle on entering the network. (see Section 4.3 below).

- b) With each setting update transmitted to the vehicle by the system, the data transmitted would contain some geographic reference or a distance to travel where the restriction applies. The system could also transmit with the setting data a 'Step-Down Sequence' for each speed restriction such that less restrictive advisory settings gently condition the motorists approach to the signal site such that he/she is compliant at the point directly beneath that site. Figure 2 to Figure 6 below illustrates a possible scenario in which the IVD conditions the approach to a restriction of REDX-50-50-50 on a Managed Motorway

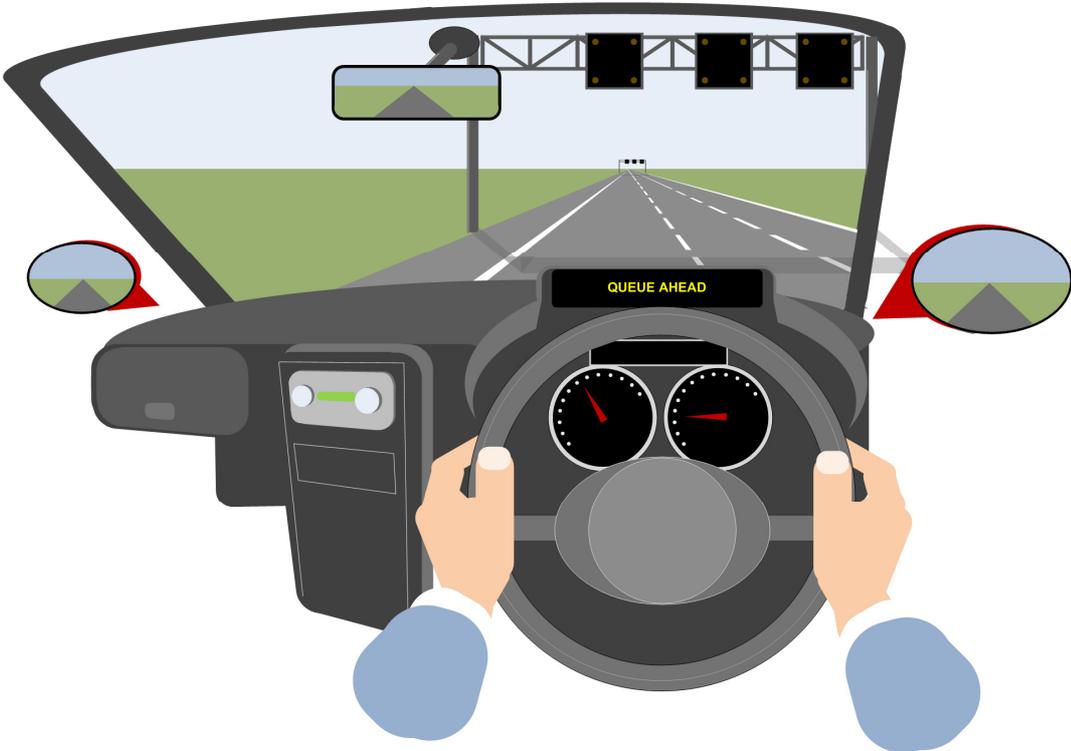


Figure 2: IVD Notified of Queue Ahead

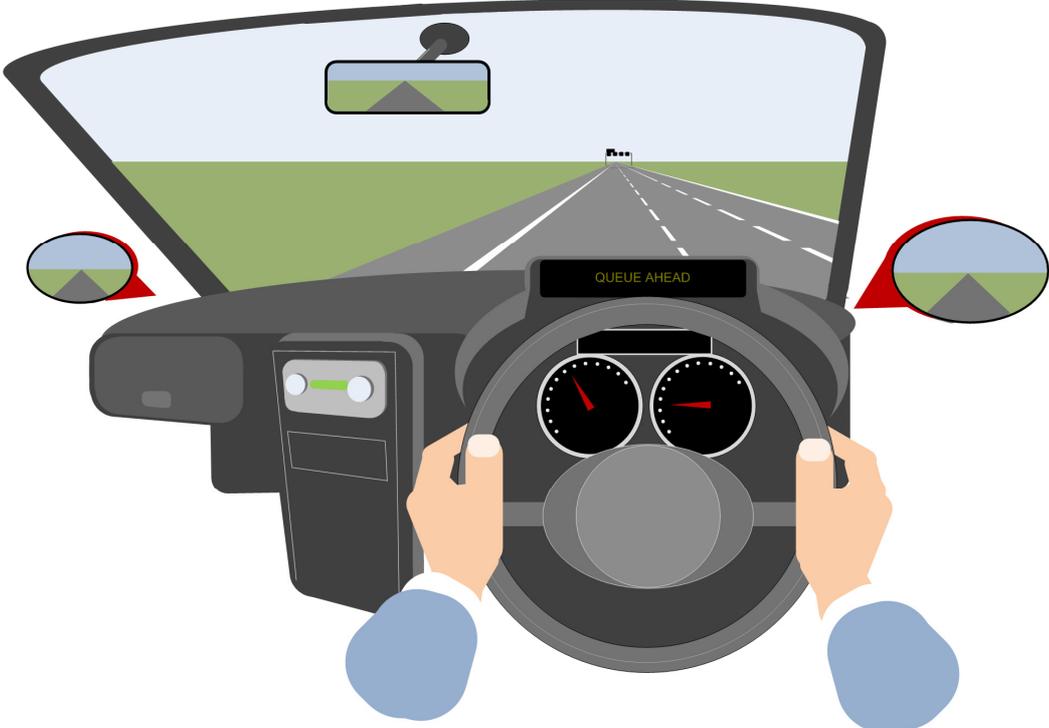


Figure 3: Vehicle begins Approach to Gantry with Signal Settings

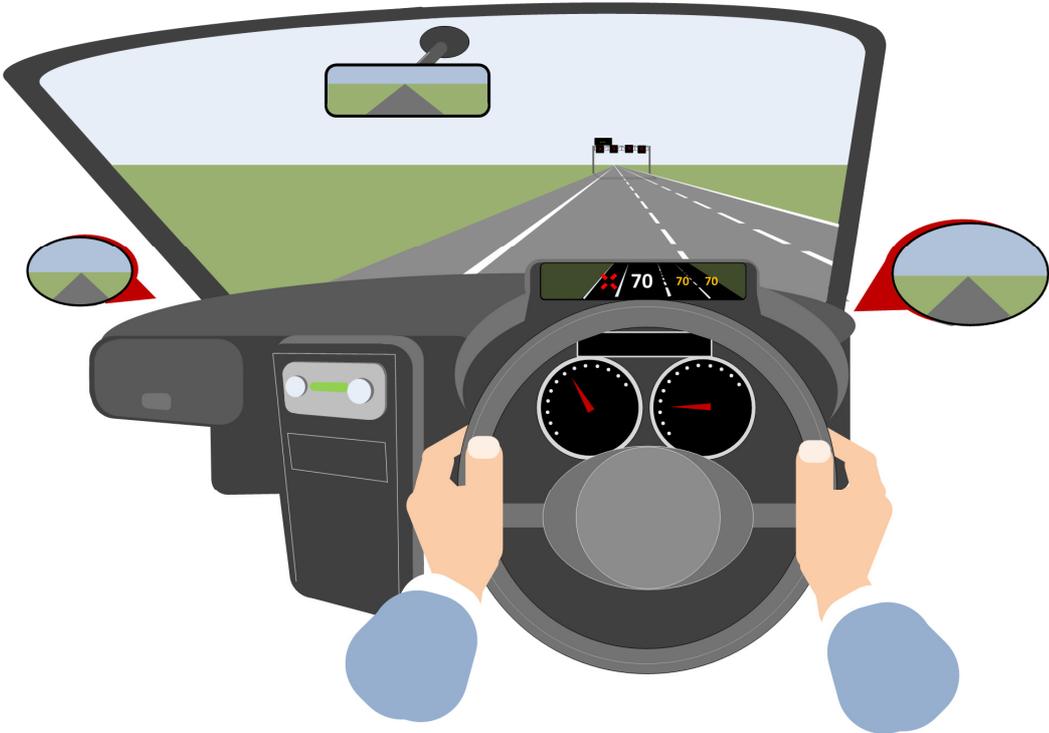


Figure 4: IVD Receives Setting Data and Displays First in Step-Down Sequence

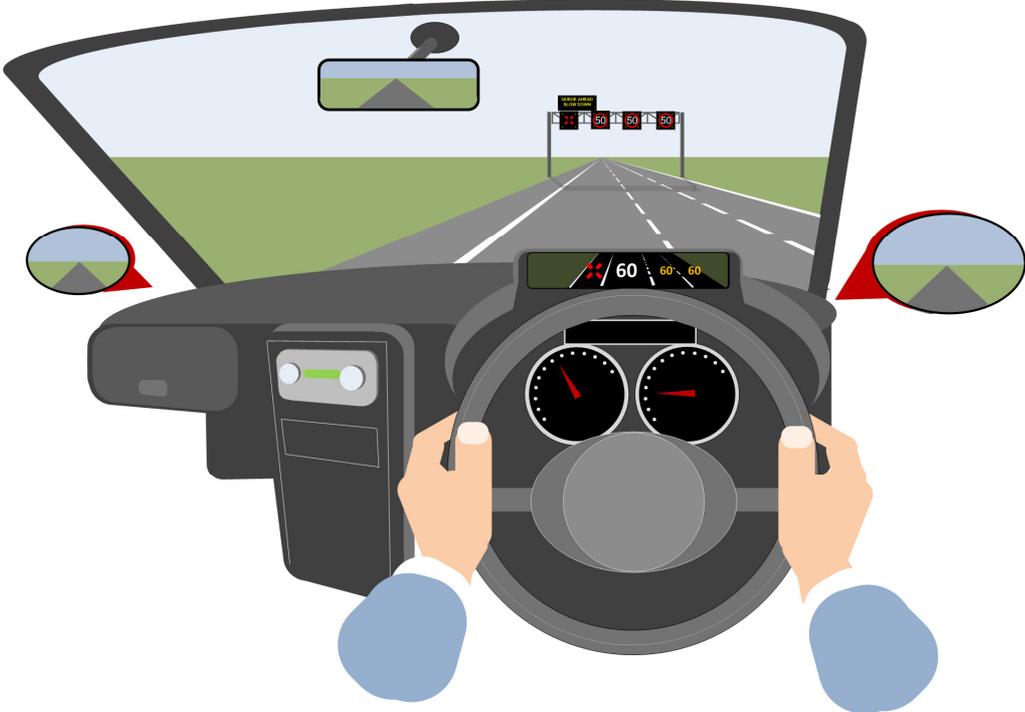


Figure 5: IVD displays next in Step-Down Sequence

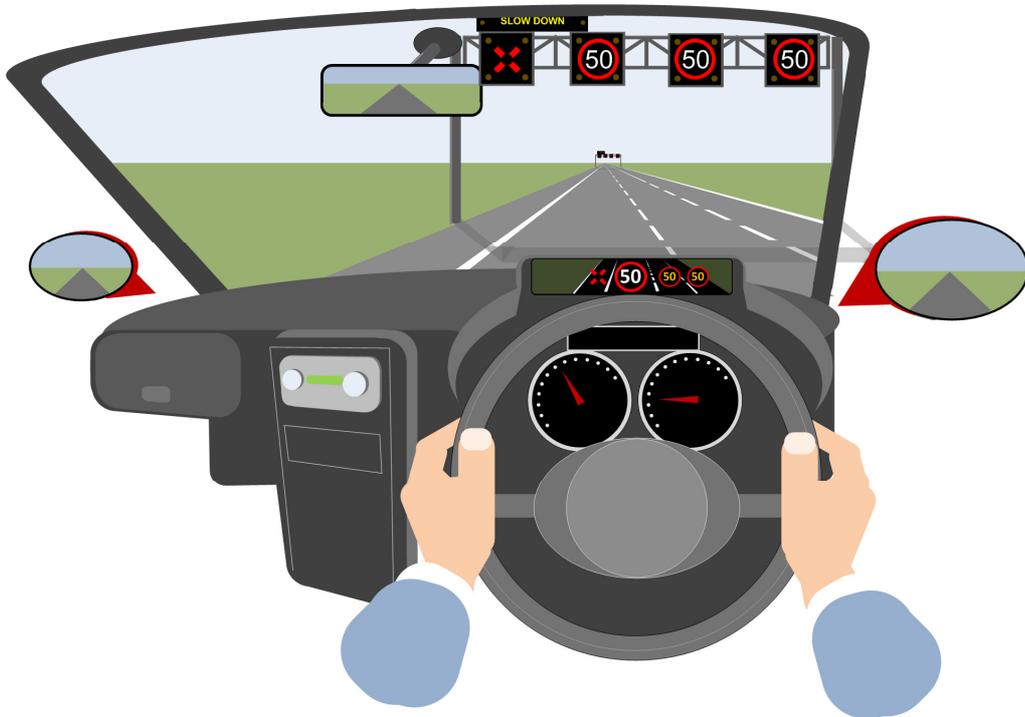


Figure 6: Final Approach – IVD Displays Target Settings

4.2.2.2 How long to display END/NR and RE?

Consider the easing of a restriction: the 'well behaved' driver will be aware the END/NR (SAC = 2 - appears as either 'End' or 'Ø') displayed on an RSD applies at that RSD location and not at the point upstream where he or she first saw it.

How will a driver interpret END/NR when it appears on the IVD? Displaying END/NR on the IVD at point upstream from the RSD site has potential to mislead the driver into believing that END/NR or RE applies at that point and not at the RSD site.

Consider, also, the fact that although the easing of the restriction applies from the RSD site and at all points downstream until superseded, on RSDs this information is intuitive and it does not require that the every signal site downstream repeats the display of END/NR or RE. I.e.: when END/NR or RE is displayed on an RSD the motorist is aware that the National Speed Limit applies from that location onwards and it is not necessary to repeat that setting on sites downstream from that site. For what duration should the END/NR or RE be displayed – how will the IVD know to clear the setting when it is no longer needed? Does this require that the data passed to the IVD specifies the duration, or perhaps the distance, for which the setting applied? Or, assuming that there is a downstream site within a reasonable distance should the 'beacon' associated with the downstream site 'transmit' 'OFF' to the RSD?

With respect to RE³, if a given signal site is the last site in a block of settings that has been cleared down to RE then the next signal site downstream will be 'OFF' (i.e. a blank signal). Therefore, if a block or other pattern of signal settings is 'CLEARed' ('RE' as opposed to 'OFFed') whilst a vehicle is travelling through that block or pattern of settings, then the driver cannot fail to see that the restriction has been eased. To avoid misleading the driver as to the point at which the RE applies it is reasonable to suppose that RE should not be displayed on the IVD until the vehicle has reached the relevant RSD location? There may be restrictions set at the signal site immediately upstream and to display RE on the IVD before the vehicle has reached the RSD displaying RE would mislead the driver into believing that RE applied at the point it is first seen and therefore that the RE supersedes the restriction that applies to the vehicles current location. As with END/NR, should the data transmitted to the IVD contain the data indicating the distance upstream from the RSD (or distance downstream from the FOP⁴ – 'First Observed Point') from which the aspect should be displayed?

Moreover, it is reasonable to suppose that RE should not be displayed on the IVD for any great distance or duration beyond the point that it is first displayed on the IVD – once the driver has been made aware of the RE then there is no reason to continue to display it. What is a reasonable duration or distance to display RE? How should this duration be conveyed to the IVD? Should the IVD be pre-configured to timeout RE? Or, should the IVD clear down the setting based on the distance travelled.

Human Factor Consideration:

The system must forewarn the motorist of a downstream restriction, or easing of a restriction, but how will the information be presented such that the location at which the restriction applies is communicated to the driver if sudden braking or premature acceleration is to be avoided.

Conclusion:

Data transmitted to the IVD should contain:

- a) Target aspect
- b) Step-Down Sequence to Target Aspect
- c) Distance to Signal Site
- d) Distance over which the setting applies

³ RE is 'timed out' by the system after a configurable period, with a default value of 3 minutes.

⁴ The First Observed Point is taken to be the point upstream of an RSD where on a clear day a driver with 20-20 vision is first able to read to message or signal setting.

4.2.3 Parity of RSD and IVD Displays

4.2.3.1 General Principle of Parity of Displays

The notion of parity between RSD and IVD displays is one wherein the same MM (Managed Motorway) information can be delivered to drivers by either means and with the same effect. This is in respect not only of messages, but also lane specific speed restrictions and diversions for traffic management, including dynamic use of the Hard Shoulder on Managed Motorways. This notion does not entail the RSD and IVD displays look the same: it allows that IVD 'displays' may be auditory whereas RSD displays are manifestly visual.

4.2.3.2 Lane by Lane Parity

4.2.3.2.1 Lane Specific Settings - the Need to display all Settings at a Signal Site

Whether a signal site comprises lane specific signal devices (e.g. lane specific Gantry Mounted AMIs), or a single device representing all lanes at the site (e.g. Post-Mounted signals and MS4s) the aspect(s) on display at a signal site represent the settings on all lanes at that site. Figure 7 to Figure 13 below show the various devices used for lane signalling.



Figure 7: An MS1 representing 40 at a 2-Lane Site



Figure 8: A Cantilever mounted MS3 representing a lane 1 closure at a 3-lane site



Figure 9: A cantilever mounted MS4 representing a lane 1 closure at a 2-lane site



Figure 10: A cantilever mounted MS4 representing a lane 1 closure at a 3-lane site



Figure 11: Gantry Mounted AMIs representing a mandatory 60 on all lanes at a 4-lane site



Figure 12: Gantry Mounted AMIs representing a lane 4 closure (STOP: SAC=4 – Notice Solid red X with red flashers) and mandatory 40s on all other lanes at a 4-lane site.



Figure 13: Gantry Mounted AMIs at an HSR (Hard Shoulder Running) site representing the Hard Shoulder closed for running (REDX: SAC=15 – notice exploded red X without red flashers) and mandatory 40s on all other lanes at a 4-lane site.

The Case from Lane Diverts: Since the RSD display represents all lanes, drivers can see which lanes are barred (barred aspects = STOP, REDX, MDVL, MDVR, LDL, LDR, HSD, tDL) and can therefore make informed decisions, e.g. not to move into a lane that is barred. To prevent drivers moving into a lane that is barred, it would be appropriate for the IVD represent a lane that is barred even though the vehicle is not travelling in that particular lane?

Since, also, if any lane on the carriageway is barred, the Signal Sequencing rules (see 4.4.2.2.1 below) will generate speed restrictions in lanes that are not barred the IVD would be required to represent those lanes too. Is it reasonable to suppose, therefore, that the IVD should represent all lanes at the vehicles location?

The Case from Centre Arrows: With RSDs drivers can see which lanes are open for running and are therefore able to make informed decisions about which lanes to use⁵. In order for drivers to make informed decisions about lane changes it would seem appropriate for the IVD to represent the lane that the Centre Arrow applies to irrespective of whether or not the vehicle is travelling in that particular lane at the time.

The point of these two case arguments is to emphasise that the information displayed by the array of lane specific RSDs mounted on a gantry pertains to the gantry site *as a whole* as much as to any RSD individually⁶. To emphasise this point, consider the fact that a signal site presents information that enables drivers to make an informed choice about their journey along that section of the motorway. These choices are not only in respect of speed but also the choice of lane. For example, whenever there is a signal setting update at an RSD on a Hard Shoulder Running (HSR) section of the motorway, assuming then that the IVD display will represent all lanes at the location then the driver should never be misled into believing that they can circumvent a restriction on any one of the normal running lanes by undertaking on the Hard Shoulder.

⁵ The diagonal arrow is an intuitive legend and drivers are accustomed to these, therefore it would seem natural for the IVD to be capable of displaying these also.

⁶ A signal site consists of one or more RSDs – see 'lane by Lane Signalling in section 4.2.3.2 below

In this respect, then, information pertains to a site rather than lanes individually. Therefore, it is reasonable to assert that the aim of achieving parity between In-vehicle displays and roadside displays is the aim of achieving parity between IVD displays and the array of settings at the signal site, rather than simply with any one RSD at that signal site.

Conclusion:

If a broadcast or zoned (see Section 4.3) transmission system is assumed wherein transmission of signal and sign setting data is not targeted at vehicles approaching a specific gantry, then all setting data for the area or zone must be transmitted and IVDs must have sufficient intelligence to process that data and update the IVD displays according to the vehicles current location. If a localised-targeted transmission system is assumed, where setting data is targeted at vehicles according to the signal site they are approaching, then the data transmitted should contain setting data for all lanes at that site and allow the IVD to 'display' that signal site data as appropriate to the outcome of Human Factor analysis subsequent to this project.

Split Gantry locations may have four or more lanes (configurable maximum = seven). Due to spatial alignment with lanes, drivers can easily see the setting associated with the lane they are travelling in (all things being equal with respect to parallax) without the need for them to be cognizant of the actual value of the lane *number* of the lane they are travelling along (though he/she may indeed be cognizant of that lane number).

Conclusion:

How would the vehicle know which lane it is in? Is it possible for the system to 'tell' the vehicle which lane it is travelling in so that it could 'highlight' the relevant lane of the IVD display representing all lanes, or, could the vehicle determine by means of GPS/Galileo or some other means, e.g. 'scanning' the road which lane it is in. It is a question that can be considered outside this present discussion since the particular lane that a vehicle may be in is an issue that is logically distinct from the data relating to the settings on display at the signal site.

Human Factor Consideration:

Will/can the drivers' abilities to mentally associate the lane by lane display on an IVD with the actual lane configuration on carriageway be relied upon? Can it be assumed they do this automatically and without training? Tidal/Contra Flow sites: up to seven lanes across both carriageways. Should the driver be presented with aspects on contra-flow carriageway, i.e. all REDXs or just that REDX on the first offside REDX lane? The number of lanes at certain signal sites on the Aston expressway is seven. In tidal flow areas the two opposite carriageways overlap and share lanes. Given this relatively large number of lanes, will the drivers always be capable of apprehending the lane number of the lane in which they are driving (i.e. without counting or thinking about it)? Is it required that the vehicle knows which lane it is on and emphasises the lane number by, for example, highlighting that lane's detail on the IVD lane display array (assuming it will be a lane array).

4.2.3.3 Which Settings to Transmit

Will the system be required to transmit signal setting data pertaining to all lanes at all sites at a split gantry location? It would not be sufficient to transmit only updates to one site at the location as this would result in a discrepancy between the IVD display and the RSD.

Conclusion:

The instation software will need to be modified to send setting updates for all settings at a site since currently it only 'transmits' setting updates to the outstation, i.e. if the output from the Signal Sequencing Algorithm (SSA) would not result in a change to the on-street setting on a particular device (e.g. if the operator clears a manual 50 but there is a MIDAS 50 stored in the MIDAS layer) then the subsystem will not 'transmit' the sequencing result for that device.

4.2.3.4 Dynamically varying the number of Lanes as Vehicles Travel along a Carriageway

The salient difference between IVDs and RSDs is that RSDs are static whereas IVDs move through the motorway network. The real significance of this when considering lane by lane parity between in-vehicle and roadside displays is that, with respect to the vehicles location the number of lanes may vary as it travels along the carriageway. The issue here is not so much to do with achieving parity between the IVD and the roadside display but with achieving parity between the number of lanes represented on the IVD and the actual lane configuration at the vehicles current location. Consider the following:

1. **Constrictions:** If there is a constriction in the number of lanes downstream from a gantry such that the vehicle reaches the constriction before it has received a setting update from the next downstream gantry, then if the IVD continues to display the settings from the three lane site upstream then the IVD may misrepresent the actual lane configuration at the vehicle's current location. An example of a constriction is at the exit from an Managed Motorway scheme where the final signal gantry will not have an Advanced Motorway Indicator (AMI) over the Hard Shoulder; this entails a constriction in the number of lanes when the Hard Shoulder has been open for running. Figure 14 below illustrates the effect of a constriction where the IVD is not been updated. It should be noted that there is no presumption that roadside transmitters are used; merely conventional iconography has been adopted.

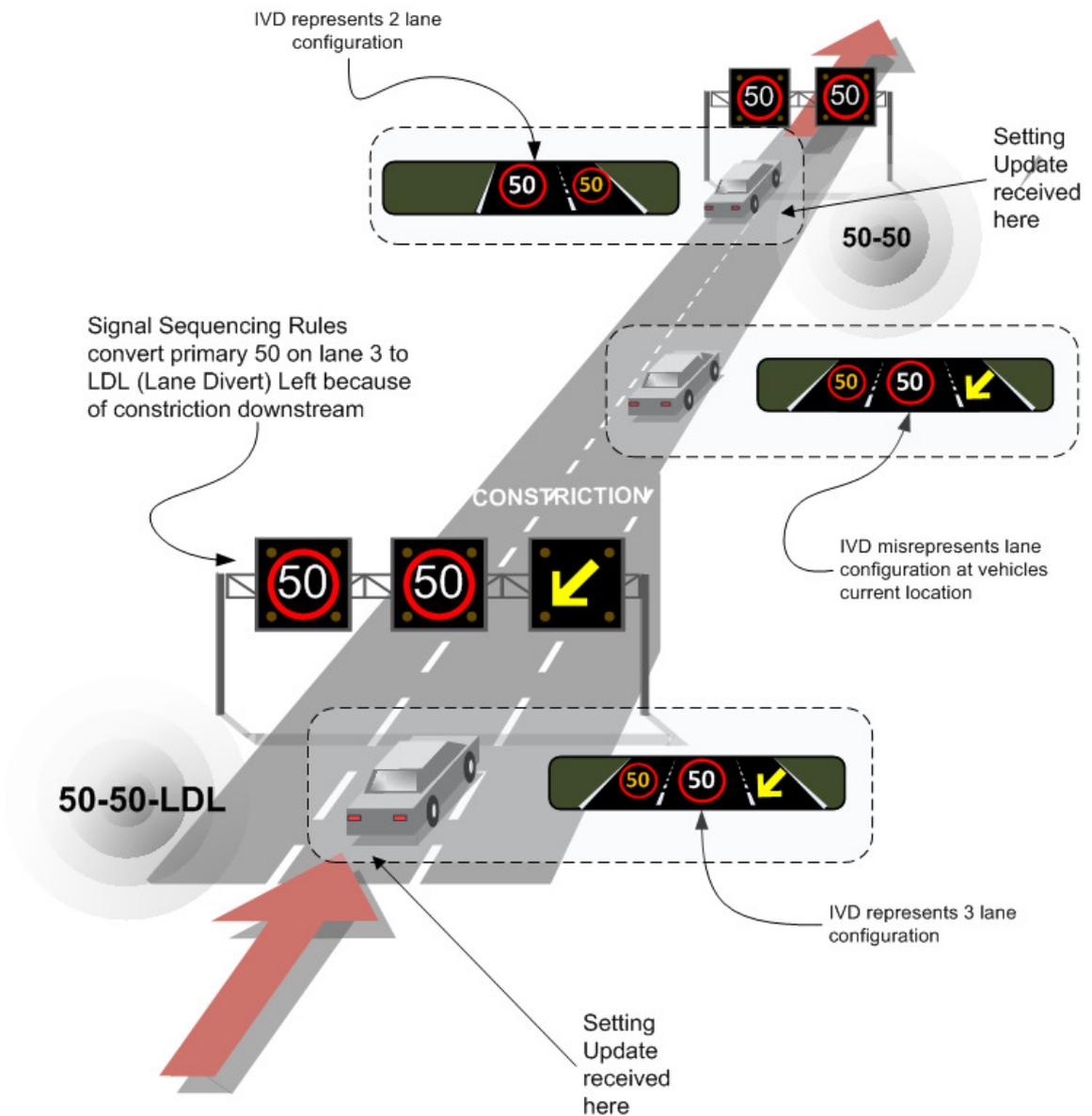


Figure 14: Possible Effect of a Constriction

2. Hatched lanes: With respect to RSDs, drivers can see hatched lane markings on the road and intuitively associate these with the blank signal above that lane. Drivers 'intuit' that an aspect see on display above the same lane at the upstream site no longer applies when that lane is now hatched. The Signal Sequencing Rules ensure that aspects other than STOP are converted to OFF (SAC=1; seen as blank signal by the motorist) at Hatched lanes. The driver is made aware of this by road markings (see Figure 15).



Figure 15: A Hatched Inner Lane

Do the hatched road markings need to be reflected by the IVD display? At the beginning of the hatching, at or at some distance upstream, any signal settings (other than STOP) pertaining to that lane currently set on the IVD must be set to OFF and either

- The dynamic IVD display indicates the running lanes only (e.g. 4 lanes becomes 3 when either the outside or inside lane becomes hatched on a 4 lane carriageway), or
- The dynamic IVD display is updated with some form of 'hatched aspect' to represent the hatched lane.

However, since the IVD display must indicate the hatched lane when a STOP is set at the hatched lane (since indicators above hatched lanes will display STOP), it may be more straightforward to employ a new 'hatched aspect'.

Figure 16 below illustrates the possible effect of a Hatched Lane.

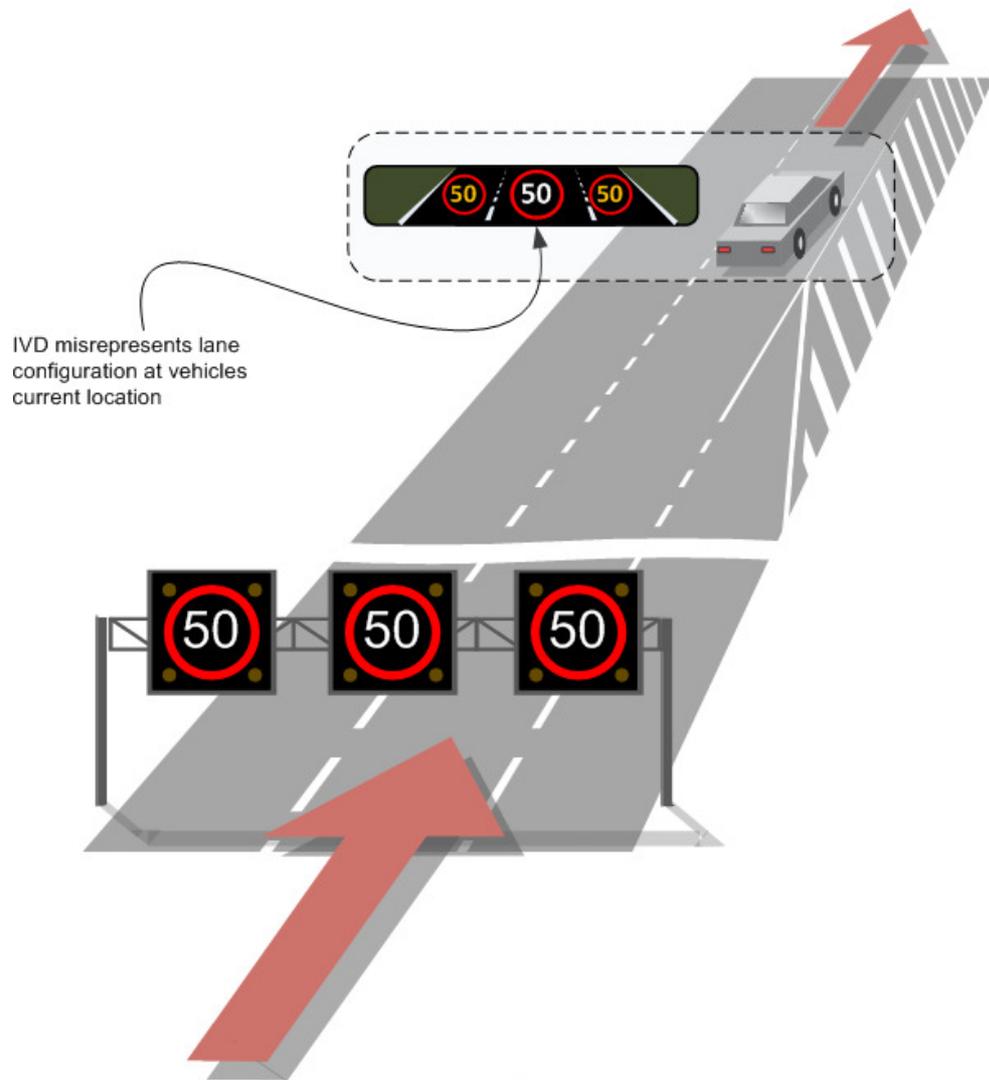


Figure 16: Possible Effect of Hatched Lanes

How will information pertaining to the geographic start point of the hatching be conveyed to the IVD? Does this entail that data transmitted to the IVD must contain the distance from the upstream gantry to the beginning of the hatched lane? Likewise, how will the IVD know at what geographic point the hatching ends? For the purposes of IVDs, should hatching itself be treated as an aspect?

Conclusion:

However hatched lanes are represented on the IVD, in relation to a moving vehicle the number of running lanes is dynamically variable as the vehicle travels past the point at which hatching begins. How should the system respond? DMRB Vol. 9 Section 4 A4.1 States that Motorway signals should not be positioned within 300m downstream of a change in the number of carriageway lanes between junctions. However, this may not always be achievable in practice due to site by site considerations such as visibility. It is possible that on a given section of carriageway running between the PFVC and the RSD spans a change in the number of lanes.

In the discussion on possible methods of conveying data to vehicles (see section 4.3) below, it is argued that the data structure of the transmitted setting update should contain either a timeout or distance value for each RSD specific (as opposed to one for each site) setting such that when the time expires or the vehicle travels the specified distance the IVD is able to clear the relevant setting down. The reasons for this are detailed in that section of this document, but the mechanism could be readily applied in this instance to clear RSD specific settings when the vehicle passes over a constriction of hatching.

Figure 17 below illustrates how a Hatched Lane Aspect may be represented on a visual IVD display.

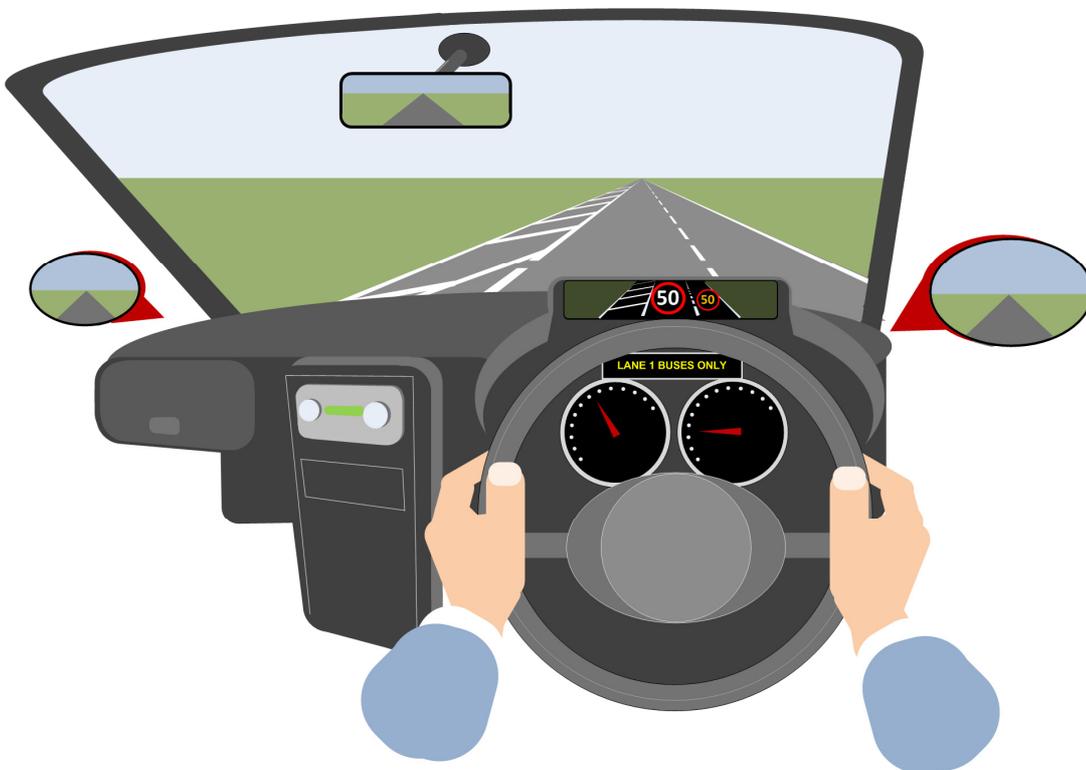


Figure 17: Possible Visual Display of a 'Hatched Aspect'

4.2.4 Messages

4.2.4.1 Introduction to Variable Message Signs (VMS)

A message sign is a motorway sign that allows the display of text messages. A message sign may have a variable element. For example, the operator may need to set the message:

M42 CLOSED / AT NEXT JCT

In this instance, the '42' is a variable part and needs to be entered by the operator.

Message signs are set in different layers. The operator sets message signs in the manual incident layer (MI), either individually, in blocks, or via plans. The operator also sets message signs in the Strategic Plan (SP) layer when setting diversions. Other subsystems such as MIDAS and TCCI make settings in their own layers. The Message Sign subsystem (see 4.4.2.3 below) maintains this layer information.

A Message Sign is, therefore, a device which is capable of displaying short textual messages for drivers, under remote control. They thus contribute towards improved driver information, and thereby improve utilisation of the road network. (MCH1655, p3)

Message Sign settings may also be generated automatically by the Message Sign subsystem in reaction to the setting of signals by an RCC operator. For example, when the operator sets a signal to 'ACCIDENT', the Message Sign subsystem may generate settings on the associated adjacent and lead-in message signs, in this instance, being '**ACCIDENT SLOW DOWN**'. The Message Sign subsystem holds configurable Rules Data specifying the message sign settings to be generated for various signalling scenarios.

The Message Sign subsystem implements 'automatic' Message Sign settings which are requested by the MIDAS (Motorway Incident Detection and Automatic Signalling) Subsystem, e.g. if the MIDAS equipment detects slow moving traffic, it may instruct the Message Sign subsystem to set message signs to '**QUEUE AHEAD SLOW DOWN**'. Message sign settings may also be requested by the Meteorological (MET) Subsystem, e.g. '**FOG PATCHES AHEAD**'.

4.2.4.2 Categories of Information Conveyed by VMSs

4.2.4.2.1 *General*

Message lists defined in the VMS subsystem configuration shall assign priority to messages on the basis of the message category. In order of priority, the Message Categories are as follows:

- Tactical Messages
- Strategic Messages

- Driver Information Messages
- Campaign Messages

The priority assigned to any given message will enable the VMS subsystem to arbitrate between the various sources requesting a VMS setting such that the message with the highest priority is set on-street.

4.24.2.2 *Tactical Messages*

Tactical messages provide supplementary information to complement signals and other traffic control signs for management of incidents or occurrences on local roads in the area. Signs set in support of tactical objectives display messages specifically related to achieving improvements on localised sections of the network. An example of a tactical sign setting might be:

OBSTRUCTION / SLOW DOWN

VMS subsystem site configuration data shall be designed such that relationships between certain VMS devices/sites and certain signal devices may be defined. The purpose of such definitions will be to enable the VMS subsystem to support on-street signal settings with tactical messages by means of *reactive* (automatic) message sign settings in response to operator initiated signal settings.

For example, when an operator sets a signal setting of '20' with implementation reason ACCIDENT, the Message Sign subsystem may respond by setting associated message signs to the following:

ACCIDENT
SLOW DOWN

4.24.2.3 *Strategic Messages*

Strategic messages provide the motorist with information and advice on the road network ahead. The aim is to improve the performance of the network by redistributing traffic efficiently when congestion occurs on some links and spare capacity is available on others. An example of a Strategic sign setting might be:

JUNCTION < m n o > CLOSED
USE JUNCTION < x y z >

4.2.4.24 *Driver Information Messages*

Driver information messages provide the motorist with information of a tactical and strategic nature, but also with messages relating to conditions on the network that may affect expected journey times, but which is not of a direct or instructional nature. This may include information on major events (e.g. shows, sports events etc.) and inter network connections such as tolled roads and crossings. An example of a Driver Information sign setting might be:

TO JUNCTION <xyz>
50 KILOMETRES
38 MINUTES

4.2.4.25 *Campaign Messages*

Campaign messages present campaign text to travellers, e.g.

TIREDNESS KILLS

4.2.4.3 The Relative Priorities of Tactical, Strategic, Driver Information and Campaign Messages

Along any given section of motorway, various combinations of message sign devices may be deployed and may be used to present information belonging to one or other of the aforementioned information categories. For example, along a MM-HSR (Managed Motorway Hard Shoulder Running) section, MS4s may be mounted above AMIs at LBS1 ('Lane below Signal 1') at signal gantries and are used to display tactical information. MS3s may be interspersed among these at other locations to display strategic information. Therefore, the driver may be presented with information obtaining to those two categories during his/her journey along that section. The important point here is that although at any given point in time the driver may be cognizant of the different sets of information, both sets of information will be relevant *at that time* but will not conflict with one another.

Effectively, for the motorist, due to inter-visibility MS4s on the MM-HSR scheme, the tactical message supporting the signal settings that control traffic flow in and out of the Hard Shoulder message is displayed to the driver for the duration of his/her passage along the Hard Shoulder and also to drivers in LBS2, 3 and 4. In this sense, then, the strategic information can be said to *persist* alongside current tactical information. This contrasts with signal settings where signal settings at consecutive sites *supersede* settings at the previous (upstream) signal site.

So, with respect to messages, drivers are able to make informed choices as to whether or not they should use the Hard Shoulder in their immediate vicinity and, at the same time, be aware that a junction some distance ahead is closed and therefore that they will need changed their intended route

Human factor considerations:

- **How long should messages persist on the IVD?**
 - **Should messages persist on the IVD display until explicitly cleared by the system?**
 - **Should tactical, strategic and other categories of information be considered separately in this respect? I.e. should tactical messages persist until cleared by the system directly whereas Strategic messages are timeout by the IVD?**
 - **To what extent should the system retain control over the length of time that a message is displayed?**
- **IVD displays are assumed to be intrusive to the drivers 'personal space' in a way that RSDs are not. Would persistent or prolonged display of Strategic and other non-tactical messages provide an unwelcome distraction to drivers? Could data be provided to the IVD that would enable the IVD to filter out strategic information that do not apply to his/her planned journey?**
- **To replicate the 'persistence' of tactical messages, should IVDs display messages until the system commands them to clear or would it be sufficient for the IVD to time messages out after a defined period (e.g. after 27 seconds – the approximate time it takes a vehicle travelling at 50 mph to travel the distance between two gantries 600m apart) such that the IVD would be updated with the downstream message before the previous message had timed out?**
- **Would the IVD be required to display concurrent messages of different categories together, or could this possibly overload the driver with too much information and therefore be a source of distraction?**

Conclusion 1:

It is beyond the scope of this project to give precise answers to these HFCs, but certainly, as with signal settings (see 4.2.3 above), it seems reasonable that in order for the system to maintain control of the information in respect of the length of time a message is displayed data conveying messages to vehicles should contain a timeout period or distance for the relevant message.

Conclusion 2:

The data conveying a message to a vehicle could communicate that message by means of either

- A unique identifier of message code for that message that is translated into text by means of, for example, a pre-configured lookup table within the IVD software, or,
- The encoded text itself to be displayed directly by the IVD

The former of these would be the more economical in terms of the amount of data that requires to be transmitted and would also allow that the lookup table be configured in a language appropriate to the driver of the vehicle.

The latter allows the system more direct control over the text to be displayed but, in this instance, the added control is more or less superficial. It does, however, allow that the IVD is always up to date since new messages are often added to the message lists but since they are ASCII based no corresponding change to the IVD software or configuration data would be required.

Conclusion 3:

It may be that the IVD could store various messages for the duration of the timeout period for each and either:

- Display only the message that is of highest priority until it times out, then display the stored messages with the next highest priority, or.
- Always display the stored message with the highest priority but allow incoming messages of lower priority to interrupt that message for an interval, long enough for the driver to heed the message, and then revert back to the higher priority message.

It may be that, in addition to a display for signal settings, IVDs require two or more message displays so that messages of different information categories can be displayed concurrently, perhaps one auditory and the other visual .

Human Factor analysis will determine how best to display various concurrent messages of different categories; for the present purpose it is sufficient that in order for the IVD to determine the appropriate message to display when, for instance, both a tactical message and a strategic message are on display along a section of the motorway, the data conveying the message should also contain a 'Message Category' code or 'priority'. The potential limitations of displaying multiple settings such as matrix and pictograms e.g. screen size will have to be considered.

4.2.4.4 Message Legends (Pictograms)

MS4s are capable of displaying both messages (text) and legends (pictograms).



Figure 18: Example of an Approved MS4 Legend (Pictogram) – ‘Strong Wind’

The MS4 Controller can set Pictograms under direct control from the RCC. It also has the facility to convert text messages and signal aspects into pictograms based on ‘key word’ symbols in the message text from a local ‘Pictogram Look Up table’. Table 1 below list some of the pictograms currently used by the HATMS.

Table 1: Local ‘Pictogram Look Up table’

Key Word Text	Legend	Key Word Text	Legend
Accident		Queue	
Accident-Use		Roadworks	
Congestion		Skid risk	
Fog		Snow	
Incident		Strong winds	
Oncoming		Workforce in	

Pictograms are stored locally at the MS4 Controller as bitmaps and are displayed by the MS4 as bitmaps. Where text is required to be displayed concurrently with a pictogram, the MS4 displays this as supporting text shown below the pictogram.

Conclusion:

Should the IVD be capable of displaying MS4 type legends (pictograms) as well as messages? Prior to Haman Factor analysis, it seems reasonable to suppose that it would be useful to provide legends such as these via an In-Vehicle device: the legends are intuitive, conform to European standards and are language independent.

The amount of data that would be required to transmit a pictogram as a bitmap would seem to suggest that the only feasible option would be to transmit either a message number or plain text to the IVD and allow the IVD to find the corresponding Legend in a pre-configured pictogram lookup table.

In order to allow remote operators to select a legend directly, i.e. with selecting a message it is considered that the structure of message data should allow both for a message code and text to be sent, or a combination of both.

4.2.4.5 Messages Displaced By Signals

Some RSDs may share space between a message sign setting and a signal setting. If a signal setting is made when there is an extant sign setting the message may be displaced by the signal setting. For example, a message setting is displaced by a signal setting on combined sign and signalling units that utilise shared display areas (e.g. MS3 motorway equipment) when there is insufficient room to display the message setting alongside the signal setting. The RSD in this instance gives priority to the signal setting when the two settings would overlap due to insufficient room on the display.

To avoid conflict, with RSDs, IVDs should not display messages that have been displaced by the RSD. Should the system only transmit to the device when the messages setting on the RSD is confirmed? What would the likely delay be between the setting of the message on the RSD and the setting of the message on the IVD? If an extant message is displaced by an incoming signal setting, would the system be required to update the IVD? How long would the process of finding an alternative take?

Conclusion:

Currently, this aspect of HATMS functionality is not controlled from the instation. The consideration here is that the issue of messages being displaced by signal settings is relevant to certain device types only. It is considered to be a Human factor issue as to whether the IVD should maintain a separate display area for signal and sign settings. For the purposes of this project it is sufficient that setting data transmitted to vehicles should contain a code to indicate that the message relates to a sign setting update or a signal setting update.

4.2.5 Message Sign and Signal Flashers

4.2.5.1 General - MS Lantern Overrides

Strategic roadside VMS (Variable Message Sign) devices are fitted with flashing amber lanterns. The lanterns flash in synchronous horizontal pairs alternating top and bottom to draw the attention of drivers to the message displayed on the VMS⁷. Unlike the Signal Subsystem, the Message Sign Subsystem, and not the outstation transponder, determines when VMS flashers lanterns are switched on or off. This enables the Message Sign Subsystem to ensure that the lanterns on a VMS device are always switched off whenever signal devices associated with the VMS device have their lanterns on. This is essential in order to ensure that the motorist is not overwhelmed and confused by flashers and that the motorist's primary focus is drawn to the signal settings which have a *tactical* significance. So, in this instance, the Message Sign subsystem sends a 'lantern override command' to the outstation to switch the message flashers off.

Human Factor Consideration:

- Do we assume separate display areas for message settings and signal settings?
- Should the IVD replicate Message Sign flashers or would they be too distracting to the driver?
- If flasher functions are required in-vehicle, should HATMS retain control of flasher synchronisation or can this functionality be specified for the IVD?
 - If flashers are controlled by the IVD then there is the possibility that flashers in the vehicle and flashers on RSDs may not be synchronised.

Conclusion:

In order to facilitate a solution that conforms with the requirements derived from a future Human Factors analysis, it is considered that every setting update, whether signal or sign, should be time-stamped by the controlling subsystem such that, flasher interval and duration could be specified for both IVD and RSD in order to ensure that synchronisation between the vehicle and the roadside device is possible.

⁷ Lantern design requirements must comply with the TSRGD ('Traffic Signs Regulations and General Directions, 2002'). Fixed Text messages are commonly used for diversion routing and local traffic management where there are a low number of route options.

4.2.5.2 Signal Flashers

Motorway signals are designed to meet the special requirements of motorways, good long range visibility for high speed vehicles, good penetration through fog and spray and a high level of illumination to overcome bright low level sunlight. All motorway signals are equipped with four amber lanterns that are designed to be visible at 500m and flash in alternating pairs from top to bottom. Motorway signals capable of displaying 'STOP' (SAC=4, seen as a solid red X) are generally equipped with four red lanterns that, when activated, flash in alternating pairs from left to right. Flashing functionality (both amber and red) is controlled by outstation software.

Human Factor Consideration:

- As with message sign flashers (see section 4.2.5), should the flasher function be replicated on the IVD display?
- Would non-synchronization of IVD and RSD flashers cause the driver to be distracted?

Conclusion:

As with message flashers, in order to facilitate a solution In-vehicle that conforms with the requirements derived from a future Human Factors analysis, it is considered that every setting update, whether signal or sign, should be time-stamped by the controlling subsystem such that, specified flasher interval and duration could be specified for both IVD and RSD to ensure that synchronisation between the vehicle and the roadside device is possible.

4.2.6 IVD Failures

How will IVD display failures be dealt with to ensure that two IVDs at the same location do not convey conflicting information to their respective drivers in relation to each other and to the associated RSD? Is it feasible for the status of all IVDs to be reported back to the instation? How will IVD display failures be dealt with to ensure that two IVDs at the same location do not convey conflicting information to their respective drivers in relation to each other and to the associated RSD? Is it feasible for the status of all IVDs to report back to the instation to IVDs? If not, then how would the IVD determine the validity of its own display?

4.3 Data Dependencies relating to the Method of Data Transfer

4.3.1 Introduction to Data Transfer Issues

This section reviews the implications of Managed Motorway objectives for the future data transmission system. The scope of this analysis specifically excludes detailed analysis of technology relating to In-Vehicle devices and the transmission systems that might be deployed. However, the analysis has identified some interesting constraints on the form that a future In-Vehicle system must take.

The most significant consideration here is that a range of possible data transfer methods, from network wide broadcasts down to very localised signal/sign site by signal/sign site short-range transmissions, or a combination of anything in between, are options upon which the specification of the structure of the data that will be transmitted from infrastructure to the vehicle may depend. The relative merits and demerits of these methods are analysed in turn but no assumption is made as to the transmission media required for any one of these options. Localised targeted transmissions, for example, could transmit via electromagnetic media (including highly directional and line of sight dependant Infrared), or, the vehicle could receive data via an entirely different technology, such as In-vehicle image analysis and recognition of extant roadside device displays.

4.3.2 General Constraints for the Data Transfer Method

4.3.2.1 Data Refresh Rates

Irrespective of the type of transmission system that will be deployed, in order to achieve some degree of parity with settings on roadside devices, and to provide sufficient forewarning of a restriction downstream, vehicles must receive setting updates within a safe margin upstream. As a first approximation, starting at the point upstream of an RSD (the FOP – First Observed Point) where a motorist with 20-20 vision is first able to read settings on the RSD under ideal conditions, a margin of safety of 10% of the distance between that point and the RSD might be appropriate. Figure 19 below is an illustration of a visual IVD display that has been updated within the margin of safety. Figure 20 below is an illustration of a visual IVD display that has not been updated within the margin of safety.

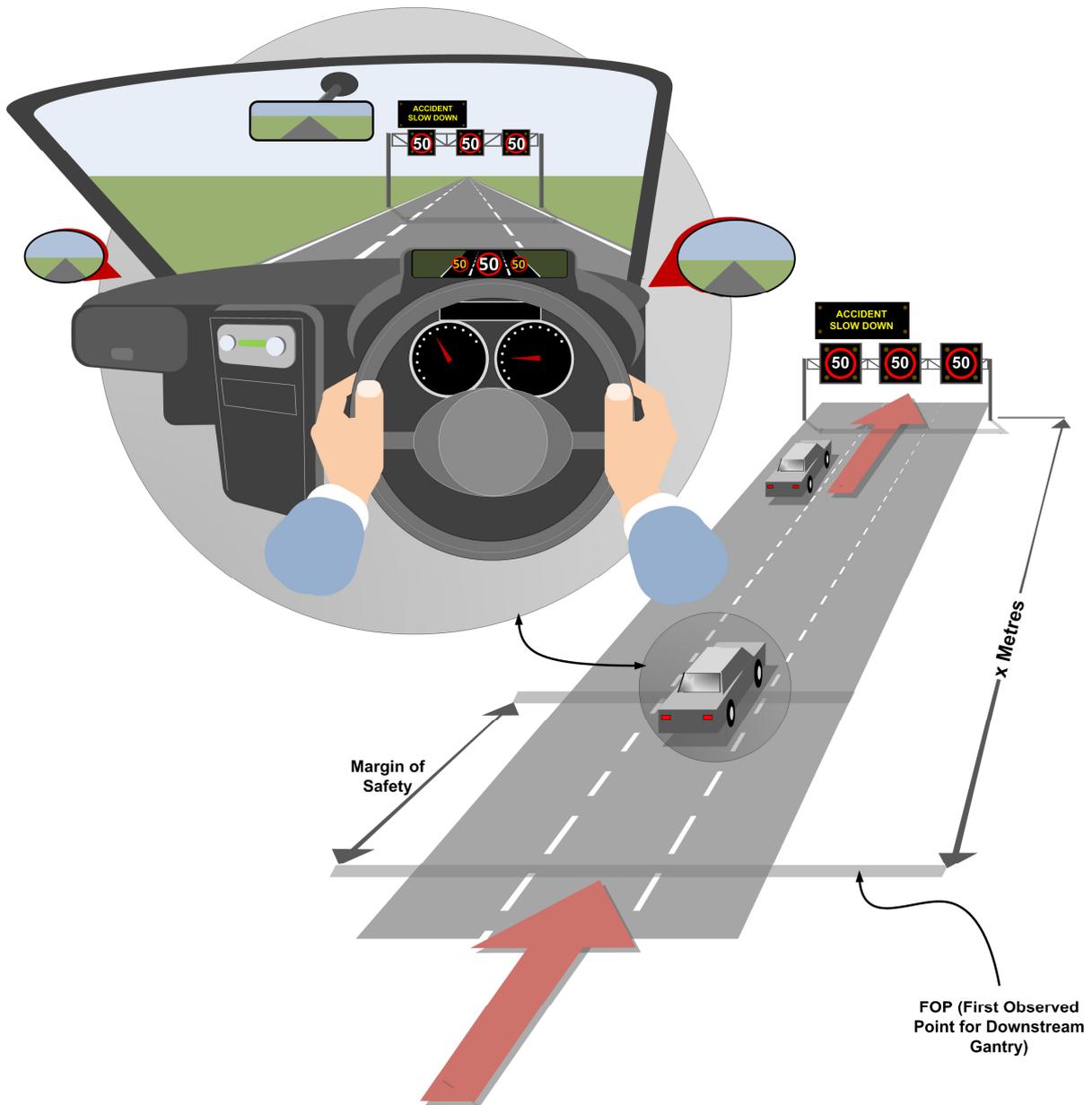


Figure 19: IVD Display updated within Margin of Safety

The IVD represented in Figure 19 is purely an impression of how a visual unit might be arranged in the vehicle, but the essential point of the representation is that in order to avoid conflict between the RSD and IVD displays and maintain confidence in the system generally, parity between the displays should be achieved within certain margins. Compare then the settings on the IVD display in this drawing with that in Figure 19 below where the IVD has not been updated within these margins.

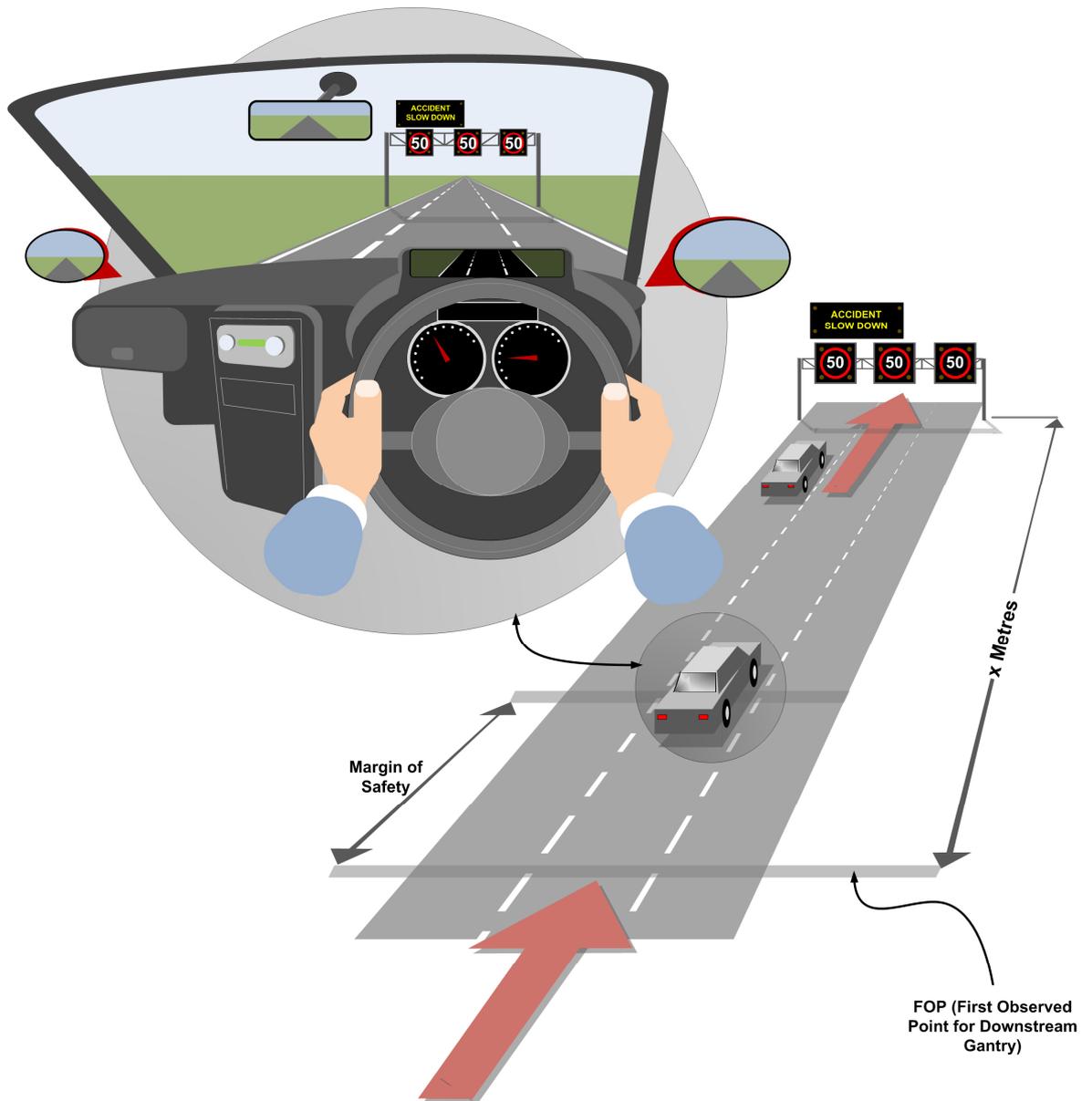


Figure 20: IVD Display not updated within Margin of Safety

Conclusion:

Assuming a vehicle speed of 70mph (31m/s) and a PFVC distance of 300m, the vehicle will traverse the 30m margin of safety this zone in 0.97 seconds. Assuming that whatever transmission technology is deployed transmissions are subject to interference caused by topography, infrastructure and even other vehicles, then signal and sign setting updates must be re-transmitted within the 0.97 seconds in order to ensure that all vehicles receive the setting update within that margin of safety.

4.3.3 Automatic IVD Display Updates

4.3.3.1 Handling END/NR and RE

In some instances, the system may be required to automatically update settings on IVDs when there is no actual change to the setting on the RSD. This does not mean necessarily entail that the system is required to automatically transmit setting updates; it could mean that the data transmitted to the vehicle contains an item that enables the IVD to automatically modify (e.g. clear) a setting after a specified interval or after the vehicle has travelled a specified distance.

To understand the need for the system to automatically update IVD displays, consider that by virtue of the static nature of RSD signal sites HATMS is not always required to *automatically* switch settings off⁸. This is by virtue of the fact that when a vehicle passes under a gantry, the aspect on display at that gantry is no longer seen by the driver. In the case of END/NR, when a vehicle passes under a gantry displaying END/NR the drivers are cognisant that the upstream restriction has been eased and the restriction does not apply to the section of motorway that they will be travelling along. So, the signal site downstream from the END/NR will be blank and may have been blank for some time – minutes, days or even months.

In the case of END/NR how will the system clear the display from the IVD? There are three options considered here:

- Option 1: The system could transmit 'OFF' to the IVD for all lanes from a transmitter at the downstream site, irrespective of the fact that the downstream site has not been subject to a recent setting request;
- Option 2: For signal setting the data conveyed could contain a timeout period or distance for the setting which the IVD would use to time out and clear the setting; or
- Option 3: The IVD could be pre-configured to time certain aspects out after a defined period.

The preferred option would be that which allows the system to maintain control over the display of information. This accords with the general principles described in Section 3.1 above.

⁸ RE (seen as either 'End' or 'Ø' on-street) as opposed to ENR/NR (also seen as 'End' or 'Ø' on-street) is timed out by the system and automatically cleared after three minutes.

Consider temporary HDS (Highest Displayable Speed) values which can be assigned to a site or block of sites. The HDS setting is a value used by SSA (the Signal Sequencing Algorithm) to convert any speed restriction requested by the operator or automatic subsystem at a particular signal site to the HDS value if the requested setting is less restrictive than the HDS value for the relevant site⁹. If, for example, the HDS at a given site is 40mph and the operator requests a setting of 50 then SSA will convert the requested 50 to 40¹⁰.

If a block of signal settings is contained within the span of an extant HDS block, then END/NR will not appear at the most downstream signal site in that block of settings. Conversely, if the block of signal settings extends further downstream than the block of HDS setting, then SSA will generate END/NR (displayed as Ø) on the RSDs at the most downstream site in the signal setting block.

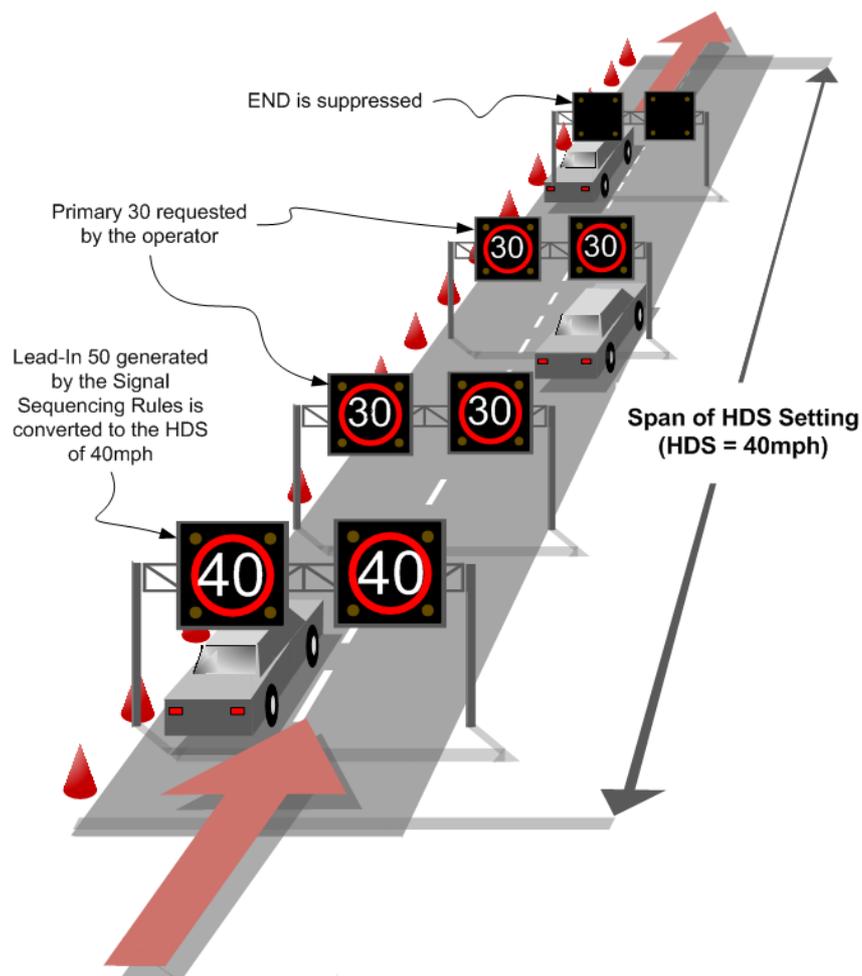


Figure 21: Effect of an HDS (1) - END Suppression

⁹ The HDS may be a temporary value imposed by an RCC operator

¹⁰ SSA applies HDS checks to primary settings and secondary settings, generated by the rules, alike.

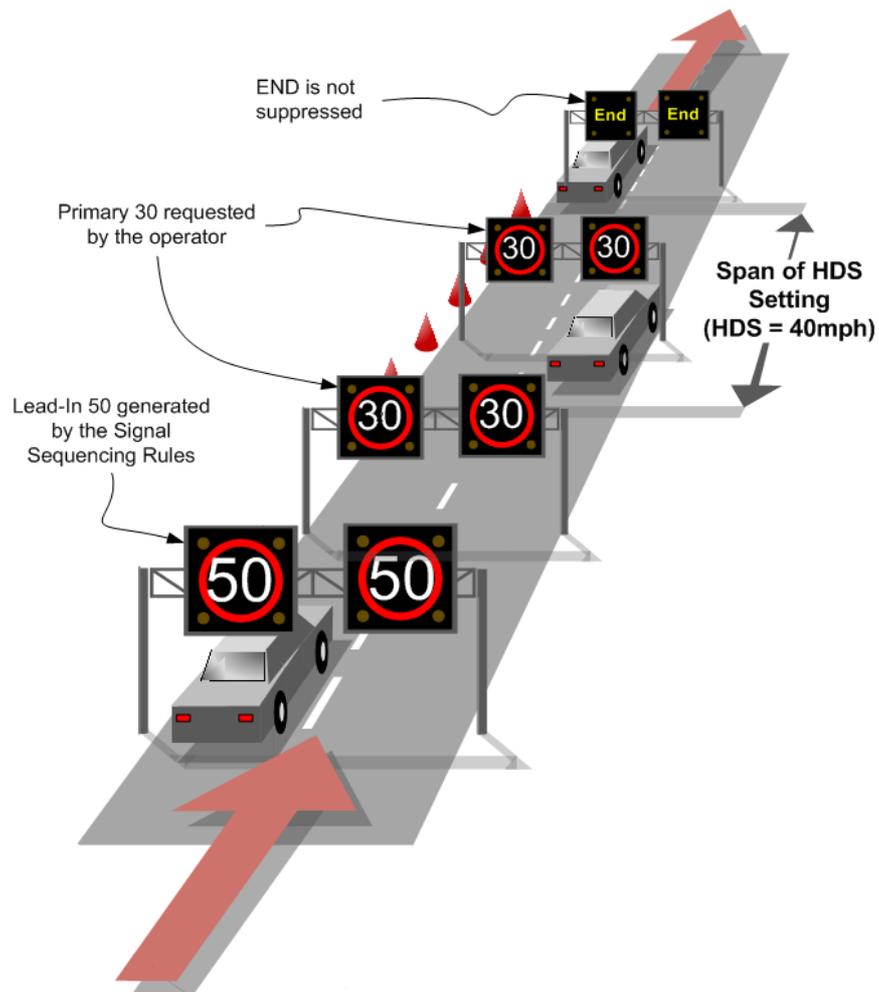


Figure 22: Effect of an HDS (2)

Now, where the National Speed limit for motorways begins at the end of a span of roadworks, the motorist is usually informed by means of a fixed signed, albeit temporary, \emptyset . If the span of road works is ascertained correctly by the operator, then settings on RSDs will not conflict with the temporary fixed signage. It is crucial, therefore, that operators correctly ascertain the span of road works when setting HDS blocks in order to avoid inadequate coverage that could result in END/NR or RE being set where road works are in operation.

In the case of END/NR not being set on an RSD downstream from a restriction, due to an HDS being set, then the speed restriction on the IVD set from the previous site needs to be cleared down automatically. This would tend to rule out the IVD being pre-configured to clear settings down on an aspect by aspect basis since the same speed restriction requires to be cleared down automatically in one instance but not in another.

When automatically clearing an IVD setting to OFF, should the IVD apply the new setting at a point directly under the blank RSD? If the blank gantry is downstream from END/NR then it is reasonable to suppose that the IVD should clear to OFF quite soon after the RSD displaying END/NR is passed. In the case of RE it is not so clear cut since there may be a block of REs, so the system will need to inform the IVD that this is the last RE in the block.

Conclusion:

In the case of a restriction no longer applying as the vehicle moves downstream (i.e. blank signal devices downstream from a block of settings) the RSD remains set to OFF, so no update is required from the Signal subsystem. However, in order to mirror an extant OFF on the RSD downstream from the most downstream setting in a block of settings from which the motorist is just leaving, the 'system' will be required to either actively transmit OFF to the vehicle or allow the IVD to clear the setting down based on distance data transmitted to it with the last signal setting update. This is in contrast to the current system wherein it is not necessary to actively inform the driver that a restriction no longer applies since the downstream RSDs were previously set to OFF and the driver can see these from the relevant PFVC.

4.3.3.1.1 *Handling Un-Signalled Exits*

Un-signalled Exits are exits from the motorway network that are not covered by HATMS roadside devices. When a vehicle exits the motorway through one of these portals, but with an extant setting on display, the IVD display will need to be cleared down since that restriction will not apply to the carriageway along which the vehicle is about to travel and will conflict with hard signage along that route.

Un-signalled exits will have fixed signs indicating the speed limit on the exit from the main motorway carriageway. Drivers can see these and understand that the previous variable speed limit seen on the main carriageway is superseded. So, the RSD has been passed and can no longer be seen and therefore does not conflict with the fixed sign on the exit. When the vehicle enters the un-signalled exit, how will the IVD be cleared to ensure that the display does not conflict with fixed signs at or near the start of the un-signalled exit?

Upstream of the gantry where the restriction was on display, the system can not know which route the driver intends to take downstream. Assuming a localised-targeted transmission system (see 4.3.7 below), it would seem reasonable to propose that un-signalled exits have dedicated 'transmitters' (Entry points such as exits from Emergency Refuge Areas {ERAs} are presumed to be signalled by virtue of inter-visibility of gantries along the motorway).

Figure 23 below illustrates the possible effect of an un-signalled exit.

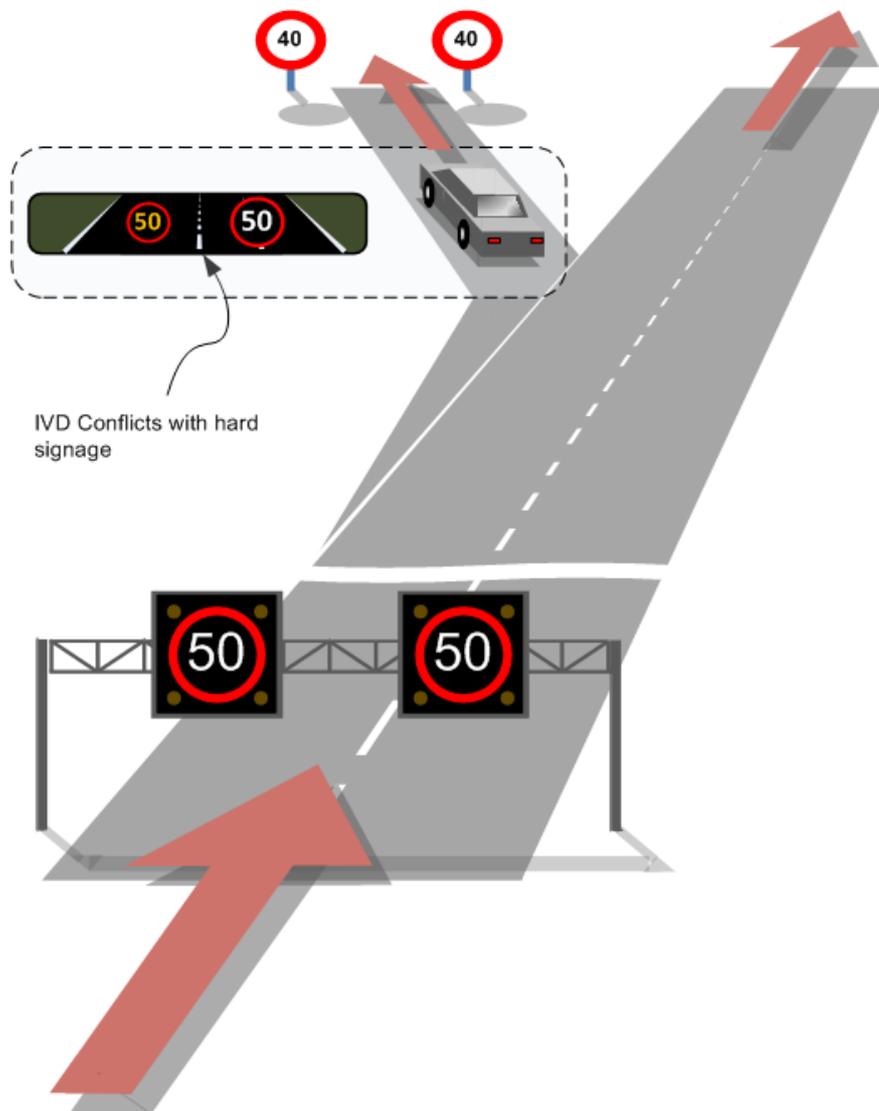


Figure 23: Possible Effect of an Un-Signalled Exit

4.3.3.1.2 *Handling Divergences and Motorway Diverts*

At any given point on a motorway carriageway there may be one to a maximum of three divergent carriageways downstream¹¹. For RSDs, if the restriction that applies to the current signal site does not apply to one or more of the divergent carriageways downstream, then the Signal Sequencing Rules will generate an END/NR aspect for the first signal site on the divergent carriageway. It is not possible for the display to contradict or misrepresent the road configuration at the point that the vehicle enters one or other of the open divergent carriageways/exits, since the motorist can no longer see the RSD display upstream of the divergence RSD. However, if the same IVD settings persist on the IVD display to a point beyond the divergence downstream from the RSD, then it could misrepresent the road configuration at that downstream point.

With respect to Motorway Diverts, when a motorist passes under a gantry displaying a Motorway Divert, before entering any of the open carriageways or un-signalled exits downstream, it is not possible for the RSD display at the site displaying Motorway Diverts to contradict, or misrepresent the road configuration at any point downstream of the divergence since the motorist can no longer see the Motorway Diverts. However, if the same Motorway Diverts persists on the IVD display to a point beyond the divergence downstream then it would misrepresent the situation at that downstream location.

How will the IVD 'know' to clear or update the setting it displays when the vehicle enters a divergent carriageway? How will IVDs handle un-signalled exits? Figure 24 below illustrates the possible effect of a motorway divert.

¹¹ Therefore up to three signal sites immediately downstream - one on each divergent carriageway

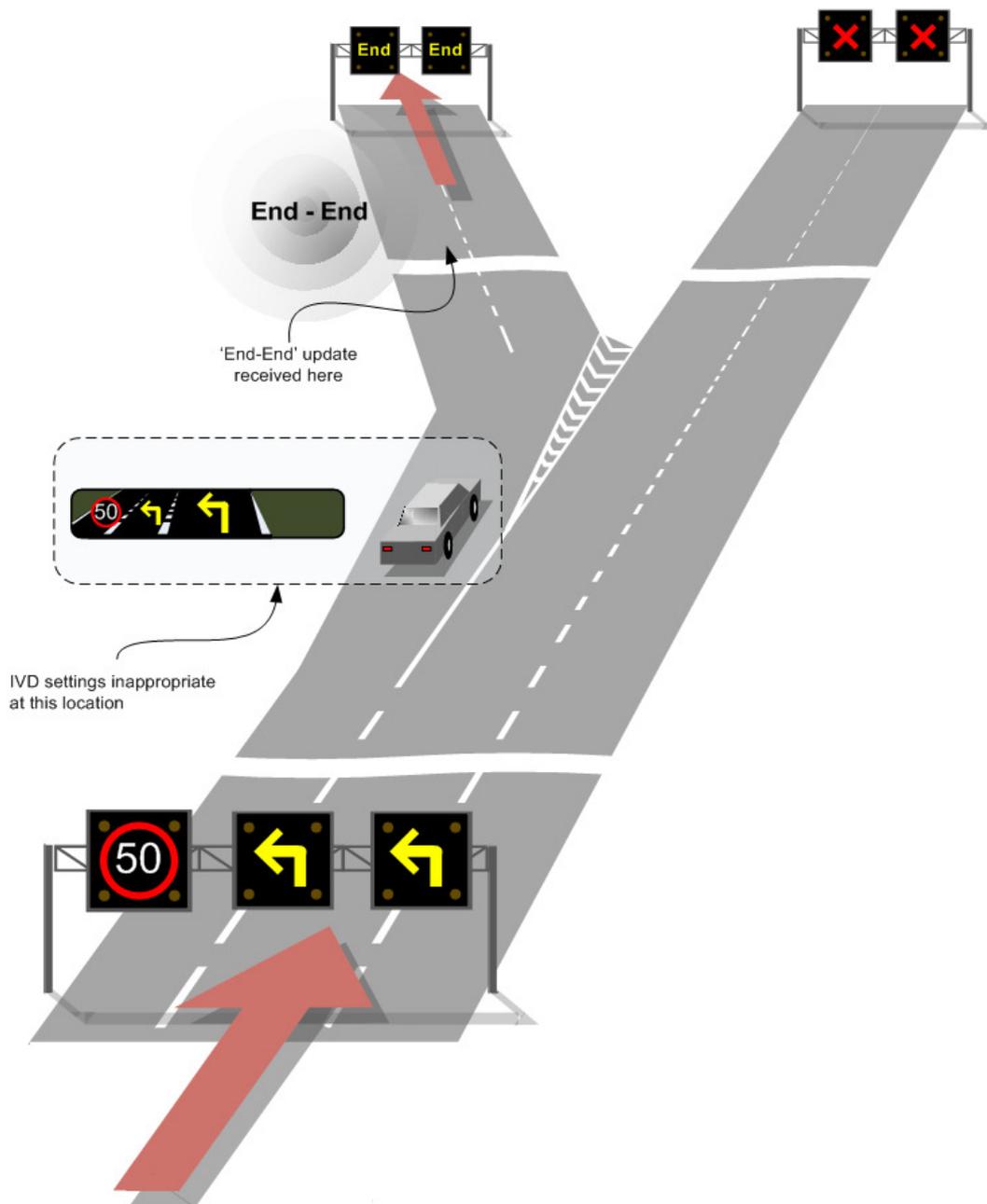


Figure 24: Possible Effect of a Motorway Divert

Conclusion:

For the following reasons, then, it is considered that the setting data conveyed to the IVD should contain a timeout or 'Applicable Distance' value for each signal setting:

1. It would preclude the need to transmit 'OFF' for every signal site that has a blank aspect;
2. It would avoid ENR/NR and RE being displayed on the IVD for longer than is necessary;
3. It would allow speed and other restrictions to persist on the IVD display only as long as necessary when a temporary HDS regime is in place such that the most downstream setting in a block of signal settings is blank rather than OFF;
4. It would allow the system to dynamically (i.e. on a site by site basis) switch settings off when, for example, the setting is a Motorway Divert (MDVR or MDVL) but the vehicle has passed the gantry displaying the Motorway Divert and has entered the divergence such that it would not be appropriate to display that aspect;
5. It would allow a particular *lane* setting to be switched off when, for example the lane configuration changes such that the initial IVD display is no longer appropriate to a vehicle's current location. For example, if there is a constriction of three lanes (lane 3 ends) to two lanes downstream from a gantry displaying a speed restriction, the Signal Sequencing Rules will convert the speed aspect on lane 3 at that gantry to a lane divert (LDL in this instance). So, if the speed restriction is 50mph, the on-street aspects at the signal site will be '50-50-LDL'. When the vehicle reaches the constriction downstream it would not be appropriate for the IVD to continue displaying '50-50-LDL' (the IVD may not yet have received a setting update from the downstream site). Misrepresenting the lane configuration at the vehicles current location has safety implications, therefore it is important the setting on lane 3 is cleared down so that IVD displays¹ '50-50'. When and where the lane setting should be cleared down is a function of the signal geometry (geometry data describing lane inter-site relationships and lane configuration), so the system would be required to dynamically assign timeouts/distance applicability values to aspects on a site by site basis.
6. It would allow the system to dynamically switch settings off when, for example, the most downstream setting would be END/NR but for the fact that the device is faulty or non-commissioned.

Both the example of un-signalled exits and motorway diversions illustrate an interesting dilemma: how can the system automatically update the VD with an appropriate setting when it cannot be determined which course a vehicle will take as it approaches a divergence and there is no indivisibility between the point of divergence and the next downstream site on the divergent carriageway? There are two possible answers to this:

1. Assuming a localised and targeted method of transmitting data to vehicles, the entrance to each divergent carriageway could be 'covered' by a dedicated 'data provider' such that on entry to the divergent carriageway the IVD receives a setting update for that section of the carriageway, or
2. Assuming the IVD deploys some form of global positioning technology, the system could send with each setting update an array of downstream settings corresponding to each of the divergences and the GS coordinates for the entry point for each. The IVD would then be required to update the settings accordingly as it enters one or other of the divergent paths.

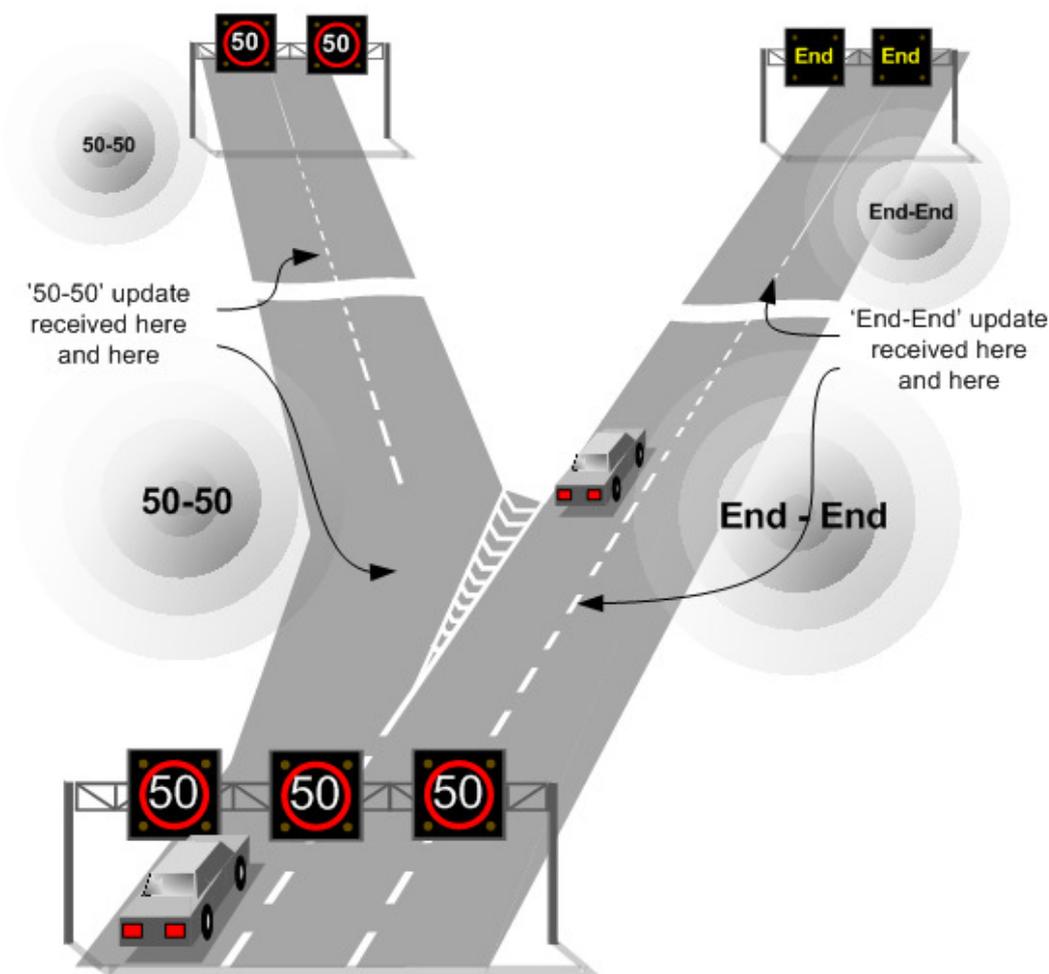


Figure 25: Divergences covered by 'transmitters'

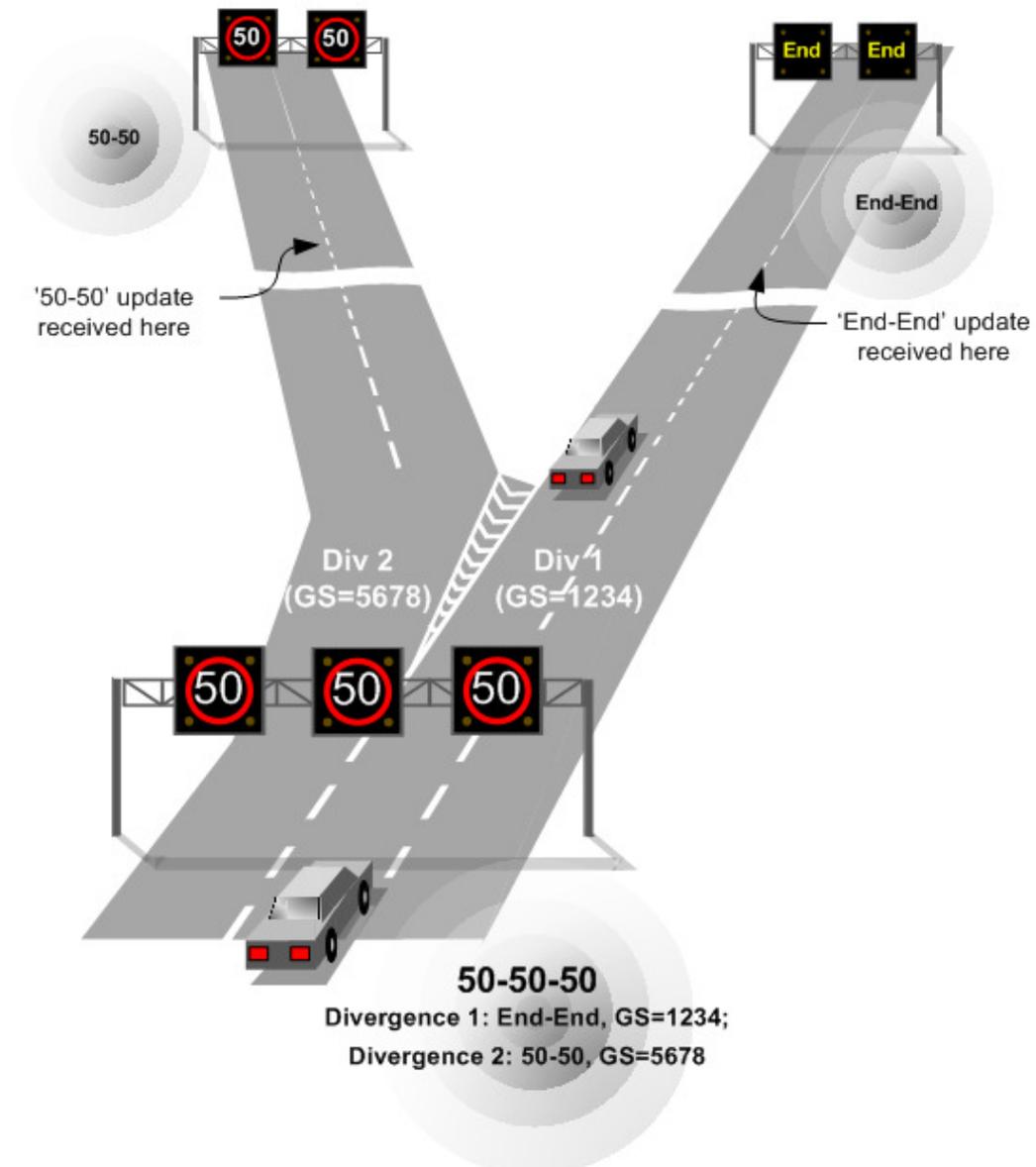


Figure 26: Divergences handled by 'transmitting' GS coordinates of divergence entry points

Conclusion:

There are advantages in both deploying dedicated 'beacons' covering carriageway divergences and providing GS coordinates for downstream divergences with setting updates. It is considered that the provision of GS coordinates for divergences presents little overhead in terms in-station processing that these allow would allow for a flexible approach to managing divergent carriageways.

4.3.3.1.3 *Aspect Countdowns*

In addition to the spatial sequencing of the Signal Sequencing Rules (see 4.4.2.2.1 below), time sequences are used to step down to low speed restrictions. This is to avoid the sudden imposition of speed restrictions on traffic. Hence, if the operator requests a 20 mph restriction the system will normally set the RSD to '40', stepping down to '30' and then to '20' at defined intervals.

The default interval between successive count stages is currently 10 seconds¹². So, if the first stage in the countdown sequence is set on-street at the same time that the vehicle reaches the point where the driver is first able to see settings on that gantry, say 300m upstream, then between reaching that point and passing under the signal gantry the driver may witness several successive stages in the countdown sequence. In this instance, how would the system achieve parity between IVD and roadside displays at every point along the vehicles approach to the signal site?

For a broadcast or zone based method of data transfer (see section 4.3.5 and 4.3.6 below) the method of transmitting successive countdown stages is the same for any other signal setting update and, therefore, the pros and cons are the same. For a localised-targeted method of data transfer, where there may be a one-to-one correspondence between a signal site and a transmitter dedicated to setting updates for that site. So, either:

- a) There is a presumption that there is sufficient 'transmission coverage' to ensure that vehicles travelling towards a signal site can and will receive signal setting updates at any point between the FOP and the signal site; or
- b) Countdown data should be transmitted to the IVD. The data would include:
 - i. The aspect to be displayed at each stage and the intervals between each stage, such that the IVD will 'auto-execute' the countdown sequence;
 - ii. A time-stamp for the start of the countdown sequence in order that the vehicle approaching the signal site executes the sequence in time with the countdown sequence on the RSD; and
 - iii. A time signal to synchronise the IVD clock with the system clock.

¹² This is configurable via the signal transponder: currently, the standard signal transponder controls signal aspect countdown functionality, though there is an extant Change Note (CN2448) that will, in its final draft, detail changes to HATMS control system architecture for the migration of Countdown functionality to the Signal subsystem.

4.3.4 The Dependency of Data Structure on the Transmission Technology

In accordance with the guiding principles in Section 3.1 above, the method of data transfer between the system and the IVD should enable the same quality of information to be provided to motorists in respect of safety, traffic management, informed driver decisions, real-time behaviour of the system, control of information and parity with roadside devices. Depending on the method of data transfer, the structure and content of data transmitted from the HATMS infrastructure to vehicles may vary considerably.

Broadly speaking, there are three options for a method of data transfer (combinations of these are not ruled out):

- Broadcast Data - Data transmitted to all vehicles on the network or about to enter it;
- Zoned Data Transfer – Data pertains to a block of signal or sign sites and is transmitted to and received by vehicles approaching and travelling through that site;
- Highly localised and targeted Data Transfer - a system that transmits data pertaining to a specific location to vehicles at or approaching that location.

4.3.5 Broadcast Data

A Broadcast Transmission System is envisaged as one wherein signal and message sign setting updates are broadcast to the entire network (or an area approximating an RCC area or nationally) as and when they occur.

4.3.5.1 Dependency on In-Vehicle Intelligence

The broadcast of signal and sign setting updates places a large dependency on intelligence built into the In-Vehicle device. This intelligence would enable the device to process setting data, store it, and apply appropriate settings according to the vehicles location on the motorway network. As a co-requisite of this it is necessary that either

- The In-vehicle device is 'pre-configured' with signal and sign geometry data so that it could apply this intelligence, or,
- For any given signal setting transmitted to the vehicle the data contains the geographic coordinates such that the IVD is able to apply the associated settings when it reaches the location.

Both of these require that the vehicle deploys global positioning technology (e.g. GPS or Galileo) or some other third party technology as a means of receiving fixing the vehicles location. It could, for example, be by means of regularly spaced roadside electronic way markers.

4.3.5.2 Volume of Data

Metrics obtained from busy RCCs¹³ show that the rate of signal setting updates processed by the system in any given one second interval is potentially large. If data is to be transferred to vehicle by means 'broadcast' mechanism then does this presuppose intelligence in the IVD that can filter the incoming data and process only which is applicable to the vehicles location? Would the IVD be required to store all the data between updates so that the IVD can update its display as appropriate as it travels through the network? What of signal and sign settings that were updated before the vehicle entered the network: how is the IVD updated in this instance?

In order for a vehicle to process incoming data and apply signal and sign settings appropriate to that vehicle's current location the vehicle will need to know its current location. Again, it is beyond the scope this study to investigate technologies that would enable this, but it would be a requirement that the vehicle can determine its current location, and this could be achieved by a range of means from satellite global positioning to roadside electronic location markers.

4.3.5.3 Ensuring All Vehicles Receive Setting Updates

If a broadcast mechanism is used, how would it ensure that all vehicles receive current (i.e. Real Time) data? What of a vehicle that has only just entered the network, or one that has stopped at services and has now re-entered the network: how would these vehicles receive the most up-to-date data on on-street signal and sign settings? Would this require the system to re-transmit current setting status data at regular intervals to ensure that every IVD is up to date? What rate of re-transmission would be required to ensure that the synchronisation of RSD displays and IVD displays is within a requisite margin of safety?

If it is assumed that broadcasts will only contain setting updates (i.e. changes to signal and sign settings) then either:

- Entry points to the motorway network, including exits from service areas, refuge areas or anywhere else along the network that a vehicle may stop, will have to be covered with some form of targeted short range transmission to ensure that vehicles entering or re-entering the network at these points are updated with any extant settings; or
- The refresh rate of data transmissions (i.e. re-transmission of data) would need to be such that the distance a vehicle entering the network (at entry slips, exits from services etc.) can travel before being updated is within a safe margin of safety (e.g., as a first approximation, within 10% of the distance between any downstream signal site and the point at which the driver can see the settings on the downstream gantry).

¹³ See Appendix C, Managed Motorway Information Objectives 'Operational Performance'

If these cannot be assumed, the system would then be required to re-broadcast all extant settings at regular intervals. Parity and concurrency between RSD and IVD settings is implicit in the guiding principles for this project. Therefore, the vehicle location at which settings for a downstream signal site, for example, first appear on the IVD display should lie within a certain distance from the point at which the driver can first see the settings on the RSD downstream.

Assuming a vehicle is travelling at 70 mph, it will travel approximately 30 metres in one second. Assuming a FOP of the RSD setting of 300m upstream from the RSD, and, assuming a safe margin for the display on the IVD of 10% of that distance (30m), then in order to ensure that IVD displays the setting within that margin the system will be required to re-transmit the setting a rate of 1 transmission per second or higher. At a rate lower than this, some/most vehicles will not receive updates within that time and parity between the RSD and the IVD will not be achieved.

4.3.5.4 Latency of Data

Real-Time behaviour is a principle that this project is working towards. If a broadcast mechanism is used, what would be the implication for the latency of data: what would the time lag between the setting of aspects on RSDs and the receipt of data by the IVD be?

The Real-Time behaviour of in-Vehicle devices will be a function of the concurrency of IVD settings with RSD settings. Any appreciable lag between the two and the In-Vehicle technology may not be considered real-time. In fact, there is a built in lag between the current instation and the outstation as the requirement to retry device settings when the outstation fails. If a Transponder does not respond to a set device message from the Signal subsystem after three consecutive attempts, the minimum time delay between sending the initial message (HDLC Set Device (CI=40H)) and registering the transponder as faulty/unobtainable is 1+ minutes (i.e. 3 x time-outs with 30 second intervals). During this interval, it cannot be determined at the instation whether the device has set on-street as requested (see 4.4.3 below for discussion Built in Delays).

This may place an architectural constrain on the future system in that so long as it is a requirement to achieve setting parity between the RSD and the IVD, it may be necessary for the current outstation to control transmission of setting data, irrespective of the state of Comms between the instation and the outstation. If this is the case, then a broadcast mechanism may not be feasible.

Conclusion:

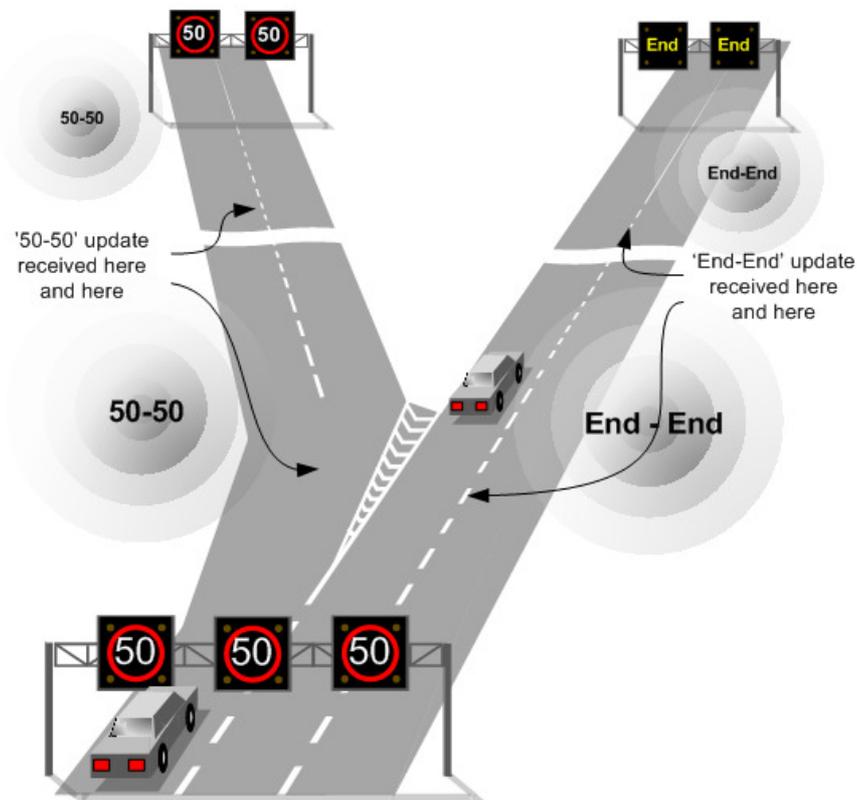
Unless the issue of delays in device status data updates between the outstation and instation can be resolved, and, given the requirement for IVD displays to achieve parity with RSD settings, a broadcast mechanism is not feasible.

4.3.5.5 A Co-Requisite – Geometry Data

If a broadcast mechanism is used, what geometry data would be required – how much would the vehicle need to know about the road network configuration, e.g. the location of signal and sign sites, the number of lanes at each site, in order for the IVD to display settings in an intuitive way?

The discussion on IVD displays above (see 4.2) concludes that IVD should represent settings on all lanes at signal sites to enable drivers to make the same informed choices that current RSD displays allow them to make. The number of lanes varies as the vehicle travels from signal site to signal site. In addition to signal site settings, there are un-signalled exits, hatched lanes, non-commissioned signals, divergences and other facets of the network geometry to consider if the IVD is to respond dynamically and not misrepresent the road configuration as the vehicle travels along. How is this geometry to be communicated to the vehicle?

A system that could transmit network geometry data to vehicles should not be ruled out. As an alternative, IVDs could be preconfigured with geometry data downloaded to the device prior to entering the network, as is the case with current satellite navigation systems. However, geometry data is modified on a regular basis as roadside infrastructure is upgraded; devices are added and commissioned etc. Prior to entering the network, each vehicle would need to be checked to ensure that it is operating with up-to-date geometry data.



4.3.6 Zoned Data Transfer

4.3.6.1 Description

The notion of a zone in this context is a grouping of contiguous signal sites and or message sign sites: a zone might consist of one or more signal sites contiguous in the transverse, longitudinal and adjacent (i.e. across a convergence) directions. On this notion, signal and sign setting updates relating to a particular zone would be transmitted to vehicles entering or travelling through that zone. A zoned based transmission system entails data packets being transmitted to vehicles that contain data pertaining to one or more signal or message sign sites (a signal site comprises one or more signal devices but a message sign site comprises one device).

As with a broadcast system, the IVD would be required to process and store this data in order to apply signal and sign settings appropriate to its location as it travels through the zone. A co-requisite of this, therefore, is that the vehicle 'knows' its current location at any one time. This could be communicated to the vehicle via:

- Global positioning technologies;
- Dead reckoning: if the data contains the distance between successive sites, and zones do not span carriageway divergences (including exit slips) then the IVD could calculate its location (longitudinally speaking) within a zone from time elapsed and vehicle speed;
- A hybrid transmission system that deploys roadside location 'marker beacons';

4.3.6.2 Advantages of a Zoned Based System

The advantages of this mechanism over a broadcast mechanism are as follows:

- A zone based transmission system does not require the IVD to be pre-configured with signal and message sign geometry data for the entire motorway network.
- Limits the amount of data required to be transmitted to a vehicle at any one time;
- Zones can be devised so that vehicles entering the network at specific points (entry to the network, exits from services and exits from Emergency Refuge Areas) can be specifically targeted and updated;
- Zone based transmissions might allow for less infrastructure (i.e. fewer transmitters) than a localised-targeted transmission system; and
- A Zone based transmission system may make it easier to resolve the issue of interference posed for targeted-localised based transmissions where two signal sites may be in close proximity.

4.3.6.3 Disadvantages of a Zoned Based System

- While a vehicle is travelling through a zone, settings at any one of the signal sites comprising that zone may change. This would require Transmitters to be located such that every vehicle travelling through the zone will receive every setting update for that zone. Given topographical constraints and possible obstruction from bridges, tunnels and other vehicles, this may not always be feasible if only a single 'transmitter' is deployed. However, zones could be designed around such topographical considerations rather than logical groupings of signal sites to mitigate this affect. In effect, this may offer little advantage over localised targeted transmissions associated with individual signal sites.
- The rate of data refresh necessary to ensure that any given vehicle approaching any given signal site will receive setting updates for that site within a safe margin of safety upstream from that device, may mean that transmitters need to be located at very specific locations along the carriageway in order to overcome topographical and other obstacles. It may be that in most cases any given site will have a dedicated transmitter associated with it. If so, then the primary reason for zones is diminished as the zone based transmission system comes to resemble a localised targeted transmission system
- Zoned transmissions would require vehicles to 'know' their location in order to process zone data and display the signal settings appropriate to the vehicles current location within the zone. The system could transmit zone based signal geometry data (e.g. distance between individual sites and the distance upstream of a signal site where the IVD should display the settings for that site) and allow the vehicle to calculate by dead reckoning the position of each site, but it would still need to know its own location as a reference point at the time the setting update occurred. This information could be conveyed to the vehicles by means of a location beacon at the entry point to the zone or through satellite positioning. Either way, it remains that vehicles that have already passed the entry point and are travelling through the zone must receive signal setting updates as they occur.

4.3.7 A Localised-Targeted Transmission/Beacon System

4.3.7.1 Description

The notion of a localised-targeted transmission system is one wherein each signal or sign site has a dedicated transmitter or beacon associated with it. It would not necessitate that the vehicle 'knows' its current location or that it is pre-configured with signal and message sign geometry data.

Possible technology solutions include Dedicated Short Range Communication (DSRC), a localized, possibly bi-directional, high-data-rate channel that would be established between a roadside device and the in-vehicle device.

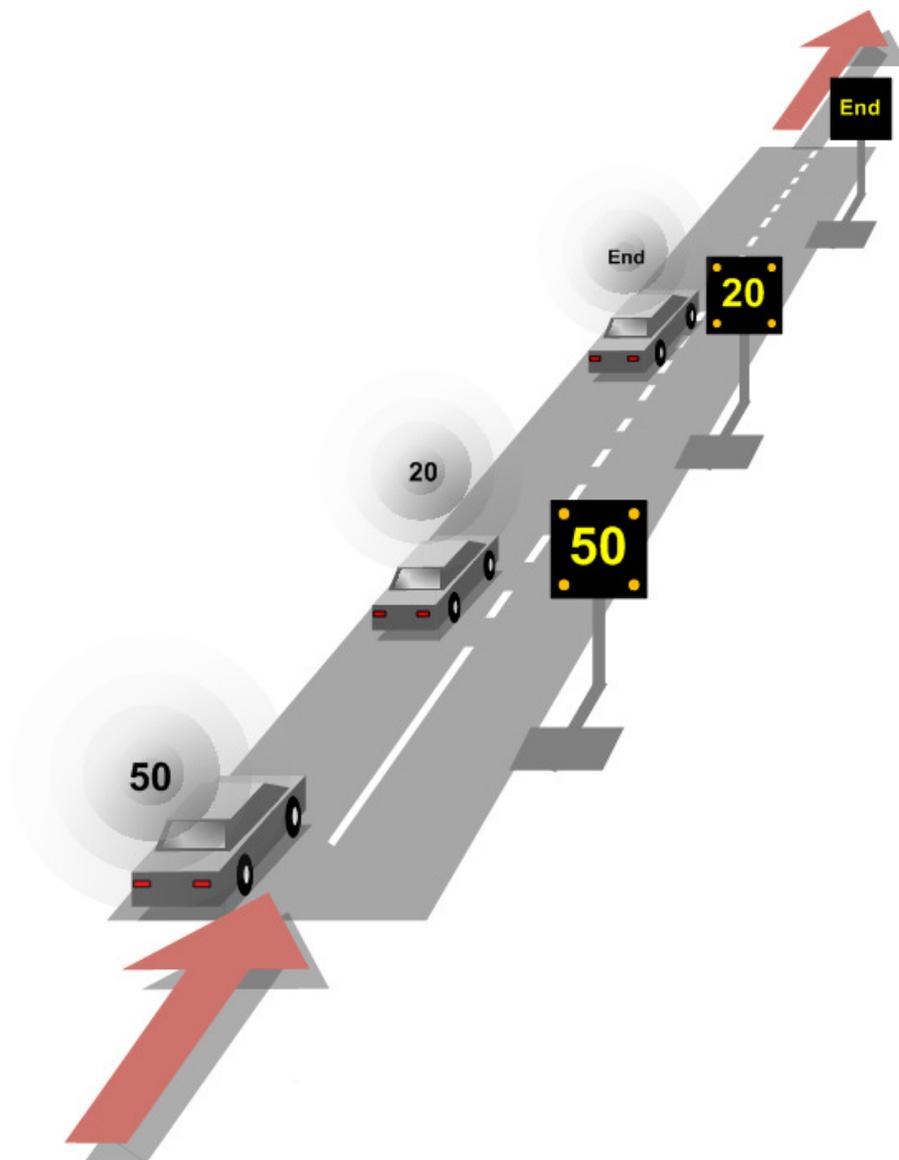


Figure 27: Impression of a Localised-Targeted Data Transfer System

In addition to transmitters or beacons dedicated to specific signal and message sign sites, the same type of transmitter could be dedicated to un-signalled entry and exit points to the motorway to ensure that:

- IVD settings are cleared down when the vehicle leaves the network; and
- To ensure that vehicles entering the network from services and ERAs are updated with the current settings on the section of motorway the vehicle is about to travel on.

Analysis of the requirements for the IVD display suggests that data transmitted to IVDs should contain details for all lanes at the signal site. For gantry mounted signal devices, the data would contain the setting on each device at that site since there is a one-to-one correspondence between lanes and signal devices. For post-mounted signals there is a many-to-one correspondence between lanes and signal devices (one signal device represents the restriction, e.g. wickets, for all lanes – see 4.4.2.2 below for discussion on the significance of wicket aspects).

4.3.8 Vehicle Location - Lane Position

. With respect to the vehicles *transverse* location on the carriageway (i.e. the lane that the vehicle currently occupies), it is a Human Factor consideration as to whether the IVD display should represent to the driver not only restrictions on all lanes, so that he/she may make informed choices about lane changes, but also the vehicles spatial alignment with the road. Figure 28 below illustrates how an IVD display may visually represent the vehicles alignment with the road. Figure 29 represents how this display may appear if the IVD cannot determine the lane that the vehicle currently occupies.



Figure 28: IVD Display indicating the Vehicle's Transverse Spatial Alignment with the Road



Figure 29: IVD Display that does not indicate the Vehicle's Transverse Spatial Alignment with the Road

Figure 30 and Figure 31 below illustrate these displays in context. It is considered that the display represented in Figure 30 presents lane specific information in a greatly more enhanced and intuitive way than does the display in represented in Figure 31.



Figure 30: Spatially Aligned IVD Display



Figure 31: Non-Spatially Aligned Display

Figure 32 below is a screenshot of a commercially available In-Vehicle satellite navigation device. It should be noted that the device represents the road configuration at the vehicle's current *longitudinal* location but does not represent the vehicle's spatial alignment with the road. It also represents the speed restriction currently set along the relevant section of road but it should be noted that it appears that no provision is made on this device for differential speed restrictions transversely across the carriageway or indeed any lane specific settings.

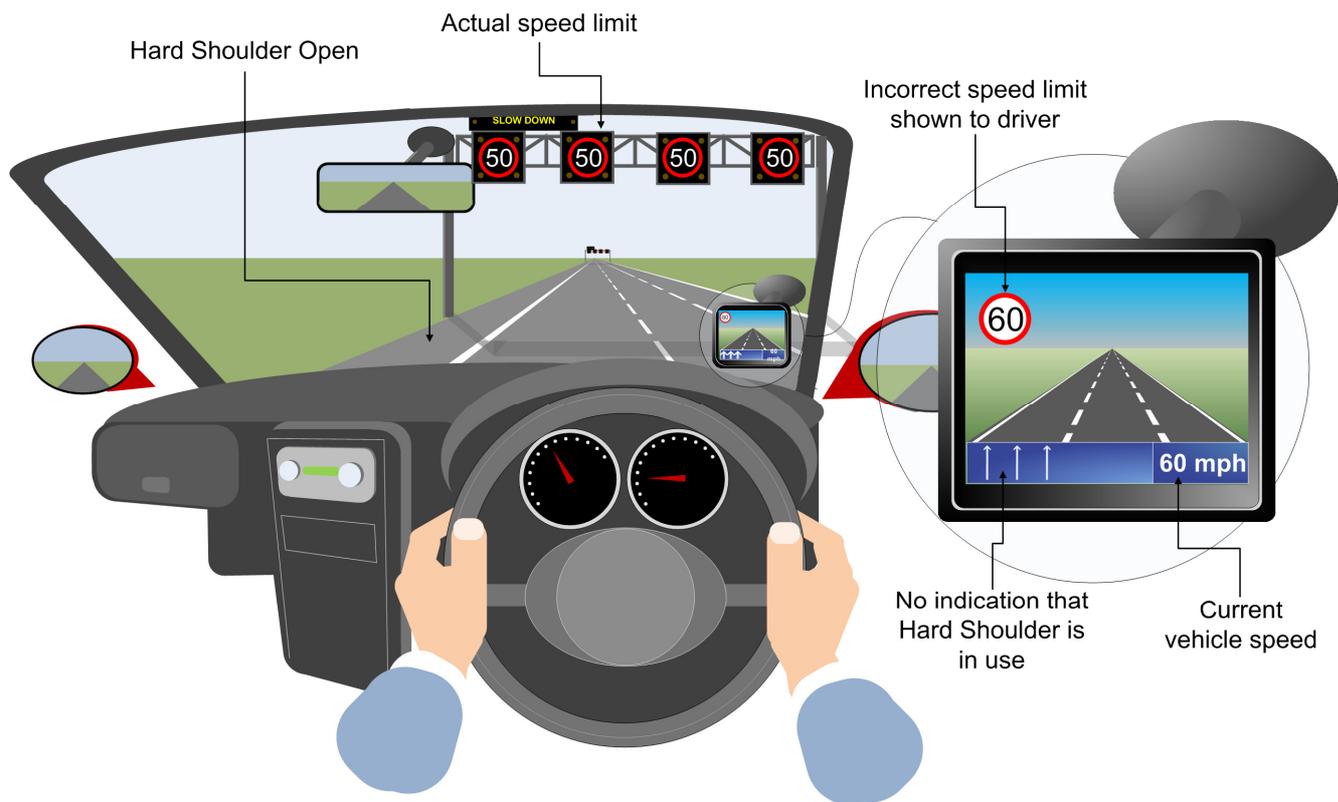


Figure 32: Accurate representation of a commercially available In-Vehicle Navigation Device

Subsequent to the completion of this project, a Human Factors analysis will be required to determine how best to present lane information to the driver, but prior to that it is assumed that the IVD should represent the vehicle's transverse spatial alignment with respect to the road. So, how will the vehicle determine which lane it is travelling in?

It is difficult to foresee how the HATMS could communicate the vehicle's current lane to the vehicle. It is assumed, therefore, that the vehicle will be required to determine this by some other means. Satellite global positioning technology is certainly advanced enough for the vehicle to determine its current location to the level of the lane it is in. Developments in In-Vehicle intelligence may also be such that the vehicle itself can 'see' which lane it is through real-time image analysis of lane markings, 'Cat's Eyes' etc.

4.4 Data Dependency on HATMS Architecture

4.4.1 Introduction to HATMS Architectural Issues

4.4.1.1 General

This section reviews dependencies between I2V (Infrastructure to Vehicle) data structure and the current HATMS Architecture. The particular focus is on how the architecture could deliver Real-Time information in vehicle and, therefore, parity between RSD and IVD displays.

4.4.1.2 Real-Time Capability of In-Vehicle Devices

With respect to signal and sign settings there are two senses of Real-Time:

- **Sense 1 - Latency of information received at the Driver's Retina:** In this sense, the starting point for the provision of MM information to drivers is taken to be the point at which that information appears on the RSD. In this sense, the system is Real-Time by definition, i.e., Real-Time by virtue of the fact that drivers see the display on a RSD and transmission between the device and the driver's retina is achieved at the speed of light. The significance of this is that since the display on the RSD is taken to be primary (see section 3.1.2.5) the Real-Time Capability of the system will be a function of the parity between IVD and RSD displays. If there is an 'appreciable'¹⁴ lag between the setting of an aspect on an RSD and the setting of that aspect on the IVD in a vehicle approaching that RSD then the information provided at the IVD might be considered to have failed the criteria for Real-Time.
- **Sense 2 - Real-Time Response to Automatic Setting Requests:** In this sense the starting point for the provision of MM information is taken to be the point at which signal and sign settings are initiated. For example, the Signal subsystem must respond to automatic setting requests from the MIDAS subsystem in response to MIDAS alerts generated at roadside loop detectors. In this respect, the Real-time capability of the system is a function of the interval between initiating signal and sign settings and actually setting the sequenced settings on-street. Performance criteria for this Real-Time behaviour are not specified as such, but it is nonetheless crucial that, in the case of Signal subsystem, responses to automatic settings from MIDAS and other subsystems appear on the display (RSD or IVD) in time to be effective in managing the traffic situation for which those settings were intended. If, in this instance, performance criteria were to be specified, then a first approximation might be that, on average, signal settings should appear on-street within 10% the configured interval for the MIDAS ON-OFF Setting Timer¹⁵.

¹⁴ Performance criteria would need to be specified.

¹⁵ The MIDAS On-OF timer is a configurable period (default = 4 minutes) during which the MIDAS subsystem will not request previously requested signal settings to be cleared. This prevents oscillation in settings.

With respect to Sense 1, although a few seconds lag between an RSD and an IVD may not compromise the Real-Time capability of the system for automatic settings (e.g. MIDAS settings in response to congestion alerts), where the duration of any given regime will be in the order of minutes, it takes on real significance for regimes such as speed aspect countdowns (see section 4.3.3.1.3 below), where the intervals between consecutive setting updates is in the order of seconds. Furthermore, it is considered that a frequent and appreciable lag between RSD and IVD displays may erode motorist confidence in the system.

Ultimately, Real-Time capability, in both senses, is a function of the system's ability to deliver the information within as yet unspecified temporal parameters, i.e., Real-Time capability of the future system will be dependant on system architecture.

4.4.2 Key Architecture – Overview of HATMS Architecture

4.4.2.1 Overview

Broadly speaking, and for the purposes of this analysis, HATMS can be divided into the Instation control system, comprising the subsystems that control outstation/roadside devices, and the outstation infrastructure, comprising device controllers and the roadside devices themselves. Figure 33 to Figure 35 illustrate the HATMS that Instation-Outstation divide inn various degrees of detail. Figure 33 illustrates the current communication protocols between the Signal and Sign Instation control subsystems and the outstation devices that they control. Notably, there is no direct IP communications between signal and sign devices and their respective control subsystems¹⁶: all communication between these subsystems and the devices they control is routed via the COBS/Commserver machine which converts the LAN protocol used for inter-subsystem communication to the relevant protocol for transactions between instation and outstation (RCC communications are not shown). For the present purposes though, COBS is considered to be no more than a router and henceforth the discussion will proceed as if the Signal and Message Sign subsystems communicate directly with the transponder controlling the relevant roadside devices.

¹⁶ There are developments taking place with the aim of achieving this.

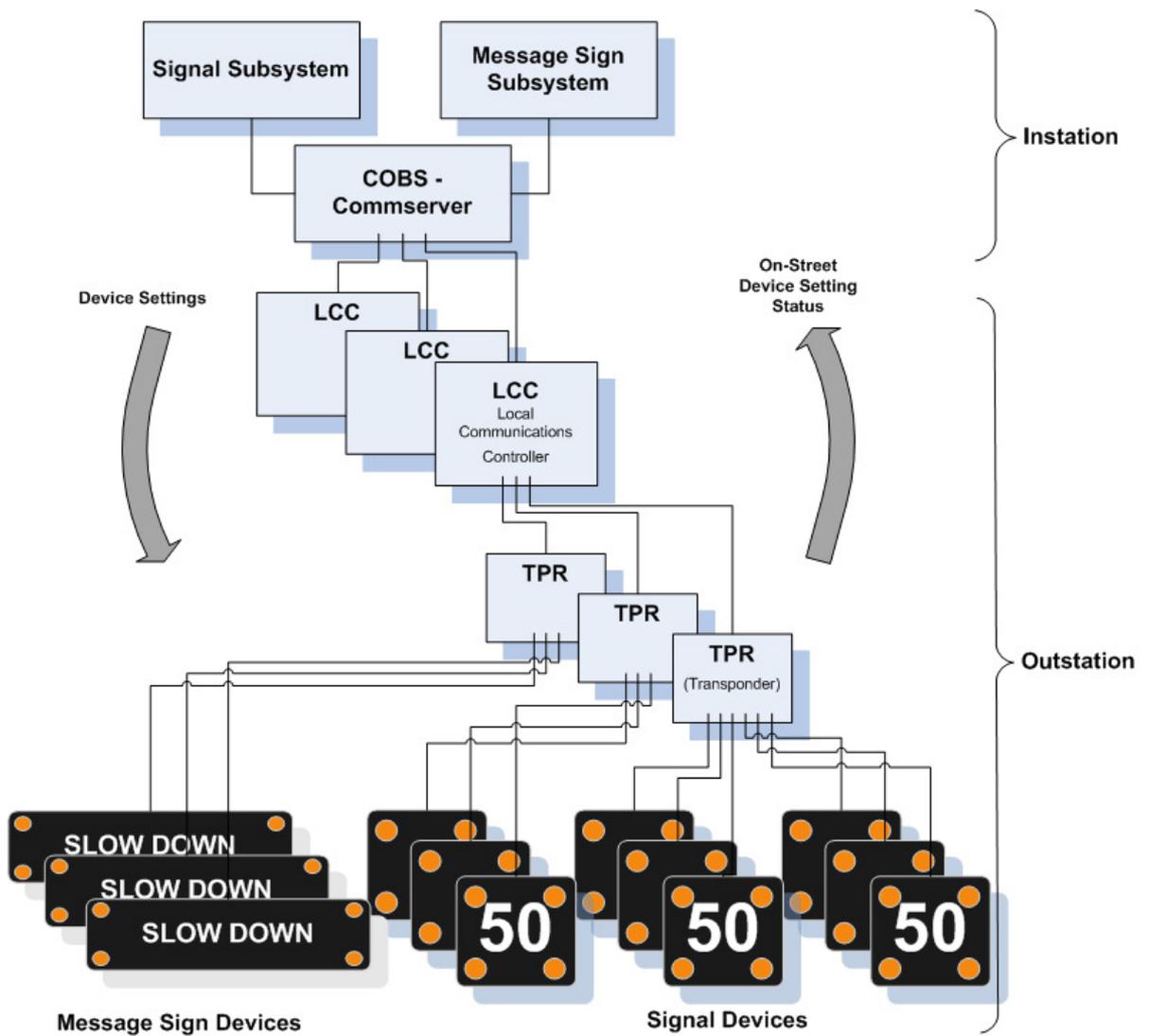


Figure 33: HATMS – Current Comms Hierarchy for Signal and Sign devices

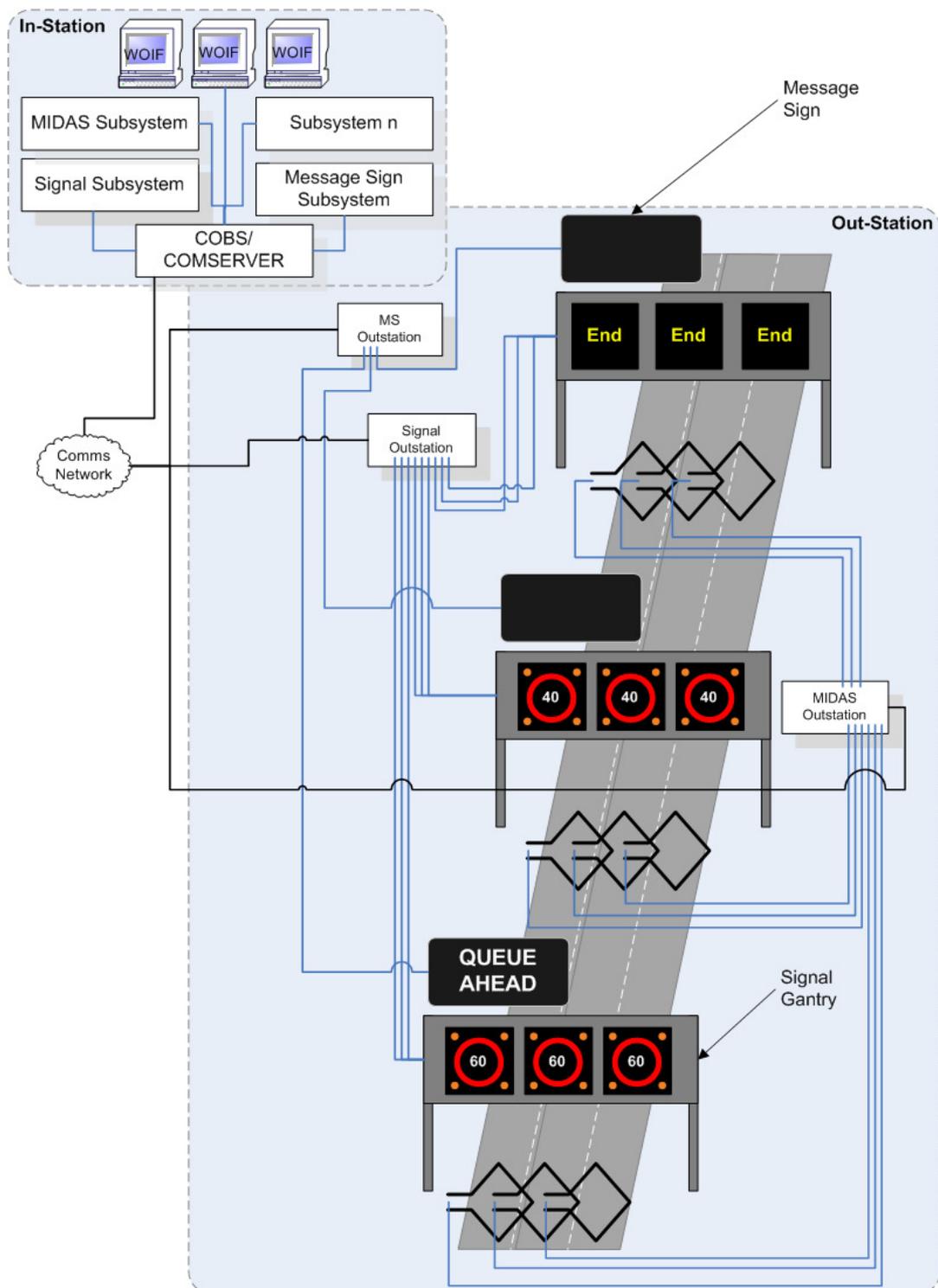


Figure 34: HATMS – Simplified Schematic

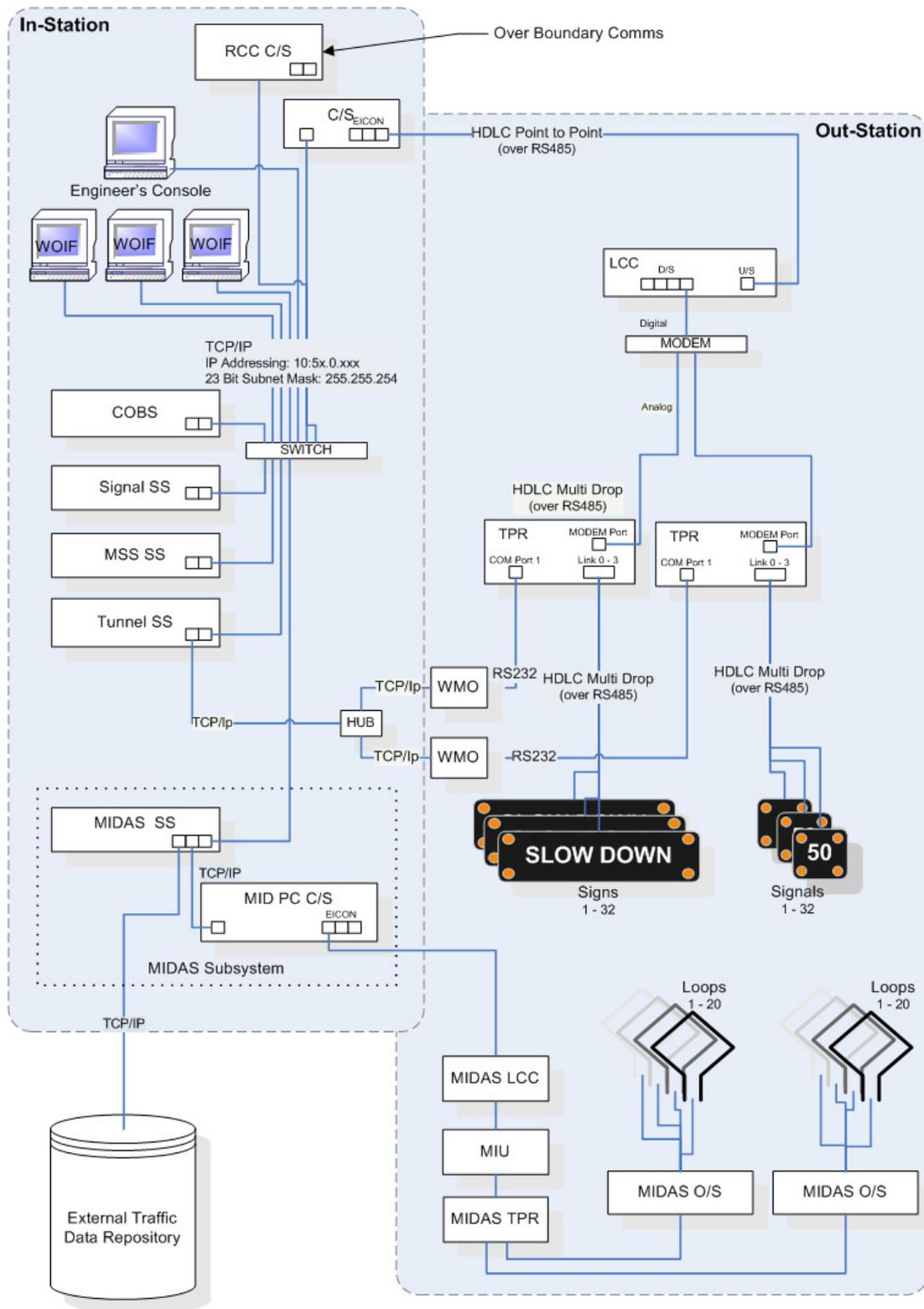


Figure 35: HATMS – Detailed Schematic (Showing Serco COBS with Separate Commserver, Tunnel Subsystem and current HDLC Comms - Not all Peripheral Shown)

4.4.2.2 The Signal Subsystem

Except in special circumstances (i.e. Tidal Recovery and Direct Tunnel Subsystem control), all signal settings requested by operators and automatic subsystems (e.g. MIDAS and MET) are processed by the Signal subsystem prior to being set on-street. The Signal subsystem executes the Signal Sequencing Rules. The reason for this is that the pattern of on-street signal settings must be consistent with respect to the Signal Sequencing rules and the implicit safety case contained therein. Therefore, a single nexus for the execution of these rules is required in order to arbitrate between the various sources (RCC operators and subsystems) competing to set signal on-street. This arbitration role can be considered to be the primary function of the Signal subsystem.

Figure 36 below illustrates the concept of the Signal subsystem as arbitrator.

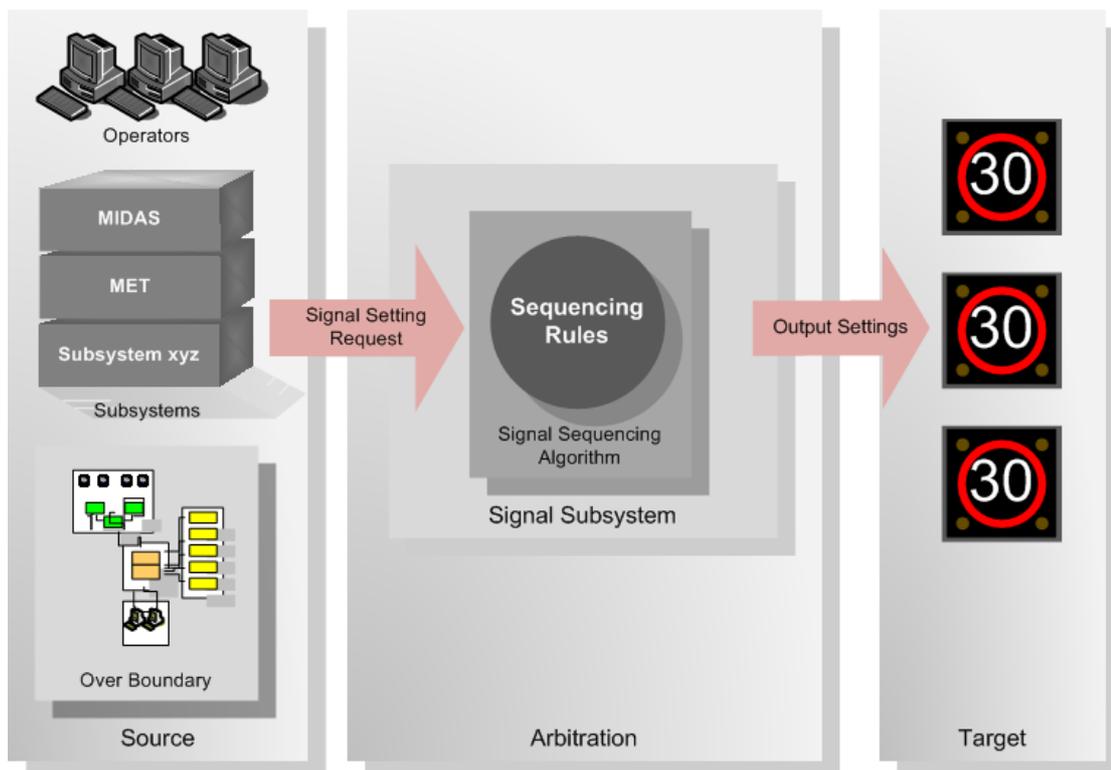


Figure 36: The signal subsystem as arbitrator

4.4.2.2.1 What is Signal Sequencing?

When, for whatever reason, an operator, or other source, requires signals at the roadside to be set to a particular aspect (speed restriction, lane closure, lane divert, 'Fog' or other), then, in order to provide sufficient warning to the motorist and to prevent undue disruption to traffic flow towards, around and away from the restriction, it is necessary to *embed* the proposed *primary* setting in a pattern of *secondary* settings that do give warning and prevent undue disruption to traffic flow.

In terms of preventing disruption to traffic flow it is useful to think of it in terms of fluid dynamics – smooth or *laminar* flow is the result of careful management and streamlining whereas disrupted or *turbulent* flow is caused by sudden protuberances and poor management at confluences. Ideally, Secondary signal settings should have a ‘streamlining’ effect.

Therefore, Signal Sequencing is the process of:

- a) Validating proposed primary settings to ensure that they are safe and appropriate to the given site type, and rejecting those settings if they are not; and
- b) Generating secondary settings that manage the flow of traffic towards, around and away from validated primary settings.

4.4.2.2 *The Signal Sequencing Algorithm*

Integral to the process of Signal Sequencing is the execution of a defined set of *Signal Sequencing Rules*. Typically, a Rule takes as input a signal site and the aspect proposed for it and says that if such and such a condition is met then, either rejects the proposed setting, or, set such and such a setting at this site or at the sites upstream, downstream, adjacent and co-located with the given site.

The effect of the Signal Sequencing Rule is to:

- Determine whether the proposed setting is valid, i.e. that it does not fall into one of the following categories:
 - **Conflicting or unsafe:** the operator, or other source requesting signal settings, should, for example, be prevented from proposing lane diverts pointing towards closed lanes;
 - **Inappropriate to the given Signal Site type:** it would, for example, be inappropriate to propose the aspect HSD (*‘Hard Shoulder Divert’*) anywhere other than at the inside lane (hard shoulder) at an ATM site (*‘Variable Lane’* site);
- Generate embedding secondary settings that ensure;
 - **Safety:** secondary settings ensure an orderly navigation to, around and away from the primary setting; and
 - **Minimal disruption to traffic flow:** secondary settings ensure the least possible disruption to traffic flow towards, around and away from the primary setting.

The execution of the Signal Sequencing Rules is controlled by the *Signal Sequencing Rules Shell*. The Rules Shell determines the order in which the Rules are executed, the number of iterations through the rules and the order in which sites are submitted to the rules. The Rules Shell can be thought of as a set of Meta-Rules with respect to the Rules themselves. Together the Rules and the Rules Shell form the SSA.

4.4.2.23 Setting Signals: Mandatory Speed Restrictions

Operators and Automatic subsystems do not request mandatory speed restrictions as such: they request speed aspects in the range SAC=5 to SAC=9 ('20' to '60'). The mandatory (Red-Ring) aspect of a speed restriction is determined by the 'On Controlled Motorway' flag in the Signal geometry data: For a given signal site, if the flag is set to TRUE, then the Signal subsystem will output a Red-Ring aspect. For example, in response to a request for '40' (SAC=7) the Signal subsystem sequences the requested setting and converts the output to '40R' (SAC=39) before sending the setting data to then outstation.

If HATMS site data is consistent between the Signal Geometry data and the outstation device data then it should not be possible to send a Set Device data (HDLC CI=40H) to the outstation for a device that is not capable of displaying a Red-Ring aspect.

4.4.2.24 Signal Subsystem Processing of Wicket Aspects

Wicket aspects are used to represent barred aspects (STOP, REDX, LDL, LDR, HSD, tDL, MDVL and MDVR) at post and cantilever (e.g. MS4s) mounted sites where a single matrix device is used to represent all lanes at the site. Table 2 below lists the various wicket aspects current used by HATMS¹⁷.

Table 2: Wicket Aspects

SAC	Description	Mnemonic	Legend
21	Lane 2 closed of 2	1T	
22	Lane 1 closed of 2	T1	
23	Lanes 1 & 2 closed of 3	TT1	
24	Lane 1 closed of 3	T11	
25	Lanes 2 & 3 closed of 3	1TT	

¹⁷ In addition to the Wicket Aspects in Table 2, various wickets representing full carriageway closures are being proposed: Extant Change Request CR2592 proposes a number of new aspects (SACs 55-58) representing full carriageway closures as wicket type aspects, for example, 'TTT' at a three lane intelligent indicator (i.e. at a site where it is specified in the geometry data that 'STOP Wickets' apply instead of STOP). This will entail modification to signal site geometry data specification (MCH1798) to include the new site type.

26	Lane 3 closed of 3	11T	
31	Lane 4 closed of 4	111T	
32	Lanes 3 & 4 closed of 4	11TT	
33	Lanes 2, 3 & 4 closed of 4	1TTT	
34	Lane 1 closed of 4	T111	
35	Lanes 1 & 2 closed of 4	TT11	
36	Lanes 1, 2 & 3 closed of 4	TTT1	

Post mounted devices may be situated either in the central reservation or at the verge (or both). Cantilever mounted devices (including MS4s mounted over AMIs on Gantries – e.g. on MM-HSR schemes) may extend over the Hard Shoulder to lane 1 (or lane ‘2’ on MM-HSR schemes).

In addition to the Wicket Aspects in Table 2 above, various wickets representing full carriageway closures are being proposed: Extant Change Request CR2592 proposes a number of new aspects (SACs 55-58) representing full carriageway closures as wicket type aspects, for example, ‘TTT’ at a three lane intelligent indicator (i.e. at a site where it is specified in the geometry data that ‘STOP Wickets’ apply instead of STOP). This will entail modification to signal site geometry data specification (MCH1798) to include the new site type.

Human Factor Consideration:

Assuming a visual display, should IVDs always mirror the RSD and display wicket type aspects, or should the In-Vehicle display always show lane specific settings?

Conclusion:

Subject to the outcome of the Human Factor analysis, the Signal Sequencing Algorithm (the Signal subsystem) will require modification in order to convert wicket aspects sent to Carriageway (Post mount type) sites to the corresponding gantry type aspect for IVDs in vehicles approaching the RSD location. So for example, the Signal subsystem would need to be modified to ensure that 'TII' is converted to 'STOP-50-50' and not, for example, 'LDR-40-40' when the appropriate gantry type setting is 'STOP-50-50'. In order to apprehend the scope of change required to do this it is necessary to understand the notion of 'Virtual Upstream Sequencing'.

4.4.2.25 Virtual Upstream Sequencing

Virtual Upstream Sequencing is the process of sequencing upstream from a Gantry site (Tidal, Tidal A, Tidal B, Gantry and Variable) to a Carriageway site (Post Mount - Carriageway, Multiple, Stop Capable Carriageway and Motorway Divert Capable Carriageway) and upstream from a Carriageway site to a Gantry site. The important feature is that there are a set of aspects that apply only to Post-mount type devices ('Wickets', i.e. TI, IT, TII, IIT, TTI, ITT, TIII, IIIT, TTII, IITT, TTTI, ITTT) and that there are no rules that generate wickets upstream from the corresponding Gantry type pattern of settings. For example, between two consecutive three lane sites if the downstream site is a Gantry where lanes 1 and 2 are set to a Lane Divert Right (LDR) then at the upstream site we would expect the appropriate Case 1 Rule to *triangulate* the lane diverts by setting Lane 1 at the upstream site to LDR where the upstream site is a Gantry site. On a post-mount device the appropriate aspect to display would be 'TII'. Since there is no rule to generate 'TII' from the Lane Diverts the method adopted by the original Rule designers was to sequence upstream from the Lane Diverts *as if* the upstream site were also a Gantry and then, subsequent to submitting the downstream site to the Case 1 Rules, convert any Gantry type aspects at the upstream site to the corresponding wicket aspect:

- a) Sequencing Gantry to Carriageway: In this instance the upstream Carriageway site is copied to a virtual Gantry site and then both the downstream site and the virtual upstream site are submitted to the Lead-In sequencing rules in the normal way. The Rules will generate gantry type aspects at the upstream virtual site (e.g. LDL and LDR). Subsequent to sequencing upstream between these two sites the generated settings are copied back to the actual upstream Carriageway site and then submitted to the C3CN Conversion Rules. These convert the Gantry type aspects to the corresponding Carriageway type aspects: e.g. Where LDL is set on lane one and only lane one at a three lane site then the aspect at the Carriageway site is converted to the wicket aspect 'TII'. Figure 37 describes this process in flow chart format.

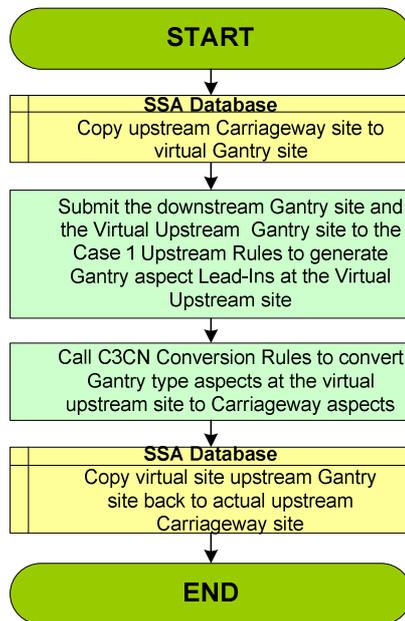


Figure 37: Virtual Sequencing – Gantry to Carriageway

- b) Sequencing Carriageway to Gantry: In this instance the downstream Carriageway site Gantry copied to a virtual Gantry site and then submitted to the C4CN Rules to convert existing Carriageway aspects to the corresponding Gantry type aspects. Therefore, TII is converted to ‘STOP-50-50’ at lanes one two and three respectively. Once the virtual downstream site has been initialized then both the virtual downstream site and the upstream Gantry site are submitted to the Lead-In rules and appropriate Lead-In aspects at the upstream site are generated. Figure 38 below represents this process in flow chart format.

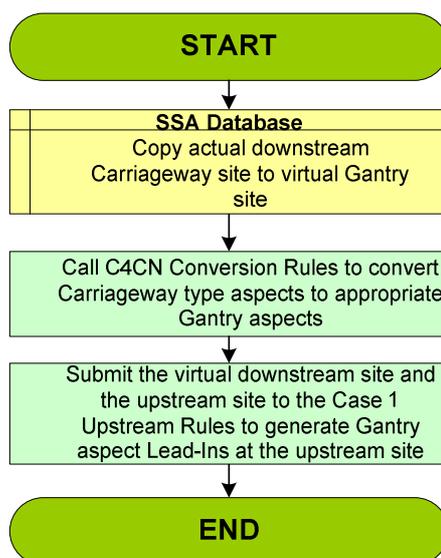


Figure 38: Virtual Sequencing – Carriageway to Gantry

To modify the Signal subsystem in order to convert wicket and other Carriageway settings to lane specific Gantry type settings will require that the SSA functionality described in this section is modified in order to preserve the appropriate gantry type settings when sequencing upstream from a Gantry site to a Carriageway site.

4.4.2.3 The Message Sign Subsystem

4.4.2.3.1 *Reactive Settings*

When an operator requests signal settings, the Signal Subsystem sequences the settings and informs the Message Sign Subsystem. The Message Sign subsystem applies a set of rules and propagates an appropriate message to one or more MS sites associated with the relevant signal sites through relationships defined in the site data. This is an automatic process ('Reactive Proposals') that only applies to Operator signal setting proposals.

4.4.2.3.2 *Automatic Settings*

When a subsystem (e.g. MIDAS & MET) requests signal settings, the Message Sign subsystem will not react to the resultant signal settings. Instead, when a subsystem requests signal settings, depending on pre-defined plans and inter-site relationships, that subsystem may also request message sign settings in support of those signal settings.

For example, a message requested by MIDAS in support of MIDAS requests signal settings:



Like the Signal subsystem, the Message Sign subsystem maintains separate layers for operator and subsystem settings. Unlike the Signal subsystem, the Message Sign subsystem can apply a priority to each of the various layers

4.4.2.3.3 *Signals & Signs: Prioritising Inputs*

The Signal subsystem prioritises signal settings on the basis of the *priority of the aspect*. Since only one signal setting is stored against a particular device in a particular layer, the Signal subsystem cannot prioritise between settings originating from the same source. If, for example, the MIDAS subsystem requests '30' for a particular device and, subsequently requests '50' for that same device, the Signal subsystem will overwrite the '30' with '50' irrespective of the fact that '50' is a lower priority aspect. The Message Sign subsystem, by way of contrast, may prioritise message sign settings on the basis of the request source and the message code.

4.4.2.3.4 *Message Sign Flasher Synchronisation*

The MS Subsystem must ensure that the lanterns on an MS device, which supports the lantern override command, are always switched off whenever the MS device's associated signal(s) have their lanterns on¹⁸. The Message Sign subsystems automatic Lantern Override functionality enables the VMS flashers on VMSs associated with signal sites to avoid overloading and distracting the driver with flashers, thereby ensuring the driver's primary focus is on signal settings. Assuming flasher functionality will be incorporated into IVD technology, should the control of flashers be retained by the subsystem in order to avoid conflict with flashers on-street. Currently, it is the Message Sign subsystem that controls flashers (i.e. switching them ON or OFF).

Human Factors Consideration:

What is the position on message flashers contra signal flashers?

Conclusion:

Subject to Human Factors analysis regarding the need for flashers and for separate signal and sign areas on the IVD display, it is considered that there should be a requirement for logic in the IVD unit to resolve conflicting flashers based on a simple truth/priority table.

4.4.2.4 The MIDAS Subsystem

4.4.2.4.1 *General*

Though not strictly pertinent to the current investigation an insight into the operation of the MIDAS subsystem is useful for understanding some of the broader issues in relation to the Real Time behaviour of the system.

4.4.2.4.2 *Midas Operation*

The MIDAS subsystem (Motorway Incident Detection & Automatic Signalling) is comprised of an Instation and various field infrastructure components which gather vehicle traffic data from roadside vehicle detectors (inductive loops) to provide Queue Protection and Congestion Monitoring data.

¹⁸ See TR2139, M:6552

A HIOCC (High Occupancy) algorithm runs on the MIDAS outstation to detect slow moving or stationary traffic and generate incident alerts. The MIDAS Outstation scans detector occupancy data every tenth of a second. Several consecutive values of instantaneous occupancy (i.e. calculated each second as the proportion of the second that a vehicle is present in the lane) are examined to see if they exceed algorithm thresholds: the algorithm takes occupancy data every tenth of a second, and gives a value of 0 to 10 for every second of time. Zero means no vehicles have occupied the sensor that second, and 10 means the sensor was occupied the entire second.

A lane is said to enter a 'HIOCC Alert State' when the instantaneous occupancy equals or exceeds the occupancy threshold during each of the preceding n seconds. Currently, if two values of 10 are given consecutively, an alert is raised. The resultant alert is routed to the MIDAS Subsystem which reacts by requesting signals and message signs to be set upstream to warn approaching vehicles.

Signals and Signs are set within the Control Office area by sending Set Device messages to the Signal Subsystem and Message Sign Subsystem across the Instation LAN. Signals or Signs may be set in another Control Office area by sending details of an incident near the boundary in a Cross-Boundary message across the RCC network.

4.4.3 Built-In Delays¹⁹

4.4.3.1 Device Status Reporting

After the Signal subsystem has sent (via COBS) a Set Device message to a signal transponder the Signals Subsystem must expect the response to arrive within a preset time. If the expected response is not received within this time, the message exchange is considered to have timed out (The Signals Subsystem reads the value for the time-out for each HDLC message type from Site data). Unless the Transponder from which a response has been timed out is known to be unobtainable, the Signals Subsystem will make up to a total of three attempts to elicit a response. If the Transponder from which a response has been timed out is known to be unobtainable, no retransmission attempts will be made. If multiple attempts are made to elicit a response from a Transponder and all are timed out, the Signals Subsystem will update the status of the device in its internal stores to Unobtainable. The timeout period for a response to a Set Signal message has a default value of 30 seconds. The SET DEVICES command itself may take from hundreds of milliseconds to minutes to execute. Figure 39 below illustrates this reporting mechanism.

¹⁹ It should be noted that when the signal transponder is eventually replaced and the Signal Subsystem communicates directly with the RSD via IP communications, built in delays at Transponder and LCC levels may disappear for the most part. Some issues may still remain that will require future analysis.

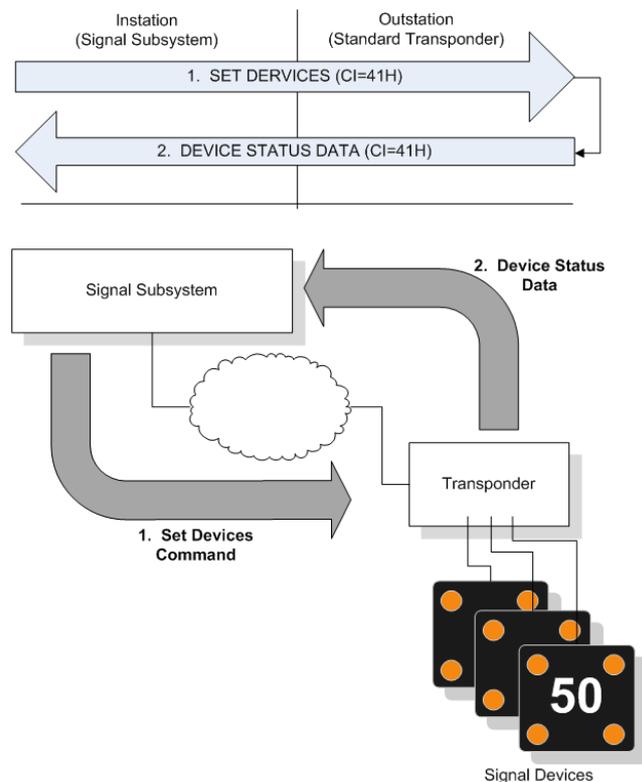


Figure 39: Device Status Reporting

If a Transponder does not respond to a set device message from the Signal subsystem after three consecutive attempts, then the minimum time delay between sending the initial message (HDLC Set Device (CI=40H)) and registering the transponder as faulty/unobtainable will be 1+ minutes (i.e. 3 x time-outs with 30 second intervals). During this interval, it cannot be determined at the instation whether the device has been set on-street as requested.

Clearly, given an overarching requirement for parity between RSD and IVD displays, a built in delay (albeit, under certain circumstances) would not be acceptable. Certainly, a delay of 1 minute or more could result in dangerously conflicting RSD and IVD settings, when, for example, if the extant setting on the IVD is LDR on lane 1 and the setting update sent to the RSD is LDL on lane 2. However, if transmission to IVDs is to be controlled directly by the instation (i.e. bypassing the RSD Transponder) then how would parity be maintained?

The method of device setting and status reporting describe in this section is integral to HATMS Architecture. At this time, it is not considered a viable option to modify the architecture in this respect. Therefore, either:

- a) The requirement to control transmissions from the instation directly should be relaxed and, instead, incorporate this functionality as an outstation function, or,

- b) Control transmissions to IVDs from the instation directly, but the instation will send setting data for transmission to a separate transmitter/beacon as and when it sends the corresponding set device data to the standard transponder.

To aid selection of one of the above two alternatives, the following features of HATMS are considered:

- Aspect Adaption / Aspect Failure;
- Unobtainable Devices;
- Aspect Validation; and
- Aspect Countdowns.

4.4.3.2 Aspect Adaption / Aspect Failure

4.4.3.2.1 *Aspect Adaption*

The system attempts to set a pre-defined alternate aspect when the requested aspect fails to set on-street (e.g. due to bulb failure that would render the aspect illegible). Each aspect defined in the outstation data has such a pre-defined alternate aspect. So for example, the pre-defined alternate aspect to '50' (SAC=8) may be '60' (SAC=9) such that if '50' cannot be set then the system will attempt to set '60' in its place. The alternate aspect may be 'OFF', 'STOP' or any other aspect. For an RSD, it is straightforward for device failures to be reported back to the instation. Device failures (e.g. bulb failures) that would render the display illegible are dealt with by the system to ensure that a safe alternative is imposed. It is not possible, therefore, for two motorists at the same location to receive conflicting information. Key considerations are as follows:

- Does the issue of Aspect Adaption mean that in order to avoid conflict between IVD and RSD settings the system should wait until the TPR reports the setting status of its devices to the instation before it can transmit to vehicles? How will this affect the latency of the information received by IVDs? Does this mean that Aspect Adaption functionality would have to be discarded²⁰? Is it safer to display nothing rather than an aspect that may conflict with the IVD?
- If the Transponder adapts an aspect then it will inform the Signal subsystem, but the Signal subsystem is not required to re-sequence the settings. In these instances, would the signal Transponder be required to send a setting update to the IVD informing it of the aspect, or should this be done by the Signal subsystem? If it were to be updated by the Signal subsystem then would this incur a significant delay as transactions take place between instation and outstation?

²⁰ There is an ongoing discussion in the HATMS community as to whether, as a part of the introduction of 'Intelligent Transponders' and the migration of Aspect Countdown functionality from the Standard Transponder to the Signal subsystem, Aspect Adaption functionality should be removed completely. At the time of writing, the stage of this discussion is not known by the author.

Assuming Aspect Adaption functionality will be retained into the foreseeable future, this functionality is significant since the current device status reporting mechanism will entail an added delay if the transmission of data is to be controlled directly from the instation, resulting in an appreciable lag between RSD and IVD settings when Adaption occurs.

4.4.3.22 *Device Failures Generally*

Irrespective of the issue of Adaption, on occasion aspects will fail to set on-street. On such occasions, should the system still attempt to impose the setting on the IVD? Consider 'Faulty Stop Lead-Ins': a Faulty Stop Lead-In occurs when the expected upstream Lead-In to STOP (e.g. '20') fails to set due to, for example, a device failure. Figure 40 illustrates a Faulty-Stop Lead-In scenario.

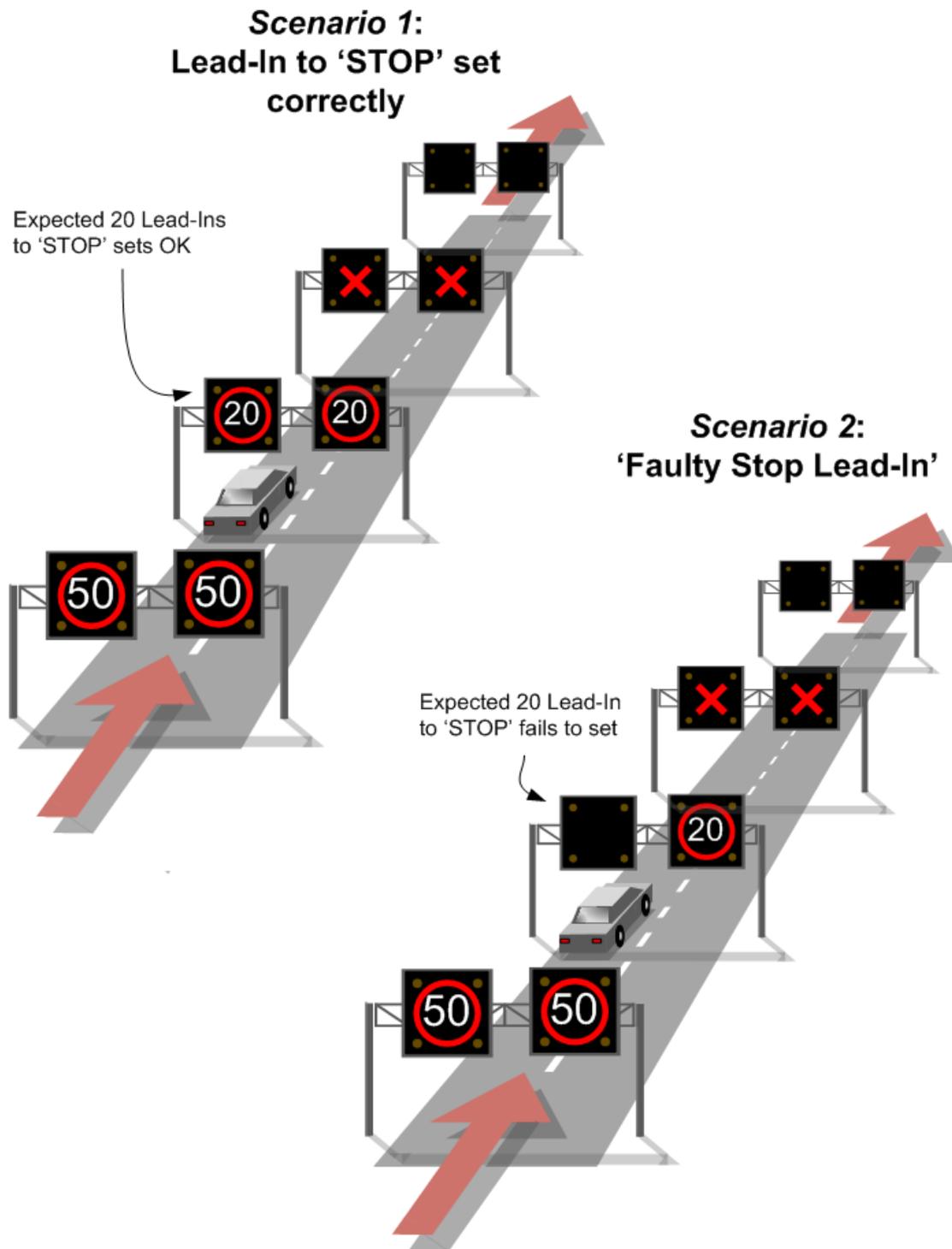


Figure 40: Faulty Stop Lead-In

When a STOP aspect (solid red 'X') is requested, the Signal subsystem sequences the STOP in order to generate any necessary secondary Lead-In, Adjacent, and Transverse and Downstream aspects. If at the site immediately upstream of the STOP, one or other of the Lead-In aspects fail to set, then the Signal subsystem will raise an alarm to the operator but set the STOP none-the-less.

There is a clear safety implication in relation to such an 'unguarded' STOP, but there may be an imperative for setting it anyway, though the operator has been warned and can therefore choose to propagate the STOP further upstream as a temporary work-around solution if required.

Human Factor Consideration:

In this instance, the future system may offer an advantage in that it can ensure that the pattern of signal settings presented to the driver is consistent with the rules irrespective of the settings at the roadside. How does this accord the principle that the RSD settings have primacy of IVD settings? In this instance, the safety case may outweigh that principle.

Conclusion:

Whatever the outcome of that Human Factor analysis, there would be some advantage in including the RSD fault status in signal setting data transmitted to vehicles. Subject to Human Factors analysis, that data could be used by the IVD to either, clear down the IVD setting, so as not to be in conflict with the IVD, or, display the setting on the IVD but alert the motorist to the fact that the on-street device is faulty and, therefore the IVD displays overrides the RSD display.

Assuming the driver should be informed of the RSD fault status (e.g. in the case of Aspect Failure), then the driver should be informed at the earliest juncture. Given the potential delays in reporting the setting status to the instation, it is considered preferable, in this instance, that the transmission of setting data to vehicles is controlled via the signal outstation.

4.4.3.3 Unobtainable Devices

Obtainability is an attribute of a signal or sign device, Transponder or Local Communications Controller (LCC): when it is operational and available to receive signal settings from the Signal subsystem it is Obtainable, otherwise it is logged by the controlling subsystem as Unobtainable. If a device is logged by the subsystem as faulty the subsystem will not send a SET DEVICE message to that device. Similarly, if a Transponder is logged as faulty the subsystem will not send a SET DEVICE to any devices belonging to that transponder.

In the case of signal settings, however, the Signal subsystem will continue to sequence settings requested for an Unobtainable device: It will store those settings locally until such time that the device is operational again, on which event the Signal subsystem will send the setting data to the outstation. For example, if an operator closes a carriageway and the upstream signal site is not obtainable but the site upstream from that is, then in order to generate the appropriate lead-in settings at the second upstream site it is necessary to generate the lead-ins to STOP at the unobtainable site, even though they will not be set on-street directly.

Since the device is Unobtainable, it may still be set to a previously requested setting: There may be no way to determine this from the In-station²¹ as the device/transponder may not be reporting back. Any secondary (lead-in, adjacent, transverse or downstream) settings sequenced from the settings on the unobtainable device will, however, be set on-street if the relevant devices are obtainable. At a gantry site, an unobtainable device may present a blank aspect whilst those on the lanes inside and outside that lane have some other aspect. Or, the unobtainable device may present an aspect that is at odds with those on the lanes in-side and outside it.

Conclusion:

As with Aspect Failures, it is considered that there would be an advantage in transmitting the setting update to the IVD irrespective of the Obtainability of the RSD. The difference in this instance is that since the transponder or LCC may be Unobtainable, it may not be feasible to control the transmission at the outstation level and, therefore, it might require that, in this instance, the Instation controls the transmission (i.e. commands to the Transmitter/Beacon) directly. Taken together with the analysis of Aspect Failures and Device Setting Status reporting, this suggests some built in redundancy that would enable paths to control the transmission of setting data.

4.4.3.4 Aspect Validation

If, for whatever reason (e.g. the site data is inconsistent), the Signal subsystem sends an invalid aspect to the Transponder, the Transponder will respond with an 'Invalid Setting' setting status. Though in theory the site data should be consistent, the site data consists of a large number of files and discrepancies between signal device/site definitions. If a setting sent from the Signal subsystem to the Transponder is rejected, does this presuppose that prior to sending a setting to the IVD, the setting needs to be validated by the associated signal Transponder? Does this require that the RSD's Transponder controls the transmission to the IVD? Essentially, this is treated as an aspect failure (see section 4.4.3.2 above).

²¹ There is no *automated* means of determining the setting on an unobtainable device: operators can be made aware of the setting on an unobtainable device by inspection of CCTV images or by reports from engineers at the roadside.

PART 4: TOP LEVEL SPECIFICATION OF THE FUTURE SYSTEM

5 IVD Functional Requirements

- R:1 The IVD shall be capable of processing all signal aspects codes, as per the SDIN (Standard Indicator) table of MCH1689, received from HATMS and displaying an appropriate In-Vehicle aspect for each (subject to compliance with regulations and further Human Factor analysis).
- R:1.1 At any given time, the IVD shall be capable of representing all lanes at any signal site. Subject to further Human Factors analysis, the representation may be either auditory or visual.
- R:2 The IVD shall be capable of displaying tactical, strategic, Driver Information and campaign messages to drivers. Subject to further Human Factors analysis, the representation may be either auditory or visual.
- R:3 The IVD shall be capable of displaying lane specific signal settings concurrently with messages.
- R:4 Where an RSD is faulty, the system shall communicate this to the IVD by means of an encoded field in the setting data message transmitted to the vehicle. The IVD shall be capable of processing this data and, subject to further Human Factors analysis, shall display the setting contained in the data and indicate the fault status of the RSD to the driver. This will ensure that he or she is aware that the IVD display overrides the faulty display at the roadside.
- R:5 The IVD shall be capable of processing signal aspect countdown data and executing aspect countdown sequences as defined in 4.3.3.1.3.
- R:6 The device should be informed of the current speed of the vehicle.

6 Architecture Requirements

6.1 Requirements for the Transmission System

- R:7 The system shall 'transmit' signal and sign setting updates to vehicles.
- R:8 Transmissions shall be localised and targeted (i.e. specific data to specific vehicles), to the extent that for any given signal or sign site, vehicles approaching that site (i.e. within a defined distance upstream of that site) shall receive the settings for that site but not for any other site.
- R:8.1 The system shall transmit signal and sign setting updates on a site by site basis (It should be noted that whilst there is a one-to-one correspondence between message sign sites and message sign devices, any given signal site may comprise one or more, up to a maximum of seven, signal devices).
- R:9 Signal and sign setting transmissions shall be repeated at regular intervals to ensure that, for any given site, vehicles approaching that site receive the settings on that site within a defined margin of distance upstream. A safe Margin of Distance is to be defined. The rate at which the system re-transmits setting data will be a function of the Margin of distance. If a safe margin of safety is defined as being within 10% of the distance between a signal site and the point upstream at which a driver under ideal conditions can first discern settings at the signal site downstream (so 30m if that distance is 300m) then the system would be required to re-transmit setting data every 0.97 seconds. This will ensure that a vehicle travelling at 70mph (31 m/s) is sure to receive every setting update.
- R:10 The layout of the transmission system shall ensure that setting updates clearing IVD settings are sent to vehicles that leave the motorway network via un-signalled exits.
- R:11 The layout of the transmission system shall be designed to ensure that vehicles entering the network at un-signalled entry points such as exits from service areas and ERA receive current settings for the section of road that the vehicle is entering.

6.2 Requirements for Modifications to System Architecture

- R:12 HATMS shall be modified so that transmissions to vehicles may be controlled either directly from the instation subsystem (i.e. the Signal subsystem for signal devices and the Message Sign subsystem for message sign devices) or directly from the outstation controlling the relevant roadside devices.

- R:12.1 When a roadside device is operational, i.e. obtainable, the instation shall send setting updates to the vehicles via the outstation. The outstation shall control the transmission of the setting data to vehicles so the presentation of information to drivers via the In-Vehicle device is timed to coincide with presentation of the same information on the roadside device.
- R:13 If the aspect fails to set on the roadside devices (e.g. due to a bulb failure) and if the outstation adapts the aspect (i.e. sets the alternative aspect to that aspect as defined in the outstation data) the outstation will control the transmission system to set the adaption aspect. If no aspect is set, the outstation shall control the transmission system to transmit the setting to the IVD irrespective of the setting on-street. In either case, the outstation shall ensure that the data transmitted to the vehicle encodes the fault status of the on-street device.
- R:13.1 If a roadside device is unobtainable, the Signal and Message Sign subsystems shall control transmissions to vehicles directly. Irrespective of the Obtainability of the RSD, the system shall transmit the setting for the device that was outputted from the Signal Sequencing rules. It is important to note that an unobtainable device may be set to the last setting requested before it went unobtainable. Irrespective of this, the Signal subsystem will continue to set settings on an obtainable device surrounding the unobtainable device. This can lead to on-street setting conflicts or the failure to provide adequate lead-in protection to restrictive settings. Therefore, in the setting data sent to the IVD, the system shall flag the RSD as unobtainable in order that the IVD may indicate to the driver the status of the roadside device and that the setting on the IVD overrides whatever aspect may be set on the unobtainable RSD.
- R:14 The Signal Sequencing Algorithm shall be modified so that appropriate gantry type settings are preserved when sequencing upstream from a Gantry site to a Carriageway site. This is in order convert wicket and other Carriageway settings to lane specific Gantry type settings, that are considered (subject to future Human Factor Analysis) more appropriate to IVD displays.

7 Data Requirements

7.1 Signal Setting Data

R:15 Signal Setting Data shall comprise of a packet of data corresponding to a signal site and will contain the following:

A field indicating the number of lanes at the site

1 to n Lane specific details each of which will comprise the following:

- The aspect to set on the IVD. Provisionally, a SAC value is considered appropriate.
- A Countdown sequencing for the aspect to set comprising the following:
 1. A value for countdown stage intervals
 2. The array of aspects in the sequence (order to be determined)
- A distance value used by the IVD to determine the point at which the setting on this lane should be cleared down automatically (e.g. in the case that there is a constriction downstream of the signal site where this particular lane will run out)
- A timestamp indicating the time at which the system set this lane setting. This field will be used by the IVD to determine at what stage in the countdown sequence it is appropriate to execute the countdown sequence in order to synchronise its aspect step-down with the step-down on the RSD.
- The fault status of the device. Values will be defined for this field that will be used by the IVD to indicate to the driver that a device is faulty, unobtainable or non-commissioned and, therefore, that the IVD display overrides the RSD display in the case that there is a discrepancy between the two.

A timestamp for the current system time, this shall be used to synchronise the IVD clock with the system clock and is necessary in order to ensure that countdown sequences are synchronised between the RSD and the IVD.

A count of downstream divergences

An Array of Downstream Divergence details each element of which would comprise the following:

- Lane specific settings for the downstream lanes
- GS coordinates for the entry point to the divergent carriageway

7.2 Message Signs Setting Data

R:16 Message Sign Setting Data shall comprise of a packet of data corresponding to a message sign site and will contain the following:

A field indicating the length of text.

A field indicating the message number. May be used by the IVD to display a pictogram from a pre-configured IVD lookup table.

A field indicating the message category. May be used by the IVD to overwrite a message of one category with that of another, e.g. it is assumed that Tactical messages would overwrite campaign messages.

A field indicating the message duration

A distance field used by the IVD to determine the point downstream of a signal site at which the IVD will automatically clear the setting down. A zero value could indicate that the setting is not cleared automatically.

A field containing the message text. May be used by the IVD to display text or to associate key words in the text with a pictogram in a pre-configured IVD lookup table.

A timestamp for the current system time, this shall be used to synchronise the IVD clock with the system clock and is necessary in order to ensure that countdown sequences are synchronised between the RSD and the IVD.

PART 5: HUMAN FACTOR CONSIDERATIONS

8 General

The analysis has identified a number of human factor considerations (HFC) that will need to be taken forward for future analysis.

The attention, physical or visual demands that in-vehicle device information places on the driver will have a significant influence on the degree to which interaction with this device information will distract drivers. Interaction with device information that places little demand on drivers may be able to be effectively time-shared with the driving task, resulting in little or no degradation in driving performance. In terms of in-vehicle information and technologies, one factor that influences task demand characteristics is the physical design of the information display and interface.

Another factor, often closely linked to interface design, that can influence the distraction potential of in-vehicle devices is the type and complexity of the task engaged in. For example, the demands of the driving task itself, such as increases in traffic density and the complexity of the traffic environment, can also influence the distracting effects of in-vehicle information.

In addition, there is a large body of evidence that suggests driver characteristics can influence the relative distracting effects of in-vehicle devices, for example, older people have a decreased ability to share their attention between two concurrent tasks due to their decreased visual and cognitive capacity and, hence, they may be more susceptible to the distracting effects of using a device while driving than younger drivers. Similarly, young novice drivers may also be relatively more vulnerable to the effects of distraction than experienced drivers.

The HFC are highlighted below.

9 Parity of road side device and in-vehicle device

Are drivers able to automatically associate the lane by lane information on the IVD with the actual lane configuration, and can drivers be relied upon to do this?

An extreme example would be a tidal/contra flow sites where there can be up to seven lanes across both carriageways. A similar system could be introduced at any point to MM. In such situations, is it required that the vehicle knows which lane it is on and emphasises the lane number by, for example, highlighting that lane's detail on the IVD lane display array (assuming it will be a lane array)?

Consideration would need to be given to the provision on an auditory alert for change of lane status (i.e. speed limit change), to ensure the change is noticed by the driver.

10 Messages

10.1 Message duration

How long should messages persist on the IVD? Signal settings on the IVD might be expected to persist until they are automatically updated or cleared by the system.

- Should messages persist on the IVD display until explicitly cleared by the system?
- Should tactical, strategic and other categories of information be considered separately in this respect? i.e. should tactical messages persist until cleared by the system directly whereas strategic messages are timeout by the IVD?
- To what extent should the system retain control over the length of time that a message is displayed?

IVD displays are assumed to be 'intrusive' to the drivers 'personal space' in a way that RSDs are not. Would persistent or prolonged display of strategic and other non-tactical messages provide an unwelcome distraction to drivers? Could data be provided to the IVD that would enable the IVD to filter out strategic information that do not apply to his/her planned journey?

To replicate the 'persistence' of tactical messages, should IVDs display messages until the system commands them to clear or would it be sufficient for the IVD to time messages out after a defined period (e.g. after 27 seconds – the approximate time it takes a vehicle travelling at 50 mph to travel the distance between two gantries 600m apart) such that the IVD would be updated with the downstream message before the previous message had timed out?

The system would need to give the driver some type of warning that they are coming up to another gantry/'information stage'/about to be given information so they can prepare to receive it and prepare expectations for the consequences. For example, a driver can see a gantry from some distance away. As a driver travels closer to the gantry they will be able to judge that the messaging sign contains information, but they will not be able to read it. They may be forming expectations and judgements about what the message display contains and are preparing to read it and change their driving behaviour (as a consequence of the information) as they approach. If information is solely coming from the in-vehicle system display and there is no warning that the information is to be expected at a certain point in time, the driver's attention and behaviour may be affected negatively.

Would the IVD be required to display concurrent messages of different categories together, or could this possibly overload the driver with too much information and therefore be a source of distraction?

We would need to consider the way in which the information is displayed, e.g. alternating between information (30mph held for 3 seconds, followed by 'accident delays junction 23-25' held for 3 seconds), or different information screens etc. Drivers would need to be able to change the preferences for this display and to toggle between/hold the information that they are particularly interested in.

11 Flashers

11.1 Message sign flashers

Should the IVD replicate message sign flashers or would they be too distracting to the driver?

If flasher functions are required in-vehicle, should HATMS retain control of flasher synchronisation or can this functionality be specified for the IVD?

If flashers are controlled by the IVD then there is the possibility that flashers in the vehicle and flashers on RSDs may not be synchronised.

All of these display variables would need to be examined during the early stages of a user trial.

11.2 Signal flashers

As with message sign flashers, should the flasher function be replicated on the IVD display?

Would non-synchronization of IVD and RSD flashers cause the driver to be distracted?

These display variables would need to be examined during the early stages of a user trial.

11.3 Message sign flasher synchronisation

What is the position on message flashers contra signal flashers?

12 Built in delays

The future system may offer an advantage in that it can ensure that the pattern of signal settings presented to the driver is consistent with the rules irrespective of the settings at the roadside. How does this accord with the principle that the RSD settings have primacy of IVD settings? In this instance, the safety case may outweigh that principle.

We would need to ensure that the RSD settings are correct and make sure they are as accurate as the in-vehicle information. Presumably the information for the IVD will be coming from the same databases as the RSD info so they should match each other and best practice?

13 Signal subsystem processing of wicket aspects

Assuming a visual display, should IVDs always mirror the RSD and display wicket type aspects, or should the In-Vehicle display always show lane specific settings?

The driver needs the cues about the surrounding lanes in order to be able to make decisions on lane changes etc. The way in which this information would be best displayed would need to be tested during the early stages of a user trial.

14 Summary comments on Human Factor Considerations

In-vehicle information systems have the potential to enhance safety, mobility and efficiency of driving, but there are concerns that the sheer number of devices making their way into the vehicle and their expanding functionality will overload drivers and distract them from the primary driving task. These concerns are based on the growing body of research indicating that use of some in-vehicle devices impairs driving performance and safety. Adding to these concerns is that there has been a general lack of consideration of the capabilities and cognitive limitations of drivers in the design of many in-vehicle systems. That is, the design of in-vehicle systems has been largely technology-driven, rather than user-driven.

The control activities and information provided by in-vehicle devices can become distracting if they divert the driver's attention or vision away from the driving task and/or interfere physically with the operation and control of the vehicle. Generally, the distraction deriving from in-vehicle devices can increase if:

- visual displays and their controls are poorly located, away from the driver's normal line of sight (therefore Head Up display may be a useful method);
- if the information displayed by the system (whether it be visual, auditory or tactile) is poorly designed, requiring excessive visual and/or cognitive attention to extract the required information; and
- if the system controls are poorly designed, such that use of them requires excessive visual and/or cognitive attention or physically interferes with driving.

Researchers and system developers acknowledge that distraction becomes less of a problem if in-vehicle systems are designed in a manner that is compatible with driving. To be compatible with driving, systems must be properly integrated within the driver-vehicle-system. Effective driver-system integration requires the application of human factors (or ergonomics) to make devices that are user-friendly and take account of human capabilities and limitations.

Vehicle manufacturers and system developers around the world are now putting considerable effort into ensuring that technologies introduced in the vehicle cockpit are designed in accordance with emerging human factors standards and guidelines for the design of these technologies.

Vehicle manufacturers and system developers have used, or proposed a number of design approaches for their in-vehicle systems in order to minimise their potential to distract drivers. These techniques include voice-recognition technology, touch screens, tactile interfaces, steering wheel controls, Head up Displays (HUDs), and workload managers/adaptive integrated interfaces.

Therefore, there is scope for adopting the best practice human factors principles that have been determined and applied by the international vehicle manufacturers and system developers in the development of this system.

In addition, there is a large body of evidence that suggests driver characteristics can influence the relative distracting effects of in-vehicle devices, for example, older people have a decreased ability to share their attention between two concurrent tasks due to their decreased visual and cognitive capacity and, hence, they may be more susceptible to the distracting effects of using a device while driving than younger drivers. Similarly, young novice drivers may also be relatively more vulnerable to the effects of distraction than experienced drivers.

PART 6: CONCLUSION

15 Summary

15.1 The Aim

The aim of this analysis has been to understand the current objectives for the provision of information to drivers on Managed Motorways and derive a set of top level requirements for modifications to the Highways Agency Traffic Management System enabling roadside and in-vehicle technologies to coexist in fulfilment of these objectives information objectives. These top level requirements relate to the following:

- The functional behaviour of the system,
- The architecture of the system, and
- The data that will be passed between the HATMS infrastructure and vehicles.

15.2 The Guiding Principles

Guiding the analysis has been a set of principles designed to ensure that:

- The safety case for the current system, whether implicit or explicit, will be maintained;
- The future system will retain control of the content of information that is conveyed to motorists, including the timing of the display of that information;
- As far as possible the design of the system is elegant and simple;
- Conflict between in-vehicle and roadside technologies will be avoided;
- Displays (whether visual or auditory) on In-Vehicle devices (IVDs) shall achieve parity with roadside devices in terms of content and timing;
- The quality of Managed Motorway information shall be maintained. By 'quality' here is meant the degree to which information provided to drivers enables them to make informed decisions so that the objectives of any given operational regime can be achieved safely and with minimal disruption to traffic flow. For example, on the current system, when a vehicle approaches a signal gantry, the driver is presented with lane specific signal settings for all lanes at that location. The driver is therefore able to make an informed choice about the speed of his approach, about lane changes that he should or should not make and about restrictions on other vehicles with which the driver must interact. The future system shall enable the same degree of decision making: this is pertinent to both the concurrent phase wherein roadside and in-vehicle technologies will coexist to fulfil the same function and to the ultimate phase wherein this function may be fulfilled by In-Vehicle devices alone;
- At this early stage in the initiative, the analysis shall aim to derive requirements that are independent on any particular technological solution. So:

- *Example 1:* Subject to further Human Factors analysis, it may be necessary that the display on an In-Vehicle device should represent not only signal settings for all lanes but also represent the vehicle's transverse location, i.e. the lane in which the vehicle is currently travelling (see Figure 41 and Figure 42).



Figure 41: IVD Display representing vehicle's current lane ('Lane below Signal' 3)



Figure 42: IVD Display not representing vehicle's current lane

It is difficult to imagine how HATMS could actively communicate the vehicle's current lane to the vehicle: it is assumed that the vehicle must determine this by some other means. However, it is not assumed that the vehicle will do this by means of satellite global positioning technology: for example, in the future it may be possible for the vehicle to achieve this by scanning road markings just as humans do.

It is sufficient for this project that the specification is such that HATMS shall provide IVDs with all lane settings at the relevant location. It shall be up to IVD manufacturer to determine how this information shall be presented in accordance with future Human Factor requirements.

- *Example 2:* It is a given that In-Vehicle devices will 'receive' data by means of some form of 'wireless technology'. However,
 - No assumption shall be made as to the wireless media, and
 - No assumption shall be made as to whether the system automatically delivers ('pushes') data to the user or whether the vehicle itself requests ('pulls') data from the system.

15.3 Conduct of the Analysis

Guided by the principles described above, the analysis has been conducted on the basis that the future system will comprise three major functional and/or architectural components. These are as follows:

- **The IVD displays:** What are the Human Factor issues surrounding these and what are the relevant constraints will the resolution of these issues impose on the future system?

- **Infrastructure to vehicle data transfer functionality:** What will be the relevant constraints or 'data dependencies' imposed by the *method* of transmission? For example, what would be the implications of a system that entailed broadcasting all data to all vehicles rather than targeting vehicles at on a location by location basis? Conversely, what constraints are imposed by the operational requirements of the system on options for 'transmission'?
- **HATMS Architecture:** what are the relevant constraints or 'data dependencies' imposed by the current functional requirements of the system embodied in system architecture?

The investigation of each of these areas has revealed a set of constraints that, broadly speaking, fall into four major categories. These are as follows:

- **Performance Constraints:** Constraints relating to requirements for system throughput of signal and sign setting requests and the implications of these for the volume of data that requires to be processed;
- **Functional Constraints:** Constraints relating to specific functionality. Sometimes these are integral to system architecture, for example, the current communications network architecture entails that instation control systems are required to retry control of outstation equipment and wait out the response before the on-street setting status of a device can be confirmed by the instation. Given the principle of maintaining parity between in-vehicle and roadside displays this is a significant feature of the architecture that requires to be considered if hysteresis between roadside and in-vehicle displays is to be kept within an absolute margin of safety. Section 4.4 discusses these issues in detail;
- **Geometric Constraints:** Constraints relating to the actual layout of the road network. These impose specific functional and performance requirements on IVDs. For example, downstream divergences, un-signalled exits and constrictions (due to lane hatching, the end of a Hard Shoulder Running scheme or simply a reduction in the number of lanes) require special handling by IVDs if the IVD is to correctly represent actual on-street restrictions and if drivers are to respond intuitively to the IVD in the way that they respond intuitively to information provided by means of static roadside displays. Section 4.3.3 analyses these issues in detail;
- **Human Factor Constraints:** Constraints relating to the way information must be presented to drivers. The example already given is of need for the system to enable informed choices with respect to lane changes. Similarly for message settings: Messages may fall into one of either Tactical, Strategic, Driver Information and Campaign message categories, each of which has a level of priority associated with it, but it is a Human Factor consideration as to the way this information should be presented in the vehicle. The significant point here is that a VMS (Variable Message Sign) site may be dedicated to messages of one or other of these categories. Since, then, on any given section of motorway, VMS dedicated to different categories may be interspersed with one another such that drivers may receive different messages but that obtain at the same time and for

the same section of road (unlike signal settings where a signal setting always overrides, or 'updates', the setting previously seen at upstream). The consideration is, then, what would be the effect on the driver if this information was presented in *the vehicle*. This is certainly a Human Factor issue, but it is sufficient for this project that data conveyed to the vehicle should enable the IVD to store and prioritise messages relevant to the section of road along which the vehicle is travelling. Again, it shall be for the IVD manufacturer to determine how this information shall be presented in accordance with future Human Factor requirements.

15.4 Towards a Specification of the Future System

From these constraints top level requirements have been derived for changes to the current system and for the structure of data that will be conveyed to vehicles. In essence, the system shall comprise a system of roadside data 'providers' controlled directly from HATMS and targeting vehicles at specific locations. These locations shall correspond to:

- Roadside signal and sign sites where roadside signal and sign sites exist, and
- Strategic locations on 'clean' (i.e. free of roadside signal and sign infrastructure) sections of motorway identified on the basis of general siting requirements for signal and sign sites

The data itself shall enable full display of all lane specific signal settings for any given location and all messages relating to the current section of motorway along which a vehicle may be travelling. The data shall enable the IVD to:

- Store and prioritize concurrent messages that apply to a given section of road,
- Clear down a message after a certain distance or duration,
- Redisplay a message that may have been displaced by a message of higher priority that has subsequently been cleared,
- Clear down a signal setting after a certain distance or duration, and
- Determine the appropriate signal settings to display when the on-street lane configuration changes or when the vehicle enters one of several alternate divergent carriageways.

This specification assumes that the vehicle will be able to determine, by some unspecified means, both its longitudinal and transverse location with respect to the carriageway.

Complex RSD flasher lantern functionality, intended to alert drivers to signal and sign settings on display, is considered to have particular Human Factor implications for the in-vehicle environment. It is considered that this functionality is best defined through Human Factor analysis and that no specific provision should be made in this specification.

16 The Road Ahead

16.1 Time Lines

Towards the end vision there will be an interim period of concurrent roadside and in-vehicle provision of Managed Motorway information before that vision of fulfilling the objectives for this information by means of In-Vehicle devices alone can be realised. Not least among the reasons for this is that the fulfilment of these objectives, and of the implicit safety case, will need to be infallibly proven before the system of roadside infrastructure can begin to be replaced. Figure 43 below illustrates the transition to the end vision through three successive phases. These are:

- *Phase 1: Preparation* (the current phase)
- *Phase 2: Concurrent Technologies*
- *Phase 3: In-Vehicle Technologies only*

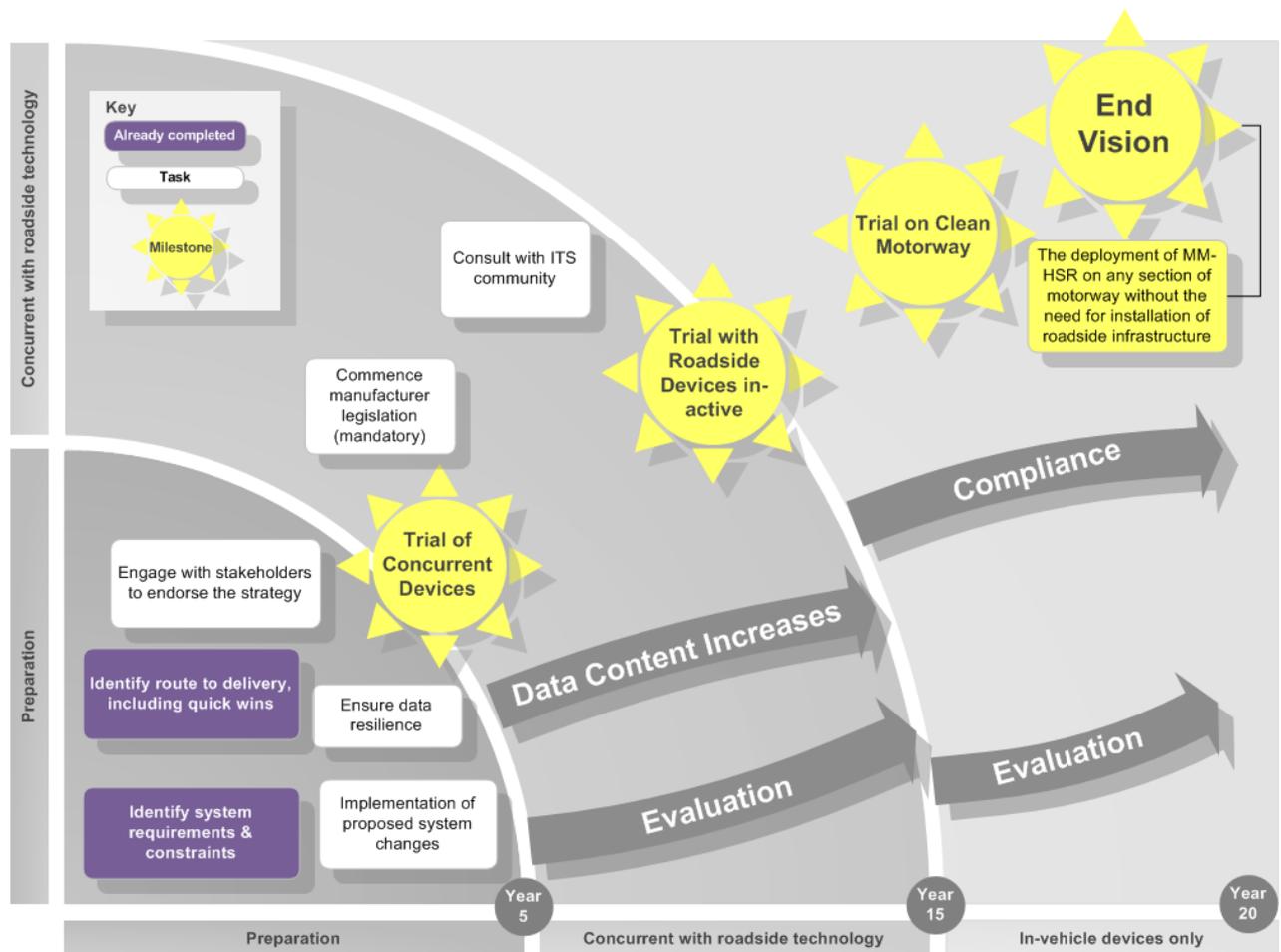


Figure 43: Transition Map

As can be seen in Figure 43 each of these phases culminates in a milestone arranged in a logical sequence. However, it should be noted that concurrency of technologies does not rule out utilising IVD technology in Phase 2 of the development to full effect on sections of motorway where there is currently no roadside signal and sign infrastructure. Indeed, though a communications system is yet to be specified and Human Factors analysis to be completed, such is the confidence that Managed Motorway information objectives can be fulfilled by means of in-vehicle technologies that it is envisaged that IVDs could be deployed relatively quickly.

16.2 Implementation

A significant proportion of the analysis is dedicated to investigating the way in which parity between IVD and RSD displays can be achieved. This is because within the scope of this project, the issue of parity is the most problematic. However, it should be noted that the specification of data in this report does not derive substantially from considerations of parity: performance requirements for signal and sign setting throughput, requirements for the handling of road geometry and Human Factor requirements such as countdown sequences, display of all lanes and message priorities, are the major determining factors in the specification of data. These factors remain the same irrespective of whether or not RSDs and IVDs are required to co-exist. Likewise, signal and sign setting throughput and the various geometric considerations have been the major determining factor in arriving at the requirement for a localised-targeted system of communications between infrastructure and vehicles. By way of contrast, the major outcome of the analysis of Parity is the requirement that where both roadside and in-vehicle technologies are utilised on the same section of motorway, then in those situations, under normal operation (i.e. fault free), communications to the vehicle must be controlled from the roadside device controller²² itself rather than from the instation.

The schematic in Figure 44 below represents communication pathways between the instation and both RSDs and IVD data senders during Phase 2. Figure 45 shows the relevant pathways in Phase 3. The important point to note with respect to modifications that would be required to effect the transition from Phase 2 (concurrent phase) to Phase 3 (IVD only phase) is that the scale of these modifications is not great. In fact, the pathway to IVDs in Figure 45 is representative of how the redundant pathway between the instation and the data sender shown in Figure 44 would be utilised during the concurrent phase to communicate with vehicles on sections of road where there is no roadside signal and sign infrastructure. In implementation terms then, the transition from Phase 2 to Phase 3 is envisaged as relatively straightforward.

²² The generic term 'Device Controller' is used to describe software/hardware that drives settings on signal and sign devices directly.

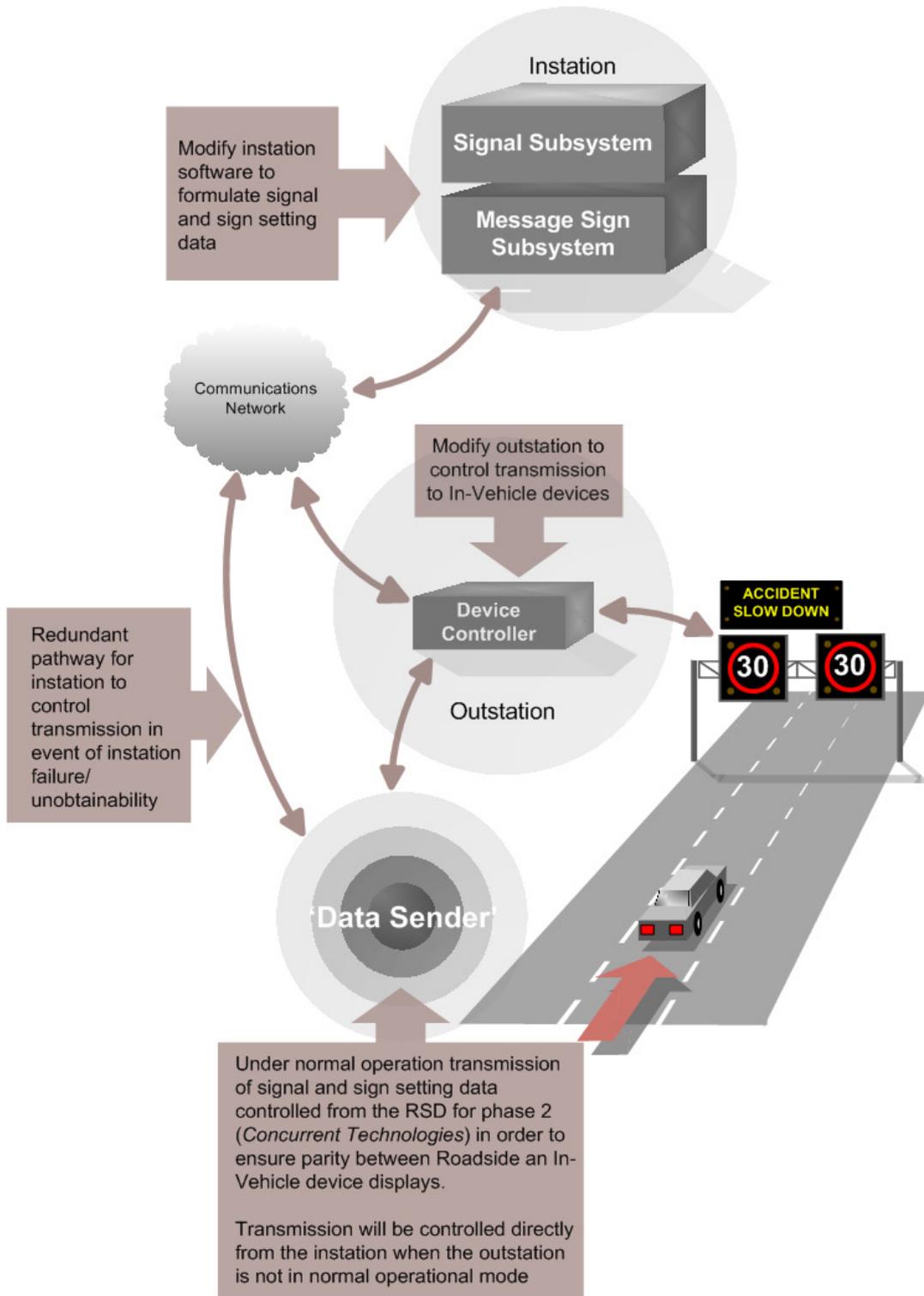


Figure 44: Controlling communications with vehicles – Phase 2 / Concurrent Phase

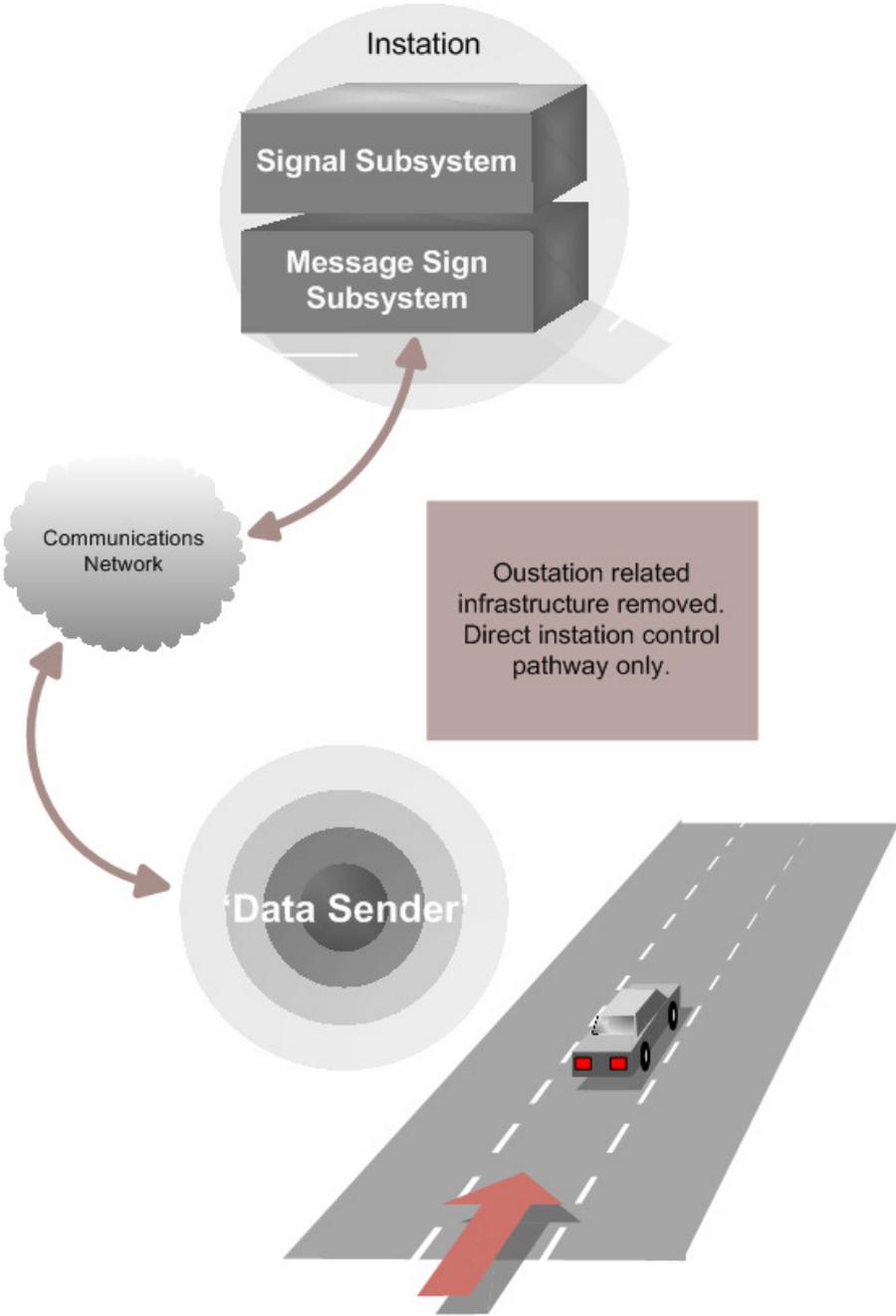


Figure 45: Controlling communications with vehicles – Phase 3 / IVD Only Phase

17 Conclusion

This project has provided a comprehensive analysis of the how the requirements for the current system would need to change when applied to future in-vehicle provision of Managed Motorway information. The analysis has shown that integration of vehicles into the HATMS system in fulfilment of the objectives for this information is technically achievable and relatively straightforward.

This study is the first step towards that integration and a future wherein MM-HSR (Hard shoulder Running) schemes may be added or extended without the need for additional expensive, energy consuming, difficult to maintain and visually intrusive roadside infrastructure. This is a future that will provide an enhanced and greatly more flexible approach to traffic management whilst retaining the current system's safety integrity proven over many years of operation.



APPENDICES

Appendix A: *Glossary and List of Abbreviations*

3L-VMSL	3 Lane Variable Mandatory Speed Limit, i.e. speed on the 3 running lanes must have been reduced to an agreed threshold (currently 50 mph but this is dependant on local factors, such as topology)
4L-VMSL	4 Lane Variable Mandatory Speed Limit: i.e. Hard Shoulder open for running
AID	Automatic Incident Detection
AMI	Advanced Motorway Indicator
ATM	Active Traffic Management.
Block	A section of carriageway between two Geographic addresses. If there could be multiple routes between the two addresses (eg clockwise and counter-clockwise on a circular route), a third Geographic Address is specified to identify a unique route.
Broadcast transmission system	A system that transmits all data to all vehicles on the network or about to enter it.
CMI	Controlled Motorway Indicator
COBS	Control Office Area Base System. That part of the instation which performs those functions which are common to all NMCS2 systems. Includes the Operator Interfaces (OI).
CVHS	Cooperative Vehicle Highway System
EMI	Enhanced Matrix Indicator. A matrix signal which has additional aspects for use on four lane carriageways. EMI are mounted on Cantilevers only. When used in conjunction with an Enhanced Message Sign (EMS), it forms a Motorway Signal Mark 2 (MS2).
EMS	Enhanced Message Sign. A sign which is used to display a variety of legends or messages. The legend or message is controlled from the instation. EMS has 2 rows of 12 characters. Can be mounted on a gantry or cantilever.
ERA	Emergency Refuge Areas
ERT	Emergency Roadside Telephones.
FTMS	Fixed Text Message Signs: are any type of VMS that display two or more fixed legends (or a blank display and one or more legends)
HALOGEN	Highways Agency Logging Environment. Halogen is the Highways Agency central source for HATMS logged data. This includes data such as matrix and variable message sign settings, Emergency Roadside Telephone and equipment faults and locations of equipment on the English motorway network.
HATMS	Highways Agency Traffic Management Systems.
HDLC	A protocol, at link level, which forms the basis of all inter-station communications on the NMCS2 data system, Closed Circuit Television (CCTV) system and the Regional Communications Controller (RCC) network. When each station communications link is set up, point to point or multi-drop, the delivery, security and integrity of each frame of data is

assured.

HDLC is the basis of a family of protocols which form the main data highway(s) for communication between Data Base Processor, Local Communications Controller, Regional Communications Controller and Transponders providing the packet message handling network.

HFC	Human Factor Consideration
HS	Hard Shoulder
HDS	Highest Displayable Speed. A value can be assigned to a site or block of sites that is used by the Signal Sequencing Algorithm to commute any speed restriction requested by the operator or automatic subsystem to the HDS value if the requested setting is less restrictive than the HDS value for the relevant site. E.g. If the HDS at a given site is 40 mph and the operator requests a setting of 50 then SSA will commute the requested 50 to 40. SSA will also apply the HDS value assigned to a site where the Rules generate a secondary setting at that site.
HSD	Hard Shoulder Divert. Appears on-street as: 
HSR	Hard Shoulder Running
I2V	Infrastructure to Vehicle
I2VT	Infrastructure to Vehicle Transmitter: Will transmit data conveying MM information from HATMS to vehicles
In-boundary	Within control of the local RCC
Instation	Those parts of the National Motorway Communications System (NMCS) which are normally located within the Control Office. See also Outstation. Often referred to as the building which contains the Control Office and provides an office type environment for equipment sited at the instation.
IVD	In-Vehicle Device: In-Vehicle device that will 'display' MM information to divers. Whether the 'display' is visual or auditory is yet to be determined.
LAN	Local Area Network
LBS1	Lane below Signal 1: is the hard shoulder for MM-HSR sections. Normal running lanes begin at LBS2.
LCC	Local Communications Controller
LDL	Lane Divert Left: appears on-street as 
LDR	Lane Divert Right. Appears on-street as 
Localised transmission system	A system that transmits data pertaining to a specific location to vehicles at or approaching that location
MDVL	Motorway Divert Left. Appears as: 

MDVR	Motorway Divert Right. Left. Appears as: 
MIDAS	Motorway Incident Detection and Automatic Signalling. A Control Office Base System (COBS) Subsystem which monitors traffic flow conditions and interacts with signal Subsystems to automatically set signals without operator intervention. Signals are set when queuing traffic is detected.
MM	Managed Motorway
Motorwarn Signals	Comprises two amber lanterns, one mounted vertically above the other, on a black backboard. The amber lanterns flash alternately.
MS2	Motorway Signal Mark 2. A motorway signal comprising an Enhanced Matrix indicator (EMI) and an Enhanced Message Sign (EMS) mounted on a cantilever structure.
MS3	Motorway Signal Mark 3. There are two types, the first consists of two lines of 12 text characters (2x12) and are mounted on portal gantries. The second type are normally mounted on a cantilever & combines Message  Sign and an Enhanced Matrix Indicator
MS4	 Motorway Signal Mark 4.
NMCS2	National Motorway Communications System 2. A system using locally based distributed processing to control telephones and signals, installed from 1988.
Outstation	Site installations outside computer centres and Control Offices, set up at convenient positions along the motorway to house communications equipment, such as Responders, distributors, signal controllers, signal switches, connectors, terminal panels, and power supply units.
FOP	First Observed Point -The optimal distance upstream of a signal or message sign site from which a driver first determines the setting on display on the RSD.
RCC	Regional Control Centres. The Highways Agency motorway network is divided between 7 RCCs. These are Eastern RCC (ERCC), South Eastern RCC (SERCC), North Eastern RCC (NERCC), South Western (SWRCC), North Western RCC (NWRCC), West Midlands RCC (WMRCC) and East Midlands RCC (EMRCC).
RMC	Regional Maintenance Contractor.
RSD	Roadside Device: Gantry, post and cantilever mounted variable message signs and signals

SAC	Standard Aspect Code. A unique number assigned to each signal setting. The actual appearance of the resultant aspect when set on-street may be the same for two or more different SACs. E.g. Hard Shoulder Divert (HSD: SAC=54) and Lane Divert Right (LDR: SAC=14) is identical (■). The significance of the SAC value is that it is used internally for special processing. In this instance, when HSD is processed by the Signal Sequencing Rules, the rules will generate a speed restriction of '60' at the lane outside the HSD, whereas processing of LDR would normally result in a 40 being set.
Safety Related	Applies to hardwired or programmable equipment where a failure, singularly or in a combination with other failures/errors, could lead to death, injury or environmental damage.
Signal site	Consists of one or more RSDs
SSA	Signal Sequencing Algorithm
TCCI	Traffic Control Centre Interface
tDL	Tidal divert left. Appears on-street as yellow: 
TPR	
TSRGD	Traffic Signs Regulations and General Directions.
V2I	Vehicle to Infrastructure. As in V2I integration.
VIC	Vehicle Infrastructure Conflict: When there is a mismatch between settings displayed In-Vehicle conflict and those on roadside devices.
WOIF	Windows Operator Inter-Face
Zone based transmission system	A combination of a broadcast transmission system and a localised transmission system.

Appendix B: *HA & DFT Document References*

DMRB Vol. 8, Sect, 2, Part 2	The Use of Variable Message Signs on All Purpose and Motorway Trunk Roads
DMRB Vol. 9, Sect, 1, Part 1	Motorway Signalling
DMRB Vol. 9, Sect, 2, Part 1	Motorways - Introduction
DMRB Vol. 9, Sect, 1, Part 2	Criteria for the Use of Gantries for Traffic Signs and Matrix Signals on Trunk Roads and Trunk Road Motorways
DMRB Vol. 9, Sect, 4, Part 1	National Motorways Communications System
DMRB Vol. 9, Sect, 4, Part 3	Motorway Signalling
DMRB Vol. 9, Sect, 4, Part 6	Guide to the Use of Variable Message Signs for Strategic Traffic Management on Trunk Roads and Trunk Road Motorways
IAN 111/09	(Interim Advice Note) Managed Motorways Implementation Guidance: Hard Shoulder Running
IAN 112/08	(Interim Advice Note) Managed Motorways Implementation Guidance: Through Junction Hard Shoulder Running
MCE 2103, O	The Signal Sequencing Rules Specification
MCE2214, B	NMCS2 Message Signs & Motorway Signals Mk 4 (MS4) Requirement for Signal Equipment (Display and Communications Electronics)
MCH1618, C	NMCS Technical Overview
MCH1655, F	NMCS2 Overview of the NMCS2 Message Sign Subsystem
MCH1689, H	NMCS2 Data System Message & Site Data Header Code Register
MCH1700, D	Compiling Site Data for the Highways Agency Traffic Management System
MCH1726, F	NMCS2 Message Sign Subsystem Site Data Document
MCH1748, F	NMCS2 System Data Organisation & Format
MCH1798, F	NMCS2 Signal Subsystem Specification Data Organisation & Format

MCX0027Z1	Indicator type 400 Series Aspects
MCX0921A001	CMI Aspects
MCX0931A001	AMI Aspects
Managed Motorways Operational Guidance	Managed Motorways Delivery Office: Operations Group v1.0 - 2nd November 2009
MANAGED MOTORWAYS - GENERIC SAFETY REVIEW	MANAGED MOTORWAYS -GENERIC SAFETY REVIEW 718471/DOC/201 Issue B, March 2009
Future Scenarios and Technology Road Map	Work Package C1 Future Technology v4.0.doc (5073144_04_04_3_002)
TR1100, D	General Specification for Motorway Signs , Signalling and Communications Equipment
TR2045, H	NMCS2 Standard Transponder
TR2070, H	NMCS Message Control Point to Point
TR 2072, F	NMCS2 Signal Subsystem Specification
TR2139, F	NMCS2 Message Sign Subsystem Specification
TR2142, F	NMCS2 Message Control Message Sign Equipment
TR2163, D	NMCS2 Message Sign Subsystem Rules Specification
TR2195, E	NMCS2 Message Signs & Motorway Signals Mk 3 (MS3) Requirement for Signal Equipment (Display and Communications Electronics)

Appendix C: *Managed Motorway Information Objectives*

Objective Category	Objective / Requirement	Characterisation as a System Comprising Various Device and Site Types	Characterisation as a System Targeting Specific Device/Site Types	Characterisation as a Physically Integrated / Wired-In Device	Characterisation as a Visual Display at a Static Site	Characterisation as a Display at a Site Spatially Linked to Lanes	Consideration for Moving Devices
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Objective Category	Objective / Requirement	Characterisation as a System Comprising Various Device and Site Types	Characterisation as a System Targeting Specific Device/Site Types	Characterisation as a Physically Integrated / Wired-In Device	Characterisation as a Visual Display at a Static Site	Characterisation as a Display at a Site Spatially Linked to Lanes	Consideration for Moving Devices																
<p><u>Operational Performance</u></p>	<p><u>VOLUME OF DATA / RATE OF SIGNAL PROPOSAL THROUGHPUT</u></p> <p>The performance criteria for the system, in terms of the rate of throughput signal setting proposals, are not specified. However, tests conducted at Serco (the maintenance contractor for the Signal subsystem) have established performance benchmarks against which the system can be evaluated as it evolves. Demands on the system are likely to increase as Managed Motorways (MM) schemes are extended and new schemes introduced.</p> <p>At the time of collating the metrics the only MM Scheme in operation was the M42 trial in the West Midlands ATM RCC (Active Traffic Management Regional Control Centre). At this time the trial was managed via a relatively small control office not yet remerged into WMRCC (West Midlands RCC). Routine operations at Eastern RCC (ERCC) incorporates a large section of the M25. This places a heavy demand on the control systems at peak rush hour and therefore provided a better indication of the likely peak operating demands.</p> <p>At peak operation at a busy RCC, The Signals subsystem is required to process signal setting requests generated by MIDAS (Motorway Incident Detection and Automatic Signalling) alerts around the RCC network at a rate in excess of 1.6/sec. In support of this, the following statistics were obtained from the LAN Audit Trail on the MIDAS subsystem and corroborated by Halogen (HA Logging Environment) records.</p> <table border="1"> <thead> <tr> <th colspan="4">ERCC, 10/09/07, 0500 – 1130 Hrs SIGNAL PROPOSAL THROUGHPUT</th> </tr> <tr> <th colspan="4">Set Device Requests (LAN=24H) Sent from MIDAS to Signals</th> </tr> <tr> <th>Time</th> <th>SDRs/10 Minute Interval</th> <th>Time</th> <th>SDRs/10 Minute Interval</th> </tr> </thead> <tbody> <tr> <td> </td> <td> </td> <td> </td> <td> </td> </tr> </tbody> </table>	ERCC, 10/09/07, 0500 – 1130 Hrs SIGNAL PROPOSAL THROUGHPUT				Set Device Requests (LAN=24H) Sent from MIDAS to Signals				Time	SDRs/10 Minute Interval	Time	SDRs/10 Minute Interval					<p>Maximum number of in-boundary devices per RCC = 5000. Maximum Number of In-Boundary Sites per RCC = 5000 Maximum devices and sites including over-boundary per RCC = 6200.</p>	<p>N/A</p>	<p>The Signal subsystem will sequence each setting request in turn and target the specific devices that are the subject of each sequenced proposal via HDLC link (future TCP/IP). Current system architecture allows throughput of signal settings at the requisite rate. This is aided somewhat by the division of the HA's motorway network into the various RCCs, each with its own dedicated control system hardware.</p> <p>Recent tests showed that at near maximum possible loading, i.e. with settings on every in-boundary device in ERCC (under factory conditions) site data, Signal Subsystem version A9.4.1 processed setting requests at a rate of 1.89/sec. At</p>	<p>N/A</p>	<p>N/A</p>	<p>The rate of signal setting updates in any given 1 second interval is potentially large (in relative terms). The updates pertain to the RCC area as a whole so during that 1 second interval most of the data will not be relevant to a given vehicle at a given location. If the transmission system deployed is a 'broadcast' mechanism does this presuppose Intelligence in the IVD that can filter the incoming data and process only that which is applicable to the vehicles location? Would the IVD be required to store all the data between updates so that the IVD can update its display as appropriate as it travels through the network? What of signal and sign settings that were updated before the vehicle entered the network: how would the IVD be updated with these?</p> <p>Do these considerations suggest that a transmission system that 'broadcasts' setting updates to all vehicles is not feasible? Do they not, rather, suggest that a targeted and localised (i.e. setting data pertaining to signal sites in proximity to the vehicle) short-range transmissions would be more practicable. Key considerations here are:</p> <ol style="list-style-type: none"> 1. If a broadcast mechanism is used, would broadcasts be network wide? If they are not network wide, is it possible to broadcast to an area mapping exactly to an RCC boundary in such that they do not interfere with broadcasts to other boundaries – would the system
ERCC, 10/09/07, 0500 – 1130 Hrs SIGNAL PROPOSAL THROUGHPUT																							
Set Device Requests (LAN=24H) Sent from MIDAS to Signals																							
Time	SDRs/10 Minute Interval	Time	SDRs/10 Minute Interval																				

Delivering Managed Motorway Information to In-Vehicle Devices: Analysis Report

1st issue

Objective Category	Objective / Requirement				Characterisation as a System Comprising Various Device and Site Types	Characterisation as a System Targeting Specific Device/Site Types	Characterisation as a Physically Integrated / Wired-In Device	Characterisation as a Visual Display at a Static Site	Characterisation as a Display at a Site Spatially Linked to Lanes	Consideration for Moving Devices
	05:40	0	08:40	93			this extreme loading, the Signal subsystem was still able to process setting requests at a rate higher than the rate at which MIDAS was sending them. Allowing for a margin of safety that requires Signals to process setting requests at ten times the observed peak rate of MIDAS setting requests, Signals is just able, under near maximum loading with extant settings, to process those requests faster than they are received. Any significant increase in the size of the RCC will, under this loading, result in delays in processing setting requests.		<p>be required to update the IVD with a new frequency as the vehicle crosses an RCC boundary?</p> <p>2. If a broadcast mechanism is used how would it ensure that all vehicles receive current data? What of a vehicle that has only just entered the network, or one that has stopped at services and has now re-entered the network: how would these vehicles receive the most up-to-date data? Would this require the system to re-transmit current setting status data at regular intervals to ensure that every IVD is up to date? What rate of re-transmission would be required to ensure that the synchronisation of RSD displays and IVD displays is within a requisite margin of safety?</p> <p>3. If a broadcast mechanism is used, what would be the implication for the latency of data: what would the time lag between the setting of aspects on RSDs and the receipt of data by the IVD be?</p> <p>4. If a broadcast mechanism is used, then what functional requirements does this entail for IVDs: Would IVDs therefore be required to process that data so that only settings relevant to the vehicles current location are</p>	
	05:50	5	08:50	85						
	06:00	2	09:00	91						
	06:10	4	09:10	96						
	06:20	14	09:20	88						
	06:30	15	09:30	94						
	06:40	19	09:40	106						
	06:50	34	09:50	36						
	07:00	48	10:00	29						
	07:10	53	10:10	38						
	07:20	47	10:20	36						
	07:30	61	10:30	56						
	07:40	86	10:40	55						
	07:50	84	10:50	51						
	08:00	66	11:00	11						
	08:10	68	11:10	12						
	08:20	69	11:20	6						
	08:30	73								
	Peak Period									
	Interval	SDRs	Rate	SDRs/Second						
	09:40 - 0950	106	1 every 6 Seconds	0.17/Second						
	<p>At peak operation, 0940 to 0950 Hrs, The Signal subsystem received 106 Set Device Requests: one every six seconds. It should be noted that on the morning of Monday the 10th of September the weather was fine and at peak rush hour visibility was good. N.B. It should also be noted that it is possible that during such a ten minute period the Signal subsystem might receive a larger proportion of the 106 Set Device Requests in a given one second interval.</p> <p>Allowing for a margin of safety that requires the Signal subsystem to process setting requests at ten times that observed peak rate of MIDAS setting requests, the minimum requirement would be for the HATMS system to process signal settings at a rate of 1.67 setting requests per second. N.B. Any given setting request (Set Device Request) may contain setting details for one to the maximum number of in-boundary</p>									

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	<p>(5000) devices, so the amount of signal setting data that may be transmitted between the instation control systems and outstations in any given second across all RCCs in England (ERCC, SERCC, NERCC, SWRCC, NWRCC, WMRCC, WM ATM and EMRCC) is potentially very large (see 'Cross Boundary Interworking' below).</p> <p>Metrics have not been obtained for message sign settings, but the demands on the Message Sign subsystem, in terms of throughput of Message Sign (MS) proposals, are expected to be an order of magnitude less than that on the Signal subsystem. That said, for every signal device for which a Message Sign registered interest is defined in the Signal Device data (Device.sig), when that device is subject to a signal setting proposal, the Signal subsystem is required to update the Message Sign subsystem which, in turn, is required to process this data (see 'Sequencing From Signal Settings' below). The same is true of all subsystems that have a registered interest in certain signal devices. The point being, that the throughput of signal proposals is a <i>system</i> performance issue, as opposed to just an issue for the Signal subsystem.</p>						<p>displayed? Would this require that, prior to entering the network, up-to-date signal and sign geometry data is downloaded to the IVD? Would this require that, prior to entering the network, the IVD is 'checked' to ensure that it is running up-to-date software? This entails replicating instation intelligence in the IVD – should a principle aim of the development be to avoid this?</p>

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Latency of Data	<p><u>REAL-TIME (SENSE 1)</u> Latency of 'Transmission' of information between roadside device and the driver.</p>	N/A		N/A	Real-Time by definition: Real-Time by virtue of the fact that drivers <i>can see</i> the display on an RSD (Road Side Device). Transmission between the device and the driver's brain is achieved at the speed of light.	As with preceding column	<p>With respect to signal settings, displays on IVDs are not real-time by definition. Whilst IVDs and RSDs co-exist alongside one another, IVD displays will be considered to exhibit real-time behaviour if there is no appreciable time difference between the setting updates on the IVD and the same setting updates on the RSD.</p> <p>Real-time capability will be a function of concurrency between the IVD and the RSD that it emulates. Achieving parity between the two systems turns, to an extent, on issues to do with device responses (SETTING STATUS messages) sent from the outstation to the Instation. (See also 'Instation Retries' and 'Outstation Retries' below)</p>
	<p><u>REAL-TIME (SENSE 2)</u> Real time Responses to Automatic Setting Requests: The Signal subsystem must respond to automatic setting requests (e.g. from MIDAS) in real-time, i.e. well within the configured interval for the MIDAS setting ON-OFF Timer.</p> <p>Performance criteria in terms of speed of throughput of signal setting requests have not been specified.</p>	N/A	N/A	Real-time capability is a function of the performance of the system (currently easily achievable)	N/A	N/A	Real-time capability will be a function of the performance of the system that includes an as yet unspecified transmission technology.
	<u>NEAR-TIME</u>	N/A	N/A	N/A	N/A	N/A	N/A
	<u>SOME-TIME</u>	N/A	N/A	N/A	N/A	N/A	N/A
Frequency Setting Updates	<p><u>SENSE 1 – SIGNAL SITE SPACING</u> In order to satisfy the requirements for signal sequencing a number of signal sites should be provided within a signalling scheme. Careful consideration should be given to the signal sequencing that can be achieved at the transition from</p>	N/A	N/A	N/A	Frequency of updates travelling along the motorway is a function of longitudinal spacing of signal	<<	To replicate this for IVDs does this presuppose transmitters sited with the appropriate spacing along the motorway equivalent to RSDs? Or, possibly, occasional transmitters that convey a packet of information

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	<p>carriageway to lane signals and vice versa. Unless special Regulations have been made the Signal Sequencing terms 'speed restriction', 'restriction' and 'speed reduction' relate to the temporary maximum speed advised using the signs prescribed as diagram 6001 to the Traffic Signs Regulations and General Directions 2002 (SI 2002 No 3113).</p> <p>Guidelines for Signal Gantry Spacing on Roads with 4 or more lanes are provided in IAN 87/07 and state that the desired spacing for inter-junction gantries is 600m with a maximum of 800m and a minimum of 100m.</p>				<p>sites (see DMRB Vol. 9, Section 1) and the vehicles speed. For example, if a block of signal settings of 60 mph is in place along a stretch of motorway then, assuming a longitudinal signal site spacing of 500m, the driver will be presented with new information every 18 seconds.</p>		<p>pertaining to a block of RSDs?</p> <p>Data Requirement: Next site, Number of lanes, settings, distance to travel to subsequent site + Subsequent site, number of lanes, settings, distance to travel to subsequent site + n*(....)?</p> <p>What if between receiving the data for the block and the data for the next block, the settings change on the first block? The settings with the first block will be out of sync. Does this require that each RSD has an I2VT associated with it?</p>

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	<p><u>SENSE 2 – TRANSMISSION RATES</u> The Signal Subsystem will send a Set Device Message (CI=46H) to a device every time the setting requested on that device changes.</p>	N/A	N/A	>>	<p>The RSD, thought of as a 'transmitter' of information, re-transmits signal setting data to the vehicle at an infinite rate, i.e. the display is 'constant' between the time that the setting is applied and the time it is cleared to OFF or replaced by another setting.</p> <p>***</p> <p>Because the display is 'constant' and geographically static, drivers approaching the vicinity cannot fail to see the display and at a point well upstream of the RSD.</p>	N/A	<p>The rate at which the I2VT can re-transmit setting data to a vehicle is a function of the technology. The granularity that this entails may be such that a vehicle can move some distance between each re-transmission. Assuming the I2VT mechanism is a local targeted transmission; would it mean that an IVD could miss a packet and, consequently, become out of sync with the associated RSD?</p> <p>***</p> <p>Assuming a system of local and targeted transmission of signal setting data, the transmission of signal setting data must be repeated at a rate sufficient to enable all vehicles approaching and signal site to receive that data within a defined safety zone upstream of the RSD. As a first approximation, starting at the point upstream of an RSD where a motorist with 20-20 vision is first able to discern the aspects on an RSD on a clear day (Point of First Visual Confirmation - FOP), a safety zone of 10% of the distance between that point and the RSD might be appropriate. Assuming then a vehicle speed of 70 mph and a FOP distance of 300m, the vehicle will traverse this zone in 0.97 seconds. Based on this value of 10% of the FOP distance, a minimum required rate for re-transmission would be in the order of 3 seconds.</p>

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Granularity of Signal Setting Updates	LEVEL OF DETAIL DOWN TO LANE LEVEL Function of Geometry and Frequency					See Geometry below	See Geometry below
Signal Site Geometry	VARIABLE LANE CONFIGURATION MOVING DOWNSTREAM Signal geometry maps to actual on-street lane configuration. This means that the number of lanes will vary as the motorist travels along a carriageway.	N/A	N/A	N/A	The driver intuitively understands that the RSD settings apply to lanes at the RSD location even though the FOP may be several hundred metres upstream and the number of lanes at the FOP may be different to the number of lanes at the RSD (e.g. where there is a constriction between the FOP and the RSD). *** DMRB Vol. 9 Section 4 A4.1 States that Motorway signals should not be positioned within 300m downstream of a change in the number of carriageway lanes between junctions.	The array of RSDs at a signal site should always match the lane configuration at that location because the gantry will have been designed that way.	Does this presuppose a dynamic IVD display in order to correctly represent the number of lanes at the point on the carriageway the vehicle is travelling over? *** If the configuration changes as the vehicle travels along the carriageway (e.g. a constriction where a three lane carriageway becomes a two lane carriageway travelling downstream) will the IVD display require updating in order to reflect this, irrespective of whether an aspect is set on the RSD? How would the lane configuration be communicated to the IVD? *** If the IVD display mirrors the display on the RSD that the vehicle is travelling towards then, depending on the actual IVD display arrangement, the driver may mistakenly interpret the IVD display to apply from the FOP rather than the RSD. Not only would this be inappropriate, but what if the number of lanes at the FOP is different to the RSD location. There is a fundamental issue here: drivers intuit that the RSD displays apply to the RSD location whereas

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							IVD displays, by their very nature, will appear to the driver to apply to the FOP. How would the design of the IVD display resolve this?

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	<p>CONSTRUCTIONS 'Constriction' here is used to describe the scenario where the number of lanes, moving up-stream to downstream, are reduced (e.g. where three lanes becomes two). Constrictions need special mention here because where there is a constriction downstream from a signal site if a speed restriction is proposed on that site then the Signal Sequencing Rules (see MCE2103 Rules C11U10 and C11U20) will generate a lane divert in the lane that runs out (LDL if the outside lane; LDR if the inside lane).</p>	n/a	n/a	n/a	n/a	RSDs display the aspect appropriate to the lane configuration at that location.	<p>If there is a constriction upstream from the RSD such that the constriction is within the FOP for that signal site then if the IVD mirrored the RSD display then the IVD display may confuse the driver since the number of lanes at the point that the IVD receives the update may be greater than the number of lanes beneath the RSD.</p> <p>DMRB Vol. 9 Section 4 A4.1 States that Motorway signals should not be positioned within 300m downstream of a change in the number of carriageway lanes between junctions. However, this may not always be achievable in practice due to site by site considerations such as visibility. It is possible that on a given section of carriageway running between the FOP and the RSD spans a change in the number of lanes.</p>
	<p>GEOGRAPHIC ADDRESSES Signal Sites (therefore devices) are associated with fixed geographic locations on the road network.</p> <p>A 'Location' consists of one to three sites. A site comprises from one to seven lanes at a location. In the case of gantry sites, there is a one to one correspondence between lanes and indicators (signal devices). At post-mounted sites there is a many to one relationship between lanes at that site and an indicator (i.e. a one to one relationship between the indicator and the site itself).</p> <p>N.B: In Site Data and Signal Sequencing terms where a Location consists of two or more sites (i.e. a 'Split Gantry'), those sites will be contiguous across a uni-directional carriageway. This division of what may appear to the motorist to comprise a single signal site</p>			In the case of a restriction no longer applying as the vehicle moves downstream (i.e. blank signal devices downstream from a block of settings) the RSD remains set to OFF so no update is required from the Signal subsystem.	The driver can see the aspects 100+ metres in advance. By virtue of this, information is conveyed to the driver at a point n*100m upstream of the RSD. The exact distance is a function of a) Visibility b) Curvature in the road c) The driver's eye sight ***	The position of the display is spatially aligned, in the transverse dimension, in relation to the road. Humans do this intuitively. Parallax is overcome by careful positioning of RSDs in relation to curves in the road.	<p>N.B: though parallax, per se, is not a consideration for IVDs, consideration needs to be given to the issue of the number of lanes at the FOP compared to the RSD location (see discussion on 'Variable Lane Configuration' in this section above).</p> <p>***</p> <p>Is it necessary for the driver to see aspects at the site (as opposed to 'lane') inside or outside the carriageway he/she is on?</p> <p>***</p> <p>In order to mirror an extant OFF on the RSD downstream from the most</p>

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	<p>is a logical division for the purposes of the Transverse Signal Sequencing Rules modelling the weaving of traffic from one side of the carriageway to the other at, for instance, the convergence and subsequent divergence of two major carriageways. See ‘Transverse Sequencing’ section below)</p>				<p>Signal Settings persist: From the control system perspective, settings persist until the operator, or automatic subsystem that requested them to be set, requests those settings to be cleared.</p> <p>***</p> <p>From the driver’s perspective, settings persist until settings at a downstream site (RSD) inform the driver that restrictions that applied to the section of motorway along which he/she <i>has been</i> travelling do not apply to the section of motorway along which he/she <i>will be</i> travelling when he/she reaches the downstream RSD. It should be noted also that in the case where inter-visibility between signal sites is not achievable, intuitively the driver will be</p>		<p>downstream setting in a block of settings from which motorist is just leaving, the ‘system’ will be required to either actively transmit OFF to the vehicle or allow the IVD to clear the setting down based on distance data transmitted to it with the last signal setting update. This is in contradistinction to the current system wherein it is not necessary to actively inform the driver that a restriction no longer applies since the downstream RSDs were previously set to OFF and the driver can see these from the relevant FOP.</p> <p>***</p> <p>N.B when clearing an IVD setting to OFF in order to ‘repeat’ the downstream RSD, should the IVD apply the new setting at a point directly under the blank RSD. If the blank gantry is downstream from and END/NR then it is reasonable to suppose that the IVD should clear to OFF quite soon after the RSD displaying END/NR is passed. In the case of RE it is not so clear cut since there may be a block of REs, so the system will need to inform the IVD that this is the last RE in the block (i.e. transmit OFF) See discussion on END/NR and Re below.</p> <p>In the case of an HDS being set then END/NR and RE will not set on the RSD therefore the system will be required to update the IVD at the point that the vehicle passes under the RSD.</p>

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					<p>cognisant that restrictions displayed on the RSD that he/she has just passed still apply.</p> <p>***</p> <p>In the case of END/NR (No Restriction), where the Highest Displayable Speed (HDS) is more restrictive than the National HDS, is set at a site the END/NR will not be displayed. In these instances the driver is aware the temporary restriction no longer applies when he/she sees that the next downstream RSD is blank. (See 'HDS' in the Signal Sequencing section below)</p>		<p>Will each RSD then have effectively two FOP a) one for lead-in settings to give advance warning and b) one at a point directly below the RSD for END/NR or RE. Or, should there be one FOP and the data content includes a distance parameter so that the IVD can decide when to set the setting – e.g. zero for lead-in settings (allowing the vehicle to set the aspect at the FOP) and, say '300' for END/NR or RE allowing the IVD to set the aspect at the RSD location when the FOP distance is 300m.</p> <p>***</p> <p>IVDs are not spatially fixed in the transverse dimension in relation to the road. Will/can the driver's ability to mentally associate the lane by lane display on an IVD with the actual lane configuration on carriageway he/she be relied upon? Can it be assumed that humans will do this automatically and without training?</p>

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	<p>SIGNAL SITE TYPES Signal Geometry allows for a number of different site types. These are not to be confused with 'Device Types'. Site Types are used by the Signal subsystem for the purposes of Signal Sequencing. Signal Sites are more or less virtual constructs that consists of one or more contiguous lanes at a single location conveying traffic in one direction along a carriageway.</p> <p>Signal Sites may be grouped in two broad categories dependant on whether they are associated to Gantry or Post-Mount Locations. These are:</p> <ul style="list-style-type: none"> a) <i>Gantry Locations:</i> 'Lane' sites (standard gantry type), 'Variable' sites (ATM gantry only – dynamic number of running lanes), 'Tidal', 'Tidal A' and 'Tidal B' (tidal gantry) sites. b) <i>Post or Cantilever Mounted Locations:</i> 'Carriageway' sites (cannot show STOP), STOP Capable Carriageway sites, Motorway Divert Capable sites and Multiple (entry slip) sites. <p>To each of these site types a subset of Standard Aspect Codes (SAC) is valid. The Signal Sequencing rules (see 'Signal Sequencing' section below) will convert requested aspects to the aspects valid to the given site as appropriate – e.g. if an operator requests lane 1, STOP at a three lane Carriageway site the rules will convert this to 'TIL'. The 'device type' of indicators at a site will be appropriate to the 'site type', e.g. a device at lane 6 at a Tidal site must be capable of displaying Tidal Aspects (SACs 'Centre Arrow', 'tDL' & 'REDX'); Red Ring Aspects are not valid at a Non-CMI (Controlled Motorway Indicator) site</p>		N/A	<p>Though sites on the opposite carriageway may be in close proximity, separate 'transmissions' targeted at each of these sites will not interfere with one another.</p> <p>***</p> <p>'Transmission' is targeted at vehicles on a particular section of motorway and is, effectively 'repeated' at an infinite rate for the duration that the restriction is in place by virtue of the device being set and the motorist can see it.</p>	N/A	<p>Gantry locations generally allow indicators to be mounted directly above the relevant lane. However, Carriageway sites (including post and cantilever mounted signal devices) do not, generally, sit directly above the lane that they may represent.</p> <p>However, wicket aspects displayed at a carriageway site are intuitive and drivers easily map the aspect to the lane configuration at that location (See 'Wicket Aspects' below).</p>	<p>Should the IVD be capable displaying the text/symbol corresponding to any valid SAC?</p> <p>***</p> <p>If it is required that IVDs always display a lane by lane setting array as with a gantry site, irrespective of whether or not the current RSD is a post-mounted and displaying wicket aspects, then a change to the Signal subsystem will be required in order to convert the post-mount type aspects (e.g. Wickets) display to the appropriate Gantry array display. So, 'TIL' might require to be converted to 'LDR-50-50' or 'X-50-50' depending on the sequencing event, and '50' on display at a three lane Carriageway site will require to be converted to '50'-'50'-'50'.</p>
	<p>SIGNAL DEVICE TYPES A number of Device Types (not to be confused with signal 'site types') are defined by the system data. Device Type definitions are used primarily by the</p>	Based on the target device type, the system is able to adapt the target	Drivers are oblivious to device types other than to	N/A	N/A	N/A	The V2I system will comprise a large number of devices all of one type (i.e. IVDs). Should aspects displayed in response to a SAC be consistent, e.g.

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	<p>outstation (signal transponder and signal head) to do the following:</p> <ul style="list-style-type: none"> a) Determine the aspect to display in response to a setting (SAC) request from the instation b) Determine whether or not to set amber, red flashers (see 'Flashers' below) or no flashers at all for a particular aspect on a particular device type. c) To determine the alternative aspect that should be set on the device if the requested aspect fails to set (see 'Aspect Adaption' below) <p>Specifically, the system's outstation data assigns a subset of valid SACs for a given device type. The byte encoded drive codes (including bits to determine the flasher) for each SAC and an alternate SAC for aspect adaption is required.</p> <p>Outstation data also defines the HDS for each device ensuring that no speed aspect can be set that represents a speed in mph that is higher than the HDS. (This functionality might be regarded as redundant since the Signal subsystem, by virtue of the Signal Sequencing Rules, will not request a speed restriction representing a speed higher than the current HDS on that device. In the event that an operator sets an HDS while there is an extant signal setting, the Signal subsystem will re-sequence extant signal settings to ensure that the on-street signal setting is updated to reflect the new HDS. See 'HDS' in the 'Signal Sequencing' section below)</p> <p>An example of different aspects on display for different device types in response to the same SAC request from the instation is the 'End' set on a 407 device (a post mounted signal) and the '∅' set on a 450 device (gantry mounted lane signal). Both these aspects are set in response to END/NR (SAC=2) or RE (SAC=3) requested by the Signal subsystem.</p>	<p>aspect in response to the SAC outputted from the Signal Sequencing Algorithm (SSA).</p>	<p>notice that: Wickets set at post-mount sites whereas 'barred aspects' (i.e. STOP, REDX, MDVL, MDVR, LDR, HSD, tDL and LDL) are displayed at gantry sites.</p> <ul style="list-style-type: none"> a) 'End' is displayed at some sites whereas '∅' is displayed at other sites <p>Red or Amber Flashers are set with some aspects at some sites but not with the same aspects at certain other sites. (See 'Flashers' below)</p>				<p>should '∅' always be displayed on the IVD in response to END/NR (SAC=2), or, should the IVD always mirror the RSD aspect so that '∅' is set on the IVD when '∅' is set on the RSD and 'End' set on the IVD when 'End' is set on the RSD?</p> <p style="text-align: center;">***</p> <p>Will this require the migration of outstation functionality that determines aspects to display codes towards the instation, or, should some intelligence be built into the IVD?</p>

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	<p><u>ADJACENCY RELATIONSHIPS BETWEEN SITES</u> Two signal sites either side and upstream of the convergence of two carriageways (e.g. where an entry slip joins the main carriageway) are said to be 'adjacent' sites and stand in defined 'adjacency' relationship with one another in the signal geometry data. The purpose of indentifying adjacency relationships in the site data is, in the main, so that the Signal Sequencing rules can equalise speeds across the adjacency and thus enable the merge of traffic and the convergence with minimal disruption to traffic flow. Adjacency relationships pertain not only to the merge of entry slips but to the merge of any two carriageways.</p> <p>Adjacent sites may be in close physical proximity to one another, even to the extent that the devices that constitute the signal sites are sometimes mounted on the same gantry (though not <i>logically</i> at the same location). N.B: A gantry comprising signal devices belonging to two adjacent sites should not be confused with a 'split gantry' (see '<u>Transverse Relationships</u>' below).</p>	N/A	N/A	Though two adjacent sites may be in close physical proximity, by virtue of a hardwired connection to the system, transmission to a site on one side of the convergence will not interfere with transmissions to the site on the other side of the adjacency.	N/A	Though drivers may see settings on the adjacent RSD, due to close physical proximity of the adjacent signal sites, those settings do not convey relevant information to that driver. The driver is aware of this and should not be distracted or confused by the display at the adjacent site	<p>Though adjacent sites may be in very close physical proximity (e.g. the devices mounted on the same gantry) and the driver can see settings on the adjacent site, it would, presumably, be confusing to the driver to display on the IVD lane information pertaining to the adjacent site alongside lane information pertaining to the carriageway that he/she is travelling along. Does this presuppose that data pertaining to these two sites is transmitted separately (Assuming targeted transmissions as opposed to broadcasts)? How will transmission interference be avoided?</p> <p style="text-align: center;">***</p> <p>If the problem of interference is insurmountable, does this presuppose that the vehicle must know what carriageway it is on and, therefore, may receive data for all sites in the area and determine which data applies to the carriageway that it is on? How big an area – what is the implication for the amount of data that is transmitted in a packet? Should broadcasts be on an area basis or a site by site basis?</p>
	<p><u>TRANSVERSE RELATIONSHIPS BETWEEN SITES</u> A gantry that spans a carriageway comprising 2 or more contiguous lanes may, for sequencing purposes, may be <i>logically</i> (as opposed to <i>physically</i>) divided into 2 or more transversely contiguous sites (max 3). These sites are defined in the signal geometry data as standing in a transverse relationship with respect to</p>	N/A	N/A	N/A	The driver is presented with aspects for all lanes at all sites at the location. He/she can therefore make informed decisions	The position of signal devices is spatially aligned with the lane configuration at the split gantry location.	Will the system be required to transmit signal setting data pertaining to all lanes at all sites at a split gantry location? It would not be sufficient to transmit only updates to one site at the location as this would result in a discrepancy between the IVD display and the RSD.

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	<p>one another. These relationship definitions are used by the Signal Sequencing rules to model flow where traffic is typically weaving across the carriageway as it moves between two consecutive locations (a location can consist of one or more transversely related sites) in an upstream-downstream direction, for example, where major carriageways converge and diverge.</p> <p>A set of transverse rules are applied to the whole location (comprising the transversely related sites) to ensure that, for example the most restrictive speed setting on a lane at an outside site at the locations is copied to all lanes to each of the inside lanes .</p> <p>Another example: there is a transverse rules that ensures that if 'Ø' is set on one lane at the location then it is copied to all lanes at the location and so on.</p>				<p>about his/her passage along the carriageway and between lanes.</p>	<p>***</p> <p>Split Gantry locations may have 4 or more lanes (logical maximum = 7). Due to spatial alignment with lanes, drivers can easily see the setting associated with the lane he/she is travelling in (all things being equal with respect to parallax) without the need for him/her to be cognizant of the actual value of the lane <i>number</i> of the lane he/she is travelling along (though he/she may indeed be cognizant of that lane number).</p>	<p>The instation software would need to be modified since currently it only 'transmits' setting updates to the outstation, i.e. if the output from SSA would not result in a change to the on-street setting on a particular device (e.g. if the operator clears a manual 50 but there is a MIDAS 50 stored in the MIDAS layer) then the subsystem will not 'transmit' the sequencing result for that device.</p> <p>***</p> <p>Will drivers always be aware the lane <i>number</i> of the lane that he/she is travelling along? I.e. Can it be assumed that the driver will always be able to associate the correct lane on the IVD with the actual lane he/she is travelling along without counting or thinking about it? If this cannot be assumed then does it presuppose that although the IVD display will represent all lanes at a site it must also indicate (highlight perhaps) the particular lane display for the lane that the vehicle is in. This would require the vehicle to 'know' which lane it is in at any given time. Can the vehicle determine which lane it is in from GPS coordinates – does this presuppose that the IVD must be pre-configured with geographic data pertaining to the motorway network before it enters the motorway network? If so, how would is this to be implemented? Or, would future technology enable an intelligent vehicle to 'see' which lane it is in, in an analogous way to the human</p>

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							driver? Clearly, the specification of the interface between the vehicle and infrastructure influence the answers to these questions.

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	<p><u>THE NUMBER OF LANES AT A SITE</u> The 'Number of Lanes' is an attribute of a signal site and varies from one site to the next. Max Number of Lanes = 7</p>	N/A	N/A	N/A	The number of lanes at a signal site does not vary (N.B. Hatched lanes and Variable Lanes sites – i.e. ATM sites – are treated separately below) therefore the arrangement of signal devices at a signal sites is not required to be dynamic.		<p>Since the device is moving the number of lanes to be represented on the IVD may need to vary as the vehicle moves from one geographical location to the next. Does this require a dynamic display (i.e. in one instance representing 3 lanes and in the next, 4 lanes)?</p> <p style="text-align: center;">***</p> <p>If IVDs must display info pertaining to all lanes at a particular location so that drivers can make informed choices, does this mean that it should be capable of representing up to the maximum number of lanes, i.e. a dynamic display? Should data transmitted to the vehicle include the number of lanes at that site? Or, should the vehicle 'know' (be pre-configured with) signal site geometry for the whole network? Prior to entering the motorway network, should geometry data for the whole network be downloaded to the IVD? What of X-Boundary - should downloaded data be local to the RCC or the whole network. If local to the RCC what does this presuppose for the location of transmission stations? What if Satellite technology is deployed? Else, if the IVD is pre-configured prior to starting a journey, how does this system ensure that the vehicle is pre-configured with the latest version of geometry data?</p>
	<p><u>HATCHED LANES</u> Hatched Lanes occur where a gantry holds signals for</p>	N/A	N/A	N/A	The driver can see lane markings on the road and	<<	Hatched Lanes? Aspects other than STOP are converted to OFF (SAC=1; seen as blank signal by the motorist)

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	<p>more running lanes than exist on the road below it. Hatched lanes often occur where merging lanes give rise to the use of hatched zones.</p> <p>At hatched lanes only STOP (SAC=4; seen as a red X by the motorist) can be displayed. All other aspects are converted to OFF except Motorway Diverts (MDVL and MDVR) which are converted to STOP (MCE2103)</p> <p>See the 'Traffic Signs Regulations and General Directions 2002' (TSRGD) diagram 1040.5 for the requirements for road markings for lane hatching.</p>				<p>intuitively associates these with the blank signal above that lane.</p> <p>***</p> <p>The driver intuits that an aspect that he/she saw on display above the same lane at the upstream site no longer applies when he/she sees that that lane is now hatched; the driver intuits that the aspect no longer applies because he/she is educated to know that lane ceases to be a running lane at the beginning of the hatching.</p>		<p>at Hatched lanes. The driver is made aware of this by road markings – do the hatched road markings need to be reflected by the IVD display?</p> <p>***</p> <p>Constraint on CVHS: at or some distance upstream from a hatched lane any signal settings (other than STOP) pertaining to that lane that were set at the site upstream must be set to OFF on the IVD and either</p> <ol style="list-style-type: none"> The dynamic IVD indicates the only the running lanes (e.g. 4 lanes becomes 3 when either the outside or inside lane becomes hatched on a 4 lane carriageway), or The dynamic IVD display is updated with some form of 'hatched aspect' for the hatched lane. <p>However, since the IVD display must indicate the hatched lane when a STOP is set at the hatched lane (since indicators above hatched lanes will display STOP), it may be more straightforward to employ a new 'hatched aspect'. This would require a change to the instation software in order to update devices accordingly, unless it is assumed that IVDs are configured with a motorway network signal geometry data prior to entering the network.</p> <p>***</p> <p>How will information pertaining to the geographic start point of the hatching</p>

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							<p>be conveyed to the IVD? Does this entail that data transmitted to the IVD must contain the distance from the upstream gantry to the beginning of the hatched lane? Likewise, how will the IVD know at what geographic point the hatching ends?</p> <p style="text-align: center;">***</p> <p>For the purposes of IVDs, should hatching itself be treated as an aspect? New SAC for Hatching used specifically for IVDs?</p>

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	<p><u>TIDAL/CONTRA FLOW LANES</u></p> <p>The number of running lanes in either direction along the carriage way varies depending on the Tidal Flow state. Gantries span the full breadth of both carriageways. There are devices mounted on both sides of the gantry and across the full span of the gantry in either direction, even though the three outermost (with respect to the direction of travel) lanes will always be set to REDX. A buffer lane is maintained through operation and is indicated as hatching on the WOIF and REDXs on-street. The lane designated as the buffer lane varies depending on the Tidal Flow state. The number of buffer lanes varies from one to two depending on the Tidal Flow state.</p> <p>The Number of lanes at Signal sites on the main carriageway of the Aston Expressway is 7. A maximum of 4 (minimum 2) lanes will be open for running in any direction at any given time.</p>	N/A	N/A	N/A	n/a	<p>Show all Running lanes and prevent use of contra-flow lanes with a buffer lane in the middle. The Device is spatially aligned with the lanes. The driver cannot be confused as to which lanes are closed and which lanes are open for running.</p> <p>***</p> <p>The buffer lane, although not indicated to the driver as such, is none the less maintained by inter-visible gantries displaying REDX from the outside running lane (but not including the outside running lane) to the outermost lane under the gantry.</p>	<p>Tidal/Contra Flow sites: up to seven lanes across both carriageways. Should the driver be presented with aspects on contra-flow carriageway, i.e. all REDXs or just that REDX on the first offside REDX lane?</p> <p>The number of lanes at certain signal sites on the Aston expressway is 7. In tidal flow areas the two opposite carriageways overlap and share lanes. Given this relatively large number of 7 lanes, will the driver always be capable of apprehending the lane number of the lane that he/she is driving (i.e. without counting or thinking about it)? Is it required that the vehicle knows which lane it is on and emphasises the lane number by, for example, highlighting that lane's detail on the IVD lane display array (assuming it will be a lane array). How would the vehicle know which lane it is in?</p>
	<p><u>ATM / VARIABLE LANE SITES</u></p> <p>Variable Lane sites are a subset of Lane (gantry) sites and are defined as such in the signal site geometry data specifically for the purposes of the Signal</p>	N/A	N/A	N/A	(See the " <u>Hard Shoulder Running</u> " below)	(See the " <u>Hard Shoulder Running</u> " below)	(See the " <u>Hard Shoulder Running</u> " below)

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	<p>Sequencing Rules: certain rules in the Primary Validation, Transverse, Upstream and Downstream rule blocks have been modified in order to facilitate the dynamic use of the Hard Shoulder as a running lane (see 'Hard Shoulder Running' below). Primarily, this entails special handling of lane divert right (LDR and HSD), REDX (represented by a red X) in order direct traffic in and out of the Hard Shoulder accordingly as the operating regime is to open or close the Hard Shoulder. RE and END/NR (both represented by 'Ø' on-street) also require special handling at Variable Lane sites.</p> <p>Recent Modifications to the Signal Sequencing rules have recently been implemented that will allow through running of junctions along the Hard Shoulder.</p>						

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	<p><u>UN-SIGNALLED EXITS</u> Any given motorway carriageway may have one or more un-signalled exits</p>	n/a	n/a	n/a	Un-signalled exits will have fixed signs indicating the speed limit on the exit from the main motorway carriageway. The driver can see these and will understand that the previous variable speed limit he/she saw on the main carriageway is superseded. The RSD is passed and can no longer be seen and therefore does not conflict with the fixed sign on the exit.	n/a	When the vehicle enters the un-signalled exit, how will the IVD be cleared to ensure that the display does not conflict with fixed signs at or near the start of the un-signalled exit?
	<p><u>DIVERGENCES</u> At any given point on a motorway carriageway there may be one to a maximum of three divergent carriageways downstream – i.e. three signal sites downstream. At any one or all of the signal sites downstream the number of lanes may be different to the current location.</p> <p>If the restriction that applies to current signal site does not apply to one or more of the divergent carriageways downstream then the Signal Sequencing Rules will generate an END/NR aspect (See <u>ENR/NR and RE</u> in the 'Aspects' section below) for the first signal site on the divergent carriageway (See <u>Downstream Sequencing</u> below)</p>	n/a	n/a	Na/	<p>The driver is updated with a display appropriate to the particular divergent carriageway that he/she is travelling on.</p> <p>***</p> <p>It is not possible for the display to contradict, or misrepresent the road configuration at the point that the vehicle enters one or other of the</p>	n/a	If the display on the IVD persists beyond the RSD location to a point beyond a divergence downstream from the RSD, then it would misrepresent the road configuration at that downstream point. How will the IVD 'know' to clear or update the setting it displays when the vehicle enters a divergent carriageway? How will IVDs handle un-signalled exits?

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					open divergent carriageways/exits, since the motorist can no longer actually see the RSD display.		

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<p>Hard-Shoulder Running</p>	<p>MM-HSR SCHEMES IAN 111/09, section 8.5 <u>Entry and Exit Scheme Signing, Road Marking and Signalling</u></p> <p>“Appropriate signing and signalling needs to be provided to inform drivers that they are entering or leaving a MM scheme and to manage traffic behaviour as it enters and exits the scheme. For the purposes of this guidance a MM-HSR scheme commences at the first gantry upon which Variable Mandatory Speed Limits can be displayed and concludes at the “Variable speed limit Ends” sign. Therefore a MM-HSR scheme includes ‘Gateway Gantries’ on approach and the ‘Final Signal Gantry’ on exit from the scheme, as well as the section up to the “Variable speed limit Ends” sign. An appropriate place to commence hard shoulder running is downstream of a junction where the Hard Shoulder creates a ‘lane gain’. Commencement of dynamic use of Hard Shoulder away from a ‘lane gain’ needs careful consideration. In order to prevent vehicles entering the hard shoulder injudiciously, where hard shoulder running is commenced away from a ‘lane gain’, carriageway markings to TSRGD diagram 1040.5 [(i.e. <i>Hatching</i>)] or variant should be installed on the approach to the section of hard shoulder that forms part of the HSR section. This hatching should extend for an appropriate distance depending on site conditions”. (See ‘Hatched Lanes’ above for a discussion on Hatching)</p> <p><u>Signing (Entry, Exit and Slip roads)</u> Drivers need to be provided with relevant information as they enter an MM-HSR scheme. This signing needs to be provided at the start of the scheme and at all subsequent entry points. Fixed signing needs to be provided at the mainline exit points of the scheme to inform motorists that they are exiting the MM-HSR area and that national speed limits now apply.</p> <p>N.B. For Signalling on MM_HSR Schemes: 1. The main carriageway entry to the scheme must</p>				<p>In the MM-HSR, because MS4s are mounted above the AMIs at LBS1 (Lane Below Signal 1) at signal gantries are used to display tactical information, and extant MS3s interspersed at other locations along the scheme are used for strategic information, there is no conflict between the two tiers of information conveyed by message signs. The driver responds intuitively so that tactical information does not negate strategic information as he/she travels along the MM-Scheme, and vice versa. (See ‘Message Signs’ in this section below)</p> <p>***</p> <p>(See ‘Hatched Lanes’ above for a discussion on Hatching)</p>		<p>(See ‘Message Signs’ in this section below) for a discussion on Message Signs.</p> <p>***</p> <p>(See ‘Hatched Lanes’ above for a discussion on implications of Hatching)</p> <p>***</p> <p>See ‘Signal Sequencing’ section below</p> <p>***</p> <p>Because at the exit from an MM scheme the final signal gantry must not have an AMI over the Hard Shoulder, this entails a constriction in the number of lanes, so, should the system update the IVD with the reduced number of lanes?</p> <p>***</p> <p>Fixed signs are located between 200 and 300 metres upstream of the next <i>advisory</i> RSD downstream from the MM-HSR scheme (i.e. the ‘Final Signal Gantry’ - the upstream <i>Mandatory</i> RSD at the end of the MM-HSR scheme).</p> <p>***</p> <p>If there is a restriction set on the advisory RSD and the FOP is greater than 200m, then will this confuse the driver if the IVD appears to be in conflict with the IVD? How will the</p>

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	<p>include two 'Gateway' gantries that can display mandatory speed limits prior to the beginning of the scheme. These two Gateway gantries must not have an AMI over the Hard Shoulder. Motorway merges must have location-specific solutions to ensure that all traffic encounters two Gateway gantries, but only if traffic on the 'link road' moves directly from one motorway to another without encountering some form of control (for example a motorway roundabout). If there is some form of control, the link road can be treated as an on-slip.</p> <p>2. Nearside and offside post mounted AMIs at all on-slips entry points (including any Motorway Service Areas) - these signals must display mandatory speed limits that are the same as those set on the mainline carriageway gantry upstream of the merge. (Therefore both the traffic on the main carriageway approaching the merge and traffic on the slip road are presented with the same information.)</p> <p>3. No additional gantries should be provided at the end of the MM-HSR scheme.</p> <p>4. At the exit from the scheme, the final signal gantry must not have an AMI over the hard shoulder. If there is a merge the combined fixed "Variable speed limit ENDS"/national speed limit signs should be placed just before the merge, and at least 300m downstream of the Final Signal Gantry. If no merge is present at the exit from the scheme, the combined fixed "Variable speed limit ENDS"/national speed limit signs should be located between 200m and 300m upstream of the next advisory signal, if the next advisory signal is more than 1 km downstream the signing should be placed between 300m and 800m downstream of the Final Signal Gantry.</p>				<p>***</p> <p>With regard to signing on Entry and Exit slips, fixed signs advising of National speed limits and RSDs stand in a constant spatial relationship. Moreover, drivers intuit (or, are trained to appreciate) that, like fixed signs, the restrictions on RSDs apply from the point directly below the RSD to a point downstream where the restriction is superseded by another restriction or is cleared.</p>		<p>IVD display be arranged so that it communicates to the driver that the restriction applies from the downstream RSD location and not at the point that he/she first sees the restriction displayed on the IVD?</p>

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	<p><u>MM-HSR & MESSAGE SIGNS</u></p> <p>See ('Message Signs' low)</p>	See (' Message Signs ' low)	See (' Message Signs ' low)	See (' Message Signs ' low)	See (' Message Signs ' low)	See (' Message Signs ' low)	See (' Message Signs ' low)
	<p><u>LANE SPECIFIC AMIS</u></p> <p>For MM-HSR additional AMIs are installed over the Hard Shoulder at gantry locations. At these locations, therefore, LBS1 (Lane Below Signal 1) is the hard shoulder. Normal running lanes begin at LBS2.</p> <p>In order to emphasis to motorists who may have become accustomed to Hard Shoulder Running that the Hard Shoulder is not a normal running lane and therefore avoid the situation wherein a motorists may simply enter the Hard Shoulder as a matter of course, road markings in the form of lane hatching (see TSRGD diagram 1040.5) should be installed on the approach to the section of the Hard Shoulder that forms part of the HSR section. This hatching should extend for an appropriate distance depending on site conditions. (IAN 111/09 Sect. 8.5)</p> <p>By virtue of the Signal Sequencing rules, whenever there is a setting other than OFF on any one of the normal running lanes (LBS2-LBS4), the AMI over the Hard Shoulder will be set to either REDX (in the case of VMSL3), HSD ('Hard Shoulder Diver Right' -in the case of the Hard Shoulder about to close or at the final signal gantry in the VMSL4 zone), or a speed restriction (in the case of an AMI over the Hard Shoulder in the VMSL4 zone, except at the final signal gantry in that zone): Hard Shoulder AMIs are never blank (i.e. set to OFF, SAC=1 or BLNK, SAC=53) when there is a setting at anyone of the other lanes at the site.</p>	n/a	n/a	n/a	(See ' Hatched Lanes ' above for a discussion on Hatching)	Since the AMI at LBS1 (the Hard Shoulder) will never be blank when there is a setting in any of lanes 2,3 and 4, drivers should never be misled into believing that they can circumvent a restriction on any one of the normal running lanes by undertaking on the Hard Shoulder.	Whenever there is a signal setting update at an RSD on an HSR section of the motorway, assuming then that the IVD display will represent all lanes at the location then the driver should never be misled into believing that they can circumvent a restriction on any one of the normal running lanes by undertaking on the Hard Shoulder.

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	<p><u>OPERATOR REGIMES – OPENING THE HS</u></p> <p>See IAN 111/09 (Transition from 3L-VMSL to 4L-VMSL)</p> <p>Prior to implementing a 4L-VMSL regime (4 Lane Variable Mandatory Speed Limit – i.e. Hard Shoulder running) a 3L-VMSL regime must be in place, i.e. speed on the 3 running lanes must have been reduced to an agreed threshold (currently 60 mph but this is dependant on local factors, such as topology).</p> <p>The driver is informed that the Hard Shoulder is open for running through tactical messages displayed on MS4s (capable of displaying full graphics) mounted over the LBS1.</p> <p>The opening of the Hard Shoulder for running is a manually initiated process, i.e., without operator intervention, a 3L-VMSL will persist irrespective of whether or not the speed threshold has been reached. (See 'Signal Sequencing' section below)</p>	n/a	n/a	n/a	n/a	<p>Tactical messages advising of the status of the Hard Shoulder are displayed on MS4s above the AMI at LBS1 and along the length of the HSR. Effectively, due to inter-visibility MS4s on the MM-HSR scheme, the message is displayed to the driver for the duration of his/her passage along the Hard Shoulder and also to drivers in LBS2, 3 and 4 so that those drivers can make an informed choice as to whether or not they should use the Hard Shoulder. Strategic messages on display at MS3s may persist and are not negated by the tactical messages on MS3s.</p>	<p>To replicate the 'persistence' of tactical messages, would it require to be determined whether IVDs display messages until the system commands them to clear or would it be sufficient for the IVD to time messages out after a defined period (e.g. after 27 seconds – the approximate time it takes a vehicle travelling at 50 mph to travel the distance between two gantries 600m apart) such that the IVD would be updated with the downstream message before the previous message had timed out?</p> <p style="text-align: center;">***</p> <p>If tactical messages are required to 'persist' for the duration that the vehicle is travelling along a section of a MM-HSR scheme, how would strategic messages on intervening MS3s be handled (see 'MESSAGE SIGNS' in this section above)? Would the IVD be required to display both messages concurrently? Or, would the IVD be required to store the Strategic message (given a higher priority value for tactical messages) until such time that any tactical messages on display are cleared and the IVD can re-display the Strategic message.</p>
	<p><u>OPERATOR REGIMES – CLOSING THE HS</u></p>	n/a	n/a	n/a	n/a	<p>As with 'Opening The</p>	<p>As with 'Opening The HS' above</p>

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	<p>See IAN 111/09 (Transition from 4L-VM SL to 3L-VM SL)</p> <p>The sequence for closing the Hard Shoulder is initiated by the operator but controlled by the HSM (Hard Shoulder Management) subsystem via requests to the Signal subsystem for signal settings. Prior to closing the Hard Shoulder a Flow Threshold has to be established to avoid premature closing. Once the threshold has been attained then, rather like tidal changeover, the Hard Shoulder is closed incrementally by diverting traffic out of the Hard Shoulder with HSD (SAC=54) at successive signal gantry locations moving upstream to downstream, followed, incrementally, by REDX (SAC=15) (See 'Aspects' section below).</p> <p>(See also 'Signal Sequencing' section below)</p>					<p>HS' above</p>	

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	<p><u>THROUGH JUNCTION RUNNING</u> Effectively, Through Junction Running involves the extension of an MM-HSR scheme, or the merging of two MM-HSR schemes spanning a junction, to allow motorists to continue in the Hard Shoulder through a junction.</p> <p>A raft of modifications to the Signal Sequencing rule has been implemented to enable this.</p>	As with HSR	As with HSR	As with HSR	As with HSR	As with HSR	As with HSR
<p><u>Closing Lanes and Carriageways</u></p>	<p><u>LANE CLOSURES</u> Operators have the ability to close a lane, a set of lanes or entire carriageways when, for example, a closure is necessary in order for the police or maintenance contractors to clear an obstruction.</p> <p>When an operator requests a lane or carriageway closure (STOP; SAC=4) the Signal subsystem will sequence the proposed STOP to generate the necessary secondary lead-in, adjacent, transverse and downstream aspects that condition the flow of traffic towards, around and away (assuming it not a complete carriageway closure) from the lane or carriageway closure.</p> <p>(See '<u>Signal Sequencing</u>' above)</p> <p>(See also '<u>STOP vs. REDX</u>' below for a description of the STOP aspect)</p>	n/a	n/a	n/a	Lane closures (STOP; seen by the motorist as a solid red X with red flashers) apply from the RSD to the point at which the motorist is advised that the closed lane is operational again: at the RSD downstream from the closure, assuming there is not an HDS set that is more restrictive than the National HDS, END/NR (which may be set as either 'End' or 'Ø', depending on the device type) will be set. However, it is possible that the motorist could be advised (by police coning, for example) that the lane is clear sooner than that.	As with all other signal settings, the motorist can clearly see which lane(s) the closure applies to.	If signal settings persist on the IVD display until they are updated or cleared when the vehicle is in the proximity of the downstream RSD, then it would not allow the motorist to use the closed lane earlier when, for example, police coning advises that the lane is operational again. The discussion on ' <u>ENR/NR and RE</u> ' below examines whether setting data sent to IVDs containing END/NR and RE might also include an 'Applicable Distance' parameter such that IVD might be capable of clearing its settings automatically once the vehicle has travelled the specified distance. Is this applicable to STOP, or, can it be assumed that the police on the ground, for example, would deploy a mobile 'beacon' so that they could clear the setting at the location they consider to be appropriate?

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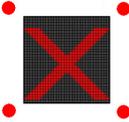
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<p><u>Motorway Diversions</u></p>	<p><u>MOTORWAY DIVERTS</u> Motorway Diverts are used upstream of a divergence to direct the entire traffic stream away from a particular carriageway: Upstream of the divergence, if the signal site comprises devices capable of displaying Motorway Divert Aspects (Motorway Divert Left - MDVL: SAC=17 - and Motorway Divert Right – MDVR: SAC=28) operators are able to divert traffic away from one or other of the divergent carriageways downstream.</p> <p>Requests for Motorway Diverts are rejected by the Signal Sequencing Rules if not contiguous with other Motorway Diverts (except that MDVR cannot appear with MDVL and vice versa at the same site), STOPS or REDXs. Locations that consist of one or more site – i.e. split gantries: see 'Signal Geometry' above – may be set with restrictions other than STOP or Motorway Diverts at sites other than the one displaying Motorway Divert.</p> <p>Upstream from the signal site set to a Motorway Divert, the Signal Sequencing rules will determine an appropriate triangulation of the lane diverts in order to direct traffic into the lanes that will continue onto the divergent carriageway or exits downstream that remain open.</p> <p>The triangulation of Lane Diverts upstream depends on the total number of open lanes (both signalled and un-signalled carriageways) downstream from the Motorway divert.</p> <p>Downstream from the Motorway Divert, the Signal subsystem will generate secondary STOPS (set as solid red 'X's with red flashers) across all lanes at the downstream signal site on the closed carriageway, and secondary END/NRs (set as either 'End' or 'Ø', depending on the device type) at the downstream signal site(s) on the open carriageway(s).</p> <p>Motorway divers, MDVL (SAC=17) and MDVR</p>	n/a	n/a	n/a	<p>Since the motorist passes under the gantry displaying the Motorway Divert before he/she enters any of the open carriageways or un-signalled exits it is not possible for the display to contradict, or misrepresent the road configuration at the point that the vehicle enters one or other of the open divergent carriageways/exits.</p>		<p>If the display on the IVD persists beyond the RSD location to a point beyond a divergence downstream from the RSD, then it would misrepresent the road configuration at that downstream point. Is this an issue for divergences downstream from RSDs generally? How will the IVD 'know' to clear or update the setting it displays when the vehicle enters a divergent carriageway? How will IVDs handle un-signalled exits?</p> <p style="text-align: center;">***</p> <p>The legends used for motorway diverts must be sufficiently and intuitively different from lane diverts in order to avoid confusion.</p>

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	<p>(SAC=28), appear as follows:</p>  <p>MDVL  and MDVR </p> <p>These are distinguished from Lane Diverts as follows:</p>  <p>LDL and tDL , LDR and HSD </p> <p>(See 'Lane Diverts' below for a description of Lane Divert Aspects).</p>						

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<u>Not Used</u>							
<u>Aspects</u>	<p><u>GENERAL - VARIABLE SIGNAL SETTINGS</u> Speed and other restrictions displayed on signal indicators may change on a moment by moment basis accordingly as remote operators and automatic subsystems request signal settings.</p>				<p>Signal settings apply at the RSD site and not at any point upstream from that site. The driver can see the settings in advance of the RSD site and can therefore adjust his/her speed or lane so that he/she is in compliance with the setting at the point he/she passes under the RSD. (see discussion on <u>'END/NR and RE'</u> in this section below for specific issues to do with those aspects)</p> <p>***</p> <p>A driver upstream of a setting on a RSD cannot miss that setting since, from the driver's perspective, the setting 'persists' for the duration it takes him/her to travel from his/her current location to the RSD location.</p>		<p>With respect to Lead-in Settings, IVDs must display signal settings at a point upstream of the relevant RSD site so that</p> <ol style="list-style-type: none"> The driver can adjust his/her speed/lane in order to comply with the restriction at the point of passing through the RSD site, and So that the IVD does not conflict with the relevant RSD. <p>In order not to conflict with the RSD settings it is reasonable to suppose that the IVD should be updated at roughly the same point at which the driver can see settings on the RSD under ideal conditions (i.e. at the FOP).</p> <p>***</p> <p>Downstream of the vehicles position there may be a one or more divergence carriageways (maximum of three). Theoretically then, at any given point the motorist may be able to see three downstream sites each comprising one or more lanes. The question then, is as to whether the IVD should display signal settings on all lanes at all downstream sites whilst the vehicle is approaching the divergence(s).</p> <p>***</p> <p>The I2VT system should not allow that the IVD can miss a setting update relating to the downstream</p>

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					<p>***</p> <p>As settings may change moment by moment, Drivers can see all setting updates to the downstream RSD that occur whilst travelling between the FOP and a point almost directly below the RSD.</p>		<p>RSD. However, what if the RSD is on a divergence that the driver does not intend to travel along? Given that vehicles are entering the network at different times, and indeed that they may be at points where reception is not achievable, this presupposes an ongoing re-transmission of data at a rate to be determined.</p> <p>Assuming some form of short range localised and targeted transmission will be the means by which vehicles receive signal setting data relating to the locality they are passing through, this presupposes a re-transmission rate sufficient for any vehicle at any point on the network to receive signal setting data relating to the downstream RSD. What is the rate (in terms of re-transmissions per second) that would be required to ensure no vehicle will miss local updates?</p> <p>A vehicle travelling at 70 mph travels 31 metres in one second. This is close to 10% of the minimum distance between gantries on Managed Motorways. What would be a safe margin?</p> <p>***</p> <p>What if the restriction is cleared after the driver passes under the gantry but well before the driver can see the next gantry if there is one? Should it be a requirement that the setting on the IVD does not persist for longer than is required?</p>

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	<p><u>VARIABLE MANDATORY SPEED LIMITS (VMSL)</u> Variable: I.e. speed restrictions displayed on signal indicators can change on a moment by moment basis accordingly as remote operators and automatic subsystems request signal settings.</p> <p>Mandatory: I.e. Speed restrictions are enforceable – on Managed Motorways, speed cameras may be mounted on the rear of AMIs. See <u>Enforcement</u> in this selection below. For present purposes the only significance of the 'Mandatory' aspect of signal settings is that Speed restrictions will be 'Red-Ringed'. See <u>Red Ringed Aspects</u> in this section below.</p>	n/a	n/a	n/a	n/a	n/a	See <u>Red Ringed Aspects</u> in this section below.
	<p><u>COMPLIANCE / ENFORCEMENT</u></p> <p>Though Enforcement is a key element in maintaining the level of compliance with operator regimes for efficient traffic management, it is beyond the scope of this study to discuss the relevant requirements or any related issues.</p>	Beyond scope	Beyond scope	Beyond scope	Beyond scope	Beyond scope	Beyond scope
	<p><u>STOP Vs. REDX : EXPLODED RED CROSSES ON HARD SHOULDER AT VARIABLE LANE SITES</u> Red Xs (not to be confused with 'REDX'; SAC=15) displayed on-street are driven in response to</p> <ul style="list-style-type: none"> a) a STOP (SAC=4) sent from the Signal subsystem in response to an operator request for a lane or carriageway closure (or as a secondary STOP sequenced from a primary Motorway Divert requested by the operator), or, b) In response to a REDX (SAC=15) requested by the HSM subsystem in response to an operator initiated HS opening or closing, or some other restriction at a lane outside LBS1 on an HSR section of an MM-Scheme c) In response to a REDX (SAC=15) requested by the Tidal subsystem in response to an operator initiated Tidal 	n/a	n/a	n/a	>>	The distinction between the solid Red X, with Red Flashers, and the exploded Red X, without flashers, is intuitive: exploded Red Xs, without flashers indicate to the driver, in an intuitive way, that a particular lane is not a <i>running</i> lane as opposed to, simply, that the lane is closed (i.e. due to an	It is not clear that on an IVD display the distinction between a solid red 'X' with red flashers and an exploded red 'X' without flashers would clearly indicate the distinction between a lane closure and a lane that is not a running lane. What alternative text or graphic could be used?

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	<p>Changeover or an automatic Tidal recover at Tidal or Signal subsystem start-up.</p> <p>Only the HSM subsystem, for MM-HSR schemes, and the Tidal subsystem, for tidal areas, request the Signal subsystem to set REDX (SAC=15).</p> <p>There are two variants of the red X displayed on-street:</p> <p>a) Exploded Red-Cross: (Derives from REDX; SAC=15) a lane control aspect indicating that a lane is not a running lane (e.g. the Hard Shoulder during on MM-HSR schemes during normal operation). See TSRGD Diagram 5003.1</p>  <p>b) Solid Red-Cross: (Derives from STOP; SAC=4) a STOP aspect indicating that the lane is closed</p>  <p>Solid Red-Crosses are accompanied with Red Flashers alternating side to side (see 'Flashers' section below). TSRGD 2009 Section 5: "The red cross shall convey to vehicular traffic proceeding in the traffic lane above which it is displayed the prohibition that such traffic shall not proceed beyond the red cross in the traffic lane until that prohibition is cancelled by a display over that traffic lane of the downward green arrow or diagonal white arrow or by a display over that traffic lane or beside [hard lane control sign]":</p>					<p>incident or some other event)</p>	

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	<div style="border: 1px solid black; background-color: #0070C0; color: white; padding: 2px; text-align: center; width: fit-content; margin: 0 auto;">End of lane control</div> <p>Whilst this use of red flashers is appropriate for lane or carriageway closures it should be clear that as a 'lane control' measure' (e.g. as an indication that the Hard Shoulder or outside lanes on the Aston expressway are not open for running), Red Flashers would be a distraction to the driver. Though IAN11/09 stipulates that Red Flashers will not accompany the resultant on-street setting, it is actually a functionality determined by the signal Transponder based on configurable site data that defines whether flashers are displayed (see the 'Flashers' section below). N.B: though AMIs over the Hard Shoulder do not display Red Flashers in response to a REDX (SAC=15) operators can request STOP on LBS1 at gantries in the MM-HSR zone in which case a Solid Red X will be displayed on-street accompanied with red flashers (STOP appears a 'STOP' on the operator interface and REDX appears as a red 'X').</p>						

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	<p>LANE DIVERTS TSRGD 2002 Section 5: “[the diagonal] arrow shall convey to vehicular traffic proceeding in the traffic lane above which it is displayed the warning that such traffic should move into the adjacent traffic lane in the direction indicated by the arrow as soon as traffic conditions”.</p> <p>There are 4 distinct SACs representing lane Diverts. These are:</p> <ol style="list-style-type: none"> 1. Lane Divert Left (LDL; SAC=16). Appears on-street as:  2. Lane Divert Right (LDR; SAC=14). Appears on-street as:  3. Hard Shoulder Divert (HSD; SAC=54). Appears on-street as:  <p>There is no difference in the on-street appearance between LDR and HSD: the distinction between the two is relevant only to the Signal Sequencing Rules: the distinction allows the Signal Sequencing rules to generate a less restrictive ‘60’ over the lane outside an HSD, whereas it will usually generate a more restrictive ‘40’ over the lane outside an LDR.</p> <p>The reason HSD was introduced, and the Signal Sequencing Rules modified to handle it, was that 40 mph was deemed to be too restrictive for the purposes</p>	<p>Amber flashers are function of the drive codes for specific devices (see ‘Flashers’ section below).</p>	<p>n/a</p>	<p>n/a</p>	<p>The meaning of the diagonal arrow Legend is intuitive and conveys to the driver the need to change lanes at, or ahead of, the location of the RSD. Driver behaviour in response is varied but drivers are educated such that they will generally have changed lanes by the time they reach the RSD location.</p>	<p>It can be seen clearly which lane the lane divert applies to.</p> <p>***</p> <p>Since the display represents all lanes, drivers can see which lanes are barred (i.e. barred aspects = STOP, REDX MDVL, MDVR, LDL, LDR, HSD, iDL- see MCE210) and can therefore make informed decisions, e.g. not to move into a lane that is barred.</p>	<p>The diagonal arrow is an intuitive legend and drivers are accustomed to these; it would seem natural for the IVD to be capable of displaying these.</p> <p>***</p> <p>To prevent drivers moving into a lane that is barred, would it be a requirement of the IVD that its display represents a lane that is barred even though the vehicle is not travelling in that particular lane? Since, also, if any lane on the carriageway is barred, the Signal sequencing rules will generate speed restrictions in lanes that are not barred; the IVD would be required to represent those lanes too. Is it reasonable to suppose, therefore, that the IVD should represent all lanes at the vehicles location?</p> <p>***</p> <p>(See ‘Constrictions’ in the ‘Signal Geometry’ section above for a discussion on scenarios wherein the number of lanes at the RSD location is not the same as the number of lanes at the point at which the IVD receives the data for that location. See also in that section, the discussion on the varying number of lanes moving downstream)</p>

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	<p>of closing the Hard Shoulder: the Hard Shoulder cannot be closed until a certain flow threshold has been exceeded; 40 mph could make this difficult.</p> <p>4. Tidal Divert Left (tDL; SAC=52). Appears on-street as yellow:</p>  <p>Tidal Divert is not set on-street with amber flashers (MCE2103). Tidal divert is requested by the Tidal subsystem in order to implement stage 1 of the change of a tidal state (e.g. Stage 1 of In-City to Normal Flow). Stage 1 directs traffic away from the lane that that will be closed in the direction of flow in the subsequent Stage of the changeover process.</p> <p>(See 'Upstream Sequencing' below for discussion of Triangulation of Lane Diverts.)</p>						

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	<p><u>CENTRE ARROWS – LANE OPEN</u> TSRGD 2002 Section 5 : “[the downward] arrow shall convey to vehicular traffic proceeding in the traffic lane above which it is displayed the information that such traffic may proceed or continue to do so in the lane beneath the arrow”</p>  <p>The downward green (“Lane Open” or “Centre Arrow” – SAC=27; MCH1689) is used in tidal areas, namely the Aston Expressway.</p>	n/a	n/a	n/a	Drivers can see that a lane is open for running from the point below the RSD.	Drivers can see clearly which lanes are open for running and can therefore make informed decisions about which lanes to use.	<p>The downward arrow is an intuitive legend and drivers are accustomed to these; it would seem natural for the IVD to be capable of displaying these.</p> <p>***</p> <p>In order for drivers to make informed decisions about their choice of lane it would seem appropriate for the IVD to represent the lane that the Centre Arrow applies to irrespective of whether or not the vehicle is travelling in that particular lane at the time.</p>
	<p><u>ENR/NR & RE</u> ENR/NR and RE are two aspects that indicate the end of block signal settings that may contain speed restrictions, barred lanes or a combination of both.</p> <p>END and NR are the same SAC (2), the only difference being that SAC=2 is displayed at the WOIF as “NR” to indicate the end of a restriction on a ‘Controlled Motorway’ whereas “End” is displayed on the WOIF to indicate the end of a restriction on a non Controlled Motorway. (N.B: ‘Controlled Motorway’ is the term used in the signal geometry data specifications to refer to sites that will display mandatory, i.e. ‘red-ring’, speed aspects instead of advisory, i.e. non red-ring, aspects)</p> <p>The actual on-street appearance of a setting of END/NR will be determined by the outstation configuration (drive codes etc): depending on the device type the on-street aspect corresponding to both END/NR and Re (SACs 2 and 3 respectively) will be either “End” or “Ø”</p>	Depending on the device type the on-street aspect corresponding to both END/NR and Re (SACs 2 and 3 respectively) will be either “End” or “Ø”	N/A	N/A	<p>As with any speed restrictions and any other signal setting, the setting applies at the RSD site and not at any point upstream from that site.</p> <p>Drivers are educated in this regard: even though they can see and are aware of the easing of the restriction several hundred metres upstream from the RSD site, conscientious drivers will not increase their speed until they have reached the RSD location.</p> <p>***</p>	N/A	<p>Would it be appropriate to display END/NR or RE on the IVD at any point upstream from the RSD, even though the driver can see the ENR/NR or RE on the RSD several hundred metres upstream from the RSD site? To display END/NR on the IVD at point upstream from the RSD site may mislead the driver into believing that END/NR or RE applies at that point and not at the RSD site. This has clear safety implications.</p> <p>Does this require that the data passed to the IVD contains GPS (or other) data from which the point at which the setting applies can be determined by the IVD?</p> <p>***</p> <p>When END/NR or RE is displayed on an RSD the motorist is aware that the National Speed Limit applies from that location onwards and it is not necessary to repeat that setting on sited downstream from that site. For</p>

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	 <p>See TSRGD, 2002 (Diagrams 6012 and 671)</p>				<p>Though the easing of the restriction applies from the RSD site and <i>at all points downstream</i> until superseded, this is intuitive and does not require that the every signal site downstream displays the RE or END/NR setting.</p>		<p>what duration should the END/NR or RE be displayed – how will the IVD know to clear the setting when it is no longer needed? Does this require that the data passed to the IVD specified a duration for which the setting applied? Or, assuming that there is a downstream site within a reasonable distance should the beacon associated with the downstream site transmit 'OFF' to the RSD.</p>

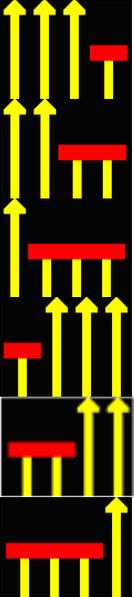
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	<p>RE RE (Restriction Eased - SAC = 3) is displayed as either 'End' or 'Ø'. RE is generated when an operator or automatic subsystem requests 'CLEAR' (as opposed to 'OFF') and is displayed on street for a configurable period (default = 3 minutes). When the period expires, the system sets the signal to OFF. The 'timeout' function is controlled by the outstation transponder rather than the Signal subsystem. The timeout of RE does not result in a Signal Sequencing event.</p> <p>REs can be set in blocks (e.g. when a block of speed restrictions is cleared) spanning one or more sites in the longitudinal direction. Similarly, when a primary setting that caused the Signal Sequencing Algorithm to generate a pattern of upstream, downstream, adjacent and transverse secondary settings is cleared, then the Signal Sequencing Algorithm will propagated RE to all those secondary locations.</p>	As in the row above	N/A	N/A	<p>The RE timeout period is configurable with a default value of 3 minutes. The driver knows that the RE aspect applies downstream from the RSD location and not from the FOP. If this is the last RSD site in a block of settings that has been cleared down to RE then the next signal site downstream will be 'OFF' (i.e. a blank signal).</p> <p>Therefore, if a block or other pattern of signal settings is 'CLEARed' (as opposed to 'OFFed') whilst a vehicle is travelling through that block or pattern of settings, then the driver cannot fail to see that the restriction has been eased.</p> <p style="text-align: center;">***</p> <p>The point of the 3</p>	N/A	<p>In order to avoid misleading the driver as to the point at which the RE applies, is it reasonable to suppose that RE should not be displayed on the IVD until the vehicle has reached the relevant RSD location? There may be a restriction at the signal site immediately upstream and to display RE on the IVD before the vehicle has reached the RSD displaying RE would mislead the driver into believing that RE applied at the point it was first displayed on the IVD. As with END/NR, should the data transmitted to the IVD contain the distance upstream from the RSD (or downstream from the FOP) that the aspect should be displayed.</p> <p>It is reasonable to suppose, also, that RE should not be displayed on the IVD for any great distance or duration beyond the point that it is first displayed on the IVD – once the driver has been made aware of the RE then there is no reason not to clear it. What is a reasonable duration to display RE? How should this duration be conveyed to the IVD? Should the IVD be pre-configured to timeout RE?</p>

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					minute timeout is to ensure that the driver cannot miss the fact that the National Speed Limit now applies.		

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	<p>RED & AMBER LANTERNS</p> <p>(See 'Flashers' below)</p>	(See ' Flashers ' below)	(See ' Flashers ' below)	(See ' Flashers ' below)	(See ' Flashers ' below)	(See ' Flashers ' below)	(See ' Flashers ' below)																							
	<p>WICKET ASPECTS</p> <p>Wicket aspects are used to represent barred aspects (STOP, REDX, LDL, LDR, HSD, tDL, MDVL and MDVR) at post and cantilever (e.g. MS4s) mounted sites where a single matrix device is used to represent all lanes at the site.</p> <table border="1"> <thead> <tr> <th>SAC</th> <th>Description</th> <th>Mnemonic</th> <th>Legend</th> </tr> </thead> <tbody> <tr> <td>21</td> <td>Lane 2 closed of 2</td> <td>1T</td> <td rowspan="6"> </td> </tr> <tr> <td>22</td> <td>Lane 1 closed of 2</td> <td>T1</td> </tr> <tr> <td>23</td> <td>Lanes 1 & 2 closed of 3</td> <td>TT1</td> </tr> <tr> <td>24</td> <td>Lane 1 closed of 3</td> <td>T11</td> </tr> <tr> <td>25</td> <td>Lanes 2 & 3 closed of 3</td> <td>1TT</td> </tr> <tr> <td>26</td> <td>Lane 3 closed of 3</td> <td>11T</td> </tr> </tbody> </table>	SAC	Description	Mnemonic	Legend	21	Lane 2 closed of 2	1T		22	Lane 1 closed of 2	T1	23	Lanes 1 & 2 closed of 3	TT1	24	Lane 1 closed of 3	T11	25	Lanes 2 & 3 closed of 3	1TT	26	Lane 3 closed of 3	11T	<p>Wicket aspects are targeted at specific signal site types: The Signal Sequencing Algorithm processes requests for primary lane closures and diversions, and, secondary closures and diversions generated by the rules themselves as it would any gantry type setting request. It then applies a set of 'Upstream Conversion' rules that convert Lane/gantry type setting patterns (e.g. LDR-50-50) to a corresponding Carriageway/post mount type setting (in this example 'T11') prior to sending a Set Device (CI=40H) message to the outstation. The system relies on true correlation between the site types (e.g. 'Carriageway') declared in the Signal Geometry Data (see 'Signal Geometry' section above) and the device types</p>	n/a	n/a	>>	<p>Wicket aspects are displayed on post or cantilever mounted devices. Though a single aspect represents each lane, because there is only one aspect displayed at the signal site there is not a one-to-one spatial relationship between the aspect and any of the lanes it represents.</p>	<p>Would IVDs be required to display wickets? If so, does this mean that data transmitted to IVDs informs the IVD of the number of the number of lanes at a site or the number of indicators? How would the IVD functionality determining a pictogram (legend) be specified??</p> <p>***</p> <p>What are the human factor considerations for the display of wickets on an IVD display? Would it be confusing to the diver to display wickets on an IVD at one location and gantry type aspects at another?</p> <p>***</p> <p>If is required that IVDs display only gantry type aspects (i.e. no wickets) then the Signal Sequencing Algorithm (the Signal subsystem) would require to be modified in order to convert wicket aspects sent to Carriageway (Post mount type) sites to the corresponding gantry type aspect for IVDs in vehicles approaching the RSD location. So for example, the Signal subsystem would need to be modified to ensure that 'T11' is converted to 'STOP-50-50' and not, for example, 'LDL-40-40' when the appropriate gantry type setting is 'STOP-50-50'.</p>
SAC	Description	Mnemonic	Legend																											
21	Lane 2 closed of 2	1T																												
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	<p>31 Lane 4 closed of 4 111T</p> <p>32 Lanes 3 & 4 closed of 4 11TT</p> <p>33 Lanes 2, 3 & 4 closed of 4 1TTT</p> <p>34 Lane 1 closed of 4 T111</p> <p>35 Lanes 1 & 2 closed of 4 TT11</p> <p>36 Lanes 1, 2 & 3 closed of 4 TTT1</p>  <p>Post mounted devices may be situated either in the central reservation or at the verge (or both – See ‘Entry Slip Roads’ in the ‘Signal Siting Requirements’ section below). Cantilever mounted devices (including MS4s mounted over AMLs on Gantries – e.g. on MM-HSR schemes) may extend over the Hard Shoulder to lane 1 (or lane ‘2’ on MM-HSR schemes).</p> <p>STOP WICKETS Extant Change Request CR2592 proposes a number of new aspects (SACs 55-58) representing full carriageway closures as wicket type aspects, for example, ‘TTT’ at a three lane intelligent indicator (i.e. at a site where it is specified in the geometry data that ‘STOP Wickets’ apply instead of STOP). This will entail modification to signal site geometry data</p>	<p>(comprising the signal site) in the outstation data.</p> <p>Subsequent to sequencing the signal setting proposal there is no way of determining from the outputted wicket aspect what the original requested primary (or sequenced secondary) barred aspect was: i.e. ‘TII’ could have been converted from ‘STOP-50-50’, equally, it could have been converted from ‘LDL-40-40’ – there is no way of knowing subsequent to the execution of the rules.</p>					

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	specification (MCH1798) to include the new site type.						

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	<p>FOG The MET Subsystem is required to implement signalling plans automatically, possibly triggered by different types of detector.</p> <p>As only a single 'Auto MET' layer exists on either the Signal Subsystem or Message Sign Subsystems, the MET Subsystem is required to resolve the conflict of signalling and signing requirements among plans waiting to be implemented automatically, before sending setting requests to the Signal Subsystem and Message Sign Subsystems respectively.</p> <p>Currently, the only MET related signal aspect is FOG (SAC=29).</p>  <p>The Transverse Sequencing Rules (see below) will propagate FOG across all lanes at a gantry site if FOG is set on any one of its lanes. FOG is a low priority aspect and will not overwrite any aspect except OFF: it is not possible under the current Rules specification, to have a mixture of FOG and some other non-blank aspect at a site.</p>	<p>Whether FOG is allowed at a site is defined in the Signal Geometry Data (Specific.sig). If an operator or the MET Subsystem proposes Fog at a 'Fog Prohibited' site SSA will convert the requested setting (the Primary) to OFF. Likewise, if the Rules propagate FOG from the primary setting to, for example, and adjacent site, and that site is flagged as 'Fog Prohibited', then the Rules Shell will, on completion of Sequencing, convert that secondary FOG to OFF.</p>	n/a	n/a	n/a	n/a	n/a
	<p>RED RING / MANDATORY ASPECTS Red Rings around speed aspects indicate that the speed restrictions are mandatory, i.e. enforceable.</p> <p>Operators, though may be aware of the distinction between Mandatory (Red Ring) and Advisory aspects cannot specifically select a Mandatory Aspect. Instead, the operator simply selects a speed restriction and the Signal subsystem will determine whether this is advisory or mandatory based on the value assigned to the CMI ('Controlled Motorway') flag for the relevant signal site in the signal geometry data.</p> <p>A CMI ('Controlled Motorway Indicator') Site MCH,</p>	n/a	n/a	n/a	Red rings can be seen clearly at a distance of several hundred metres (see Traffic Signs Regulations and General Directions, 2002)	n/a	IVDs should indicate to the driver whether the speed restriction is Mandatory or Advisory. A Red Ring would be the natural solution.

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	<p>1798: Signal System Data Organisation and Format. stipulates that For CMI's the Aspect Code must be that of a mandatory speed. The use of 'Controlled Motorway' here is very specific and should not be confused with the same term when used to distinguish non-Managed Motorways from managed Motorways. The Signal subsystem will generate a Mandatory (Red-ring) aspect or an Advisory aspect accordingly as the CMI flag for the relevant site is TRUE or FALSE.</p> <div style="display: flex; flex-direction: column; align-items: center;"> <div style="display: flex; align-items: center; margin-bottom: 10px;"> 20R (SAC=37)  </div> <div style="display: flex; align-items: center;"> 20 (SAC=5)  </div> </div>						

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	<p>SETTING ASPECTS – OUTSTATION RETRIES TR2045, M:1376: When required to send data to a motorway device using the RS485 MULTI MESSAGE messages, the Standard Transponder must do the following.</p> <ul style="list-style-type: none"> - Transmit RS485 MULTI MESSAGE (INCOMPLETE) messages, (CF=(2BH)), containing two byte instalments of data in the same order as received in the DEVICE DATA message. (M:1376.1) - Transmit the final two bytes of data in a RS485 MULTI MESSAGE (COMPLETE) message (CF=(2CH)). (M:1376.2) - One RS485 ACKNOWLEDGEMENT message (CF=(21H)) must be received in response to each RS485 MULTI MESSAGE (INCOMPLETE) message, before the next one in the sequence may be sent. An RS485 ACKNOWLEDGEMENT message must also be received in response to the RS485 MULTI MESSAGE (COMPLETE) message. <u>If an ACKNOWLEDGEMENT is not received for any of the MULTI MESSAGE (INCOMPLETE) or MULTI MESSAGE (COMPLETE) messages in the sequence, the transponder must transmit a blank MULTI MESSAGE (COMPLETE) message (i.e. with the data fields set to 00H) to abort the sequence and must then try to send the complete multi message sequence again. The multi message sequence may be sent up to 3 times. (M:1376.3)</u> - Once either the multi message sequence has been transmitted successfully or the retry sequence has been exhausted, <u>the transponder must wait a minimum delay time of 300 ms from the time the MULTI MESSAGE (COMPLETE) message was</u> 	n/a	n/a	It is straightforward for the status of all RSDs to be reported back to the instation	n/a	n/a	<p>How will IVD display failures be dealt with to ensure that two IVDs at the same location do not convey conflicting information to their respective drivers in relation to each other and to the associated RSD? Is it feasible for the status of all IVDs to be reported back to the instation? How will IVD display failures be dealt with to ensure that two IVDs at the same location do not convey conflicting information to their respective drivers in relation to each other and to the associated RSD? Is it feasible for the status of all IVDs to be reported back to the instation to IVDs? If not then how would the IVD determine the validity of its own display?</p> <p style="text-align: center;">***</p> <p>If the route between the Instation and the IVD were to bypass the RSD Transponder, then how would built in Outstation delays (e.g. due to retries) be mimicked in order to synchronise RSD and IVD displays? Does this consideration suggest a constraint on the future architecture whereby the RSD transponder controls the timings of transmissions to IVDs?</p> <p style="text-align: center;">***</p> <p>What are the Human Factor considerations when there is a perceptible difference in timings between RSD and IVD displays? Would, for example, a perceptible delay undermine confidence in the system? What is the threshold for</p>

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	<p>transmitted and then output a STATUS REQUEST command, (CF=(22H)), to the motorway device. (M:1376.4)</p> <ul style="list-style-type: none"> - <i>Wait for a STATUS REPLY message, (CF=(23H)), from the motorway device, (within the constraints of the RS485 protocol). (M:1376.5)</i> 						<p>delays with respect to driver confidence in the system?</p>

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	<p><u>SETTING ASPECTS – INSTANTATION RETRIES</u> TR207 Sect. 11: After a set message has been from the Signal subsystem (via COBS) the Signals Subsystem must expect the response to arrive within a preset time. If the expected response is not received within this time, the message exchange must be considered to have timed out. The Signals Subsystem reads the value for the time-out for each HDLC message type from Site data.</p> <p>Unless the Transponder from which a response has been timed out is known to be unobtainable, the Signals Subsystem must make up to a total of three attempts to elicit a response. If the Transponder from which a response has been timed out is known to be unobtainable, no retransmission attempts must be made.</p> <p>If multiple attempts are made to elicit a response from a Transponder and all are timed out, the Signals Subsystem must consider the device to be unobtainable. The HDLC (40H) Set Devices Complete Response Period in seconds; default 30 seconds (300 seconds when 21 bit LCC is used) ((MCH1798)).</p>	n/a	n/a	<p>If a Transponder does not respond to a set device message from the Signal subsystem after three consecutive attempts, the minimum time delay between sending the initial message (HDLC Set Device (CI=40H)) and registering the transponder as faulty/unobtainable is 1+ minutes (i.e. 3 x time-outs with 30 second intervals). During this interval, it cannot be determined at the instation whether the device has set on-street as requested.</p>	n/a	n/a	<p>If a transponder does not respond to a set device message from the Signal subsystem after three consecutive attempts, the minimum safe time (i.e. to avoid potential conflict between the RSD and the IVD) the sending the initial request to the transponder and transmitting the setting update to the IVD is 1+ minutes. How can the potentiality of conflict be eliminated given that during this time the actual on-street RSD setting status cannot be determined?</p>

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	<p>ASPECT ADAPTION / ASPECT FAILURE The system attempts to set a pre-defined alternate aspect when the requested aspect fails to set on-street (e.g. due to bulb failure that would render the aspect illegible). Each aspect defined in the outstation data has such a pre-defined alternate aspect. So for example, the pre-defined alternate aspect to 50 (SAC=8) may be 60 (SAC=9) such that if 50 cannot be set then the system will attempt to set 60 in its place. The alternate aspect may be OFF, STOP or any other aspect.</p> <p>If the Transponder 'adapts' an aspect, it informs the Signal subsystem but there is no requirement for the Signal subsystem to re-sequence the setting.</p> <p>TR2045 Section 3.3.12.3 If a Signal motorway device (Signal Driver) reports a change of aspect status (in the 5 bit Aspect Drive Code) to the Standard Transponder, the Standard Transponder will attempt to adapt the aspect where applicable. Where a non-signal motorway device reports a change of aspect status the Standard Transponder will not attempt to adapt the motorway device. In either case the Standard Transponder will report status changes to the COBS.</p> <p>M: 425 Where a Standard Transponder is not able to set an aspect specified in a SET DEVICES message it must attempt to set the indicator to the alternative aspect defined in the Outstation Site Data. Where a COBS requested indicator setting is not possible or, at any time, a STATUS REPLY message from a Signal Driver indicates that an aspect has failed or cannot be set, the Standard Transponder must attempt to set the adaption appropriate to the requested setting as defined in the Outstation Site Data. (M: 425.1)</p> <p>If an indicator has been successfully adapted, the Standard Transponder must make no further attempts to set the originally requested setting. The only exception is when a communications failure occurs between the Standard Transponder and the Signal</p>	n/a	n/a	It is straightforward for device failures to be reported back to the instation. Device failures (e.g. bulb failures) that would render the display illegible or even misleading are dealt with by the system to ensure that a safe alternative, e.g. an adaption aspect (which could include 'OFF') is imposed. It is not possible, therefore, for two motorists at the same location to receive conflicting information.	N/A	N/A	<p>Does the issue of Aspect Adaption mean that in order to avoid Vehicle Infrastructure Conflict (VIC) that the system is required to wait until the TPR (Transponder) sends a DEV STAT update to the instation before it can transmit to vehicles? How will this affect the latency of the information received by IVDs? Does this mean that Aspect Adaption functionality would have to be discarded? Is it safer to display nothing rather than an aspect that may conflict with the IVD?</p> <p>***</p> <p>If Transponder adapts an aspect then it will inform the Signal subsystem, but the Signal subsystem is not required to re-sequence the settings. In these instances, would the signal Transponder be required to send a setting update to the IVD informing it of the aspect or should this be done by the Signal subsystem? If it were to be updated by the Signal subsystem then would this incur a significant delay as transactions take place between instation and outstation?</p> <p>***</p> <p>If the aspect fails to set on-street does this mean that in order to avoid VIC that the system is required to wait until the TPR sends a DEV STAT update to the instation before it can transmit to vehicles? How will this affect the latency of the information received by the IVD? What would it mean for user confidence if Gantries were set to OFF due to failures but the IVDs displayed aspects – Which would the motorist trust?</p>
May 2010	<p>Driver in which case the sequence to set the originally requested setting must be made. (M: 425.2)</p> <p>If an indicator which has been successfully adapted subsequently fails, the Standard Transponder must</p>			181			

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	<p><u>UNOBTAINABLE DEVICES & TRANSPONDERS</u></p> <p>'Obtainability' is a Boolean attribute of a roadside device, Transponder or LCC that has the value TRUE when the relevant entity is operational and available to receive signal settings from the Signal subsystem.</p> <p>If a device is logged by the Signal subsystem as faulty the Signal Subsystem will not send a SET DEVICE message to that device. If a Transponder is logged as faulty the Signal Subsystem will not send a SET DEVICE to any devices attached to that transponder. The Signal subsystem will, however, sequence settings requested for that device and store them locally until such time that the device is operational, on which event the Signal subsystem will send the setting data to the outstation. So, for example, if an operator closes a carriageway and the upstream signal site is not obtainable but the site upstream from that is, then in order to generate the appropriate lead-in settings at the second upstream site it is necessary to generate the lead-ins to STOP at the unobtainable site, even though they will not be set on-street directly.</p> <p>When a Transponder becomes unobtainable all devices belonging to that Transponder are logged as un-obtainable and indicated as such on the WOIF.</p> <p>When an LCC becomes unobtainable all Transponders, and therefore all devices, belonging to that LCC are logged as unobtainable.</p> <p>When a device becomes un-obtainable, the last reported setting, i.e. last reported by the Transponder before the device/Transponder/LCC became un-obtainable, is displayed at the WOIF.</p>	n/a	n/a	<p>When the outstation (Transponder or device) becomes obtainable again the Signal subsystem will re-transmit the setting.</p> <p>***</p> <p>When a device is unobtainable the actual on-street setting on that device can only be confirmed by inspection, i.e. via CCTV or on-site inspection.</p> <p>***</p> <p>Engineers/RMCs may or may not have the facility to manually (i.e. 'plugging in' at the roadside) drive a device that is unobtainable to 'OFF', or some other appropriate aspect.</p>	<p>The driver will not see the most recent sequenced settings associated with the RSD. Any secondary (lead-in, adjacent, transverse or downstream settings) sequenced from the settings on the unobtainable device will, however, be set on-street if the relevant devices are obtainable.</p> <p>The previously set (i.e. before the device became unobtainable) may still be set on-street. The operator should be aware of this (they will be indicated on the WOIF) and can therefore make an informed decision as to whether these previous settings, in conjunction, with the newly sequenced settings on nearby sites causes a dangerous scenario.</p>	<p>At a gantry site, an unobtainable device may present a blank aspect whilst those on the lanes inside and outside that lane have some other aspect. Or, the unobtainable device may present an aspect that is at odds with those on the lanes inside and outside it. Until the fault is cleared this may confuse of undermine the driver's confidence in the system.</p>	<p>Should the IVD display always reflect or mirror the RSD display? If an RSD presents an anomalous setting due to failure at the outstation, should the IVD, by way of contrast, display the setting intended by the In-station? Would this be safer? Should the system send the device status of the RSD to the IVD so that the faulty status of the RSD can be conveyed to the driver?</p> <p>***</p> <p>If the RMC or other engineer is able to 'manually' (i.e. by passing the control system) drive the signal device to display such and such an aspect, does this require that the IVD should be 'driven' as a part of the manual process also? How would this be achieved?</p>

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	<p>ASPECT VALIDITY HATMS deploys a number of signal device types and site types. Signal Device Types relate to the actual physical device. A Site type is a construct that consists of one or more lanes each of which will map to a device in the case of a Gantry site, else, in the case of a Carriageway (e.g. Post Mounted) site the site itself maps to a single device. Depending on the device type and or site type various aspects will be valid or invalid as the case may be. For example: REDX is invalid at a 409 device type. 'STOP' is invalid at a 'CARRIAGWAY' site type; 'Fog' is invalid at a site flagged as 'Fog Prohibited' in the signal site geometry data; 'REDX' is invalid at any lane other than Lane 1 at a Variable Lane site or the outside lane(s) at a Tidal, Tidal A or Tidal B site.</p> <p>If an aspect requested by an operator or automatic subsystem is not valid for a particular site then the Signal Subsystem (SSA) will reject the proposal with a Primary Validation error (except 'Fog' at a Fog Prohibited site where the Signal Subsystem will send a Warning to the requesting source and convert the requested setting to OFF).</p> <p>If, for whatever reason (e.g. the site data is inconsistent), the Signal sends an invalid aspect to the Transponder the Transponder will respond with an 'Invalid Setting' setting status.</p>	<p>Depending on the device or site type a particular aspect will be valid or invalid as the case may be.</p> <p>If the Signal subsystem sends a signal setting targeted at a device for which that particular setting is not valid (e.g. 'IT' to a 421 – gantry type – device instead of 'STOP') then the Transponder will reject the message with an 'Aspect Undefined' status. The requested aspect will not set on-street. This should never happen in theory but it depends on the consistency between the device definitions in in-station device data (Device.sig) and the outstation data (Outsite.dat). The site data should be validated at the point of data entry at the Highways Agency Data Entry Package (HA DEP).</p>	<p>n/a</p>	<p>n/a</p>	<p>n/a</p>	<p>n/a</p>	<p>Though in theory the site data should be consistent, the site data consists of a large number of files and discrepancies between signal device/site definitions across files have occurred. If, then, a setting sent from the Signal subsystem to the Transponder is rejected, does this presuppose that prior to sending a setting to the IVD, the setting requires to be validated by the associated signal Transponder? Does this require that the RSD's Transponder controls the transmission to the IVD?</p> <p style="text-align: center;">***</p> <p>It is presumed that the IVD will not validate any aspect it receives. Any SAC is valid?</p>
	<p>UNGUARDED STOPS STOP is not set on-street until the appropriate upstream lead-in aspects are set. Currently, this is controlled by the Signal subsystem in response to a</p>	<p>n/a</p>	<p>It is practicable for the Instation to control the setting of STOP by monitoring</p>	<p>It is straightforward to report Device Setting STATUS back to the</p>	<p>N/A</p>	<p>N/A</p>	<p>What if the aspect fails to set on-street – does this mean that in order to avoid VIC that the system is required to wait until the TPR sends a DEV STAT update to the instation</p>

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	<p>Dev STAT update from the outstation informing that the upstream site has set to the appropriate secondary lead-in. If, for whatever reason, the appropriate lead-in aspect to STOP fails to set on-street, and is reported as such by the Transponder, then the Signal sub-system will instruct the Transponder to set STOP anyway but will send a Warning to the operator. The point of this is to warn the operator of a situation where motorists are not given sufficient lead-in warning of an upcoming lane of carriageway closure. The operator can therefore make an informed decision to modify the on-street settings.</p>		<p>the status of devices.</p>	<p>Instation.</p>			<p>before it can transmit to vehicles? How will this effect the latency of the information received IV.</p> <p style="text-align: center;">***</p> <p>As with faulty/unobtainable devices, should the IVD display the setting even through it is not set on-street?</p>

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	<p>NON-COMMISSIONED DEVICES If a device is not commissioned then the Signal Subsystem will not send a SET DEVICE to that device. The Signal subsystem will, however, sequence settings from that device as if it were commissioned and store them locally so that subsequent sequencing events may factor the settings into the sequencing process. So, for example, if an operator closes a carriageway and the upstream signal site is not commissioned but the site upstream from that is, then in order to generate the appropriate lead-in settings at that upstream site it is necessary to generate the lead-ins to STOP at the non-commissioned site even though they will not be set on-street.</p>	n/a	n/a	The Signal subsystem will not send the sequenced settings to the non-commissioned device so the motorist will not be presented with the sequenced settings for that site.	n/a	n/a	As with faulty/unobtainable devices, should the IVD display the setting even through it is not set on-street?
<p>Signal Sequencing (Spatial)</p>	<p>GENERAL Signal Sequencing is the process that generates an appropriate pattern of signal settings to be displayed on motorway matrix indicators in response to operator and other setting requests. The pattern of settings is determined by a set of 'Signal Sequencing Rules' that, when executed, act on inputted (Primary) settings to generate upstream, adjacent, transverse and downstream settings that will enable traffic management on lane by lane basis: i.e. safely manage the flow of traffic towards, around and away from an incident, or other scenario, and with minimal disruption to traffic flow.</p> <p>The Signal Sequence Rules and Rules Shell are defined in MCE2103</p> <p>Commutable Aspects The notion of 'Commutable Aspects' wherein speed restrictions outputted from SSA may be commuted to less restrictive speed restrictions by the rules shell is currently being discussed in the community. The consideration is that in some situations speed restrictions outputted from SSA are more restrictive than they need to be. One solution may be to introduce a configurable item to the signal site data such that, on a site by site basis, 40 (SAC=7), for</p>	(See Geometry Data Above)	n/a	n/a	The principles of traffic flow management through signalling, as expressed in the Signal Sequencing, are <i>predicated</i> on static display devices, though this is nowhere expressed as such. If the system had been designed around the moving devices then the Signal Sequencing rules may have taken a different form.	<<	How will the future system preserve the implicit safety case for the Signal Sequencing Rule? See all sections

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	<p>example, could be commuted to 50 (SAC=8). To preserve the integrity of the safety case implicit in the Rules, the aspect should be commuted by the Rules shell post execution of the rules.</p>						

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	<p>UPSTREAM SEQUENCING Due to the high vehicle speeds and large volumes of traffic on motorways, it is essential that motorists are not instructed to make sudden changes in speed or course. A 30 mph speed reduction between signals is considered safe. Therefore a lead-in sequence is set upstream of the restriction if it is below 40 mph. For example, where a 30 mph speed restriction is required the signal upstream of the restriction would be set to 50 mph.</p> <p>The main emphasis for Upstream Sequencing (the execution of the Upstream Rules) is, therefore, to effect an orderly and safe approach to a restriction downstream: so, for example, '50' could be set at the signal site upstream from a site displaying '20'.</p> <p>When, for example, an operator requests a lane or carriageway closure (STOP), SSA will generate the necessary secondary upstream speed restrictions to slow traffic and upstream triangulated lane diverts to direct traffic around the closure.</p>	n/a	n/a	n/a	Signal sites are longitudinally spaced so as to ensure sufficient lead-in.	n/a	<p>The main emphasis is on conditioning traffic flow so that drivers can decelerate safely but be in compliance with the restriction at the point they pass under the signal site. With RSDs the fact that the restriction applies from the RSD location is intuitive (or, at least, drivers are trained to appreciate this) even though they see the restriction from a point some distance upstream. However, if the same restriction is displayed on an IVD at the FOP, would this mislead the driver into believing that the restriction applies at the FOP rather than from the RSD location downstream? Would this cause unnecessary and sudden breaking? How will this be resolved? Would the solution require that the data transmitted to the IVD includes the distance to the RSD or, possibly, the geographic coordinates/location for the RSD for the IVD?</p> <p>Regarding the issue of misleading the driver as to the point at which the restriction applies can be resolved, should the IVD display the signal settings at a point upstream of the RSD approximating the FOP? If so, what would be a safe approximation? Assuming a vehicle is travelling at 70 mph, then that vehicle will travel approximately 30 metres in one second. Assuming a FOP of 300m and a safe margin for the timing of the display on the IVD that would allow the vehicle to travel of 10% of that distance (30m), then the system will be required to re-transmit the current setting status of the RSD to vehicles</p>

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							<p>in the vicinity of the FOP at a rate of 1 transmission per second or higher in order than all vehicles approaching the RSD receive the setting data for that location within a safe margin.</p>

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	<p><u>TRANSVERSE SEQUENCING</u> In order to discourage undertaking, if a speed restriction is set on an outer lane at a lane signalled site, the same, or lower, speed restriction is set on all inner lanes. This is known as transverse sequencing. The highest speed that can be displayed is 10 mph below the permanent speed restriction for that site; therefore the maximum speed that can be displayed on a motorway signal is 60 mph.</p> <p>Transverse sequencing allows for a combination of different settings across a carriageway including a combination of barred aspects (STOPS, REDXs, Motorway Diverts and Lane Diverts) and speed restrictions and also differential speed.</p>	N/A	N/A	N/A	>>	The driver can see all settings that apply across the carriageway irrespective of the particular lane he/she is travelling in. The driver can, therefore, make an informed decision as to his/her passage along the carriageway – i.e. as to speed and lane.	In order to allow the driver the same degree of decision making capability, should the IVD display all aspects set at the signal site, and in a spatial arrangement emulating the spatial arrangement of the RSD display?
	<p><u>ADJACENCY SEQUENCING</u> The main aim of Adjacency Sequencing (execution of the Adjacency Rules) is to bring about an orderly merge of two traffic streams at a convergence. The primary means of achieving this is through the equalisation of speeds across the convergence. So for example, if there is a speed restriction of 40 mph at lane 1 on the main carriageway and there is an adjacent slip entering on the inside, then the Adjacency Rules will propagate '40' (SAC=7) to the outside lane on the entry slip.</p> <p>Subsequent execution of the Transverse rules on the entry slip signal site will propagate the '40' to the inside lanes at that site.</p>	n/a	>>	Though adjacent sites may be physically close, transmission to one device at one site will not interfere with transmissions to the adjacent site.	n/a	Due to close physical proximity, drivers may actually see the settings on the site adjacent to the site they are approaching. Drivers intuitively apprehend the relationship between the road layout and signal sites. Provided compliance with the siting requirements (see ' Signal Siting Requirements ' section below) the display of settings on and	Does the close proximity of adjacent sites present a problem for transmission systems, assuming that the only feasible transmission system involves localised and targeted transmissions of signal and sign setting data? How will vehicles on the main carriageway, for example, be targeted in such a way that transmissions targeted at vehicles travelling on the entry slip are not interfered with, and vice versa?

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						adjacent slip, for example, should never confuse or be a source of distraction to drivers on the main carriageway.	

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	<p>DOWNSTREAM SEQUENCING Downstream Sequencing (execution of the Downstream Rules) is primarily concerned with generating aspects that inform the driver that the restrictions he/she has been driving through no longer apply. This process usually culminates in 'End' or 'Ø' being set on-street (See 'ENR/NR and RE' in the 'Aspects' section above). However, if the HDS set on a particular site is more restrictive than the National HDS then the rules will not propagate 'End' or 'Ø' to that site (see 'HDS – Highest Displayable Speeds' in this section above).</p> <p>Not all Downstream Rules are involved with the easing of restrictions. Certain Downstream rules are concerned with, for example, 'gap filling': if an END/NR or RE is set at a site that sits between two other sites (in the longitudinal direction) that are set with speed restrictions then a certain Downstream Rule will propagate the most restrictive speed restriction at the downstream site to the site set to END/NR or RE.</p>	(See ' ENR/NR and RE ' above).	(See ' ENR/NR and RE ' above).	(See ' ENR/NR and RE ' above).	(See ' ENR/NR and RE ' above).	(See ' ENR/NR and RE ' above)	(See ' ENR/NR and RE ' above).
	<p>DISTANCE DEPENDENCY CHECKS The Rules Shell may convert aspects outputted from the Upstream and Downstream Sequencing rules to more restrictive or less restrictive settings depending on the longitudinal distance between the two sites in question. So, for example, if two sites are in very close proximity longitudinally, then the rules engine shell may, depending on pre-defined distance dependency values, convert the output of the rules to a more restrictive setting (e.g. '50' is converted to '40'). Conversely, if the longitudinal spacing is quite large, the rules engine shell may convert the output of the rules to something less restrictive (e.g.: 'LDR' to '50'; '30' to '40'; 'End' to 'OFF' and so on).</p> <p>Distance dependency checks are based on the source aspect (i.e. the aspect inputted to the given rule), the target aspect (i.e. the aspect sequenced from the source aspect) and the distance between the source</p>	n/a	n/a	n/a	n/a	n/a	Since the processing is internal to the In-Station control system and prior to any communication between the In-Station and the Out-Station, this has no real significance for V2I Integration.

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	<p>site and the target site. As the distance increases, the rules shell may substitute the initial target aspect outputted from the rule with an increasingly less restrictive setting until, ultimately, OFF is substituted.</p> <p>Only in a very few cases do the rules themselves take into account the distance between sites. An example of a rule that does take into account distance is C11B05 which propagates LDL (Lane Divert Left) upstream from an LDL if there is a STOP set less than 100 metres downstream from that LDL.</p> <p>Distance dependency tables for Upstream and Downstream Sequencing are defined Section 5 of MCE2103.</p>						

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	<p>HDS– HIGHEST DISPLAYABLE SPEEDS By means of configurable site data and run-time operator requests an HDS (Highest Displayable Speed) value can be assigned to a site or block of sites. The HDS value is used by SSA to commute any speed restriction requested by the operator or automatic subsystem to the HDS value if the requested setting is less restrictive than the HDS value for the relevant site. E.g. If the HDS at a given site is 40 mph and the operator requests a setting of 50 then SSA will commute the requested 50 to 40. SSA will also apply the HDS value assigned to a site where the Rules generate a secondary setting at that site.</p> <p>There is a configurable 'National HDS' field in the Signal Site configuration data. The default value of this is 60 mph (see MCH1798). If the HDS on a given site is less than the National HDS (i.e. more restrictive than the National HDS) then SSA will commute any RE or END/NR aspect requested (i.e. Primary setting) at that site to OFF. Neither will SSA will assign any secondary RE or OFF/NR at that site.</p> <p>HDS settings are set by operators to ensure that the output of the Signal subsystem does not conflict with temporary fixed signed speed restrictions at the roadside, e.g. around road works.</p> <p>When an operator sets or clears a temporary HDS the Signal subsystem will re-sequence all current signal settings in order to update the actual on-street settings.</p> <p>Note on the specification of HDS functionality There is an extant Change request (ref CR2481) for Temporary HDSs be dealt with by Signal Subsystem alone. Prior to that, there are a number of outstanding issues to do with the way HDS handling within SSA is specified: certain of the sequencing rules defined in MCE2103 specify that propagated aspects should be converted to the HDS for the given site if the HDS is more restrictive than</p>	<p>Certain signal sites will have a predefined HDS less than the National HDS value. This has no specific significance for present purposes.</p>	<p>N/A</p>	<p>N/A</p>	<p>If a block of signal settings is contained within the span of an extant HDS block, then END/NR will not appear at the most downstream signal site in that block of signal settings. Conversely, if the block of signal settings extends further downstream than the block of HDS setting, then SSA will generate END/NR (displayed as Ø) on the RSDs at the most downstream site in the signal setting block.</p> <p>Where the National Speed limit for motorways begins at the end of a span of road works, the motorist is usually informed by means of a fixed signed, albeit temporary, Ø. If the span of road works is correctly ascertained by the operator, then settings on RSDs will not conflict with</p>	<p>N/A</p>	<p>In the case of an HDS being set then END/NR will not set on the RSD downstream from a restriction. I.e. the signal that would normally be set to END/NR would be blank. Would the system be required, therefore, to actively inform the vehicle that the signal is blank, even though that signal may not have been subject to a setting for some considerable time?</p>

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	<p>that proposed by the rule, e.g.:</p> <p>C2U30: (ASPS = ITTT or TTTI) == ASPSU = [[40, 40R]~CMI, HDS]MIN</p> <p>Others do not, e.g.:</p> <p>C11U60: (ASPS, L = [SPEED, REDRING]~CMI).(ASPS, L + 30 mph <= [60, 60R]~CMI) == ASP SU, L = [50, 50R]~CMI</p> <p>Where the rule itself does not specify that the aspect should be converted to the HDS for that site then it is left to the Rules Shell to arbitrate, MCE2103:</p> <p>"5.8 ADDITIONAL SHELL CHECKS For adjacent, upstream and downstream sequencing rule blocks, three additional checks are introduced. If the aspect given by the rule is a speed greater than the current HDS for the site, OFF is substituted."</p> <p>However, section 6.6 of MCE2103 states the following:</p> <p>"The aspect derived from the rules may be modified under certain circumstances by the shell. If an aspect given by the rules is greater than the current HDS for the site then the shell will substitute an alternate aspect. For an aspect being set at Incident level the substituted aspect is OFF. For an aspect being set at Plan and Blanket level the substituted aspect is the most restrictive of the HDS or the Proposal."</p> <p>The first thing to note here is that the 'plan' layer is in fact identical with the incident layer.</p> <p>The second thing to note is that in respect of the blanket layer sections 5.8 and 6.6 are contradictory</p>				<p>the temporary fixed signage. It is crucial, therefore, that operators correctly ascertain the span of road works when setting HDS blocks to avoid inadequate coverage and END/NR or RE being set where road works are in operation.</p>		

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	<p>and no mention is made of the subsystem layers.</p> <p>The third thing to note is that 'layering' itself is defined in TR2072 and is a function of the Signal Subsystem and not SSA. Therefore either:</p> <ul style="list-style-type: none"> a. the functionality defined in sections 5.8 and 6.6 of MCE2103 should be redefined in TR2072 and the functionality itself be removed from SSA to the Signal subsystem (to maintain that distinction for the moment) where layering takes place, or b. All sequencing rules should commute aspects to the HDS if that is the more restrictive <p>Mostly, it is the Transverse rules that specify that an aspect should be set to the temporary HDS, but some of the conversion rules do also, so some lead-in results may appear inconsistent. This raises two questions:</p> <ul style="list-style-type: none"> 1. Does not the distinction between the plan-incident and blanket layers in respect of lead-ins being commuted to OFF appear arbitrary and confusing? 2. Is it safe and non-arbitrary to commute 20-50 to 20-OFF when the temporary HDS at the upstream site is 40 mph whereas 20-40 remains unchanged? <p>Though the Signal subsystem is implemented as true to the specification the inconsistencies that exist result in settings that, under certain scenarios, are clearly confusing and have resulted in several incidents being raised.</p>						

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	<p>IMPLEMENTATION REASONS A signal setting requests sent to the Signal subsystem for sequencing is sent with an Implementation Reason, i.e. a code indicating the reason that the signal(s) requires to be set.</p> <p>Implementation Reasons have no function in the Signal Sequencing process as such, but are sequenced by SSA in order that the correct implementation reason is assigned to each secondary setting: a given secondary setting will derive from a certain primary setting, so the implementation reason for that secondary setting should derive from the implementation reason from <i>that</i> Primary and not some other Primary setting that happens to be set on-street.</p> <p>The sequenced Implementation Reasons are passed to the Message Sign subsystem in order that it may sequence the correct sign settings during 'reactive' message sign proposal processing (See 'Implementation Reasons' in the 'Variable Message Signs' section below).</p>	(See ' Implementation Reasons ' in the ' Variable Message Signs ' section below).	(See ' Implementation Reasons ' in the ' Variable Message Signs ' section below).	(See ' Implementation Reasons ' in the ' Variable Message Signs ' section below).	(See ' Implementation Reasons ' in the ' Variable Message Signs ' section below).	(See ' Implementation Reasons ' in the ' Variable Message Signs ' section below).	(See ' Implementation Reasons ' in the ' Variable Message Signs ' section below).
	<p>MET SEQUENCING (See 'FOG' in the 'Aspects' section above)</p>						
<p>Signal Sequencing (Temporal)</p>	<p>COUNTDOWN SEQUENCES In addition to spatial sequencing, time sequences are used to step down to low speed restrictions. This is to avoid the sudden imposition of speed restrictions on traffic. Hence, if the operator requests a 20 mph restriction the computer will normally set the signals at 40 for five seconds before stepping to 30 and then to 20 after a further five seconds.</p> <p>A countdown sequence can apply to any aspect. This sequence (aspects and intervals between each) is configurable.</p> <p>Currently this functionality is controlled by the signal Transponder. In the future this functionality will be</p>	N/A	N/A	N/A	A vehicle travelling at 70 mph covers 31 metres in one second. Given that the minimum distance between gantries on Managed Motorways may be as little as 300 metres, an interval between countdown stages of 10 seconds means that the motorist may only	N/A	<p>Possible Data Requirement: Either:</p> <ul style="list-style-type: none"> a) The entire countdown sequence is sent to the IVD with a time stamp so that the IVD can determine how to execute the sequence, or b) The Signal subsystem will be modified to send each aspect in the sequence to the IVD via the I2VT at the configurable intervals. <p>The method defined in b) might ensure parity between the IVD and RSD displays, assuming reasonable parity in speed of transmission</p>

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	<p>migrated to the Signals subsystem as part of the scheme to introduce Intelligent Indicators.</p> <p>The countdown sequence commences as soon as the Transponder receives the SET DEVICE message from the Signal subsystem.)</p>				<p>see one aspect in the countdown sequence.</p>		<p>between the two systems and, moreover, that all things are equal with respect to the speed of device status reporting between the outstation and the instation.</p> <p>The method outlined in a) above might ensure parity between the IVD and RSD displays but would require certain intelligence to be built into the IVD for it to determine which aspect in the countdown sequence to start at since a match between the IVD and the RSD will be dependant on the time at which the vehicle receives the data if the IVD and the RSD are to be in sync.</p> <p style="text-align: center;">***</p> <p>Assuming the driver has time to see more than one stage in the countdown sequence on the RSD, then would this require that the IVD is also updated/mirrors every setting on the RSD as it travels towards that RSD?</p>

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<p>Flashers</p>	<p>GENERAL MCE0107 - A flashing light source incorporated into a Variable Message Sign or Motorway Signal display which is designed to draw attention to the Sign or Signal. ("Conspicuity Device"). Required to accompany certain defined Aspects.</p> <p>DMRB Vol. 9, Sect 4, A4/3 Motorway signals are designed to meet the special requirements of motorways, good long range visibility for high speed vehicles, good penetration through fog and spray and a high level of illumination to overcome bright low level sunlight. All motorway signals have amber lanterns that are designed to be <u>visible at 500m</u>.</p> <p>The Traffic Signs Regulations and General Directions 2002 <u>Warning signal for motorways and all-purpose dual carriageway roads</u> 45. - (1) A traffic sign for conveying the warning specified in paragraph (2) to vehicular traffic on a motorway or an all-purpose dual carriageway road shall be a light signal of the size, colour and type shown in diagram 6023. (2) The warning conveyed by the light signal shall be that (a) there is a hazard ahead on the motorway or all-purpose dual carriageway road; and (b) drivers should drive at a speed which does not exceed 30 mph until they are certain that the hazard has been passed or removed. (3) When the light signal prescribed by this regulation is operated, each lamp shall show an intermittent amber light at a rate of flashing of not less than 60 nor more than 90 flashes per minute and in such a manner that one light is always shown when the other light is not shown</p> <p>A System of flashing lanterns (amber or red) on an INDICATOR or VARIABLE MESSAGE SIGN which may be activated in conjunction with the display of a FACE or ASPECT. Flashing is a function of the drive</p>	<p>Whether or not a signal device employs flashers is a function of the device type and the drive code assigned to the particular aspect (byte 2 of the drive code: 01 = Amber, 10 = Red - MCH1689). For example, amber flashers are displayed with '20' on 451 (post mounted) and 452 (entry slip pairs) device types but not 450 (gantry mounted) device types (MCH1689 SDIN table 450-451-452)</p>	<p>n/a</p>	<p>Flashing functionality (both amber and red) is controlled by outstation software.</p>	<p>Flasher lanterns are designed so that drivers can see amber flashers at 500m. The driver sees the flasher for duration he takes him/her to travel 500m (22.5 seconds travelling at 50 mph). Since the duration is relatively short, and given that the device is external to the vehicle, this provides adequate warning but does not distract or annoy the driver.</p>	<p>n/a</p>	<p>Should IVDs be cable of displaying these? Would they prove too distracting from inside the vehicle?</p> <p>Should the IVD repeat the flasher but switch it off after a defined period so as not to overload the driver's senses?</p> <p>***</p> <p>Assuming the flasher function would be replicated by the IVD, should control of the flasher function be migrated to the instation?</p> <p>***</p> <p>With respect to an IVD, is it intuitive to only display flashers depending on the local RSD device type? The driver cannot be expected to know the difference, so would this undermine driver confidence in the system if the IVD displayed flashers at some points but not at others?</p> <p>It may be a Human Factors issue as to whether they are audible or visual. As to the on-off and synchronisation of alerts, I think that HATMS <i>may</i> need to retain control so that, for example, message alerts do not conflict with signal alerts. Would the intelligence to resolve conflicting MS and signal alerts reside in the IVD or be retained in HATMS?</p>

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	<p>code assigned to aspects in the outstation data and is not controlled by instation functionality. (MCH1616)</p> <p>DMRB Vol 9 Section 1 TD46/05 <u>Motorwarn Signals</u> 2.4 A Motorwarn signal comprises two amber lanterns, one mounted vertically above the other, on a black backboard. The amber lanterns flash alternately. Motorwarn signals are verge mounted and when activated denote a 30mph speed restriction is advised.</p> <p><u>Post Mounted Matrix Signals</u> 2.5 A Post Mounted Matrix Signal (MS1) comprises a matrix indicator panel and four amber lanterns mounted on a backing panel and post. The amber lanterns flash in synchronous pairs from top to bottom to draw attention to a restriction set on the sign.</p> <p>2.9 Entry slip road signals are provided in pairs at the entry to sections of motorway controlled by MS3 or gantry mounted lane signals. Entry slip = road signals comprise an MS1 with red lanterns in addition to amber. The red lanterns flash in synchronous pairs from side to side and are only used when all lanes of the carriageway ahead are closed. The red flashing lanterns must be accompanied by the wicket symbol illustrated in TSRGD diagram 6032.1, i.e. incorporating the symbol prescribed as diagram 6008.1, 6006.2 or 6009.3..</p> <p>2.17 Gantry mounted lane signals can display temporary maximum speed advised, risk of fog ahead warnings, lane divert and lane closure aspects. The amber lanterns flash in synchronous pairs from top to bottom to draw attention to maximum speed advised, fog warnings and lane divert aspects set on the signal. The red lanterns flash in synchronous pairs from side to side to indicate the closure of a lane. The red flashing lanterns must be accompanied by the red 'X' illustrated in TSRGD diagram 6031.1.</p> <p>MCE0107 3.3.6 Flashing Lantern Operation</p>						

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	<p>M:312 The facility shall be provided to allow the amber flashing lanterns to operate for a period of one minute following receipt of a SET request for a Mandatory Speed Limit Aspect, when the previous display was a different Mandatory Speed Limit Aspect. <u>This shall be configurable at the AMI Roadside Controller.</u></p> <p>MCE2214 D.8 FLASHER CONFIGURATION. The setting of Flashers shall be configurable using the Engineer's Terminal. The Configuration shall be stored in the MS4 Controller. For each different combination of display, as shown below, it shall be possible to Enable or Disable the setting of flashers. It shall be possible to enable any combination of flasher settings. It shall be possible to set all or no displays showing Flashers. The default setting shall be option A (EMI Aspect Only) 'Enabled'; all other modes 'Disabled'.</p> <p>EXAMPLE Indicator Type: 407/427 The Indicator type 'Standard Aspect Code' flashing lantern, aspect and aspect adaption settings. Standard Aspect Flashing</p> <p>EXAMPLE Indicator Type: 407/427 The Indicator type 'Standard Aspect Code' flashing lantern, aspect and aspect adaption settings. Standard Aspect Flashing Code Lantern Aspect Adaption 1 OFF OFF OFF 2 OFF N.R. OFF 3 OFF R.E. OFF 4 RED STOP 20 5 AMBER 20 30 6 AMBER 30 40 7 AMBER 40 50 8 AMBER 50 60</p>						

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	9 AMBER 60 OFF 10 AMBER 70 80 11 AMBER 80 OFF 23 AMBER TT1 40 24 AMBER T11 50 25 AMBER 1TT 40 26 AMBER 11T 50 29 AMBER FOG AMB 30 AMBER Q OFF 51 AMBER AMB OFF						

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	<p>AMBER FLASHERS Amber Flashers may appear on one lane but not the lane outside it or inside it.</p> <p>Amber Flashing is a function of the driver code</p> <p>Amber flashes alternate top to bottom.</p>	As above	n/a	n/a	From the driver's perspective, this is an Intuitive use of amber flashes	n/a	Should the IVD replicate amber flasher functionality?
	<p>RED FLASHERS Red Flashers may appear on one lane but not the lane outside it or inside it. Amber Flashing is a function of the driver code</p> <p>Red flashes alternate left to right.</p> <p>Red flashers, unlike amber flashers, are switched on irrespective of the device setting status. So, for instance, if the signal aspect fails due to bulb failure, the red flasher will still be switched on.</p>	As above	n/a	n/a	From the driver's perspective, this is an Intuitive use of red flashes	n/a	Should IVD replicate red flasher functionality?
	<p>FLASHER SYNCHRONISATION TR2199 3.4.3.5 FLASHER SYNCHRONISATION, (CF=(27H)) Message I:3325 The FLASHER SYNCHRONISATION, (CF = (27H)) message is the mechanism by which the Standard Transponder ensures that lantern pairs associated with individual display devices flash in 'harmony' rather than to their own 'clock'.</p>	n/a	n/a	n/a	Synchronisation of flashers avoids overloading the driver's senses and the distraction that this causes.	n/a	Should IVD replicate synchronisation functionality – Data requirement: how to effect synchronisation?
	<p>ERA OCCUPANCY FLASHERS Currently, there is no flasher technology deployed in ERAs (Emergency Refuge Areas) to warn passing motorist that the ERA is occupied. Operator inspection of CCTV images and MIDAS loop detection can be used to initiate driver information messages warning of ERA occupancy. Future developments in automatic ERA occupancy detection may include 'Adaptive CCTV'. The Adaptive CCTV</p>						

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	<p>Display system uses live and historical data from the existing HA MIDAS Gold system and combines these with information from a commercial CCTV based AID (Automatic Incident Detection) system to continually assess which sections of the road network are likely to be of most interest to the RCC operators. CCTV images of these stretches of road are then automatically displayed on the video wall (DDS) at the RCC, with relevant information overlaid on the images.</p>						

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	<p><u>SEPARATOR PIT BEACONS</u> These are roadside amber flashing beacons that alert maintenance engineers of high oil and silt levels in roadside runoff separator pits. Currently they are not integrated into the HATMS communications network.</p>	n/a	n/a	n/a	n/a	n/a	Could these alarms be transmitted to IVDs in maintenance engineers' vehicle? This would reduce a source of distraction to other road users. Would this require access/security levels assigned to data so that IVDs could filter on a need to know basis?
<u>Signal Siting Requirements</u>	<p><u>SIGNALS AT INTERCHANGES</u> DMRB Vol. 9, Sect 4 (A4/3): Additional MS1s are provided at interchanges on the approaches to all merges. Immediately prior to a merge two signals should be provided, one on the connecting slip road and one on the main carriageway. The signal on the main carriageway may be an MS2 or gantry mounted lane signals. These signals are also referred to as Speed Equalisation Signals. Each signal should be mounted on a post on the right hand verge or central reserve as appropriate.</p> <p>Merge signals should be omitted when they are less than 500m downstream of the previous diverge.</p> <p>Within interchanges it is possible that more than one set of signals will have the same motorway address. Where this situation occurs early advice from the Highways Agency should be sought.</p>	See ' Adjacency Sequencing ' above					
	<p><u>ENTRY SLIP ROADS</u> DMRB Vol. 9, Sect 4 (A4/31):</p> <ol style="list-style-type: none"> Entry slip road signals are provided at the entry points to a motorway where there is a need to close the slip road and prevent vehicles joining the motorway. Entry slip road signals are provided under the following circumstances: <ul style="list-style-type: none"> (i) where gantry mounted motorway signalling is provided at junctions with the facility to divert traffic from the motorway (ii) when cantilever MS3 are provided at the junction diverge prior to the entry (iii) at combined motorway to motorway to 	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.

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	<p>all purpose road junctions, when there are facilities for diverting traffic from one or more of the motorways.</p> <p>3. When entry slip road signals are used they should be provided in pairs with a signal sited in each verge, nearside and offside. The signals shall be capable of displaying the aspects shown in <u>diagram 6032.1 in the Traffic Signs Regulations and General Directions 2002 (SI 2002 No 3113)</u>.</p> <p>4. They should be sited to give maximum warning to approaching motorists in order to avoid potentially dangerous vehicle manoeuvres close to the entry slip road.</p>						

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	<p><u>SIGNALS AT THE START OF A MOTORWAY</u> DMRB Vol. 9, Sect 4 (A4/3): 1. Where an all purpose road feeds directly into a motorway gantry mounted lane signals shall be provided: (i) Where the road merges with the motorway as a slip road the gantry is provided prior to the point where the two carriageways merge. (ii) Where the road ends and becomes the motorway the gantry is provided immediately after the start of the motorway. 2. An additional gantry will be required in advance of the start of motorway except where the speed limit of the approach road is less than 40 mph. This gantry will also be used for mounting direction signs and its location will be dictated by signing requirements. Special site approval will be required before signals may be sited on such a gantry. Where the approach road is a high speed road more than one additional gantry may be required.</p>				No special signal settings required at the start of the motorway		What data needs to be provided to the IVD on entry to the Motorway network?
	<p><u>PROXIMITY</u> DMRB Vol. 9 Section 4 A4.1 Motorway signals should not be positioned within 300m downstream of a change in the number of carriageway lanes between junctions. DMRB Vol. 9 Section 4 A3.3.3 Central reserve MS1 should not be sited within 300m of a change in the number of lanes.</p>	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.
	<p><u>VISIBILITY</u> Motorway signals are designed to meet the special requirements of motorways, good long range visibility for high speed vehicles, good penetration through fog and spray and a high level of illumination to overcome bright low level sunlight. All motorway signals have amber lanterns that are designed to be visible at 500m.</p>	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.	See ' Signal Sequencing (Spatial) ' and ' Aspects ' sections above for general discussion.

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	<p>Signals should be sited to provide continuous visibility for a distance of 500m. This may not always be possible.</p> <p>The horizontal alignment of a motorway should be taken into consideration when positioning gantries for lane signalling. Parallax problems may occur due to the curvature of the road – signals may appear to be over a different lane when viewed from a distance. DMRB Vol. 9, Sect 4, A4/3</p>						

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	<p><u>STOPPING DISTANCES</u> When positioning signals consideration should be given to stopping sight distance (SSD) and the potential obstruction to SSD by signal mounting structures. See TD9. DMRB Vol. 9, Sect 4, A4/5</p>	<p>See 'Signal Sequencing (Spatial)' and 'Aspects' sections above for general discussion.</p>	<p>See 'Signal Sequencing (Spatial)' and 'Aspects' sections above for general discussion.</p>	<p>See 'Signal Sequencing (Spatial)' and 'Aspects' sections above for general discussion.</p>	<p>See 'Signal Sequencing (Spatial)' and 'Aspects' sections above for general discussion.</p>	<p>See 'Signal Sequencing (Spatial)' and 'Aspects' sections above for general discussion.</p>	<p>See 'Signal Sequencing (Spatial)' and 'Aspects' sections above for general discussion.</p>

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	<p><u>GANTRY MOUNTED SIGNALS</u> 3.26 Where the provision of gantry mounted lane signalling is justified, signals shall be provided over each running lane as follows: 300m (+/- 100m) downstream from junction and Motorway Service Area entry slip road merges; (b) on the approaches to motorway interchanges and junctions on one mile, half mile, final, supplementary and confirmatory gantries. A supplementary gantry is required at the mid point of a two or more lane parallel diverge or parallel lane drop where the parallel length exceeds 800m; (c) between junctions at 1,000m (+0%, -20%) spacings; (d) intra junction if the distance between the confirmatory gantry [re (b)] and the first gantry following the junction merge [re (a)] is greater than 1200m. The lane signalling gantry shall be located at the mid point. 3.27 In addition, the following gantries shall be provided with a 2x12 Message Sign: (e) the first gantry following a junction or Motorway Service Area entry slip road merge [re (a)]; (f) gantries between junctions [re (b)], excluding supplementary gantries; (g) intra junction gantries [re (d)]; (h) gantries over the diverge nose; (i) one mile Advance Direction Sign gantries at nonstrategic junctions; (j) half mile Advance Direction Sign gantries at nonstrategic junctions displaying MIDAS and tactical legends only (including tactical diversion legends); (k) final Advance Direction Sign gantries at a two lane parallel diverge, displaying MIDAS and tactical legends only (including tactical diversion legends). The above criteria do not apply in Scotland.</p>	<p>See 'Aspects' section above for general discussion. See also 'Lane Specific AMLs' in the 'Hard Shoulder Running' section above for relevant discussion.</p>	<p>See 'Aspects' section above for general discussion. See also 'Lane Specific AMLs' in the 'Hard Shoulder Running' section above for relevant discussion</p>	<p>See 'Aspects' section above for general discussion. See also 'Lane Specific AMLs' in the 'Hard Shoulder Running' section above for relevant discussion</p>	<p>See 'Aspects' section above for general discussion. See also 'Lane Specific AMLs' in the 'Hard Shoulder Running' section above for relevant discussion</p>	<p>See 'Aspects' section above for general discussion. See also 'Lane Specific AMLs' in the 'Hard Shoulder Running' section above for relevant discussion</p>	<p>See 'Aspects' section above for general discussion. See also 'Lane Specific AMLs' in the 'Hard Shoulder Running' section above for relevant discussion</p>

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<p><u>Variable Message Signs</u></p>	<p>MESSAGE SIGNS GENERAL A message sign is a motorway sign that allows the display of text messages. A message sign may have a variable element. For example, the operator may need to set the message:</p> <p style="text-align: center;">M42 CLOSED AT NEXT JCT</p> <p>In this instance, the '42' is a variable part and needs to be entered by the operator. Message signs are set in different layers. The operator sets message signs in the manual incident layer (MI), either individually, in blocks, or via plans. The operator also sets message signs in the Strategic Plan (SP) layer when setting diversions. Other subsystems such as MIDAS and TCCI make settings in their own layers.</p> <p>A Message Sign is, therefore, a device which is capable of displaying short textual messages for drivers, under remote control. They thus contribute towards improved driver information, and thereby improve utilisation of the road network. (MCH1655, p3)</p> <ul style="list-style-type: none"> - Message Sign settings may be generated automatically by the MS Subsystem in reaction to the setting of Matrix Signals (by the operator), e.g. if the operator specifies the reason 'ACCIDENT' when setting a Matrix Signal, this may result in the adjacent and lead-in Message Signs being set to 'ACCIDENT SLOW DOWN'. The MS Subsystem holds configurable Rules Data specifying the Message Sign settings to be generated for various Matrix Signalling scenarios. - The MS Subsystem implements 'automatic' Message Sign settings which are requested by the MIDAS (Motorway Incident Detection and Automatic Signalling) Subsystem, e.g. if the MIDAS equipment detects slow moving traffic, it may instruct the MS Subsystem to set Message Signs to 'QUEUE AHEAD SLOW DOWN'. - Automatic Message Sign settings may be requested by the Meteorological (MET) Subsystem, e.g. 'FOG PATCHES AHEAD'. <p>DMRB Vol. 9, Part 6 TA83/05 OPERATIONAL OBJECTIVES: STMS (Strategic Message Signs) schemes are likely to deal with the</p>	<p>>></p>	<p>Messages that may be displayed on MS devices are pre-defined in Configuration Data held by the MS Subsystem. The NMCS2 operator is not allowed to create Messages but has to select from a Message list. It should not be possible, therefore, for a message to be sent to a device that is not capable of displaying that particular message, for example, when the text length exceeds the dimensions of the display array.</p>	<p>MS devices are hardwired into the system therefore transmissions can be targeted at specific devices even though they may stand in close physical proximity to other devices, e.g. signal and sign devices.</p>	<p>The driver can see the sign setting from a point some distance upstream from the MS RSD location. MS information is 'relevant' from the point that the driver first sees the RSD display.</p>	<p></p>	<p>How long should messages persist on the IVD. Signal settings on the IVD might be expected to persist until they are explicitly cleared by the system (except, possibly, downstream settings such as END/NR and RE which may be required to 'timeout' downstream of the RSD set to the END/NR or RE). Is it the case that a message conveys information different in nature to that conveyed by a signal setting therefore once the driver has understood the message should not the message be cleared from the IVD to avoid prolonged distraction?</p> <p style="text-align: center;">***</p> <p>If a navigation system (e.g. Tom Tom) is used alongside but separate to the IVD, then should the messages sent from that navigation system to the driver be coordinated with messages conveyed via the IVD so that they do not overlap and overload the driver's senses? The assumption there is that they are separate. The implication, however, is that they must work together, which may mean that Navigation devices such as Tom Tom would be required to conform to whatever future requirements for IVDs may derive from this study – one for a workshop?</p>

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	<p><u>MS INFORMATION CATEGORIES</u> DMRB Vol. 9 Section 4:</p> <p><u>Driver Information Legends</u> - provide the motorist with information of a tactical and strategic nature, but also with messages relating to conditions on the network that may affect expected journey times, but which is not of a direct or instructional nature. This may include information on major events (e.g. shows, sports events etc.) and inter network connections such as ferries, tolled roads and crossings. An example of a Driver Information sign setting might be: TO J15 (BRISTOL) 42 MILES 38 MINUTES</p> <p><u>Tactical Control</u> - provides supplementary information to complement matrix signals and other traffic control signs for management of incidents or occurrences on local roads in the area. Signs set in support of tactical objectives display messages specifically related to achieving improvements on localised sections of the network. An example of a tactical sign setting might be: OBSTRUCTION/SLOW DOWN</p> <p><u>Strategic Traffic Management</u> - provide the motorist with information and advice on the road network ahead. The aim is to improve the performance of the network by redistributing traffic efficiently when congestion occurs on some links and spare capacity is available on others. An example of a Strategic sign setting might be: M42 CLOSED AT NEXT JCT</p> <p><u>Campaign</u> – present campaign text to travellers, e.g. THINK BIKE</p>		<p>The site data for each MS device refers to the Message list which is applicable to that device. While different MS devices can use different Message lists, many devices will share the same Message list. Moreover, certain message sign devices have relationships with signal sites in the MSS site data, others do not. This allows that certain message signs will be subject to reactive settings when the associated signal devices are subject to signal settings (see 'Signal Setting Implementation Reasons' in this section below).</p>	<p>Tactical information is targeted at specific devices at specific locations and can therefore be conveyed to the motorist at the same time and place that associated signal information is received by the driver.</p>	<p>At any one point in time, the driver may be cognisant of a hierarchy of information (Tactical, Strategic, Driver Information and Campaign). The Message Sign subsystem determines the priority of the various messages and where they should be displayed. Unlike signal settings, the information displayed on a VMS does not necessarily negate ('overwrite' or 'update') information presented to the driver on the previous upstream message sign: though tactical messages, supporting as they do signal settings, update previously seen tactical messages, they do not negate the last seen Strategic or Driver Information message.</p> <p>Targeting specific</p>	<p>Positioning of MS4s above LBS1 on HSR schemes emphasises to the driver that the tactical message on display applies to the Hard Shoulder. Even so, the spatial alignment of VMSs with particular lanes is not as crucial as it is with signal devices.</p>	<p>Will the IVD be required to display Strategic messages (and legends?) alongside tactical messages? If the IVD uses the same display for all message categories (Tactical, Strategic or whatever) then does this presuppose that the data transmitted to the IVD must contain a priority parameter to ensure that tactical messages are not overwritten by strategic or some other category of message? If Strategic messages are overwritten by tactical messages then will this mislead the driver into believing that the strategic situation has changed? Should the IVD be capable of displaying tactical and strategic messages concurrently?</p> <p>***</p> <p>If a strategic message is not relevant to the drivers intended route or destination, would it be a distraction and annoyance to the driver?</p> <p>How much in-vehicle messaging is too much – at what point does it amount to a distraction?</p> <p>***</p> <p>If the IVD has only one window for both tactical and strategic messages then would this result in a constant updating of that display and be a source of distraction for the motorist?</p>

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					<p>devices means that both tactical and strategic (and other categories of information) can be conveyed together along the same section of carriageway.</p> <p>***</p> <p>Strategic information that is not of interest to a driver (i.e. the information does not apply to his/her destination) is not distracting to the driver.</p>		

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	<p>TYPES OF MESSAGE SIGN</p> <p>An MS device is a Variable Message Sign (VMS). VMS is a generic term describing a sign displaying text Messages and/or Symbols. The MS Types, supported by the MS Subsystem, fall into the following two categories:</p> <p>MS Type 1XX Enhanced Message Sign (EMS) device types, i.e. MS devices where the legend, or Message, to be displayed can be down-loaded from the NMCS2 instation whenever the MS device is to be set.</p> <p>MS Type 2XX Message Sign (e.g. Fixed Text Message Sign [FTMS]) device types where a small set of legends are fixed in the MS device, and only a code selecting the legend for display is transmitted from the NMCS2 instation whenever the MS device is to be set. (MCH1655)</p> <p>The MS Type numbers (101-199 and 201-299) are allocated to the various sign types (e.g. 2*12 EMS, 3*18 MS3) in the above two categories.</p> <p>The Messages which may be displayed on the MS devices are pre-defined in Configuration Data held by the MS Subsystem. The NMCS2 operator is not allowed to create Messages but has to select from a Message list.</p> <p>The site data for each MS device refers to the Message list which is applicable to that device. While different MS devices can use different Message lists, many devices will share the same Message list.</p> <p>Typically, MS Type 1XX (EMS) devices of the same MS Type share the same Message list, with the list containing as many as 500 Messages. The site data for each (MS Type 1XX) device identifies any of the Messages which are forbidden at the device site.</p> <p>For MS Type 2XX (non-EMS) devices, the Message list associated with each MS device contains up to 48 Messages and there is little sharing of Message lists.</p>	As with Signal types	As with Signal types	As with Signal types	As with Signal types	As with Signal types	<p>Should the IVD be capable of displaying MS4 type legends (pictograms) as well as messages?</p> <p>If IVDs are required to display legends then is the IVD to be a 'dumb' terminal and allow the system to transmit the legend data, or, should the IVD be pre-configured with legend data so that if legends were assigned codes, for example, then the system would transmit a legend code which the IVD would map to the correct legend?</p> <p style="text-align: center;">***</p> <p>Will the IVD be required to display Tactical messages (and legends?) alongside tactical signal settings?</p>

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	<p>In the MS Subsystem's Configuration Data, a Message can be defined as belonging to more than one Message list. For example, Messages belonging to the Message list associated with 2*12 EMS devices are also likely to be defined as members of the Message list used by 2*16 EMS devices.</p> <p>MS4s are capable of displaying both messages (text) and legends (pictograms).</p>						

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	<p>MESSAGE LISTS The Messages which may be displayed on the MS devices are pre-defined in Configuration Data held by the MS Subsystem. The NMCS2 operator is not allowed to create Messages but has to select from a Message list. The site data for each MS device refers to the Message list which is applicable to that device. While different MS devices can use different Message lists, many devices will share the same Message list.</p> <p>Specific Messages are targeted at specific MSS device types. This means that at each step the list of Message texts offered for selection by the operator takes into account the Line selections any Messages that are banned at the chosen device site (e.g. 'USE HARD SHOULDER' where no hard shoulder exists).</p> <p>TR2163, M:2302 In applying a rule instruction, the MS Subsystem must use the Site Data, MS Type Data and Messages Data to check if a Message is valid for an MS device.</p>	<p>This will allow that tactical messages, for example, can be targeted at certain sites and strategic messages at other sites.</p> <p>Another example of messages banned at certain sites: Lane specific Messages should not be allowed at sites where there could be confusion over the meaning of lane numbers. Examples are MS sites on entry carriageways and at MS sites where there is a main carriageway and an adjacent 'slip' carriageway</p>	n/a	n/a	n/a	n/a	Should the IVD the display of messages be generic enough to be capable of displaying any message?

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	<p>SEQUENCING FROM SIGNAL SETTINGS AT each RCC, MS site data defines relationships between certain MS devices/sites and certain signal devices within the RCC boundary. The purpose of these definitions is to enable the Message Sign subsystem to support on-street signal settings with tactical messages by means of <i>reactive</i> message sign settings in response to operator (Plan-Incident layer) initiated signal settings.</p> <p>For example, when an operator sets a signal setting of '20' with implementation reason ACCIDENT, the Message Sign subsystem may respond by setting associate message signs to the following: 'ACCIDENT/SLOW DOWN'</p> <p>In addition to relationships between signs and signals on the same carriageway, some MS devices will have defined relationships with signals across an adjacency: i.e. where two carriageways (one or both of which may be an entry slip) converge such that the two <i>signal</i> sites are located on the respective carriageways either side of the convergence. The MS Site Data will define a link between the MS and the 'main' signalling site (i.e. the signal site on the same carriageway as the MS device) and to an 'adjacent' signalling site (i.e. the signal site on the other side of the adjacency). The site data also allows that any given MS device may be linked to a downstream signal site on the main carriageway and even a downstream signal site on an adjacent slip.</p>	n/a	Site data pertaining to automatic systems (e.g. MIDAS) will also define relationships between devices controlled by those subsystems (e.g. MIDAS loop sites) and signal and sign devices. So, for example, a MIDAS alert may result in a signal Set Device Request being sent to the Signal subsystem in conjunction with a MS Set Device Request to the Message Sign subsystem containing an appropriate Driver Information or Tactical message or message code that will support the requested signal settings.	n/a	Signs associated with signal sites 'support' those sites when signal settings are imposed; drivers see the speed restriction on a signal RSD and see the accompanying sign setting on the VMS and therefore are aware of the reason they are being instructed to slow down. This supports the following objectives: <ul style="list-style-type: none"> • supporting diversion routes and controlling traffic on these routes • satisfying drivers' needs for reliability and consistency in information and legends 	n/a	How will messages displayed on IVDs support signal settings on display at the IVD? How will the IVD display support the following objectives? <ul style="list-style-type: none"> • Supporting diversion routes and controlling • Traffic on these routes • Satisfying drivers' needs for reliability and consistency in information and legends
	<p>SIGNAL SETTING IMPLEMENTATION REASONS A signal setting request sent to the Signal subsystem</p>	(See ' Sequencing from Signals ' in this section above)	(See ' Sequencing from Signals ' in this section above)	(See ' Sequencing from Signals ' in this section above)	(See ' Sequencing from Signals ' in this section above)	(See ' Sequencing from Signals ' in this section above)	(See ' Sequencing from Signals ' in this section above)

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	<p>for sequencing from whatever source will include an Implementation Reason (i.e. the reason the source is requesting the signal setting). Valid Implementation Reasons are:</p> <p style="text-align: center;">CLEAR, ACCIDENT, CONGESTION, OBSTRUCTION, LARGE LOAD, PEDESTRIANS, UNCONFIRMED, PART CLEAR, INCIDENT, FOG, ONCOMING VEHICLE, CLOSURES / DIVERSIONS, ANIMALS, DEBRIS, ROADWORKS – CONING, ICE, SECURITY, TEST and UPDATE - INITIALISATION.</p> <p>Implementation Reasons have no real function in the Signal Sequencing process as such. However, for the purposes of Message Sign subsystem sequencing from signal settings, Implementation Reasons are sequenced by SSA in order that each secondary setting has the correct Implementation Reason assigned to it: Each secondary setting will derive, ultimately, from a certain primary setting, so the Implementation Reason for that secondary setting should derive from the Implementation Reason attributed to <i>that</i> Primary, and not to some other Primary setting that happens to be sequenced with it.</p> <p>With respect to these 'Reactive' Message sign proposals, the Message Sign subsystem will only sequence from operator (Plan/Incident) layer settings passed from the Signal subsystem. For Message Sign settings in other layers, the relevant subsystem will send a setting request direct to the Message Sign subsystem, e.g. MET will send the message number for 'FOG PATCHES AHEAD' to be displayed. The Message Sign subsystem will determine the priority of competing message settings and will set the on-street message accordingly. If there are other messages stored against that devices in the subsystem layers on the Message Sign subsystem then the Message Sign subsystem will determine which to set based on the priority of the message and the layer. Conflicting</p>		this section above)			this section above)	

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	messages (i.e. message on two MSS devices that convey conflicting information to the driver) are resolved by the Message Sign subsystem through the application of a set of pre-defined Conflict Rules.						

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	<p>MESSAGE SIGNS ON MM-HSR SCHEMES MS4s (capable of displaying full graphics) are deployed at each signal gantry location (mounted above LBS 1, or LBS 1 and 2) along MM-HSR Schemes. The main objective is to provide information to the motorist on the status of the Hard Shoulder, e.g.:</p> <p style="text-align: center;">Use hard shoulder for Jct 4 only</p> <p>In addition to messages specific to the status of the Hard Shoulder, various other tactical messages are approved for use on MS4s deployed on MM-HSR schemes, e.g.:</p> <p style="text-align: center;">Accident / SLOW DOWN</p> <p>It is not normally possible to use MM-HSR MS4s for strategic messages (e.g. "M40 CLOSED J10, FOR LONDON USE M6(S), M1(S)"). However, in the M42 trial area existing MS3s have been retained and can be used for strategic purposes. These are interspersed at various locations along the scheme.</p>	<p>MS3s displaying strategic information exist alongside (though not co-located with) tactical MS4s on MM-HSR schemes. The information displayed on MS3s does not negate or 'overwrite' information displayed on MS4s, and vice versa. By extension, Tactical information does not necessarily overwrite strategic information, and vice versa: i.e., the driver will be aware that the tactical message does not negate the strategic message seen at the previous upstream MS3, and vice versa.</p>	<p>n/a</p>	<p>n/a</p>	<p>MS4s are designed so that 400 mm characters are visible at 300+ metres.</p> <p>MS4 messages on MM-HSR schemes convey tactical information to the driver at the associated signal FOP. By virtue of the nature of messages, from the driver's perspective, the message is relevant at the point that he/she is first able to read it.</p>	<p>On MM-HSR schemes, MS4s tend to be located above LBS1 (this will be the Hard Shoulder where VMSL-4 is possible). Through use, drivers will be accustomed to associating messages with Hard Shoulder information.</p>	<p>(See 'MS Information Categories' in this section above)</p>
	<p>MESSAGES DISPLACED BY SIGNAL SETTINGS Some signs may share space between the Message Sign setting and the Signal setting. After a message has been set which uses some of the shared space, if a Signal setting is made the message will be displaced. For example, a Message setting is displaced by a Signal setting on combined Sign and Signalling units that utilise shared display areas (e.g. MS3 motorway equipment) when there is insufficient room to display the Message setting alongside the Signal setting. The motorway equipment gives priority to the Signal setting when the two settings would overlap due to insufficient room on the display. Whenever this situation occurs, the motorway equipment 'blanks out' the Message on the display (TR2139, Sect. 11.6)</p>	<p>n/a</p>	<p>n/a</p>	<p>Failure to display a message, owing to space on the display being taken up with a signal setting, can be reported back to the control system.</p>	<p>Displaced messages will not be seen by motorists.</p>	<p>n/a</p>	<p>Do we assume separate display areas for messages and signal settings?</p> <p>To avoid conflict, with RSDs, IVDs should not display messages that have been displaced by the RSD? Should the system only transmit to the device when the messages setting on the RSD is confirmed? What would the likely delay be between the setting of the message on the RSD and the setting of the message on the IVD?</p> <p>If an extant message is displaced by an incoming signal setting, would the</p>

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	<p>If the device displaces a message due to an extant of incoming signal setting, then, if the MS Subsystem has not already done so, and the line lengths of the required Message fit within the reduced width of the available display area, it must retry setting the required Message on the motorway. If that fails, the Message Sign subsystem which will then attempt to set a predefined alternated message. If that in turn is displaced (i.e. does not fit with the extant signal setting), then the Message Sign subsystem will attempt to set an alternate message to that and so on until an alternate that fits with the signal setting is found or there are no more alternatives.</p>						<p>system be required to update the IVD? How long would the process of finding an alternative take?</p>

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	<p>MESSAGE SIGN LANTERN FLASHERS All Strategic VMS should be fitted with flashing amber lanterns. The lanterns should flash in synchronous horizontal pairs alternating top and bottom to draw the attention of drivers to the message displayed on the VMS. Lantern design requirements must comply with the TSRGD. (DMRB, Vol. 9, Sect. 4)</p> <p>Fixed Text messages are commonly used for diversion routing and local traffic management where there are a low number of route options. They may most effectively be used to display messages linking to a predetermined diversionary route, marked by symbols, e.g. "Follow A1 for London". Symbols for use on directional signs are shown in Part VII of Schedule 13 of The Traffic Signs Regulations and General Directions 2002....When the diversionary route is displayed, flashing amber lanterns, as referred to in A3.1.2 shall be used. (DMRB, Vol. 9, Sect. 4)</p> <p>Unlike the Signal Subsystem (see 'Flashers' section above), the Message Sign Subsystem will specify whether it requires Flashers on VMS lanterns to be switched on or off. The instruction for the outstation to switch lanterns is bit encoded in the DEVICE DATA message (CI=(49H) and (4AH)) sent from the Message Sign subsystem via COBS to the MS Transponder.</p> <p><u>MS Lantern Overrides</u> The MS Subsystem must ensure that the lanterns on an MS device, which supports the lantern override command, are always switched off whenever the MS device's associated signal(s) have their lanterns on. To achieve this, the MS Subsystem must use the lantern override command. (TR2139, M:6552)</p> <p>When overriding Lanterns, the instruction to switch VMS Flasher Lanterns on or off is bit encoded in a Set Devices (CI=(40H) AND (44H)) message sent from the Message Sign subsystem via COBS to the MS Transponder.</p>	n/a	n/a	MS devices are hardwired into the system therefore transmission of Lantern Overrides can be targeted at specific devices even though they may stand in close physical proximity to other devices.	VMS flashers are an effective means of drawing the motorist's attention to strategic and other messages. *** The Message Sign subsystems automatic Lantern Override functionality enables the VMS flashers on VMSs associated (see ' Sequencing from Signals ' in this section above) with signal sites avoids overloading and distracting the driver with flashers and allows that the driver's primary focus is on signal settings.	n/a	<p>Assuming flasher functionality will be incorporated in IVD technology, in order to avoid conflict with flashers on-street, should the control of flashers be retained by the control system – Currently, it is the Message Sign subsystem that controls flashers (i.e. switching them ON or OFF).</p> <p>***</p> <p><u>Message Flashers vs. Signal Flashers:</u> Assuming an IVD display that allows concurrent display of signal and sign settings, should the IVD replicate VMS flashers? Would it require dedicated flashers associated with the message area of such a display? If so, how would these flashers be controlled – would the IVD cancel message flashers if there are active signal settings, or, would the system be required to instruct the IVD to cancel the message flashers?</p>

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<p>Fixed Signs</p>	<p><u>FIXED TEXT MESSAGE SIGNS (FTMS)</u> DMRB, Vol. 9 Sect. 4, Chapter A3.2</p> <p>FTMS are any type of VMS that display two or more fixed legends (or a blank display and one or more legends). There are currently a number of technologies used in such signs, the more common being active light emitting (as above), flexible roller blind and rotating plank or prism, the latter two normally being electro mechanical. Of these types the rotating plank or prism is most suitable for strategic use. Because of the drawbacks noted below, FTMS are now not widely used and are generally most suitable for signing diversion routes.</p> <p>FTMS are normally mounted on posts installed in the motorway verge, or on Portal Gantries. The main drawbacks of FTMS are:</p> <ul style="list-style-type: none"> • They can not be routinely tested without displaying the message which may confuse road users • Unless they are regularly exercised they are prone to electro-mechanical failure. <p>The rotating plank or prism sign normally consists of a series of planks or prisms that align to form a flat sign face. When required to show a different aspect, the planks or prisms realign to present a different sign face. Either the whole sign face can be changed in this way, or only those parts of the sign face that need to be changed. In this way the number of legend options available can be increased.</p> <p>The arrangement of text used for display purposes on rotating plank or prism signs must either be as prescribed in the TSRGD or specially authorised by the overseeing organisation.</p> <p>Point of Interest: A feasibility study has been undertaken at Serco to investigate looking at how modifications to the Belfast (Road Services) variant of the HATMS could enable the Signal subsystem to control signal settings on prismatic 'repeater' signs</p>	n/a	n/a	Rotating plank or prisms are not (currently) used to display speed restrictions controlled by the instation on the HATMS network. They are generally used for strategic signing but are not well favoured since they are hard to test without confusing motorists, are prone to failure and are difficult to maintain.	n/a	n/a	As with variable signals and signs

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	along the Belfast Westlink. Moreover, on the Belfast Westlink, verge mounted rotating planks are used to indicate the availability of the Hard Shoulder as a 'part time running lane' lane for buses during the morning rush hour.						

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	<p><u>DISTANCE MARKERS & LOCATION SIGNS</u> IAN 111/09 Section 10.5.8 Driver location signs should preferably be located within an ERA, co-located with the existing distance marker post. If the distance marker post is not located in the ERA, then a supplementary DLS (Driver Location Sign) must be provided within the ERA. Each driver location sign must have a unique reference (comprising the route number, carriageway identifier and kilometrage). A driver location sign (DLS) on the nearside of a motorway informs drivers of:</p> <ul style="list-style-type: none"> • The motorway route number • The direction of travel • The precise location on the route 	n/a	n/a	n/a	This ensures that if a driver has stopped within an ERA the driver can see the driver location sign and read the legend without having to leave the vehicle (especially important for mobility impaired drivers who may be able to use a mobile telephone but cannot easily get out of their vehicle to use an ERT). The maximum longitudinal spacing of driver location signs of 500m must not be exceeded.	n/a	This is information that might be very useful to provide to the motorist via an IVD, if for example, the motorist is mobility impaired and cannot view the location marker, or if it is obscured e.g. due to severe weather.
	<p><u>TEMPORARY SIGNAGE FOR TRAFFIC MANAGEMENT</u> These are not currently controlled from HATMS.</p>	n/a	n/a	n/a	See discussion on a mobile beacons in the 'Lane Closures' section above.	n/a	See discussion on a mobile beacons in the 'Lane Closures' section above.
<u>Cross-Boundary Interworking</u>	<p><u>CROSS BOUNDARY INTERWORKING</u> The HA motorway network is divided between 7 Regional Control Centres (RCCs). These are Eastern RCC (ERCC), South Eastern RCC (SERCC), North Eastern RCC (NERCC), South Western (SWRCC), North Western RCC (NWRCC), West Midlands RCC (WMRCC) and East Midlands RCC (EMRCC). Each RCC has a dedicated set of control system hardware (COBS, Signal, Message, MIDAS, MET, TCC, HSM, Tidal subsystems (not all RCCs will have Tidal and HSM). All roadside devices within the geographic</p>	n/a	n/a	Transmissions between instation and outstation are limited to the respective RCC.	n/a	n/a	If a broadcast mechanism is used, would broadcasts would be network wide? If they are not network wide, is it possible to broadcast to an area mapping exactly to an RCC boundary in such that they do not interfere with broadcasts to other boundaries – would the system be required to update the IVD with a new frequency as the vehicle crosses an RCC boundary?

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	<p>boundary of a given RCC are controlled by the instation equipment allotted to that RCC.</p> <p>Cross boundary interworking is automated and achieved by means of telecommunications between the respective RCCs. So, for example, when an in-boundary (i.e. 'in-boundary with respect to a given RCC) operator selects in-boundary signals within a defined proximity to the RCC boundary and proposes settings on those signals (the 'primary' settings), the over-boundary RCC is informed of the proposal and, in turn, sequences the operator proposed primary settings in order to generate any necessary secondary lead-in etc. settings that require to be set over that boundary.</p>						