traffic systems and signing

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Guidance for the calibration and optimisation of Smart Motorway systems

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CONTENTS

1 INTRODUCTION

1.1 BACKGROUND

The Highways Agency's (HA) Smart Motorways (SM) schemes are now in operation across the Strategic Road Network (SRN). SM is a method of reducing congestion on the SRN by utilising dynamic traffic management tools as an alternative to carriageway widening.

The exact approach used has (and continues to be) developed over time and varies from scheme to scheme, but can generally be defined as: influencing the behaviour of road users on the motorway (or joining the motorway) to create traffic conditions which are less likely to result in flow breakdown.

An SM scheme shall be installed to address one or more congestion seed points where it has been shown that the scheme improves journey time, journey time reliability and throughputs. Schemes consist of a number of technology systems including vehicle detection and variable speed limits to monitor and control traffic on the SRN.

The success of these technology schemes are heavily dependent on the appropriately timed setting and removal of the signs and signals to enable effective application of the traffic management strategies within the SM operational regime, such as All Lane Running (ALR), Hard Shoulder Running (HSR)[1] and Controlled Motorways (CM).

There are also additional safety objectives achieved through the High Occupancy (HIOCC) Queue Protection algorithm which can set speed limits while an SM scheme is in operation.

1.2 SCOPE AND PURPOSE

This document is limited to providing guidance to help equip the HA and its partners to calibrate and optimise Smart Motorways (SM) schemes. It does this by:

- Recommending the contents and acceptance criteria of a set of products that could be generated by the parties involved, and which demonstrate the performance of an SM system;
- Providing guidance as to how these products could be produced and how to carry out the optimisation activities on which they depend.
- Illustrating the use of the CALO Software Toolkit for organising scheme data and performing the calculations required for flow threshold calibration and optimisation.

This guidance also sets out the specialist training needs, essential for individuals with a role in calibration and optimisation process.

With relevant knowledge and support, the best practice set out can help ensure consistency of calibration and optimisation between adjacent SM schemes, other operational regimes or the SRN as a whole. As such, the activities that are required for SM calibration and optimisation may not be restricted to those described within this document.

The products described are focused on the performance of the system, working to the assumption that measuring the performance of the system is the best indicator of whether the necessary activities have been completed.

This document is for anyone who is involved in carrying out any task related to the calibration or optimisation. This equates to three broad readerships/roles:

- Those contracted by the HA directly, via the Scheme or via the Maintenance Contractor, to carry out the calibration and optimisation of Schemes, termed Calibration or Optimisation Engineers;

[1] Also referred to as Dynamic Hard Shoulder (DHS) and is the terminology used for the purposes of this document.

- Those in the HA responsible for the success of the Scheme, termed HA Scheme Representatives; and
- Highways Agency specialists or their specialist representatives termed Central Client-Side Specialists (CCSS).

It may be appropriate to adapt these roles to fit the needs of a particular scheme, as long as the responsible, accountable, consult and inform (RACI) matrix is updated (Section 4), all parties are clear on their roles and the products as specified are produced.

This document is also intended to inform those associated with the optimisation of SM schemes, but not directly involved with any of the activities, such as site data designers, commissioning engineers and HA traffic technology officers.

1.3 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

Table 1: Definitions of selected terms used in this document

Asset Handover	When all the civil infrastructure and technology infrastructure assets of the Scheme have been constructed and passed to the Maintenance Service Provider in accordance with BD62 and MCH1349
Calibration	The process of defining flow thresholds at which to set or remove signal settings, including opening or closing a Dynamic Hard Shoulder running lane, by reference to observed or expected system performance The process continues until all Operational Regimes have gone live and the system is handed over
Calibration Engineer	An engineer responsible for determining flow thresholds in the Scheme Commissioning Stage, provided by the Scheme
Commissioning Stage	The stage in the delivery of an SM scheme in which the technology, algorithms and processes are enabled for operation. This stage continues until System Handover
Congestion	A term used to describe traffic conditions which are indicative of stop/start driving conditions on a normally free-flowing stretch of carriageway
Congestion Seedpoint	The location (in space) and start and end points (in time) from which stop/start traffic behaviour propagates upstream
Dynamic Hard Shoulder (DHS) schemes	DHS schemes have two running states – CM (where the hard shoulder is closed to traffic) and DHS (where the hard shoulder is open to traffic)
DHS Flow Thresholds	Values used by the Controlled Motorways algorithm to set congestion settings, signals and messages when the hard shoulder is open to traffic under DHS
Go-Live Event	The point in time where an Operational Regime becomes active
HA Scheme Representative	HA Staff or designated representative acting on behalf of Scheme delivery
Link Flow State Thresholds	Values assigned to vehicle detector sites and used by the system to indicate when operators should begin the Dynamic Hard Shoulder opening and closing processes on a particular link
Operating Parameters	The values used by the SM system algorithms to control the timing, content and location of the information and instructions communicated automatically (or semi-automatically) by the system

Operational Regime	A combination of information and instructions communicated to drivers at a one location to achieve a particular mode of operation
Operational Stage	Stage in the delivery of an SM scheme, post System Handover, in which the system is used on an ongoing basis to implement the designed operational regimes
Optimisation	The ongoing period of monitoring and adjustment after calibration and following implementation of the Operational Regimes
Optimisation Engineer	An Engineer responsible for determining flow thresholds in the Operational Stage, provided by the Maintenance Provider or HA on behalf of the region
Optimisation Measures	Actions taken to adjust a changeable element, that improves system performance
Recurrent Congestion	Congestion recurring at a particular location arising from typical driver behaviour under otherwise normal conditions
Scheme	Overall project installing an SM System to a specific location, embracing the Designer, Delivery Partner and Maintainer, under contract to the HA Project Sponsor, any of whom may provide a Calibration Engineer
Site Data Designer	The person responsible for loading flow thresholds into the signal control system
Standard Flow Thresholds	Values used by the Controlled Motorways algorithm to set congestion settings, signals and messages for standard running (e.g. normal ALR or when the hard shoulder lane is closed to traffic (formerly referred to as '3-lane flow thresholds'))
System	The combination of configurable technology, algorithms and processes which respond to traffic conditions as an input and communicate dynamic instruction and information to drivers as an output.
System Calibration	System calibration can be defined as adjusting the changeable elements (or configuration parameters) of a system such that the best possible System performance is achieved
System Handover	Transition between Commissioning and Operational Stages, where Scheme Assets have already been passed to the Maintenance Provider (Completion) and the SM system is ready to be handed over for operation and ongoing optimisation responsibilities
System Optimisation	The practice of adjusting the changeable elements of a system such that the best possible performance is achieved
Traffic conditions	The properties of a group of vehicles within spatial and temporal bounds, usually described by measures such as average traffic speed, vehicle counts and/or density

Table 2: Abbreviations used in this document

ALR	All-Lane Running
ASC	Asset Support Contractor
BB3MM	Birmingham Box Phase 3 Managed Motorways
CALO	CALibration and Optimisation
CCSS	Central Client-Side Specialist
CM	Controlled Motorways
DHS	Dynamic use of the Hard Shoulder
DHSR	Dynamic Hard Shoulder Running (synonymous with DHS)
FB	Flow Band
GNSS	Global Navigation Satellite System (generic)
GPS	Global Positioning System
HA	Highways Agency
HALOGEN	Highways Agency LOGging ENvironment
HIOCC	HIgh OCCupancy (queue detection algorithm)
HSR	Hard Shoulder Running (generic term)
LFS	Link Flow State
MIDAS	Motorway Incident Detection and Automatic Signalling
MM	Managed Motorways (now Smart Motorways)
MS	Microsoft
MTV	Motorway Traffic Viewer (also known as MotoGraph) space-time plot of traffic speeds.
M2M	Motorway-to-Motorway (intersection)
RCC	Regional Control Centre
RedX	Red 'X' or equivalent display to close or stop traffic in a lane
RM	Ramp Metering
RTMC	Regional Technology Maintenance Contractor
SM	Smart Motorways (formerly Managed Motorways)
SRN	Strategic Road Network
TechMAC	Technology MAintenance Contractor
VMSL	Variable Mandatory Speed Limits

1.4 APPLICATION IN DEVOLVED ADMINISTRATIONS

The strategic roads network (SRN) is a devolved responsibility in England and each network operator typically has its own Chief Engineer. Whilst this guidance seeks to ensure a consistent and resilient UK wide approach, some differences in operational detail and organisational responsibilities apply on Strategic Road Networks in Northern Ireland, Scotland and Wales. All references to organisations and agencies herein apply to their counterparts in other countries unless otherwise stated.

1.5 IMPLEMENTATION

This guidance document provides best practice for calibration and optimisation of smart motorway scheme. Although it is not mandated, this document shall be used forthwith on all current and future smart motorway maintenance contracts to ensure performance consistency on smart motorways unless there are very good reasons to the contrary. Maintaining Organisations shall confirm this guidance application to particular contracts with the Overseeing Organisation.

1.6 ASSUMPTIONS MADE IN THE PREPARATION OF THE DOCUMENT

This document sets out best practice guidance for calibration and optimisation of current smart motorways to ensure consistency across schemes. This document may be subject to change as innovations and new ways of working evolve.

1.7 FEEDBACK AND ENQUIRIES

For feedback and enquiries relating to the contents of this document, please contact:

mmcalo@highways.gsi.gov.uk

with a copy to: cab@mottmac.com

For queries relating to the provision of training or technical advice relating to SM optimisation *CALO Toolkit* Support, please contact Traffic Technology Division:

mmcalo@highways.gsi.gov.uk

2 APPLICATION OF CALIBRATION AND OPTIMISATION

2.1 OVERVIEW

For the purpose of understanding the role of Calibration and Optimisation within schemes, it is important that the SM system not only be understood in terms of its ultimate inputs and outputs, i.e. traffic data and signs and signals respectively, but also the specialist processes to determine operating parameters that are required to enable the signs and signals to be set and removed at the appropriate time.

Calibration identifies the appropriate flow thresholds which set and remove signal settings, including opening or closing a Dynamic Hard Shoulder running lane, by reference to observed or expected system performance. The calibration process continues until all Operational Regimes have gone live, post System Handover.

Optimisation provides continual improvement to a scheme through an ongoing period of monitoring and adjustment following implementation of the Operational Regimes, post System Handover.

Figure 1 illustrates the Scheme Life-cycle, where each of the key activities is staged to support scheme delivery from Pre-Works to Post-Handover.

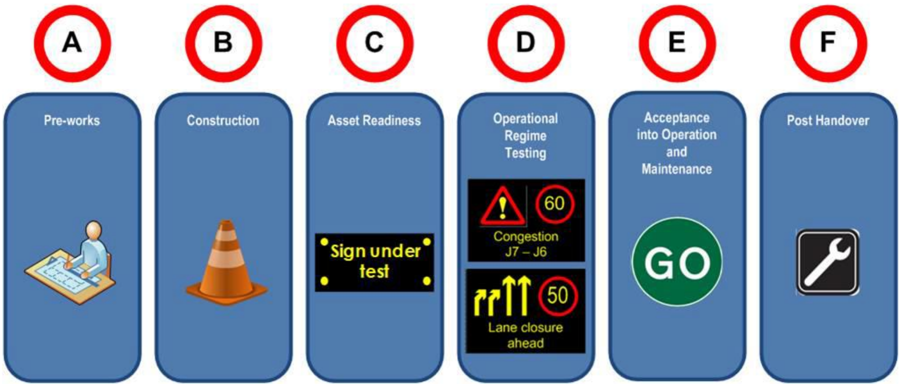

Figure 1: Scheme Life-cycle

Calibration takes place in stages A-E and Optimisation takes places in stages E-F, where stage E contains a transfer of responsibility from the Scheme to Operations.

A number of prerequisites exist for the calibration, in particular traffic data used to identify the configurable parameters should be obtained prior to construction, within stage A.

In order to provide calibration and optimisation, each technology provision will have been proven to have been installed and working correctly prior to calibration. This confirmation is provided during the third Site Acceptance Test (SAT3) performed within the Operational Regime Testing (Stage D).

2.2 SM SYSTEM INPUTS

On a day-to-day basis the essential input is traffic data. This is typically 56-days of traffic data obtained during stage A. MIDAS data is primarily used for this purpose although there may also be a requirement to obtain data from alternative vehicle detector sources that provide traffic flows.

This data is required to enable calibration of signal setting thresholds before a Scheme goes live, and data collection should be an integral part of the Scheme development plan.

2.3 SM SYSTEM OUTPUTS

An SM system, as distinct from the Scheme as a whole, can be defined as the combination of configurable technology, algorithms and processes which respond to traffic conditions as an input and communicate dynamic instruction and information to drivers as an output. This definition effectively limits the system to those elements within the control of those designing, building and operating the scheme; the system ends at the interface with the driver. The main outputs of the SM system are control of signs and signals for:

- Variable speed limits;
- Dynamic lane status instruction, particularly that related to the opening of the hard shoulder;
- Additional supplementary information in the form of text or pictogram aspects.

2.4 SM SYSTEM ACTIVATIONS

Calibration activities focus primarily on signal output although signals can be generated by four sources:

- Queue Protection – The HIOCC (High Occupancy) algorithm sets 40mph speed limits upstream of queuing traffic. Alerts are generated in response to a vehicle occupying one or more vehicle detector (e.g. MIDAS loop) sites for longer than a pre-defined threshold. 50mph or 60mph speed limits are set as ‘lead-in’ signals;
- Congestion settings – For all schemes including ALR the CM algorithm sets 60mph and 50mph VMSL to delay the onset of flow breakdown at congestion seedpoints as well as aiding recovery of free-flowing conditions at the end of the peak period. CM alerts are generated in response to smoothed total flow recorded at a vehicle detector site across all lanes. Smoothed average speed is used as a control measure to keep reduced speed limits displayed when flow levels start to drop due to flow breakdown;
- DHS – On a DHS section, 60mph speed limits are set when the hard shoulder is open as a running lane. Lower speed limits can be set by the other elements of the system but the speed limit will not rise above 60mph while the hard shoulder is open; and
- Manual control – Regional Control Centre (RCC) operators have the capability to set speed limits due to incidents or road works.

2.5 OPERATING PARAMETERS

SM schemes apply strategies in a *dynamic, responsive* manner: dynamic in that the speed limits are variable and, in some cases, the hard shoulder can be opened or closed; and responsive in that the strategy is applied based on the traffic conditions at a place and time, in an automated way, although RCC Operators also interact manually with the system in setting signals and messages, and opening and closing the hard shoulder.

Due to the dynamic and responsive nature of SM strategies, the SM system uses a set of parameters which determine the conditions under which strategies should be deployed. These parameters are the values used by the SM system algorithms to control the timing, content and location of the information and instructions communicated automatically (or semi-automatically) by the system. See Annex F for a list of the operating parameters which the system utilises.

The majority of parameters are not usually adjusted between SM schemes. Flow thresholds, however, require site specific calculation and optimisation to enable good system performance. Each vehicle detector site within an SM scheme uses up to three sets of flow thresholds:

- Standard Flow Thresholds – Used by the system to set CM signals for standard running (e.g. normal ALR or when the hard shoulder lane is closed to traffic);
- Link Flow State (LFS) Thresholds – Assigned to some vehicle detector sites and used under DHS to indicate when operators should begin the hard shoulder opening and closing processes on a particular link; and
- DHS Flow Thresholds - Used by the system to set CM signals under DHS

Note that speed thresholds may also need to be recalibrated during the Commissioning phase if traffic responds to signal settings in an unexpected way (e.g. exhibits a greater level of compliance with the speed limits than anticipated).

2.6 SM SYSTEM PERFORMANCE

Typically the Operational Regimes for SM implementations provide dynamic instructions and information to drivers in response to particular traffic conditions to ensure the traffic flow through the scheme is maximised. The SM System can be said to be performing well *if the instructions and information delivered are appropriate to the conditions*.

The effectiveness of the Operational Regimes and their impact on traffic may be assessed through System and Scheme performance monitoring and evaluation. System performance monitoring is about verifying that the system is performing in the way in which it was designed to work in order to achieve the Scheme objectives.

SM System performance is defined by a set of measures in Annex C.2 (for clarity, the Scheme performance and verifying that the objectives have been achieved is outside the scope of this document). Many of the principles of calibration and optimisation are applicable to a range of technology or traffic management schemes, however in developing the CALO Toolkit (Annex D) a specific definition of SM scheme has been applied, namely that on any section of motorway it:

- Seeks to address one or more recurrent congestion seed points by altering driver behaviour, with some schemes utilising an existing hard shoulder as a running lane dynamically; and
- Uses variable speed limits and lane status instruction(s) to do so.

Guidance is based on current considerations, such as typical commissioning schedules, site data preparation timescales and signal sequencing rules. These are likely to change over time and as such, the specification of products rather than standard instruction means calibration and optimisation shall be adaptable to these changes.

It shall also be recognised that scientifically, an absolute optimisation of a SM System is not possible and that limitations exist outside the control of those implementing a particular scheme. These may be limitations due to the particular design or site that has been selected, or system limitations such as those associated with signal setting algorithms. As such, the process set out is based on a generic SM scheme implementation and any system performance shall be further considered in the context of implementation within a specific scheme.

2.7 APPROACH TO OPTIMISATION

In order to support both Calibration and Optimisation Engineers in assessing and quantifying an SM System's performance, HA governance is essential. This ensures suitable measures have been applied and are regularly reviewed to ensure the SM system is operating optimally. A set of performance-based products (Section 4) has been developed which enables suitable demonstration that the scheme is achieving its desired outcomes and is optimised as so far as reasonably practicable.

3 ROLES AND RESPONSIBILITIES

3.1 KEY ROLES

Within the calibration and optimisation process there are four key roles that require consideration, these are;

- *Calibration Engineer*

  This individual or party is typically appointed by the Scheme and is responsible for generating all the scheme products shown in Section 4. The Calibration Engineer shall calculate and optimise flow thresholds (Annex F) and identify and recommend optimisation measures (Annex I), providing technical guidance to support the tasks they shall be required to carry out.

  The role is handed over to the Optimisation Engineer at the end of the relevant COM4 (or COM6 if DHS) 12 month monitoring period (Annex A). However to ensure consistency, it is recommended that the Calibration Engineer is commissioned for the duration of the scheme lifecycle, stages A- E. *Note Scheme assets shall be handed over after a Scheme is 'open to traffic' (i.e. Asset Handover) and is not affected by the extended monitoring.*

  The Calibration Engineer shall be a primary user of the CALO Toolkit (Annex D).

- *Optimisation Engineer*

  This party or individual is appointed by the HA and is responsible for generating the operational products shown in Section 4. The Optimisation Engineer shall calculate and optimise flow thresholds, identifying and recommending optimisation measures. Annex I provides technical guidance to support the tasks they shall be required to carry out.

  It is recommended that the Optimisation Engineer is commissioned for the duration of the scheme lifecycle, stages E and F. However, the role shall be formally handed over by the Calibration Engineer at the end of the relevant COM4 (or COM6 if DHS) 12 month monitoring period. *For the avoidance of doubt, a collaborative approach should be undertaken during COM4 monitoring period.*

  The Optimisation Engineer shall also be a primary user of the *CALO Toolkit* (Annex D).

- *HA Project Sponsor*

  This role is likely to be filled by the individual responsible for the overall delivery or ongoing operation of the SM scheme. This shall be the HA Project Sponsor during the Commissioning Stage and the HA Area or Technology Manager during the Operational Stage. They shall be responsible for signing off the majority of the products described in Section **Error! Reference source not found.**. They shall be required to be aware of the overall specification for each product and to apply the assessment criteria.

  Specific guidance (Annex B) provides a clear and concise definition of what they should expect from the other parties and what shall be expected of them.

- *Central Client-Side Specialist (CCSS)*

  This role is likely to be filled by a team of HA and/or third party specialists, acting across all SM schemes. This role can be defined by the list below:

  - To provide technical advice and training for Calibration and Optimisation Engineers;
  - To review products and assist HA Scheme Representatives in assessing products against the acceptance criteria;
  - To carry out administration and scheme set-up tasks within the *CALO Toolkit;*
  - To produce System Monitoring Notes for schemes in operation;
  - To identify and share best practice; and
  - To carry out troubleshooting activities and address common problems.

The roles identified shall be either accountable or responsible for some or all of the activities set out, that requires consultation in the majority of activities when neither accountable nor responsible for those activities.

In addition, three further stakeholders exist within calibration and optimisation requiring consultation or to be informed, these roles are;

- *Site Data Designer (Scheme or Regionally)*
- *RCC Technology Manager*
- *RTMC (ASC) Representative*

Training is available to equip key roles and stakeholders with suitable provision to carry out their duties (Annex H).

3.2 DEVELOPING AND MAINTAINING EXPERTISE

It is recognised that the knowledge and capability required for optimisation should be developed centrally within the HA, and disseminated more widely across the HA and its partners. This shall enable the HA to ensure optimisation practices are carried out as efficiently and consistently as possible, and to better identify where future development and improvement may be needed as the exact implementation of SM shall often vary from scheme to scheme and designs of SM shall evolve over time (e.g. using less or different technology infrastructure). These considerations have been included.

3.3 ASSIGNING RESPONSIBILITY

Although roles are as defined above, the parties responsible for carrying out those roles are likely to differ from scheme to scheme, depending on the particular arrangements of the scheme and more general organisational arrangements of the HA and its partners. As such Annex B provides further advice on the capability and responsibility requirements to help guide the assignation of responsibility for a particular scheme.

4 CALIBRATION AND OPTIMISATION PRODUCTS

4.1 OVERVIEW OF PRODUCTS

Products which are *required to be produced* by those responsible for the calibration or optimisation of an SM scheme are detailed herein. *Recommendations* as to their structure and content are detailed herein. The products required depend on whether the scheme is in Commissioning or Operational stage. The products for each of these two stages are identified in Table 3. Some of the activities described in this document are one-off deliverables whilst others are ongoing activities, as such not all activities are inter-dependent and can be completed in a different order to that in the table below, as long as the dependencies described in each section are adhered to.

Table 3: Calibration and Optimisation Products

Optimisation Products	**Functional Roles[2]**							
Product Name (Reference)	**Calibration Engineer**	**Optimisation Engineer**	**Project Sponsor**		**CCSS**	**(Regional) Site Data Designer**	**RCC Technology Manager**	**ASC / RTMC**
	Project Team	**Operation**	**Project Team**	**Operation**				
Optimisation Plan (COM1)	R		A		C	C	C	I
Initial Flow Thresholds (COM2)	R		A		C	I		
System Performance Preview (COM3)	R		A		C		C	I
System Monitoring Report (COM4)	R	C*	A	I*	C	I	C	I
Initial DHS Flow Thresholds (COM5)	R		A		C	I		
Systems Monitoring Report – DHS (COM6)[3]	R		A		C	I	C	I
Optimisation Log (COM7)	R**	R**	A**	A**	C	I	C	I
System Monitoring Notes (OPR1)		C		A	R		I	I
Annual System Performance Review (OPC1)		R		A	C	C	C	I

** Until COM4 has been successfully handed over, 12 months post Asset Handover*

*** Responsible and Accountable parties are dependent on the position within the scheme lifecycle. Typically Scheme would produce COM7 and Operation would provide updates as required.*

[2] Definitions of Responsible, Accountable, Consult and Inform are in accordance with those set out in GD04, Chapter 7.

[3] COM5 and COM6 products are relevant to DHS schemes only. They are not required for ALR or CM schemes.

4.2 OPTIMISATION PLAN (COM1)

4.2.1 Description

The Optimisation Plan (COM1) shall act as a plan for calibration activities to be carried out during the Commissioning period of the SM scheme. Suitable arrangements should be made for collecting traffic data prior to the Scheme works, to enable calculation of initial thresholds.

COM1 shall be produced at the start of a scheme, and shall be maintained and updated where necessary throughout the whole life of the scheme. COM1 shall be initially delivered to and signed-off by the HA Scheme Representative before any of the other products can be received.

4.2.2 Contents

COM1 shall include the information specified in Table 4.

Table 4: COM1 Contents

<table>
<tr><th>Ref</th><th>Item</th></tr>
<tr><td colspan="2">Scheme Information</td></tr>
<tr><td>A.1</td><td>The location of the scheme on the network, i.e. the motorway and scheme extents (to the nearest marker post, for both directions separately).</td></tr>
<tr><td>A.2</td><td>The location of junctions (where the slip roads join the main carriageway, to the nearest marker post).</td></tr>
<tr><td>A.3</td><td>The Scheme should be divided into sections, where sections are defined as: a continuous stretch of the main carriageway for which a consistent number of lanes are present and contains no points where traffic may leave or join the carriageway. Stretches of carriageway adjacent to slip roads should be treated as separate sections from the preceding carriageway due to the movement of traffic between the main carriageway lanes and the slip road.</td></tr>
<tr><td>A.4</td><td>Sections should be described in the following terms:
Their status for the period in which traffic data was recorded, i.e.:
The number of lanes currently present
The presence of a hard shoulder
The presence of a parallel slip road lane
Whether the section is ‘between junctions’, ‘within a junction’ or ‘adjacent to a slip road’
Their planned SM status:
Use of the hard shoulder: permanent conversion (ALR), dynamic use (DHS), or not applicable
The presence of mandatory or advisory variable speed limits</td></tr>
<tr><td colspan="2">Commissioning Plan</td></tr>
<tr><td>B.1</td><td>The dates for each stage of the commissioning programme and what each stage consists of operationally (with particular reference to the activation of vehicle detector sites, and VMSL activation (including ALR and DHS).</td></tr>
<tr><td>B.2</td><td>The dates when site data loads are planned to take place and the associated data entry period.</td></tr>
<tr><td colspan="2">Optimisation Products</td></tr>
<tr><td>C.1</td><td>Identification of the individuals (where appropriate) fulfilling the following roles for the scheme:
Calibration Engineer(s) (in the Commissioning stage)
HA Scheme Representative(s)
Central Client-Side Specialist(s)
Site Data Designer(s)
Optimisation Engineers(s) (in the Operational stage) – if known</td></tr>
</table>

<table>
<tr><th>Ref</th><th>Item</th></tr>
<tr><td>C.2</td><td>The date when each of the following products are to be first delivered to the designated recipient(s):
COM2 - Initial Standard Thresholds or ALR Thresholds
COM3 - System Performance Preview Report
COM4 - System Monitoring Report – CM and ALR
COM5 – Initial DHS Thresholds
COM6 - System Monitoring Report – DHS
If none of the sections in the scheme utilise DHS (i.e. all hard shoulders are permanently converted) then COM5 and COM6 are not required</td></tr>
<tr><td>C.3</td><td>If more than one of each of the products is to be produced (i.e. a staged commissioning approach is being used) then this shall be communicated.</td></tr>
<tr><td>C.4</td><td>The date on which the Optimisation Log shall be handed over to the Optimisation Engineer.</td></tr>
<tr><td colspan="2">Traffic Data</td></tr>
<tr><td>D.1</td><td>A list of all the sections in the scheme which should have vehicle detectors enabled for generating speed and flow alerts:
From the first day of operation;
After new vehicle detector data can be validated; or
Not at all.
This can be referred to as the Detector Enablement Strategy.</td></tr>
<tr><td>D.2</td><td>The traffic data that shall be used in the production of COM2, and COM5 if required. Initial thresholds shall normally be calculated using traffic data recorded between the Scheme boundaries prior to commencement of works for the Scheme.
Data should meet the specification given in Annex E where it is indicated that a minimum of 56 days of data prior to the Scheme works should be collected. Where vehicle detector data is unavailable, alternative sources should be sought, or detectors should be enabled temporarily to collect relevant data before construction begins.</td></tr>
<tr><td colspan="2">Site Data</td></tr>
<tr><td>E.1</td><td>Initial calculation of flow thresholds (COM2) shall be carried out before the VMSL site data load is installed. Therefore, COM1 should identify which of the following information sets shall be used to aid the initial threshold calculation process:
An uninstalled draft site data (MS Access database)
Locations of gantries (pointers to be generated in scheme set-up)
None of the above (gantries shall be assumed to be located at regular intervals and pointers assigned)</td></tr>
<tr><td colspan="2">Training and advice</td></tr>
<tr><td>F.1</td><td>Training requirements of individuals</td></tr>
<tr><td>F.2</td><td>Questions</td></tr>
<tr><td>F.3</td><td>Clarifications</td></tr>
</table>

4.2.3 Acceptance criteria

The product shall contain all of the elements of Table 4 above.

4.3 INITIAL STANDARD FLOW THRESHOLDS INCLUDING ALR (COM2)

4.3.1 Description

For every Smart Motorways scheme, a set of standard flow thresholds is required for installation in the site data load that shall enable the setting of Controlled Motorways signals on the scheme. For an ALR scheme, the extra lane is taken into account by factoring up the thresholds calculated from the initial 3-lane data collected, as only data without ALR shall be available initially[4].

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[4] The CALO Toolkit performs this factoring automatically.

Initial standard flow thresholds including ALR (COM2) shall be delivered to the Scheme's Site Data Designer in time to assign the thresholds to the appropriate vehicle detectors and enter them into the site data load (as referenced in COM1).

The initial standard flow thresholds for a scheme shall be generated using historical data, and shall take place before the Operational Regime Testing stage of a scheme. Annex C.4 contains guidance for the calculation of initial thresholds. The *Threshold Calculation Tool* within the Smart Motorway *Calibration and Optimisation (CALO) Toolkit* can be used to support this process, including converting ALR thresholds automatically (Annex D). *If an ALR scheme is to be enabled as 3-lane running with the hard shoulder coned off, before being converted to 4-lane running, the 3-lane thresholds calculated from the historical data should be used. It should also be noted that thresholds are independent of HIOCC activation ('HIOCC live').*

4.3.2 Contents

COM2 shall include, for each scheme section, information specified in Table 5[5].

Table 5: COM2 Contents

Ref	Item
A.1	Indication as to whether or not vehicle detectors within that section should be used for generating speed and flow alerts (i.e. the Detector Enablement Strategy).
A.2	The proposed status of each section in the scheme: ▪ Use of the hard shoulder: permanent conversion (ALR), dynamic use (DHS), or not applicable ▪ The presence of mandatory or advisory variable speed limits
A.3	The threshold values to be applied to vehicle detector sites within each section designated for generating speed and flow alerts. The following thresholds are required in this product (see Section C.4 for further information): ▪ Rising flow thresholds (bands 2 and 3) ▪ Falling flow thresholds (bands 2 and 3) Speed thresholds should be included if there are to be any changes to the standard thresholds. This includes schemes where an alternative set of speed thresholds are in place, or other special cases (e.g. ALR schemes limited to 60mph during the day and enforced with average speed enforcement may need speed threshold adjustments if there is an unexpected variation in base lined compliance assumptions.)
A.4	Any other calibration measures that have been identified up to that point which would require a change to site data.

4.3.3 Acceptance criteria

The product shall contain all of the elements of Table 5.

Information should be presented in an unambiguous manner, to be easily understood by the Site Data Designer.

4.4 SYSTEM PERFORMANCE PREVIEW REPORT (COM3)

4.4.1 Description

The System Performance Preview[6] Report (COM3) shall be delivered to the HA Scheme Representative to give assurance that SM performance is as optimal as possible from commencement of CM operation.

---

[5] It is recommended practice for COM2 to issue the elements of Table 5 in the form of the plots featuring simulated signals generated by the CALO Toolkit and any supplementary information required that provides suitable reasoning for the decisions taken.

[6] This corresponds to the System Preview facility in the CALO Toolkit.

COM3 shall be generated once the vehicle detection devices are commissioned and standard running is underway (e.g. no 50mph limit due to ongoing road works). This is part of the Operational Regime Testing stage of a scheme. Annex C.5 contains guidance for System Performance Monitoring. The *System Preview Tool* within the *CALO Toolkit* can be used to support this process (Annex D).

4.4.2 Contents

COM3[7] shall be such that the above description is fulfilled and the acceptance criteria are met. This may vary depending on the scheme, the calibration measures required and the preferences of the HA Scheme Representative.

A suggested structure would be:

1. Summary of traffic conditions
2. Smart Motorways expected operation
3. Calibration measures
4. Expected system performance

If COM3 shows that the signalling would not be acceptable, modifications should be identified such that the scheme could be enabled. This could range from a small change, such as disabling a vehicle detector for CM, to a large change, such as collecting further data to re-calibrate the thresholds.

4.4.3 Acceptance criteria

COM3 should satisfy the HA Scheme Representative that upon enabling of mandatory Controlled Motorways signals within the scheme, that signal output shall be as appropriate as is reasonably possible.

System performance information should be presented in an unambiguous manner, to be easily understood by the Scheme Representative.

Any statements about system performance should be supported with suitable evidence.

Reference should be made to all of the applicable performance measures.

Suitable explanation for any areas of sub-optimal performance should be given.

4.5 SYSTEM MONITORING REPORT – CM AND ALR (COM4)

4.5.1 Description

The System Monitoring Report – CM and ALR (COM4) is required to confirm optimal operation in Standard CM or ALR schemes and detail any optimisation measures that have been or shall be taken.

The Calibration Engineer shall produce a System Monitoring Report after each Go-Live Event and then continuing (for non DHS schemes) monthly for a period of 12 months following Asset Handover. COM4 shall include evidence of acceptable scheme performance. This product should be delivered to the HA Scheme Representative via the CCSS. Annex C.5 contains guidance for system performance monitoring. The *System Monitoring Tool* within the *CALO Toolkit* can be used to support this process (Annex D).

Simulation used in the production of COM3 shall be as if signals were only set by the CM algorithm. However, COM4 shall be based on live output and incorporate HIOCC and manual settings (DHS output shall be included in COM6).

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[7] It is recommended practice for COM3 to issue daily reports based on the output of the System Preview facility in the CALO Toolkit over the course of a week, followed by a System Performance Preview Report summarising the week.

4.5.2 Contents

COM4[8] should be such that the above description is fulfilled and the acceptance criteria are met. This may vary depending on the scheme, the calibration measures required and the preferences of the HA Scheme Representative. A suggested structure would be:

1. Summary of system performance with reference to the SM system performance measures (Annex C.2);
2. Examples including space-time plots supporting the performance summary using output from the System Monitoring Tool;
3. Comparison with the expected performance detailed in COM3;
4. Details of any further optimisation measures that have been recommended since the production of COM3;
5. Recommendations for ‘programme-wide’ optimisation measures outside the control of the Calibration Engineer to be investigated by the CCSS;
6. A review schedule for assessing the impact of optimisation measures, if necessary.

4.5.3 Acceptance criteria

System performance information should be presented in an unambiguous manner, to be easily understood by the Scheme Representative.

Any statements about system performance should be supported with suitable evidence.

Reference should be made to all of the applicable performance measures (Annex J). Performance measures relating to DHS are included in COM6 and shall not be required for this product.

Suitable explanation for any areas of sub-optimal performance should be given, bearing in mind that ALR schemes may not set signals due to the increase in capacity.

4.6 INITIAL DHS FLOW THRESHOLDS (COM5)

4.6.1 Description

For every DHS Smart Motorways scheme, a set of Link Flow State and DHS flow thresholds is required for installation in the site data load that shall enable the Dynamic use of the Hard Shoulder within the scheme.COM5 should be delivered to the Scheme’s Site Data Designer in time to assign the thresholds to the appropriate vehicle detectors and enter into the site data load (as referenced in COM1).

The DHS flow thresholds and LFS for a scheme shall be generated using historical data, and shall take place before the Operational Regime Testing stage of a scheme.

Annex C.4 contains guidance for the calculation of initial thresholds.

The *Threshold Calculation Tool* within the *CALO Toolkit* can be used to support this process (Annex D).

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[8] It is recommended practice that COM4 is to issue weekly reports based on the output of the System Monitoring facility in the CALO Toolkit over the course of a month, followed by a System Monitoring Report summarising the month. For CM and ALR scheme, this product should highlight any recommended final changes to thresholds as a result of the monitoring period (these could be listed in a separate report). For non-DHS schemes, a short report should be issued monthly, based on the output of the System Monitoring facility, for the first 12 months of the scheme following Asset Handover, before System Handover can be undertaken

4.6.2 Contents

COM5 shall include, for every section of the DHS scheme, the information specified in Table 6[9].

Table 6: COM5 Contents

Ref	Item
A.1	Indication as to whether or not vehicle detectors within that section should be used for generating speed and flow alerts (i.e. the Detector Enablement Strategy).
A.2	The proposed presence of mandatory or advisory variable speed limits for each section of the scheme.
A.3	The threshold values to be applied to vehicle detector sites within each section designated for generating speed and flow alerts. The following thresholds are required in this product (see Section C.4 for further information): ▪ Rising flow thresholds (bands 4 and 5) ▪ Falling flow thresholds (bands 4 and 5) ▪ Rising LFS thresholds ▪ Falling LFS thresholds Speed thresholds should be included if there are to be any changes to the standard thresholds. This includes schemes within the West Midlands region, where an alternative set of speed thresholds are in place.
A.4	Any other optimisation measures that have been identified up to that point which would require a change to site data.

4.6.3 Acceptance criteria

The product should contain all of the elements of Table 6.

Information should be presented in an unambiguous manner, to be easily understood by the Site Data Designer.

4.7 SYSTEM MONITORING REPORT – DHS (COM6)

4.7.1 Description

For every DHS Smart Motorways scheme (or section of a DHS Smart Motorways scheme to be independently commissioned) a System Monitoring Report – DHS (COM6) is required to confirm optimal operation in DHS mode and detail any calibration measures that have been or shall be taken.

The Calibration Engineer shall produce a System Monitoring Report after each Go-Live Event and then continuing monthly for a period of 12 months without major fault following Asset Handover. COM6 shall include evidence of acceptable performance. This product should be delivered to the HA Scheme Representative via the CCSS.

Annex C.5 contains guidance for system monitoring.

The *System Monitoring Tool* within the *CALO Toolkit* can be used to support this process (Annex D).

COM6 shall be based on live output and shall incorporate all signal settings in non-DHS and DHS modes.

4.7.2 Contents

COM6[10] should be such that the above is fulfilled and the acceptance criteria are met. This may vary depending on the scheme, the calibration measures required and the preferences of the HA Scheme Representative. A suggested structure would be:

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[9] It is recommended practice for COM5 to issue the elements of Table 6 in the form of the plots featuring simulated signals generated by the CALO Toolkit and any supplementary information required that provides suitable reasoning for the decisions taken. This could be provided in the same report as COM2.

1. Summary of system performance with reference to the SM system performance measures (Annex I);
2. Examples including space-time plots supporting the performance summary using output from the System Monitoring Tool;
3. Comparison with the expected performance detailed in COM3;
4. Details of any further optimisation measures that have been recommended since the production of COM3;
5. Recommendations for 'programme-wide' optimisation measures outside the control of the Calibration Engineer to be investigated by the CCSS;
6. A review schedule for assessing the impact of calibration measures, if necessary.

4.7.3 Acceptance criteria

System performance information should be presented in an unambiguous manner, to be easily understood by the Scheme Representative.

Any statements about system performance should be supported with suitable evidence.

Reference should be made to all of the applicable performance measures.

Suitable explanation for any areas of sub-optimal performance should be given.

4.8 Optimisation Log (COM7)

4.8.1 Description

Every optimisation measure proposed or implemented throughout the life of a scheme is to be recorded in the Optimisation Log. It is considered to be the responsibility of the Calibration and Optimisation Engineers to ensure that the Optimisation Log is kept up to date.

COM7 is a live document which should be reviewed by the CCSS on a regular basis, and before it is handed over by the Calibration Engineer to the Optimisation Engineer at Scheme Handover.

4.8.2 Contents

The information specified in Table 7 shall be provided for every optimisation measure proposed and implemented. A template for COM7 is provided in Annex G.

Table 7: COM7 Contents

Ref	Item
For every optimisation measure *proposed*	
A.1	Date
A.2	Measure
A.3	Expected impact
A.4	Proposer
A.5	Who the recommendation is proposed to
For every optimisation measure *implemented*	
B.1	Date of implementation
B.2	The corresponding proposed measure

[10] It is recommended practice for COM6 to be undertaken after COM4 summary report is issued. To issue weekly reports based on the output of the System Monitoring facility in the CALO Toolkit over the course of a month, followed by a System Monitoring Report summarising the month, highlighting any recommended final changes to thresholds as a result of the monitoring period (though these could be listed in a separate report). A short report should be issued monthly, based on the output of the System Monitoring facility, for the first 12 months of the scheme following SM Go-live and before System Handover can take place.

Ref	Item
B.3	Confirmation that the measure was implemented and that it has produced the desired effect in terms of system performance
B.4	Review date (if necessary)

The Optimisation Log should also include an additional table to act as a ‘wish list’ of system improvements. This shall form a list of desired optimisation measures outside the immediate influence of the Calibration or Optimisation Engineer. These shall be reviewed by the CCSS team to help form a strategy for future system developments.

4.8.3 Acceptance criteria

Every optimisation measure suggested or implemented should be included in COM7 with the information listed in Table 7.

4.9 SYSTEM MONITORING NOTES (OPR1)

4.9.1 Description

During the Operational Stage of an SM system, the CCSS team may issue System Monitoring Notes (OPR1) to the Optimisation Engineer. These shall identify sub-optimal performance and prompt the Optimisation Engineer to investigate further.

The Optimisation Engineer should respond within the timescale stipulated in the OPR1 (A.6).

Annex C.6 provides guidance for responding to System Monitoring Notes.

4.9.2 Contents

An OPR1 should be generated if sub-optimal performance is identified by the CCSS in the process of a routine check. These checks should be undertaken 2 or 3 times a year and continue through the life of the scheme.

An OPR1 should include, for every section of the scheme, the information specified in Table 8.

Table 8: OPR1 Contents

Ref	Item
A.1	The location within the scheme of where sub-optimal performance has been observed.
A.2	The date(s) on which it was observed.
A.3	The total period of observation.
A.4	The nature and severity of the sub-optimal performance, with reference to the system performance measures.
A.5	Evidence to support the above.
A.6	The timescale within which the Optimisation Engineer should respond.

4.9.3 Acceptance criteria

The product should contain all of the elements of Table 8.

Information should be presented in an unambiguous manner, to be easily understood by the Optimisation Engineer. Any statements about system performance should be supported with suitable evidence.

4.10 ANNUAL SYSTEM PERFORMANCE REVIEW (OPC1)

4.10.1 Description

For every scheme in operation, Annual System Performance Review (OPC1) reports are to be produced by the Optimisation Engineer and issued to the HA Scheme Representative via the CCSS through the life of the scheme. OPC1reports on the ongoing performance of the scheme and detail any optimisation measures that have been or shall be taken. Annex C.5 contains guidance for system performance monitoring.

The *System Monitoring Tool* within the *CALO Toolkit* can be used to support this process (Annex D). OPC1 shall be based on live output and shall incorporate all signal settings including both non-DHS and DHS modes.

4.10.2 Contents

The contents of OPC1 should be such that the above is fulfilled and the acceptance criteria are met. This may vary depending on the scheme, the optimisation measures required and the preferences of the HA Scheme Representative. A suggested structure would be:

1. Summary of system performance with reference to the SM system performance measures (Annex C.2);
2. Examples supporting the performance summary using output from the System Monitoring Tool;
3. Comparison with the performance detailed in previous OPC1 issues and in COM3;
4. Details of any significant optimisation measures that have been recommended since the production of the previous OPC1;
5. Recommendations for ‘programme-wide’ optimisation measures outside the control of the Optimisation Engineer to be investigated by the CCSS;
6. An update of any existing review schedule for assessing the impact of optimisation measures.

4.10.3 Identified scheme improvements

If improvements to the scheme are identified as part of OPC1 and the HA scheme representative provides funding to make changes, the Optimisation Engineer is responsible for undertaking the re-optimisation of the scheme. This involves following the calibration process and producing COM2, COM3 and COM4 (also COM5 and COM6 if it is a DHS scheme). The Optimisation Plan initially produced for calibration should be followed, with relevant updates, and the Optimisation Log should be maintained throughout. The 12 month monitoring period in COM4 (or COM6) shall not be required, as the scheme shall then revert back to the OPR1 and OPC1 reporting.

4.10.4 Acceptance criteria

System performance information should be presented in an unambiguous manner, to be easily understood by the Scheme Representative, any statements about system performance should be supported with suitable evidence. Reference should be made to all of the applicable performance measures and suitable explanation for any areas of sub-optimal performance should be given.

5 SCHEDULING PRODUCTS

Annex A provides an overview of where the products are required in relation to a generic SM Scheme implementation and timelines of all the tasks required in the development of products within the Commissioning and Operational stages of a scheme.

It is recognised that a commissioning plan may vary greatly from scheme to scheme, so the products are designed to be flexible to the different approaches of individual schemes. As such, timelines set out should be treated as a guideline. It also shows the first years of the operational stage of a scheme, highlighting the tasks going forward from System Handover and continuing through the life of the scheme. The System Performance Review (OPC1) shall be conducted annually, while the actual number of System Monitoring Notes (OPR1) produced shall vary depending on the performance of the scheme.

6 REFERENCES

- MCH1744: NMCS2 MIDAS Signal and Sign Setting Strategy
- MCH1753: NMCS2 Site Data Specification
- IAN111/09 Managed Motorway Implementation Guidance – Hard Shoulder Running
- IAN112/08 Managed Motorway Implementation Guidance – Through Junction Hard Shoulder Running
- IAN161/13 Managed Motorway Implementation Guidance – All Lanes Running
- IAN 182/14 Major Schemes: Enabling Handover into Operation and Maintenance
- GD04/12 Standard for Safety Risk Assessment on the Strategic Road Network
- www.halogenonline.dft.gov.uk
- www.midas-data.org.uk
- www.sitedatacentre.com

END OF MAIN DOCUMENT

ANNEX A CALIBRATION AND OPTIMISATION SCHEDULE WITHIN THE SCHEME LIFECYCLE

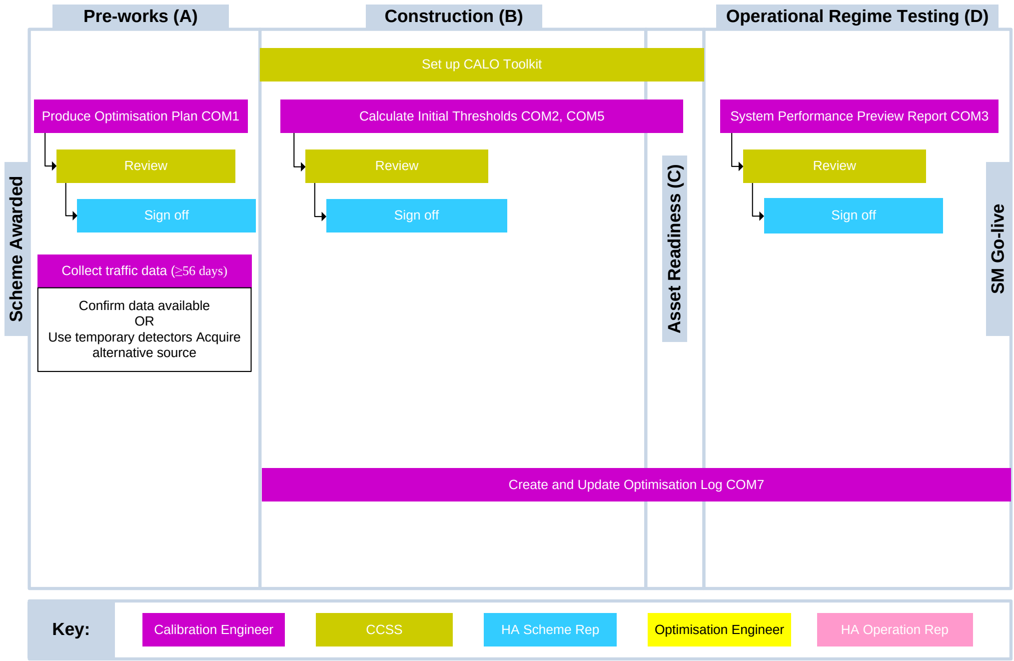


Figure 2: Calibration and Optimisation Products with the Scheme Life-cycle Stage A-D

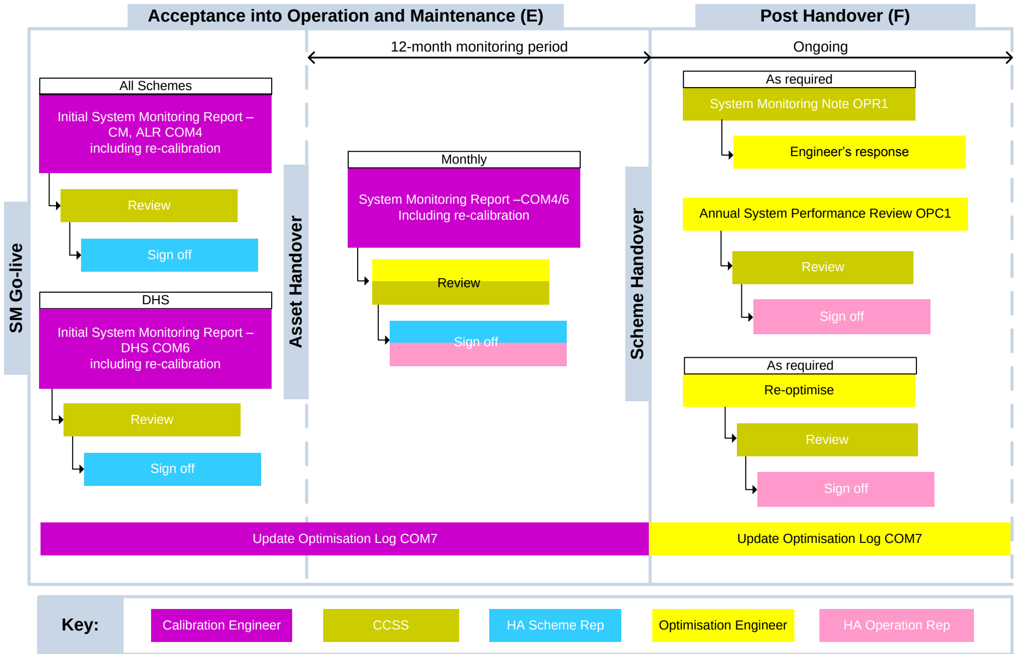


Figure 3: Calibration and Optimisation Products with the Scheme Life-cycle Stage E-F

END OF Annex A

ANNEX B CALIBRATION AND OPTIMISATION COMPETENCIES AND LEVELS OF AUTHORITY REQUIREMENTS

Table 9: HA Scheme Representative Description

<table>
<tr><th colspan="3">HA Scheme Representative</th></tr>
<tr><th>Tasks</th><th>Required competencies</th><th>Required authority</th></tr>
<tr><td>Commissioning Stage

Sign off:
▪ Optimisation Plan (COM1)
▪ System Performance Preview Report (COM3)
▪ System Monitoring Reports (COM4, COM6)

Participate in review of documents with Central Client-side Specialist

Operational Stage

Sign off:
▪ System Monitoring Notes (OPR1)
▪ Annual System Performance Reviews (OPC1)</td><td>Ability to understand review outputs

High level understanding of SM optimisation</td><td>Authority to accept product and initiate next stage of scheme delivery

Authority to request further investigation relating to products</td></tr>
</table>

Table 10: Central Client-Side Specialist (client-side) description

Central Client-Side Specialist		
Tasks	**Required competencies**	**Required authority**
Commissioning Stage Provide guidance and training Set up *CALO Toolkit* for initial threshold calculation Review: ▪ Optimisation Plan (COM1) ▪ System Performance Preview Report (COM3) ▪ System Monitoring Reports (COM4, COM6) Sign off: ▪ Thresholds (COM2, COM5) **Operational Stage** Provide guidance and training Maintain *CALO Toolkit* set-up and data provision Produce: ▪ System Monitoring Notes (OPR1) Review: ▪ Annual System Performance Review (OPC1)	Complete understanding of SM optimisation process including the toolkit and performance measures Knowledge of best practice across schemes Ability to deliver training and answer questions In depth knowledge of existing guidance Knowledge of specific scheme Ability to use the toolkit including scheme set-up Ability to be a trusted advisor to the HA Scheme Representative	Authority to speak for the HA on relevant technical matters Authority to approve training resource Contractual mechanism to provide training/advice Scheme setup privileges in *CALO Toolkit* website Authority to load site data in *CALO Toolkit* website Authority to assign users in software toolkit Authority to act autonomously on HA's behalf in matters of performance monitoring Authority to require response to performance notes

Table 11: Calibration / Optimisation Engineer description

Calibration / Optimisation Engineer		
Tasks	**Required competencies**	**Required authority**
Commissioning Stage - Calibration Data provision Calculate standard and DHS flow thresholds and link flow state thresholds (COM2, COM5) Implement thresholds Produce: ▪ Optimisation Plan (COM1) ▪ System Performance Preview Report (COM3) ▪ System Monitoring Reports (COM4, COM6) Implement improvement measures identified in reports Produce Optimisation Log (COM7) **Operational Stage - Optimisation** Respond to System Monitoring Notes (OPR1) Produce Annual System Performance Reviews (OPC1) Implement and log improvement measures identified in reports (COM7) Undertake re-optimisation of the scheme (following the requirements for calibration and the production of the COM products) if required by OPR1 or OPC1	Knowledge of data Knowledge of the scheme Knowledge of what products are required Understanding of what is needed for optimisation Ability to use toolkit, including: ▪ Identification and classification of congestion on space-time plots ▪ Understand performance measures ▪ Assess appropriateness of simulated signal output Knowledge of the essentials of SM operation and performance Understanding of changeable elements and their impact Ability to communicate optimisation measures and performance Knowledge of performance Ability to fix technology faults or arrange for them to be fixed Ability to make recommendations to operators Ability to use audit function of toolkit	Authority to commit to deliver products Ability to influence commissioning and site data schedules Contract to produce products Authority to request and /or undertake data collection User account for the *CALO Toolkit* Authority to recommend site data changes Accountability for scheme performance Authority to commit to measures Authority to carry out maintenance or request maintenance Authority to make recommendations to operators

END OF Annex B

ANNEX C GUIDANCE FOR CALIBRATION AND OPTIMISATION PRODUCT DEVELOPMENT

C.1 PRE-REQUISITES

Calibration and Optimisation Engineers should have received training from the CCSS team before developing any product. Training course details are specified in Annex H. The CCSS team can also offer specialist advice to supplement the guidance provided here. The guidance covers the following tasks:

- Measuring system performance (Section C.2);
- Applying optimisation measures (Section C.3);
- Calculating initial thresholds (Section C.4);
- Monitoring performance (Section C.5); and
- Responding to System Monitoring Notes (Section C.6).

C.2 MEASURING SYSTEM PERFORMANCE

C.2.1 Defining performance

An SM system can be said to be performing well if *the dynamic information and instruction delivered to road users is appropriate to the prevailing traffic environment within which it is being communicated.*

Therefore, measuring performance can be seen as assessing the appropriateness of that information and instruction for the traffic environment at a given place and time.

Appropriateness could be defined in a variety of ways, but all definitions should be based on the experience of drivers using the scheme. This document suggests that appropriateness, in terms of SM system output, can be defined as consisting of the set of elements listed below.

- Success of the SM system in indicating that the operators should open the hard shoulder at a seedpoint location before the onset of congestion;
- Success of the SM system in keeping the hard shoulder indicator on at a seedpoint location until the flow level is reached at which flow breakdown would no longer be expected to occur;
- Success of the SM system (when DHS is not available) in setting 50mph speed limits before the onset of regular congestion;
- Success of the SM system (when DHS is not available) in keeping 50mph speed limits set at a seedpoint location until the flow level is reached at which flow breakdown would not be expected to occur;
- Success of the SM system in not setting variable speed limits at times and locations at which they fulfil no safety improvement or congestion reduction purpose;
- Success of the SM system in not indicating that the hard shoulder should be open at times and locations at which it fulfils no safety improvement or congestion reduction purpose; and
- Success of the SM system in presenting consistent (i.e. not over variable) speed limits to road users.

The *CALO Toolkit* uses a set of performance measures which quantify each of these elements.

Each of these performance elements are the basis of the five performance measures provided in the CALO Toolkit:

- Congestion settings correctly implemented at flow breakdown and recovery
- Hard shoulder open when flow would otherwise break down
- Speed limits not set unnecessarily

- Hard shoulder not open when it is not needed
- Signals not changing rapidly

Annex I provides a summary of the performance measures.

C.2.2 Data used for measuring performance

Calibration and Optimisation Engineers should apply combined analysis of SM system output and traffic conditions to make an assessment against each of these measures.

System output (signal and message data) is available through the Highways Agency Logging Environment (HALOGEN) which can be accessed at halogenonline.dft.gov.uk.

Traffic conditions for operational schemes and for most schemes in commissioning can be analysed using MIDAS data (see Section C.4.1 for guidance on traffic data).

Hard shoulder opening times can be derived from both sources, either by observing a variable speed limit setting displayed over a hard shoulder, or by observing non-zero value traffic counts on hard shoulder vehicle detector sites.

The CALO toolkit automatically collects the live HALOGEN and MIDAS data.

C.2.3 Tools for assessing performance – Space-Time Plot

For operational SM schemes, a key tool for carrying out combined analysis has been the Motorway Traffic Viewer (MTV) software package for producing space-time plots of traffic speed and, in particular, the “Daily Plot” presentation of signal and message data overlaid on traffic speed, flow or occupancy data. This form of visualisation shall be referred to as *space-time plot* visualisation for the remainder of this document.

In addition to the tools described next, the *CALO Toolkit* provides space-time plot visualisation to support the analysis using both simulated and actual signal output as appropriate. This visualisation provides a means of assessing system output on a day-by-day basis.

Annex J provides additional guidance on how this style of visualisation can be used to observe performance. Also, the training provided by the CCSS team contains content relating to this, including several examples.

C.2.4 Tools for assessing performance – CALO Toolkit

Annex D provides information on how to access the *CALO Toolkit.*

The *CALO Toolkit* possesses the functionality to automatically calculate thresholds after the Calibration or Optimisation Engineer has identified congestion seedpoints. The resulting signalling is assessed according to the performance measures to provide an indicative score for the scheme. These performance scores are not a replacement for analysis but are instead an aid for assessing performance at a glance and communicating changes in performance within optimisation products.

The *Threshold Calculation Tool* and *System Preview Tool* within the *CALO Toolkit* have signal simulation capability, i.e. because no real signals are currently being set, the tool calculates what would have been set and presents this in exactly the same way as real signal data.

Optimisation measures should be taken which would be expected to improve one or more of the performance elements.

C.3 APPLYING OPTIMISATION MEASURES

C.3.1 Selecting optimisation measures

Figure 4 provides an overview of a suggested process for implementing optimisation measures.

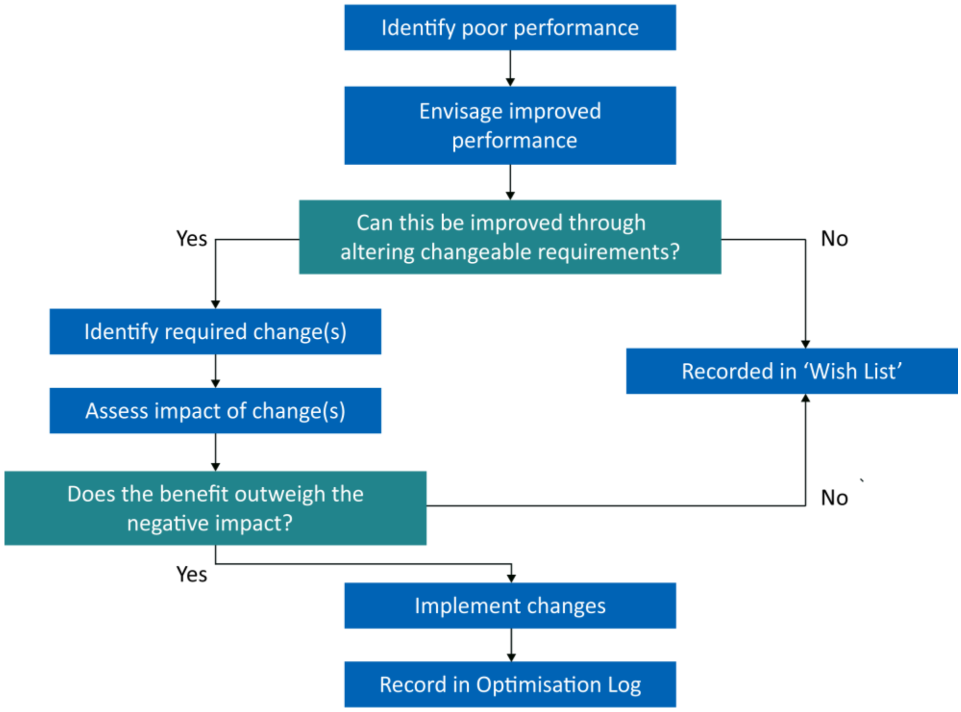


Figure 4: Process for implementing optimisation measures

Section C.2 describes how system performance can be measured. Measuring performance enables areas of poor performance to be identified. It shall then be determined if the improved performance can be achieved through an available optimisation measure.

An optimisation measure is an alteration to one or more of the changeable elements of an SM system such that system performance is improved. This guidance does not attempt to list all of the possible elements that may require alteration. For every new scheme, it should be expected that to optimise performance, at least one measure that has not previously been taken shall be necessary.

Changeable elements available to Calibration or Optimisation Engineers in either the Commissioning or Operational Stage of an SM scheme can generally fall into one of four categories:

- Operating parameters (Section 2.5);
- Technology unit performance – For example, any faults which may occur with vehicle detectors or signals that shall affect the system output;
- Other site data issues – For example, the relationships between technology units; and
- Operator processes and behaviours – For example, unnecessary opening of the hard shoulder or signals set for overnight road works being left on into the following day.

The *CALO Toolkit* should be the main tool for identifying the need for optimisation measures and assessing their impact. Additional investigation may be required, for which a general framework is described below.

- *Understanding of the system*

  The SM system is defined as *the combination of configurable technology, algorithms and processes which respond to traffic conditions as an input and communicate dynamic instruction and information to drivers as an output*. The more insight a Calibration or Optimisation Engineer can gain into how the technology, algorithms and processes operate and interact, the better they shall be at identifying effective optimisation measures.

  This understanding should also include the difference between the changeable elements (broadly defined above) and the 'fixed' elements (such as algorithms and scheme technology design) which shall be outside the immediate influence of a Calibration or Optimisation Engineer.

  Annex K provides an overview of how the algorithms within the SM system operate as well as the hard shoulder opening and closing process.

- *Sources of data for analysis*

  The two main sources of data for selecting appropriate optimisation measures shall be MIDAS vehicle detector data and signal (and message) from HALOGEN. The *CALO Toolkit* utilises live and historic data from both of these sources. For access to MIDAS and signal data for additional analysis visit www.midas-data.org.uk and www.halogenonline.dft.gov.uk respectively.

  Other data sources include Alert Logs, Op Logs and Fault Logs (all available through the two links above).

- *Knowledge of the particular scheme*

  It is very important that the Calibration or Optimisation Engineer is aware of the particular operational, design and geographic features of the scheme which is being analysed. Whilst applying the same general strategies and technologies, SM schemes are likely to be different in regards to these features.

  In order to maintain a full understanding of the particular scheme it may be necessary to engage with relevant parties such as the scheme designer and RCC operators. Information such as scheme drawings, maps and video footage of a scheme drive-through may all be useful.

  A key source of information about the scheme is the site data itself. If not available directly from the Site Data Designer, site data databases can be downloaded at www.sitedatacentre.com.

- *Drawing on previous experience*

  The approach to calibration and optimisation described in this document is largely based on an approach that has developed through the optimisation of the SM schemes that are currently operational. The lessons learned from these schemes and the other schemes to be implemented in the coming years shall be important in selecting effective optimisation measures. The main source for sustaining and sharing this knowledge shall be the CCSS team.

The CALO Toolkit Training Course is a key source of learning in all of these areas. See Annex H for an overview of the course.

It may be found that, after investigation of possible optimisation measures, performance cannot be improved. In this case, it should be noted in a 'wish list', recorded as part of the Optimisation Log. The CCSS Team shall use this to investigate system and programme-wide optimisation measures, i.e. changeable elements outside the control of the Calibration or Optimisation Engineer.

Optimisation measures that improve performance in one area may negatively affect performance in another. This is particularly true for flow thresholds (see Section C.4). Therefore, it is important to assess the full impact of the change before recommending it for implementation.

C.3.2 Implementing optimisation measures

The ability of a Calibration or Optimisation Engineer to directly implement optimisation measures shall depend on their role within the wider delivery team. However, it is likely that in most cases the recommended optimisation measures shall be implemented by a different party.

The following list suggests the likely parties who would implement optimisation measures in the general categories defined in Section C.3.1:

- Operating parameters – Site Data Designer;
- Technology unit performance – Technology maintainer (e.g. ASC/ RTMC);
- Other site data issues – Site Data Designer; and
- Operator processes and behaviours – RCC.

In the Commissioning period the Scheme may possibly be responsible for measures relating to the first three categories.

The Calibration or Optimisation Engineer should identify the key parties who they shall be required to work with to implement optimisation measures. Any recommendations should:

- Be made with ample time to review and implement;
- Consider site data load schedules and similar dependencies; and
- Provide explanation and justification.

Every optimisation measure that is recommended should be recorded in the Optimisation Log both at the time of recommendation and at the time of implementation.

C.4 CALCULATING INITIAL FLOW THRESHOLDS

Uniquely amongst the available changeable elements, flow thresholds shall always require site specific calculation for a new scheme to enable good system performance. The *Threshold Calculation Tool* within the *CALO Toolkit* is provided specifically for this purpose.

Each vehicle detector site assigned within site data for generating CM alerts has a set of default thresholds which shall be changed for each site. These values were applied originally for the M25 J10-16 CM scheme and shall not be suitable for other schemes.

Flow thresholds are variable within and between schemes and system performance is greatly influenced by the suitability of these.

The categories of flow thresholds that shall be required for a particular section within an SM scheme shall depend on the operational status of that section. Table 12 defines which thresholds shall be required for each category of section.

Table 12: Required thresholds for each category or section

CM	DHS	ALR	Thresholds required
No	No	No	None
Yes	No	No	Standard flow
Yes	Yes	No	Standard flow, LFS and DHS flow
Yes	No	Yes	Standard flow (but see below)

For DHS sections, Standard thresholds should be calculated first, then the LFS and DHS thresholds should be derived from the Standard values.

For ALR sections, this same calculation is automatically applied to thresholds created using the historical data in order to form the standard thresholds. If an ALR scheme is to be enabled as 3-lane running with the hard shoulder coned off, before being converted to 4-lane running, these 3-lane thresholds calculated from the historical data should be used.

Flow thresholds are referred to in site data in relation to the flow band (FB) which they define. Standard flow thresholds are associated with FB2 and FB3, and DHS flow thresholds with FB4 and FB5. Rising and falling thresholds are assigned for each flow band. For a description of how the SM system uses these thresholds see the overview of the CM algorithm provided in Annex K.

Flow thresholds are calculated during the commissioning period using a three stage process:

- Traffic data analysis – involving the identification of recurrent congestion seedpoints (i.e. locations that are known to be susceptible to flow breakdown) and then the speed and flow conditions at the point of flow breakdown and recovery, to determine initial thresholds.
- System simulation – used to predict system output, prior to implementation of operational regimes on the scheme, based on historic traffic data and the initial calculated thresholds.
- Combined analysis - of traffic data and simulated output data, allowing analysts to judge whether the output is appropriate to the input.

Flow thresholds are limited in that each of the threshold values used at a vehicle detector site shall be a whole number and cannot vary depending on the time of day or any other external factor. Because of this, calculating flow thresholds often involves finding a balance between the positive and negative impact of the resulting information to drivers. This is addressed in the specific guidance for each type of flow threshold in the following sub-sections.

C.4.1 Collecting traffic data

C.4.1.1 Historic traffic data

CM flow thresholds are changed through the site data design process. Initial thresholds should be included in the site data load which enables CM settings on the SM scheme. This may involve delivering initial Standard and DHS thresholds (COM2 and COM5) to the Site Data Designer several weeks prior to that date and probably prior to the activation of vehicle detectors on the scheme. For this reason, initial thresholds are likely to be calculated using historic traffic data from before the commencement of works for the SM scheme. These timescales should be considered in producing the Optimisation Plan (COM1) and discussed with relevant stakeholders such as the Site Data Designer and Scheme’s Commissioning Manager.

Flow thresholds are assessed using combined analysis of traffic data and simulated output data. Therefore, confidence in the analysis increases with the following properties of the data sample:

- The size of the sample, i.e. the number of days for which data is available;
- The granularity of the data, both spatially and temporally; and
- The currency of the sample, i.e. how up-to-date the sample is.

C.4.1.2 Accessing historic MIDAS data

In most cases MIDAS vehicle detector data shall be available for new schemes, as MIDAS is installed on a significant proportion of the strategic road network, particularly at congested areas. The *CALO Toolkit* automatically accesses MIDAS data for the previous 3 years. Data required outside that period can be utilised for a particular scheme as long as it is uploaded in the format specified in Annex E.

Note that many of the vehicle detectors installed on the strategic road network may not provide useful data. Although used operationally, many sites have been disabled for traffic counting. Furthermore, vehicle detector faults may mean portions of MIDAS data may have to be discounted. Therefore, at many locations only two or three sites shall be enabled and usable per link. This shall provide sufficient traffic flow data but is unlikely to be enough to enable seedpoint identification. In these cases, vehicle detectors should be temporarily enabled before works commence in order to collect the required traffic data.

If sufficient MIDAS data are available for the scheme (or part of the scheme) then the Scheme Set-Up tool in the *CALO Toolkit* shall assist the selection of an appropriate data set. Historic MIDAS data can also be downloaded at www.midas-data.org.uk once a username and password have been issued.

C.4.1.3 Alternative data sources

In cases where the available MIDAS data are insufficient, alternative data sources can be considered. Data is to be sufficient to enable:

- The identification of recurrent congestion seedpoints;
- The identification of traffic flow levels at the seedpoint location before, after and during the duration of the seedpoint; and
- The measurement of traffic flow levels on all (or most) of the sections within the scheme.

Congestion seedpoints are usually identified through the use of traffic speed data at a range of locations. Observing congested speeds at one particular location in a section is not usually enough in itself to determine the characteristics of a seedpoint.

Other than MIDAS, there are several other technologies applied on the SRN which could conceivably be used to identify seedpoints and/or traffic flows. It is the responsibility of the Calibration or Optimisation Engineer to ensure this data is recorded and provided to the CCSS in the specified format. The CCSS assigned to the scheme can provide advice on how alternative data sets can be sourced.

Alternative data sources have various levels of availability, cost and technical specification associated with them. Examples include GNSS (GPS) data, vehicle detectors installed by the National Traffic Information Service, HIOCC alerts and temporary radar devices.

C.4.2 Initial Standard Flow Thresholds

C.4.2.1 Purpose

As described in Annex F.1, a vehicle detector site's flow thresholds are used in conjunction with its speed thresholds to generate congestion alerts. The primary purpose of these alerts is to have 50mph speed limits set at a seedpoint section before the onset of the flow breakdown and remain on until flow has dropped below the flow level at which flow breakdown would no longer be expected to occur.

The alerts generated should also result in 60mph settings being displayed for a short period before and after the 50mph settings and preceding the first location at which the 50mph speed limit is displayed.

C.4.2.2 Traffic data analysis

In order to select thresholds that shall best achieve the purpose described above, it is first necessary to identify where recurrent congestion seedpoints have been observed on the stretch of motorway on which the SM scheme shall be installed.

The scheme is likely to have one or more recurrent congestion seedpoints as SM is generally installed in congested areas. However, it is possible that no seedpoints have yet been observed and that the scheme is being implemented to counter congestion caused by a predicted rise in traffic flows.

The identification of seedpoints requires assessment of the traffic data visualisation by the Calibration or Optimisation Engineer. Each day being investigated should be viewed individually and its characteristics noted

The *Threshold Calculation Tool* enables this analysis to be carried out efficiently and accurately (see Annex D.3).

Following this process, sections of the SM scheme can be assigned as either having or not having an observed congestion seedpoint. The process for calculating initial Standard thresholds depends on whether or not the section has an observed seedpoint.

C.4.2.3 Sections without an observed seedpoint

If no seedpoint is found to occur on a given section then it can be assumed that, based on the available data, the capacity of the section has not yet been reached. Therefore CM signals shall not yet be required. However, traffic flow levels may rise (and they may have risen since the analysed data was recorded) and so there is still a need to set thresholds so that the system is able to respond appropriately if traffic levels rise.

For sections with no observed seedpoint the *Threshold Calculation Tool* shall assign 'first pass' thresholds that are greater than the maximum observed flow and therefore would not result in any signals being set in the analysis period, i.e. signal simulation shall present no signals generated by vehicle detector sites in these sections. These 'first pass' thresholds are based on the thresholds assigned to adjoining sections and those assigned within previous schemes, as well as the observed flow.

As with all initial thresholds presented by the *Threshold Calculation Tool*, these automatically generated thresholds shall not be accepted by the Calibration or Optimisation Engineer without visual assessment of a sample of plots.

C.4.2.4 Sections with an observed seedpoint

As stated above, the primary purpose of Standard thresholds is to have 50mph speed limits set at a seedpoint section before the onset of the flow breakdown and remain on until flow has dropped below the flow level at which flow breakdown would no longer be expected to occur. Accompanying these, 60mph speed limits would ideally be set for a short period before and after the 50mph settings.

Figure 5 presents an example of where Standard thresholds would ideally be set in relation to observed traffic flow during a peak period.

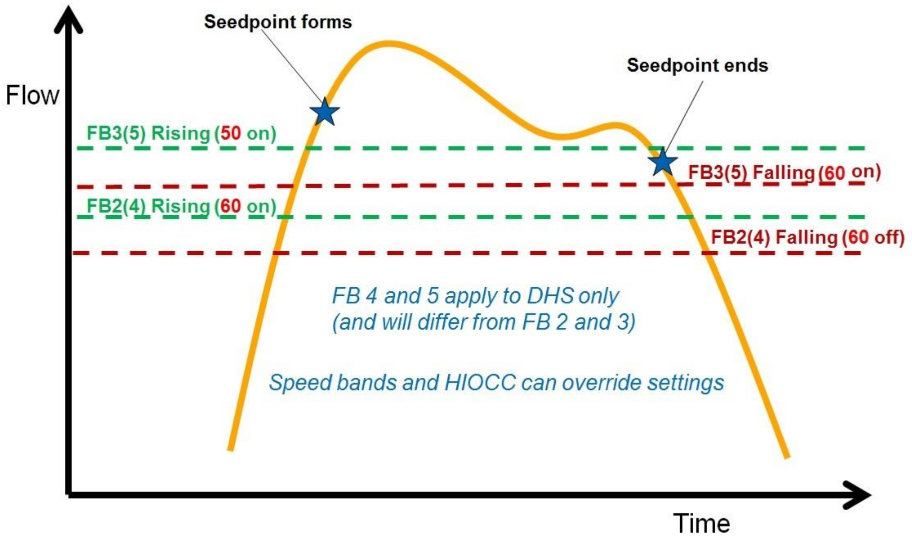


Figure 5: Standard (DHS) Flow Thresholds set in response to a congestion seedpoint

As shown in Figure 5, ideally FB3(5) thresholds would be set either side of the congestion seedpoint and the FB2(4) at lower values relative to those. Therefore, if a section has been identified as containing a recurrent congestion seedpoint then selecting initial flow thresholds depends on knowing the flow values at which flow breakdown occurs.

In doing so there are two important facts that should be considered:

- The flow value at which the seedpoint occurs shall vary from day-to-day; and
- Flow values at which the seedpoint has been observed to occur may be reached on some days (or at a different time in the same day) without the seedpoint forming.

Therefore, selecting appropriate thresholds is about finding the balance between the positive and negative effects of the signal output. For example, selecting FB3(5) thresholds based on the lowest flow value at which the seedpoint is found to occur shall ensure that 50mph speed limits shall be set before the onset of all seedpoints in the sample. However, this may also mean that 50mph signals shall set on some days for much longer periods than necessary or set at times when they are not required at all.

In terms of the performance elements defined in Annex C.2.1, this means the balance between setting speed limits at the right time to address the congestion seedpoint, and not setting speed limits at times and locations at which they fulfil no safety improvement or congestion reduction purpose.

The *CALO Toolkit* supports this analysis.

As described earlier, the *Threshold Calculation Tool* enables the user to efficiently and accurately identify and record congestion seedpoints. Using this analysis the tool then automatically records the flow conditions under which each occurrence is observed, which is recorded and displayed.

The *Threshold Calculation Tool* automatically simulates signal output and calculates the combined performance measure for a range of possible threshold values. It shall then select the values with the highest performance score as ‘first pass’ thresholds.

Based on these thresholds the Tool simulates signal output for the whole data sample and displays them on space-time plots. These should then be assessed by the Calibration or Optimisation Engineer, taking into account the particulars of the scheme and any operational preferences of road users and stakeholders.

C.4.3 Initial Link Flow State Thresholds

C.4.3.1 Purpose

LFS thresholds should generate alerts to the RCC which shall result in the hard shoulder being opened before the onset of flow breakdown and closed after the flows have fallen lower than the flows at which flow breakdown would be expected to occur.

C.4.3.2 Setting LFS thresholds

The ideal hard shoulder opening time on an SM link is just prior to the time when flow breakdown would be expected to occur at a congestion seedpoint. Therefore, the timing at which the hard shoulder should be opened is the same as the timing at which the 50mph CM settings should be set. In a sense, for the sections with DHS, the 50mph should be considered as a ‘fall back’ option for situations when the hard shoulder cannot be opened. Because the ideal conditions for which the 50mph should be set are known through the Standard threshold calculation process then the FB3 flow thresholds should act as a guide for selecting LFS thresholds.

No additional analysis of traffic data is required, but consideration should be given the length of time that the RCC shall take to safely open the hard shoulder on the section once prompted to begin the process by the LFS indicator, i.e. if the intention is to have the hard shoulder opened at the same flows as 50mph CM signals would be set at, the LFS Rising threshold should be set at a flow value less than the FB3 threshold by an amount representative of the time taken by operators to complete the hard shoulder opening process.

Consideration should also be given to the LFS thresholds in relation to the FB2 (60mph) thresholds. While there may be a degree of confidence that reaching the FB3 threshold shall usually be followed by a period of flow breakdown, the same degree of confidence may not be assigned to the FB2 threshold. If either of the LFS thresholds is lower than the relevant FB2 thresholds, then there is an increased risk of generating LFS alerts at times when DHS is not required.

The *Threshold Calculation Tool* shall automatically calculate LFS thresholds for every section assigned with DHS. These shall be based on the first pass Standard flow thresholds and a time assumed to allow an RCC to carry out the hard shoulder opening and closing thresholds.

As with the Standard thresholds suggested by the tool, the suggested LFS thresholds can be manually amended by the Calibration or Optimisation Engineer before inclusion in COM5. The assumed time required to carry out the hard shoulder opening and closing processes may differ between schemes and RCCs. Engagement with the relevant RCC is recommended to assess their needs for LFS thresholds.

C.4.3.3 Sections with hard shoulder permanently converted (ALR)

Sections with on which the hard shoulder is being permanently converted into an additional running lane, require only Standard flow thresholds which take into account the additional lane. If an ALR scheme is to be enabled as 3-lane running with the hard shoulder coned off, before being converted to 4-lane running, the 3-lane thresholds calculated from the historical data should be used initially before 4-lane thresholds are enabled.

The *Threshold Calculation Tool* shall present initial ALR thresholds by calculating Standard thresholds for the section and estimating the proportion of traffic expected to utilise the new lane under heavy traffic conditions. This shall be dependent on whether or not hard shoulder running (DHS or ALR) is also implemented in the downstream junction (i.e. through junction running) and the proportion of traffic expected to use the downstream diverge.

Calculating appropriate thresholds for permanent ALR sections depends on the analysis of congestion seedpoints that occur on the section after the hard shoulder has been converted. For this reason initial ALR thresholds cannot be calculated using historic traffic data (i.e. before the hard shoulder is converted) with the same level of confidence as Standard thresholds for a carriageway already in full use. It is important therefore that the initial thresholds are reassessed once ALR running has been operational for a period.

C.4.4 Initial DHS Flow Thresholds

C.4.4.1 Purpose

DHS Flow Thresholds are used for generating CM alerts when the hard shoulder is open as a running lane, either permanently or dynamically.

These are for inclusion in COM5 for DHS.

Vehicle detector sites in DHS sections shall require both Standard and DHS flow thresholds. When the hard shoulder is closed the system shall use the Standard thresholds for generating CM alerts. When the hard shoulder is open as a running lane the system shall use the DHS thresholds.

The purpose of the DHS thresholds is to generate appropriate CM settings when DHS is in operation. Therefore, calculating appropriate DHS thresholds depends on analysis of congestion seedpoints that occur on the section when the hard shoulder is open.

For this reason initial DHS thresholds cannot be calculated using historic traffic data (i.e. before DHS is implemented) with the same level of confidence as Standard thresholds. It is important therefore that the initial DHS thresholds are reassessed once DHS has been operational for a period.

Until that reassessment can be carried out using DHS traffic data, initial DHS thresholds should be calculated using the data available. The *Threshold Calculation Tool* shall present initial DHS thresholds based on the Standard thresholds selected and the proportion of traffic expected to utilise the hard shoulder under heavy traffic conditions. This shall be dependent on whether or not DHS is also implemented in the downstream junction (i.e. through junction running) and the proportion of traffic expected to use the downstream merge.

As with the Standard thresholds suggested by the tool, the suggested DHS thresholds can be amended by the Calibration or Optimisation Engineer before inclusion in DHS thresholds submitted to the Site Data Designer (COM5).

C.4.5 Motorway-to-Motorway Intersections and Ramp Metering

Where optimisation is to be done in the vicinity of a motorway-to-motorway (M2M) intersection, where there shall be substantial slip road flows, pointers might need to be set up in the site data from the main carriageway to slip roads.

Ramp Metering (RM) may be introduced on some sections, but it is not thought that this would have a significant effect on optimisation.

C.5 MONITORING PERFORMANCE

Performance monitoring is necessary to generate System Monitoring Reports (COM4 and COM6), Annual System Performance Reviews (OPC1) and System Monitoring Notes (OPR1).

The performance monitoring of an SM system is the regular application of the approach described in Annex C.2. The *System Monitoring Tool* within the *CALO Toolkit* takes live MIDAS vehicle detector and signal data for the required assessment of performance, and shall be used to support this process (Annex D.5). The user shall be able to select the period for which they want to observe and the tool shall return plots for the range of days selected.

COM4 and COM6 products shall be generated based on the performance of the system in the first few weeks of CM/ALR and DHS operation respectively. For generating these products it is recommended that monitoring take place on a daily basis, e.g. every morning of the period analysing the plot visualising the previous day's data.

System Monitoring Notes shall be generated by the CCSS team as and when sub-optimal performance is observed. They shall have access to the same visualisation via the *System Monitoring Tool*. They shall be responsible for regularly assessing each of the active SM schemes. The frequency with which this assessment shall take place for a particular scheme shall depend on resource availability, but is likely to be on a monthly basis.

The *System Monitoring Tool* shall aid the monitoring process by automatically calculating performance scores for the performance measures described in Annex C.2.1. These shall be presented for all days and for the overall sample period selected.

For a step-by-step guide in using the System Monitoring Tool see Annex D.5.

C.6 RESPONDING TO SYSTEM MONITORING NOTES

Once an SM scheme is in operation, the Optimisation Engineer shall be responsible for continually monitoring the performance of the system (Annex C.5) and having optimisation measures implemented where necessary (Annex C.3). To ensure this function is carried out as effectively as possible, the CCSS shall carry out regular checks of the performance of systems and issue System Monitoring Notes to the Optimisation Engineer if sub-optimal performance is observed.

System Monitoring Notes shall contain the information specified in Annex C.6.

They shall identify sub-optimal performance of the SM system, providing the time, location, nature and severity of sub-optimal performance. The System Monitoring Note shall also present a timescale within which a response is required.

The System Monitoring Note shall not identify the required optimisation measure(s).

There are two appropriate responses to a System Monitoring Note:

- Identify the optimisation measure(s) that shall be taken to improve performance in the relevant area following the calibration process and producing the COM products as detailed in Section 4.
- Explanation as to why the sub-optimal performance cannot be improved, either because of negative side-effects of making the required optimisation measure or because of the limitations of the system.

END OF Annex C

ANNEX D THE CALO TOOLKIT

D.1 OVERVIEW OF THE CALO TOOLKIT

The *CALO Toolkit* is a web-based analysis tool that has been developed to support the generation of the products specified in this document. It consists of three component tools as shown in Figure 6.

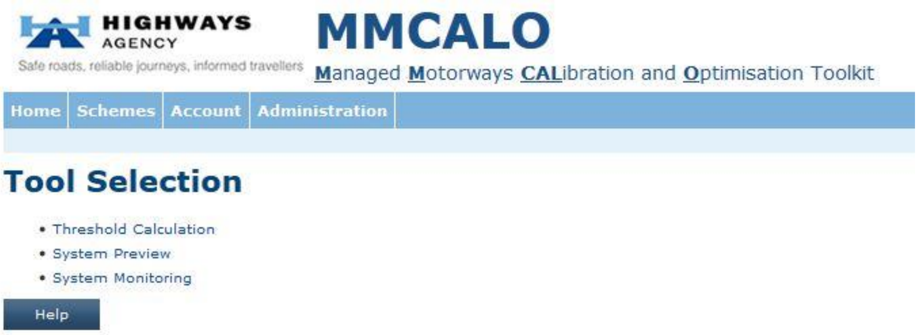


Figure 6: The components of the CALO Toolkit

The following sub-sections provide an overview and step-by-step user process for each of the tools, i.e. the Calibration or Optimisation Engineer. It also provides guidance for the administrative and set-up functions of the toolkit, which shall be carried out by the CCSS team.

A Toolkit Help document can be downloaded via the toolkit website for further guidance.

D.2 LOG-IN AND SET-UP

D.2.1 Overview

Before the *CALO Toolkit* can be used to help optimise an SM scheme, user access shall be established and the site configured to allow the analysis of the particular scheme.

The CCSS team shall be responsible for carrying out the required set-up tasks. Other administrative functions are described in Annex D.6.

All the information required for this to be done shall be provided in the Optimisation Plan.

Users can only be granted a username and password once they have completed the training course.

D.2.2 Prerequisites

D.2.2.1 Beginning calibration of a new SM scheme

The following process describes the steps to be taken for an SM scheme in, or about to enter, the Commissioning Stage from when the Optimisation Plan is signed off by the Scheme Representative to the point when the Calibration Engineer is able to begin using the *Threshold Calculation Tool*:

- The Optimisation Plan shall identify the data set to be used in the calculation of initial Standard thresholds. This data should then be ‘delivered’ to the Administrator. If historic MIDAS data is to be used then identifying the range of dates which shall be analysed shall suffice. For other data sources it shall be necessary to send the data to the CCSS team in the format specified in Annex E.
- Once the data has been successfully delivered, the Administrator shall provide the Calibration Engineer with an estimated date from which they can begin using the toolkit.
- The Administrator shall then follow the process described in Annex D.2.3.
- Once completed, an email shall be sent to the Calibration Engineer informing that they are now able to use the *CALO Toolkit* to calculate initial thresholds for their particular scheme.

- Following the hyperlink provided in the email shall take the user to the website **Log On** page (Figure 7), in which the user shall be able to enter their details.
- This page shall also provide users with a link to follow if any of their user details have been forgotten.
- Successful completion of the **Log On** page shall take the user to the **Scheme Selection** page. The user shall then be presented with a list of available schemes from which they can select the scheme they wish to analyse.
- The user shall be taken to the **Tool Selection** page where they shall be able to select one of the three component tools of the toolkit.

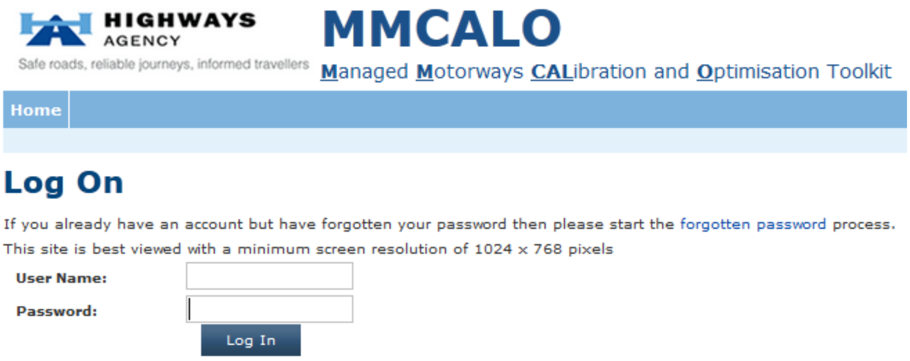


Figure 7: Screenshot of the Log On page

D.2.2.2 Beginning optimisation of an existing SM scheme

If the SM scheme is already in operation but not yet included within the *CALO Toolkit*, the following process should be followed:

- The user should access the *CALO Toolkit* **Log On** page at www.mmcalo.org.
- If not a registered user, **Home** then **Register** should be selected and the application process followed, though access shall only be granted to those who have completed the training course.
- Once user details have been provided the user shall be able to access the site.
- Successful completion of the **Log On** page shall take the user to the **Scheme Selection** page. The user shall then be presented with a list of available schemes from which they can select the scheme they wish to analyse.
- The user shall be taken to the **Tool Selection** page at which they shall be able to select one of the three component tools of the toolkit.

D.2.3 Processes

D.2.3.1 Setting up a scheme

Upon receiving an email providing notification of a new SM scheme to be included within the *CALO Toolkit*, the Administrator (CCSS user) should follow the process below:

Scheme characteristics

- The administrator can create a **New Scheme**, by selecting the **Scheme** page, then selecting **Create New Scheme** at the bottom of the table.
- The user shall then be prompted to provide the following information (Figure 8):
    - The title by which the scheme is referred (e.g. M25 Section 1 J16 - J23 Live Scheme [User]);
    - The motorway on which the scheme is situated; and

- The boundaries (to the nearest marker post) of the scheme for either carriageway.

- The user shall select the **Save** and **Next** buttons and be taken to the **Data Selection** page.

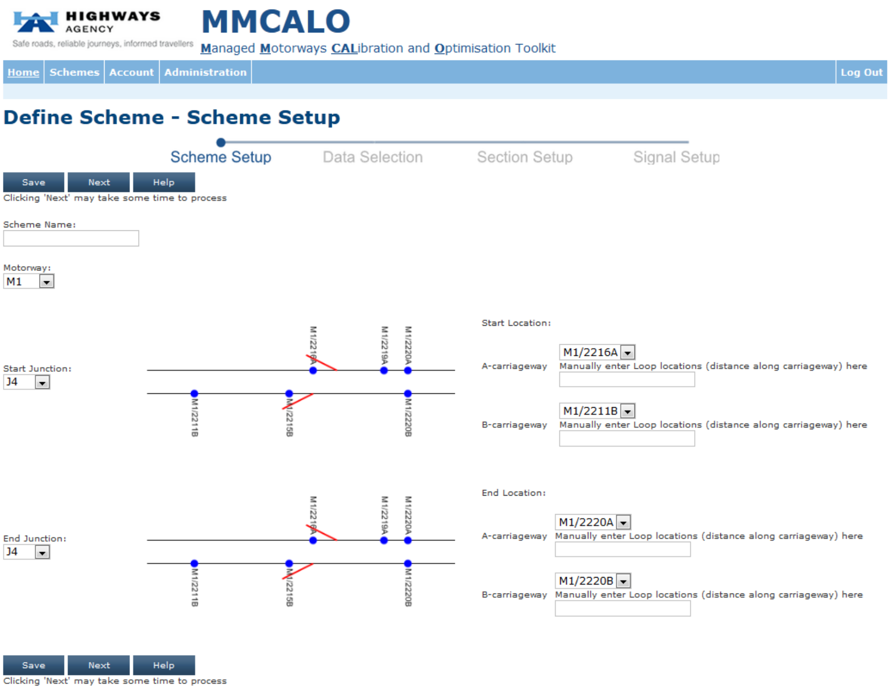


Figure 8: Screenshot of the Scheme Set-Up page

Traffic data

- Upon completion of this page the user shall be directed to the **Data Selection** page, where they shall be able to view the data availability for each month in the past year and select the months to be used for analysis.
- The user shall select the months that they want to analyse then select the **NEXT** button.
- The Optimisation Plan shall define the sample of historic traffic data to be used in the calculation of initial thresholds.
- If the data defined are historic MIDAS data (from the previous 3 years) then the data shall be available to the toolkit automatically.
- If the data defined is from another source then the user should follow the link to the process described in section Annex D.6.1.2.

The Section Setup

- This page identifies the boundaries for the sections within the scheme. These shall have been defined within the Optimisation Plan to the nearest marker post.
- For each section the user shall then assign its planned SM status, i.e.:
  - The number of lanes the section shall have when the system is implemented; and
  - Whether or not the section shall have Dynamic use of the Hard Shoulder.
- The Optimisation Plan shall also include a Detector Enablement Strategy which shall indicate if any sections should be initially excluded from generating CM alerts.

Signals for simulation

- Upon completion of this page the user shall be directed to the **Signals Set-Up** page.
- The Optimisation Plan shall also identify which of the following approaches shall be used to aid the initial threshold calculation process:
  - An uninstalled draft site data (Microsoft Access database);
  - Locations of signals (pointers to be generated in scheme set-up); and
  - None of the above (signals shall be assumed to be located at regular intervals and pointers assigned).
- These shall be used to assign gantry locations for the simulation of signals
- If the future location of signals is provided through an uninstalled draft site data or some other means (e.g. scheme drawings) then the **Manually Add Signals** option shall be selected.
- The user shall then input the location of gantries (in terms of geographic addresses) for which the tool shall automatically assign detector-to-signal pointers.
- If no information is provided in the Optimisation Plan about the future location of signals then either of the following two options to locate signals at regular intervals shall be selected: either **1 Signal per 800m** or **1 Signal Per 1500m**. The tool shall then automatically locate signals at regular intervals throughout the scheme and assign detector-to-signal pointers.
- Then select the **OK** button.

Motorway-to-Motorway Intersections and Ramp Metering

- Where optimisation is to be done in the vicinity of a motorway-to-motorway intersection, where there shall be substantial slip road flows, pointers need to be set up in the site data from the main carriageway to slip roads.
- Ramp Metering (RM) may be introduced on some sections, but it is not thought that this would have a significant effect on optimisation.

D.3 THRESHOLD CALCULATION TOOL

D.3.1 Overview

The Threshold Calculation Tool is to aid the generation of initial Standard flow thresholds (COM2) and DHS flow thresholds (COM5). It does this by supporting the initial threshold calculation process described in Annex C.4.2.

The *Threshold Calculation Tool*:

- Provides visualisation for the selection and analysis of congestion seedpoints;
- Simulates signal output; and
- Visualisation of signal output allows for combined analysis to be conducted.

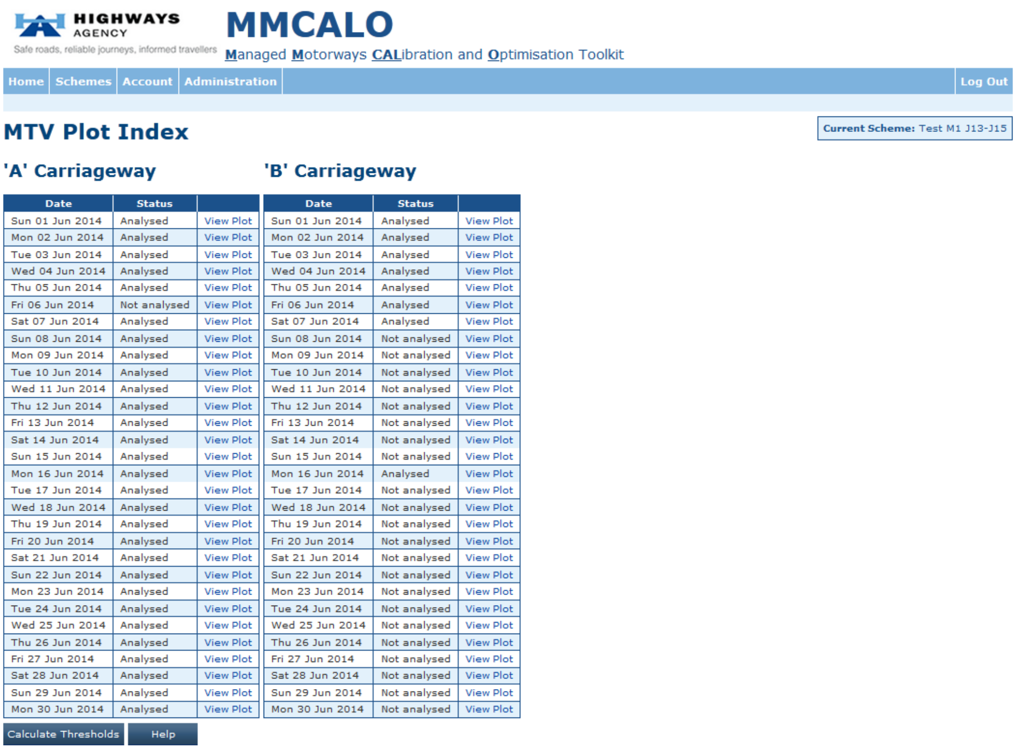
D.3.2 Process

Once a new user (or an existing user with a new scheme) has followed the process described in Annex D.2.2.1 they shall be able to use the *Threshold Calculation Tool*. The following process describes how this tool can be used to support the calculation of initial thresholds:

Seedpoint analysis

- The user shall select their scheme from the **Scheme List** prior to seedpoint analysis.
- The user shall select *Threshold Calculation Tool* on the **Tool Selection** page and be taken to a **MTV Plot Index** page (Figure 9) listing all of the days, for each carriageway, which are to be used in the calculation of initial thresholds.
- Next to each day shall be an indication of whether or not the day has been analysed for congestion seedpoint.

- A space-time plot visualisation for a particular day can be viewed by selecting the relevant **View Plot** link from the list.
- The user shall then visually identify recurrent congestion on the plot presented (Figure **10**). If a recurrent congestion seedpoint is observed on the plot, then the user shall select the start and end times and location of the seedpoint by clicking on the relevant points of the plot.
- The tool shall log this information and display the seedpoint in a table on the same page.
- This table shall be populated with as many seedpoints are identified on the plot.
- The user shall be able to remove entries from this table if entered incorrectly.
- Once seedpoints have been selected on a particular day then the **Mark Day As Analysed, Next** button should be selected. This should also be selected if no recurrent seedpoints were found to occur on that particular day as the traffic data shall still be used in the calculation of first pass thresholds.
- The user shall have the option of excluding a day from analysis by selecting the **Exclude Day** button at the top of the page. This should only be selected if there is insufficient data to make an assessment of that particular day or if a significant incident or road closure is evident.
- The user can either move from plot-to-plot by using the **Previous Day** and **Next Day** links or by selecting plots on the **MTV Plot Index** page. The user can combine marking a day as analysed with moving to the next plot by clicking the **Mark Day As Analysed, Next** button.
- If the user logs out and logs back in again the status of the plots shall be stored.
- Once every plot in the sample has been selected as either analysed or excluded, the user shall select the **Calculate Thresholds** button on the **Plot Index** page.



'A' Carriageway

Date	Status	
Sun 01 Jun 2014	Analysed	View Plot
Mon 02 Jun 2014	Analysed	View Plot
Tue 03 Jun 2014	Analysed	View Plot
Wed 04 Jun 2014	Analysed	View Plot
Thu 05 Jun 2014	Analysed	View Plot
Fri 06 Jun 2014	Not analysed	View Plot
Sat 07 Jun 2014	Analysed	View Plot
Sun 08 Jun 2014	Analysed	View Plot
Mon 09 Jun 2014	Analysed	View Plot
Tue 10 Jun 2014	Analysed	View Plot
Wed 11 Jun 2014	Analysed	View Plot
Thu 12 Jun 2014	Analysed	View Plot
Fri 13 Jun 2014	Analysed	View Plot
Sat 14 Jun 2014	Analysed	View Plot
Sun 15 Jun 2014	Analysed	View Plot
Mon 16 Jun 2014	Analysed	View Plot
Tue 17 Jun 2014	Analysed	View Plot
Wed 18 Jun 2014	Analysed	View Plot
Thu 19 Jun 2014	Analysed	View Plot
Fri 20 Jun 2014	Analysed	View Plot
Sat 21 Jun 2014	Analysed	View Plot
Sun 22 Jun 2014	Analysed	View Plot
Mon 23 Jun 2014	Analysed	View Plot
Tue 24 Jun 2014	Analysed	View Plot
Wed 25 Jun 2014	Analysed	View Plot
Thu 26 Jun 2014	Analysed	View Plot
Fri 27 Jun 2014	Analysed	View Plot
Sat 28 Jun 2014	Analysed	View Plot
Sun 29 Jun 2014	Analysed	View Plot
Mon 30 Jun 2014	Analysed	View Plot

'B' Carriageway

Date	Status	
Sun 01 Jun 2014	Analysed	View Plot
Mon 02 Jun 2014	Analysed	View Plot
Tue 03 Jun 2014	Analysed	View Plot
Wed 04 Jun 2014	Analysed	View Plot
Thu 05 Jun 2014	Analysed	View Plot
Fri 06 Jun 2014	Analysed	View Plot
Sat 07 Jun 2014	Analysed	View Plot
Sun 08 Jun 2014	Not analysed	View Plot
Mon 09 Jun 2014	Not analysed	View Plot
Tue 10 Jun 2014	Not analysed	View Plot
Wed 11 Jun 2014	Not analysed	View Plot
Thu 12 Jun 2014	Not analysed	View Plot
Fri 13 Jun 2014	Not analysed	View Plot
Sat 14 Jun 2014	Not analysed	View Plot
Sun 15 Jun 2014	Not analysed	View Plot
Mon 16 Jun 2014	Analysed	View Plot
Tue 17 Jun 2014	Not analysed	View Plot
Wed 18 Jun 2014	Not analysed	View Plot
Thu 19 Jun 2014	Not analysed	View Plot
Fri 20 Jun 2014	Not analysed	View Plot
Sat 21 Jun 2014	Not analysed	View Plot
Sun 22 Jun 2014	Not analysed	View Plot
Mon 23 Jun 2014	Not analysed	View Plot
Tue 24 Jun 2014	Not analysed	View Plot
Wed 25 Jun 2014	Not analysed	View Plot
Thu 26 Jun 2014	Not analysed	View Plot
Fri 27 Jun 2014	Not analysed	View Plot
Sat 28 Jun 2014	Not analysed	View Plot
Sun 29 Jun 2014	Not analysed	View Plot
Mon 30 Jun 2014	Not analysed	View Plot

Figure 9: Screenshot of the MTV Plot Index page

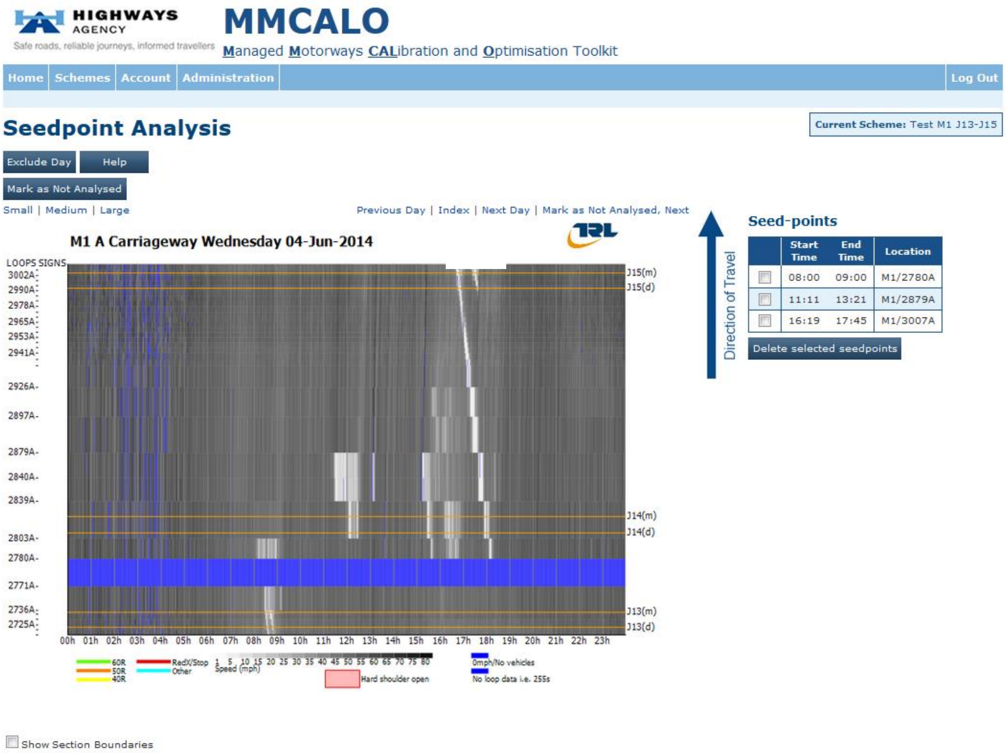


Figure 10: Screenshot of a Seedpoint Analysis page

Threshold calculation and simulation

- The tool shall then present a message to the user informing them that the threshold calculation and signal simulation is now in progress. It shall inform the user that an email shall be sent to them informing them of completion.
- The tool shall carry out the calculation of ‘first pass’ initial thresholds and simulate system output as if those thresholds had been implemented on the data sample.
- The user shall be emailed when this task has been completed.
- From that point on, the user shall be able to log back into the system and view the results of the simulation by selecting the scheme, then **Threshold Calculation Tool**.
- They shall then be taken to a **MTV Plot Index** page listing all of the days, for each carriageway, from the date entered up to and including the previous day.
- A space-time plot visualisation for a particular day with simulated signal and LFS data overlaid can be viewed by selecting the day from the list.
- The user can either move from plot-to-plot by using previous and next buttons or by selecting plots on the **MTV Plot Index** page.
- There is a **Show section boundaries** button to show boundaries on the plot.
- Plots can be extracted as Portable Network Graphic (.png) files
- Vehicle detector sites can be removed from generating output in future simulations by selecting the site from the drop down list at the bottom of the page then selecting the **Disable** button. Once the thresholds have been calculated and an email has been sent to the calibration engineer confirming this the MTV Plot Index shows additional functions:
    - View Report
    - Alter Thresholds

  - Run Simulation
- A comments box is also available for the calibration engineer to make notes.
- The user shall be able to select the **View Report** button. This shall present to the user a **Thresholds** table and a **Link Flow State** table showing the 'first pass' thresholds calculated by the tool, a list of **Disabled Vehicle detectors**, and a summary table of **Performance Scores**.
- For each of the elements in the **Performance Scores** table the user shall be able to select a **Download Details** link. This shall allow the user to download a .csv file with a detailed performance data for further analysis if required.
- Accessible from both the **MTV Plot Index** page and the individual MTV Plot pages shall be the **Alter Thresholds** page. This shall allow the user to change any of the thresholds previously calculated. Selecting the **Run Simulation** button shall then re-simulate the system output and recalculate performance measures.
- The MTV plots also have additional features once the simulation has been run. This includes a View Flow Profiles button where a loop site can be selected and a graph shall appear displaying the flow profile of that selected loop.

D.4 SYSTEM PREVIEW TOOL

D.4.1 Overview

The *System Preview Tool* provides a visualisation of system performance allowing combined analysis of traffic data from newly installed vehicle detectors and simulated signal output. This shall utilise the to-be-installed site data database and allow the user to validate the thresholds and identify any other optimisation measures relating to the site data or, potentially, equipment faults. This can be used for the production of System Performance Preview Reports (COM3).

Once data begin to be recorded by the vehicle detector sites installed as part of the SM scheme, the *System Preview Tool* takes the data and simulates the system output that would have been generated if CM had been enabled and LFS alerts were being generated. The *System Monitoring Tool* shall display traffic speed data and simulated output in a space-time plot.

D.4.2 Process

The process below describes how the user would access the visualisation provided by the *System Preview Tool*:

- The user shall select the *System Preview Tool* in the **Tool Selection** page and be taken to a page asking them to enter the date they would like to start the *System Preview Tool* from, i.e. the date on which data from newly installed vehicle detectors first became available.
- Entering a valid date then selecting the **OK** button shall take the user to a **Plot Index** page listing all of the days, for each carriageway, from the date entered up to and including the previous day.
- A space-time plot visualisation for a particular day with simulated signal and LFS data overlaid can be viewed by selecting the day from the list.
- The user can either move from plot-to-plot by using previous and next buttons or by selecting plots on the **Plot Index** page.
- Plots can be extracted as Portable Network Graphic (.png) files
- Comments related to the plot can be made in the **Notes** box.
- Seedpoints can be selected in the same way as in the *Threshold Calculation Tool* process (Annex D.3.2). This shall enable the tool to recalculate performance scores with the additional data.
- Performance scores and notes can be viewed by selecting the **View Report** button on the **MTV Plot Index** page.

- The user shall also be able to enter *Threshold Calculation Tool* using the current site data as a starting point to see the effect changes to site data are likely to have.

D.5 SYSTEM MONITORING TOOL

D.5.1 Overview

The *System Monitoring Tool* provides space-time plot visualisation of system performance allowing combined analysis of traffic data from newly installed vehicle detectors and actual signal output. This shall take live data feeds for both sources.

This can be used to support the production of COM4, COM6 and OPR1.

Once the site data load enabling the operation of CM on the scheme has been implemented then actual signal settings shall be generated by the system and recorded in HALOGEN. From that point on the *System Monitoring Tool* shall display data feeds for both vehicle detector and signal data and visualise both live and historic data through space-time plots.

D.5.2 Process

The process below describes how the user would access the visualisation provided by the *System Monitoring Tool*:

- The user shall select the *System Monitoring Tool* in the **Tool Selection** page and be taken to a page asking them to enter the start and end dates for the period they would like to start the analyse.
- Entering valid dates then selecting the **OK** button shall take the user to a **MTV Plot Index** page listing all of the days, for each carriageway, from the date entered up to and including the previous day.
- A space-time plot visualisation for a particular day with simulated signal and LFS data overlaid can be viewed by selecting the day from the list.
- The user can either move from plot-to-plot by using previous and next buttons or by selecting plots on the **MTV Plot Index** page.
- Plots can be extracted as Portable Network Graphic (.png) files
- Comments related to the plot can be made in the **Notes** box.
- Seedpoints can be selected in the same way as in the *Threshold Calculation Tool* process (Annex D.3.2). This shall enable the tool to recalculate performance scores with the additional data.
- Performance scores and notes can be viewed by selecting the **View Report** button on the **MTV Plot Index** page.
- The user shall also be able to enter *Threshold Calculation Tool* using the current site data as a starting point to see the effect changes to site data are likely to have.

D.6 TOOLKIT ADMINISTRATION

D.6.1 Administrator options

D.6.1.1 Add site data

It is the responsibility of the Administrator to ensure that the correct site data are being used by the toolkit. Awareness of site data loads shall be maintained through access to the Site Data Centre website (www.sitedatacentre.com).

If a new site data has been installed in a particular region then the Administrator shall upload the site data database using the following process:

- The Administrator shall go to the Site Data Centre website and download the latest site data to their local hard drive and unzip it.
- They shall then select **Add Site Data** link on the **Administration** page.
- They shall then enter the location of the site data file, the date it was installed and the RCC it is for.

- The site data shall then be uploaded to the database.

D.6.1.2 Third party data upload

Data from sources other than MIDAS can be uploaded to the toolkit using the following process:

- The Administrator shall select the **Third Party Data Upload** link on the **Administration** page.
- They shall then enter the location of the data file
- The traffic data shall then be uploaded to the database.

D.6.1.3 User list

Users can be added to the toolkit website using the following process:

- The Administrator shall select the **User List** link on the **Administration** page.
- They shall then be taken to the **Edit Users** page where they shall select the **Add New User** link.
- The following information shall then need to be entered for the new user:
    - Name;
    - Username;
    - Company;
    - Email Address;
    - Whether or not the user shall be an administrator;
    - Password (if nothing is entered a password shall be randomly generated for the user); and
    - The SM schemes which they shall be able to view and edit.

The details of existing users can be added in the same way by selecting the relevant **Edit** link on the **Edit User** page.

On the **Edit User** page the Administrator shall also have the option to delete user accounts and reset a user’s password.

D.6.1.4 User Log

This logs all users that use the site. The following is stated on the user log page:

- Name;
- Username;
- IP;
- Login Date;
- Administrator;
- Email;
- Company;
- Delete button;

Only Administrators can view this user log.

D.6.2 User options

The toolkit contains a Help function. A **Help** button is located on every page. Selecting this shall take the user to the relevant section in the Toolkit Help document. If the Toolkit Help document does not provide sufficient clarification to the user then they should contact the Administrator (the CCSS team) at the details provided in Section 1.7.

Similarly, if any queries or service provision issues are identified by the user then they should contact the Administrator immediately at the same address.

If the user would like to edit their personal details, such as username, password or contact details, then they should contact the Administrator, quoting current and new details.

END OF Annex D

ANNEX E DATA SPECIFICATION FOR INITIAL THRESHOLD CALCULATION

E.1 HISTORIC TRAFFIC DATA

Smart Motorway schemes require site-specific Flow Thresholds and Link Flow State thresholds to be included in site data. To calculate initial thresholds that shall result in appropriate system output when first commissioned, historic traffic data shall be required to be analysed. This should be recorded between the scheme boundaries prior to commencement of works for the scheme.

The data is to be sufficient to enable:

- The identification of recurrent congestion seedpoints, i.e. the location (in space) and start and end points (in time) from which stop/start traffic propagates upstream, on a regular basis.
- The identification of traffic flow levels at the seedpoint location before, after and during the duration of the seedpoint.
- The identification of maximum traffic flows recorded on section of the Smart Motorway scheme on which congestion seedpoints are not located.

E.2 RECOMMENDED MINIMUM

The type and amount of data required to do this with confidence shall be dependent on the frequency and consistency of seedpoints.

A recommended minimum for flow data is:

- Main carriageway total traffic flows for 5 minute periods on all ‘between junction’ and ‘within junction’ sections of the scheme, for 56 days.

A recommended minimum for speed data is:

- Main carriageway average speeds for 5 minute periods recorded at 1km intervals throughout the length of the scheme, for 56 days.

It is appreciated that sometimes there can be difficulty obtaining 56 days of data, or even that MIDAS data may not exist before construction of the Scheme. However, the need to obtain sufficient prior data (by whatever means) is emphasised, and this should be an integral part of the Scheme plan.

E.3 FORMAT FOR CALO TOOLKIT

Available MIDAS data from traffic counting vehicle detector sites, available in feeds from MIDAS Gold server, shall be continuously uploaded to the database and available for analysis. If there is no MIDAS data available, it shall be possible for traffic data from other sources to be uploaded provided it is in XML format matching the schema below. In summary this shall contain:

- Date and time (this should be expressed in the format yyyy-mm-ddThh:mm:ss e.g. 2012-01-24T12:40:00);
- Geographic address made up of motorway, marker post and carriageway (e.g. M25/4564A);
- Average speed value for each time period; and
- Total flow for each time period.

The XML schema for the data is as follows:

```xml
<?xml version="1.0" encoding="utf-8"?>
<xsd:schema xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xs="http://www.w3.org/2001/XMLSchema" xmlns:xsd="http://www.w3.org/2001/XMLSchema"
attributeFormDefault="unqualified" elementFormDefault="qualified">
  <xs:element name="ArrayOfDataPacket">
    <xs:complexType>
      <xs:sequence>
        <xs:element maxOccurs="unbounded" name="DataPacket">
          <xs:complexType>
            <xs:sequence>
              <xs:element name="TimeOfData" type="xs:dateTime" />
              <xs:element name="GeographicAddress" type="xs:string" />
              <xs:element name="AverageSpeed" type="xs:unsignedByte" />
              <xs:element name="Flow" type="xs:unsignedByte" />
            </xs:sequence>
          </xs:complexType>
        </xs:element>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xsd:schema>
```

An example file for one minute on one vehicle detector is as follows:

```xml
<?xml version="1.0" ?>
  <ArrayOfDataPacket xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema">
   <DataPacket>
    <TimeOfData>2011-11-07T12:32:00</TimeOfData>
    <GeographicAddress>M25/4565A</GeographicAddress>
    <AverageSpeed>77</AverageSpeed>
    <Flow>20</Flow>
  </DataPacket>
</ArrayOfDataPacket>
```

END OF Annex E

ANNEX F OPERATING PARAMETERS

F.1 HOW THE SYSTEM USES FLOW AND SPEED THRESHOLDS

The following process describes how flow and speed thresholds are used by the system:

- Traffic uses the SM scheme;
- Vehicle detector sites (e.g. MIDAS loops) detect the presence, speed and length of individual vehicles;
- The system records minute-by-minute flow and speed and smooth's the data;
- Total flow is calculated across all lanes and average speed across all lanes;
- The system assigns the vehicle detector site to a particular flow band depending on the total flow and a particular speed band depending on the average speed. Each vehicle detector site has a set of rising and falling thresholds for both flow and speed which mark the boundary for each band;
- When a new band is reached an alert (either speed or flow) is generated;
- Combinations of these alerts produce a congestion level for that site;
- When the congestion level changes, an alert is generated to the signal sub-system;
- The system then applies a set of rules to the alerts generated by related vehicle detector sites. This then generates a signal sub-proposal to set a combination of speed limits.

F.2 CONTROLLED MOTORWAY SPEED AND FLOW THRESHOLDS

Each vehicle detector site used for setting CM signals is, on a minute-by-minute basis, assigned to a both a Flow Band (FB) and a Speed Band (SB) based on the total flow recorded across all lanes and the average speed recorded across all lanes. Each vehicle detector site has a set of Rising Flow Thresholds and a set of Falling Flow Thresholds which mark the boundary of each FB. For example, if the site is currently in Flow Band 2 it would need to cross the FB3 Rising threshold to enter FB3 or the FB2 Falling threshold to enter FB1. Rising and Falling Speed thresholds are used in a similar way.

Depending on the flow and speed bands which are assigned to the site, a congestion level is also assigned through a speed/flow look-up table. Table 13 presents an example of a speed/flow look-up table. This congestion level relates to a set of signals and messages which shall be proposed by the system. Generally, congestion level 1 sets 60mph signals and congestion level 2 sets 50mph signals. Congestion level 3 is not normally used but when it is, it is used to set 40mph signals. In the case of the example below, thresholds associated with FB4-FB7 shall be set artificially high so as to never be reached.

Table 13: Example of a speed/flow look-up table

	FB0	FB1	FB2	FB3	FB4	FB5	FB6	FB7
SB0	0	2	2	2	3	3	3	3
SB1	0	2	2	2	3	3	3	3
SB2	0	1	1	2	3	3	3	3
SB3	0	0	1	2	3	3	3	3
SB4	0	0	1	2	3	3	3	3
SB5	0	0	1	2	3	3	3	3
SB6	0	0	1	2	3	3	3	3
SB7	0	0	1	2	3	3	3	3

F.3 OTHER PARAMETERS

Parameter	Unit	Description	Default value
Aggregation Period	Minutes	Indicates how often smoothed flow and speed data are recalculated.	1
Update Time	Minutes	Indicates how often signal settings are updated.	1
Smoothing Factor	-	The proportion of the smoothed speed or flow value consisting of the flows and speeds recorded in that minute.	0.15
Minimum On-Time	Minutes	The minimum period of time for which a speed limit can be shown on a signal.	4
Minimum Off-Time	Minutes	The minimum period of time before a new speed limit can be displayed on a signal following a previous limit being removed.	4
Occupancy Period	Seconds	The period for which a vehicle detector has to be occupied by a vehicle for a HIOCC alert to be generated.	2
Link Flow State Thresholds	Veh/hour	The flow values at which the Link Flow State indicator for a particular link is activated (rising threshold) or deactivated (falling threshold).	-

END OF Annex F

ANNEX G OPTIMISATION LOG TEMPLATE

Optimisation Log

Scheme: M6 J4-5 | Last Updated: 27/12/2012 | By: B Jones

	Measures Proposed					Measures Implemented		
Ref	Date Proposed	Measure	Expected Impact	Proposed By	Proposed To	Date Implemented	Impact	Review Date
1	25/01/2012	Raise FB2 Rising Threshold from 75 vch/min to 80 vhc/min on loop sites 4671A,4702A and 4735A	Reduction in unnecessary inter-peak 60mph settings betw een J4 and 4a northbound	J.Smith	B.Jones	20/02/*2012	Reduction in unnecessary inter-peak 60 mph settings in first w eek of operation	20/05/2012

END OF Annex G

ANNEX H CALIBRATION AND OPTIMISATION TRAINING COURSE

H.1 MODULE 1: TRAFFIC BEHAVIOUR

This module provides candidates with a basic understanding of traffic behaviour on motorways and trunk roads with a focus on equipping candidates for the subsequent module on SM operation. This module covers the basic observable parameters of traffic flow (speed, occupancy and flow), how they interact and how they can be measured. It consists of the following sessions: (a) Properties of traffic; (b) Flow, flow breakdown and capacity; and (c) Gathering traffic data.

H.2 MODULE 2: SM OPERATION

This module provides candidates with an understanding of both the theory and the practice of SM operations. The rationale behind each element of SM is explored in terms of the traffic flow theory covered in the first module. The practicalities of implementing and configuring each regime are then considered including examples from real schemes. The module also includes a brief history of SM and an overview of the SM system. It consists of the following sessions: (a) Elements of SM; (b) Visualising the performance of a scheme; (c) Architecture of Smart Motorways; and (d) History of the application of SM.

H.3 MODULE 3: PRODUCTS, PROCESS AND GUIDANCE DOCUMENTS

This module covers the process of delivering an optimised SM scheme including the required roles and competencies required, the products that shall be delivered and the processes for interaction with other parties with a role in scheme delivery or operation whose activities may impact optimisation. It consists of the following sessions: (a) Who does what in SM Optimisation; and (b) Tasks, products and guidance.

H.4 MODULE 4: THRESHOLD CALCULATION AND OPTIMISATION

This module explores the technical tasks required to calculate thresholds and optimise a scheme. This module focuses on the underlying tasks and the requirements that drive them to ensure that candidates have a strong understanding in this area before moving on to look at the CALO Toolkit itself. It consists of the following sessions: (a) SM system performance; and (b) SM algorithms and parameters.

H.5 MODULE 5: USING THE CALO TOOLKIT

This module enables candidates to use the CALO Toolkit. It consists of the following sessions: (a) Optimising a scheme; (b) Overview of the toolkit; (c) Getting started with the toolkit; (d) Regular system monitoring; (e) Performance scores in system monitoring; (f) Scheme setup and data selection; (g) Seedpoint analysis in threshold calculation; (h) Initial thresholds and signal simulation; (i) Performance measures in threshold calculation; (j) Altering thresholds; and (k) System preview mode.

This module also contains a number of practical exercises, namely;

- Exercise 1: Identifying Issues – System Monitoring
- Exercise 2: Seedpoint analysis
- Exercise 3: Identifying issues and improvements

END OF Annex H

ANNEX I SM SYSTEM PERFORMANCE MEASURES

Each of the performance measures presented here is based around five desirable qualities of an SM system:

- Congestion settings correctly implemented at flow breakdown and recovery
- Hard shoulder open when flow would otherwise break down
- Speed limits not set unnecessarily
- Hard shoulder not open when it is not needed
- Signals not changing rapidly

Each of these *elements of performance* is represented by an individual performance measure. There is also a combined measure which takes into account all of these elements to assign a single system performance score to the scheme. The aim of this combined score is to support users in quantifying the trade-off between different aspects of performance. It is not suitable for comparing one scheme to another as it shall depend on the size of the scheme, the number of vehicle detectors and signals, underlying traffic demand and the operational regimes implemented, all of which vary between schemes.

I.1 COMMISSIONING STAGE

In the commissioning stage, performance measures are calculated based on historical traffic data and simulated signal data created using thresholds chosen by the user. In this case, the traffic data represents what would happen without SM and the performance measures reflect this.

I.1.1 Measure 1: Flow transitions

The percentage of flow breakdown and recovery for which a 50mph speed limit is set for at least 5 minutes before and after.

This measure tests whether speed limits are displayed correctly at flow breakdown and recovery. These are the moments in which the main benefit is realised from congestion settings, so every transition that is dealt with correctly shall be beneficial to traffic.

I.1.2 Measure 2: Correct link flow state alarm (hard shoulder opening)

The percentage of the time between flow breakdown and recovery for which the hard shoulder would be open according to the LFS.

The link flow state alarm is activated when the LFS rising threshold is exceeded and deactivated when LFS drops below the LFS falling threshold. In operation, this would be used as a trigger for opening the hard shoulder. To prevent flow breakdown, the hard shoulder should be open at a seedpoint for the period starting at flow breakdown and ending at recovery.

I.1.3 Measure 3: Unnecessary speed limits

The percentage of speed limit settings which are not within 2km or 15 minutes of any congestion.

This measure tests whether speed limits have been unnecessarily set, causing traffic to slow and resulting in longer journey times.

I.1.4 Measure 4: Incorrect link flow state alarm (unnecessary hard shoulder opening)

The percentage of time for which the hard shoulder is open (according to the LFS) during which flow breakdown is not occurring.

This measure tests whether the LFS alarm is active at times when the hard shoulder does not need to be opened. The LFS alarm should only activate at seedpoints when flow breakdown has occurred or is imminent. The LFS should not activate where no seedpoint has been observed.

I.1.5 Measure 5: Rapidly varying signals

The number of times per day which signals go down/up/down or on/off/on unacceptably quickly.

This measure is designed to detect signals which vary rapidly in a way which undermines driver confidence.

I.2 OPERATIONAL STAGE

In the Operational stage, performance is calculated using recent traffic and signal data rather than simulated signals as in Commissioning. Because the traffic data are taken from the operational scheme the data shall show the effect of the SM interventions, particularly hard shoulder running, which is likely to have mitigated much of the flow breakdown observed in the Commissioning traffic data. Because of this fundamental difference, the performance measures cannot be calculated in the same way in Operation as they were in commissioning, and the meaning of the measures is subtly different in some cases.

Performance can also be calculated from simulated signals during operation, but again the traffic data shall include the effects of the existing scheme, so the 'operational stage' performance measures shall be used.

I.2.1 Measure 1: Flow transitions

The percentage of flow breakdown and recovery for which a 50mph speed limit is set for at least 5 minutes before and after.

This measure tests whether speed limits are displayed correctly at flow breakdown and recovery. These are the moments in which the main benefit is realised from congestion settings, so every transition that is dealt with correctly shall be beneficial to traffic.

I.2.2 Measure 2: Hard shoulder opening in response to LFS alarm

Percentage of time for which the LFS alert was active that the hard shoulder was open.

The link flow state alarm is activated when the LFS rising threshold is exceeded and deactivated when LFS drops below the LFS falling threshold. In operation, this should be used as a trigger for opening the hard shoulder.

I.2.3 Measure 3: Unnecessary speed limits

The percentage of speed limit settings which are not within 2km or 15 minutes of any congestion.

This measure tests whether speed limits have been unnecessarily set, causing traffic to slow and resulting in longer journey times.

I.2.4 Measure 4: Necessity of opening of the hard shoulder

The percentage of time for which the hard shoulder was open when there was either an active LFS alert or congestion.

This measure tests whether the hard shoulder was opened when the LFS alarm was not active and no congestion was present on the link. Whilst it is not possible to say with certainty what would have occurred if the hard shoulder was not open, the fact that the LFS has not been exceeded and no congestion is observed suggests that there is no evidence that opening the hard shoulder shall be beneficial.

I.2.5 Measure 5: Rapidly varying signals

The number of times per day which signals go down/up/down or on/off/on unacceptably quickly.

This measure is designed to detect signals which vary rapidly in a way which undermines driver confidence.

END OF Annex I

ANNEX J ASSESSING PERFORMANCE THROUGH SPACE-TIME PLOT VISUALISATIONS

For operational SM schemes, a key tool for carrying out combined analysis has been the space-time software package for space-time visualisation of speeds and, in particular, the “Daily Plot” presentation of signal and message data overlaid on traffic speed, flow or occupancy data.

The *CALO Toolkit* provides improved space-time plot visualisation to support the analysis using both simulated and actual signal output as appropriate. This visualisation provides a means of assessing system output on a day-by-day basis.

J.1 SPACE-TIME PLOTS

Figure 11 presents an example of a space-time plot. The axes represent time and space and the background represent 1-minute averaged speeds, where black is 80mph and white is 0mph, with greyscale in between. Signals are overlaid in the form of different coloured bars, depending on the speed limit displayed.

This visualisation is powerful because it allows the identification of seedpoints – the location at which a ‘block’ of congestion originates. It also allows users to verify that the signals were set appropriately.

The Key to the plot is intended to be self-explanatory as far as possible, but for completeness its elements are listed in the table below.

Greyscale background	Traffic speed in each 500m x 1 minute cell is represented by a shade of grey varying from white at 0 mph to black at 80 mph or greater. This means that congestion shows up as grey with jam waves as lighter regions.
Speed limits	The most common speed limits displayed are 60 mph (green), 50 mph (orange), and 40 mph (yellow) set by HIOCC queue protection. Light blue ‘other’, if present, normally means the national speed limit is set.
RedX/Stop	Space-time plots are not able to distinguish between these signs which mean ‘lane closed’ and ‘traffic in lane shall stop’ respectively, the latter being indicated in a gantry based system by additional flashing red lights.
Medium blue bar	Indicates that no data are available, either because of loss of data feed or because vehicles are not moving.

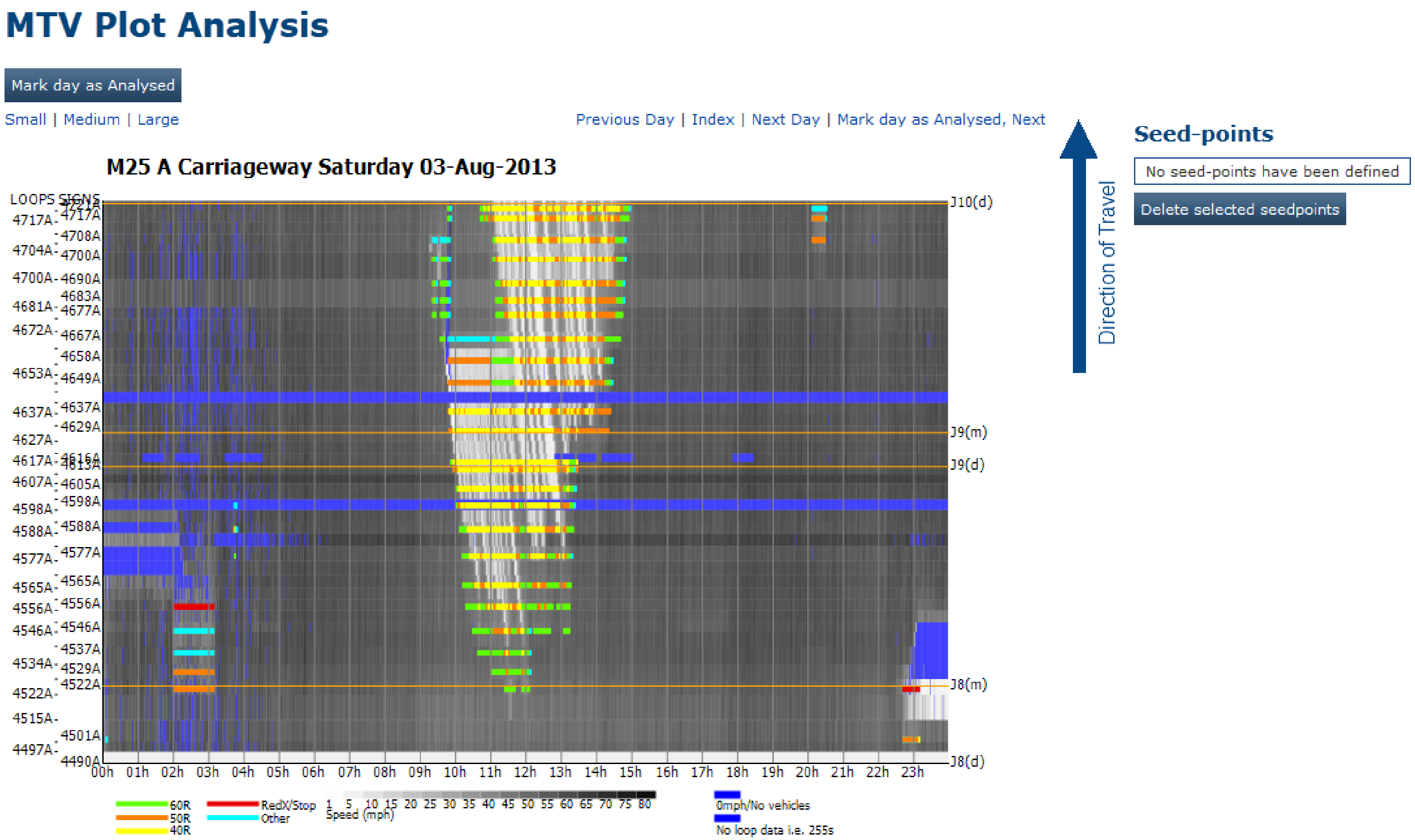


Figure 11: Example Space-Time Plot

J.2 SEEDPOINT IDENTIFICATION

Slow moving traffic can be recognised by areas of white or light grey on space-time plots. The shape of these areas can tell a user a lot about the nature of the event which caused them. SM seeks to address recurrent congestion seedpoints. Therefore, to assess performance it is important to be able to recognise whether congestion is recurrent and caused solely by high traffic flows or whether it is the result of an incident, such a collision or an obstruction.

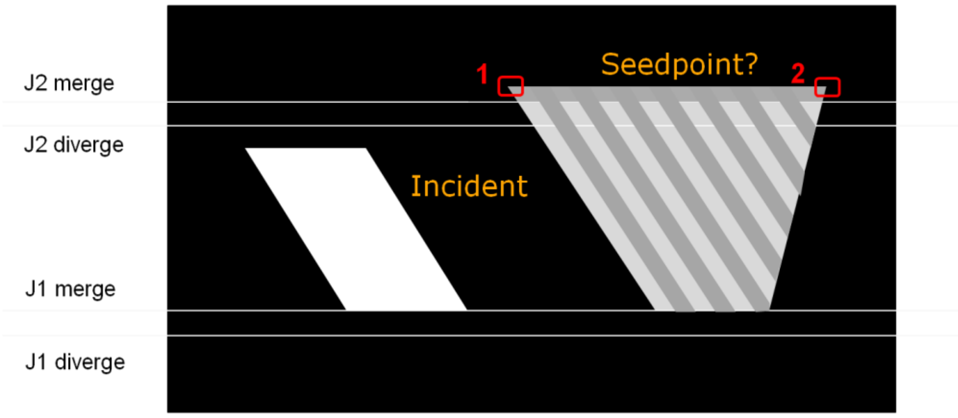


Figure 12: Simplified space-time plot

Figure 12 represents a simplified version of a space-time plot. This is to highlight the typical difference in features between congestion caused by incidents and recurrent congestion seedpoints.

When flow breakdown has occurred, the region of slow moving traffic travels backwards up the carriageway. Therefore, slow moving traffic caused by flow breakdown shall always have a leading edge which slopes in the opposite direction to the direction of travel. Flow breakdown caused by an incident or blockage shall typically be very sharply defined and bright white as vehicles come to a complete halt behind the obstruction. The start point can be in any location on the carriageway. Typically, this kind of congestion is only relieved when the obstruction is removed and the queue can move away, starting with those at the front, with those at the back moving away later. For this reason incidents shall typically result in a parallelogram-shaped area of white.

Flow breakdown caused by merging traffic typically results in slightly faster moving traffic, often with shockwaves within the area of congestion. This kind of congestion is normally relieved by falling demand with the shockwaves growing shorter as fewer vehicles join them forming a trapezium shape on the plot. To determine whether this congestion is recurrent, multiple plots would be analysed.

J.3 SEEDPOINT SELECTION

The *CALO Toolkit* requires the user to select the location and start and end times of a recurrent congestion seedpoint. This enables the toolkit to calculate ‘first pass’ thresholds and performance scores. The seedpoint information is recorded by clicking twice on the space-time plot. The first click should be at the earliest, furthest-downstream point of the congested area, i.e. the point at which traffic conditions at that location first start to create shockwaves of slow moving traffic travelling back upstream. This is indicated by point 1. Figure 12 presents an idealised example and on real space-time plots this point is unlikely to be as obvious. The following list provides a few characteristics to keep in mind:

- There is usually a drop in speed due to the traffic behaviour at the seedpoint location.
- However, traffic data at the seedpoint itself may not show such a dramatic drop in speeds as shall be seen in the shockwaves that form as a result of it.
- The seedpoint can often be identified by following the first shockwave down the carriageway and backwards in time to the point at which there is a change in speed.

- Thresholds and performance scores are calculated on a section by section basis or signal by signal basis rather than on a vehicle detector by vehicle detector basis. Therefore, the exact location of the point clicked may not always be as important as the time for which it is clicked.

The second point at which the user is required to click is the point at which the seedpoint ends, indicated by point 2 on Figure 12. The location of a recurrent congestion seedpoint remains constant while it is occurring. Therefore, the tool only requires the user to identify the time that the seedpoint ends and not the location. This point can be identified in a similar way at the start point, although characterised by a rise in speeds rather than a drop. It should be kept in mind that resulting shockwaves may continue for a while after the seedpoint has dispersed.

J.4 RECOGNISING PERFORMANCE ISSUES

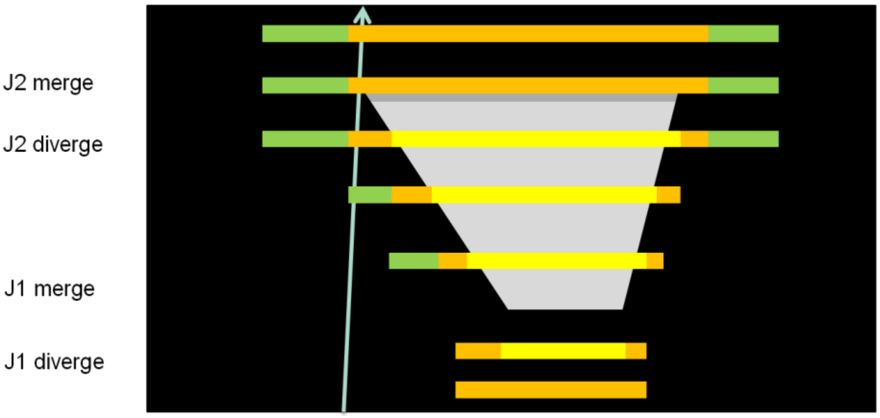


Figure 13: Simplified space-time plot showing congestion settings

When recurrent congestion has been identified, a key thing to check is that the congestion settings are on at the seedpoint prior to flow breakdown and remain on until recovery, such as in the three signals around Junction 2 in Figure 13 above. The vehicles involved in the initial occurrence of flow breakdown should have passed a 50mph limit before experiencing congestion. The tail back should be picked up by Queue Protection with 40mph limits being set. Additional 50mph and 60 mph limits shall be set by the signal smoothing algorithm.

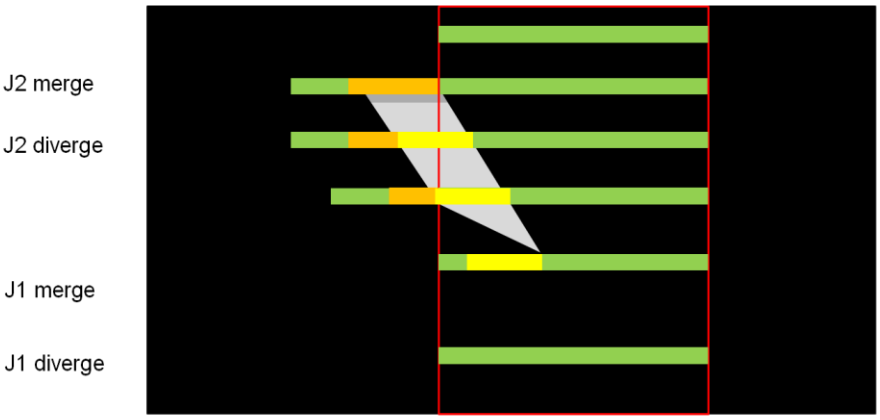


Figure 14: Simplified space-time plot showing signals set for Dynamic use of Hard Shoulder

Note that assessing performance in this way is relevant only dynamic sections, i.e. DHS and not ALR.

The key thing to look for that the hard shoulder is open whenever recurrent congestion is observed. In the first months or years of operation, it is likely that no recurrent congestion shall occur when the hard shoulder is open, due to the extra capacity. However, it is possible that there shall be occurrences of congestion when the hard shoulder is not open for some reason (illustrated in Figure 14). These occurrences should be investigated as they have a significant negative impact on traffic and on driver perception. Where possible, measures should be identified that shall allow the hard shoulder to be opened before congestion occurs. Incorrect hard shoulder opening can be due to incorrectly set LFS alerts (although these should be reasonable if the scheme has been through the pre-commissioning optimisation process) or operator behaviour.

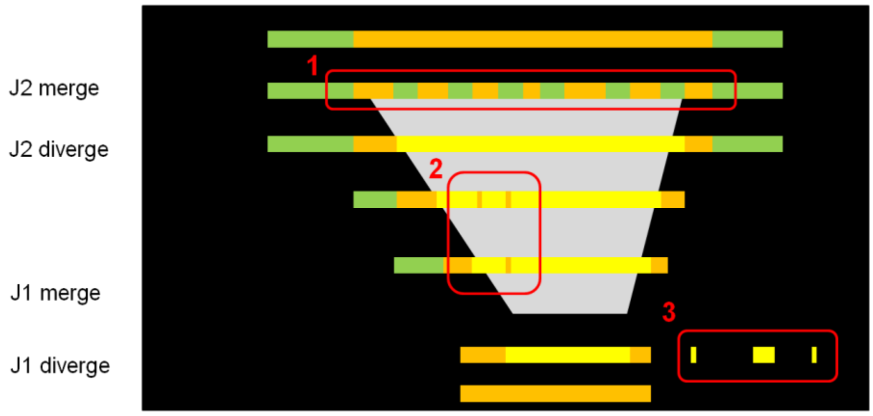


Figure 15: Simplified space-time plot showing rapidly varying signals

Variability can be the result of either Queue Protection or Congestion Settings or an interaction between the two. Figure 15 illustrates three examples:

1. This type of variability can occur where rising and falling thresholds are too close together, causing the Congestion Settings to fluctuate between 50/60 or 60 and the national speed limit.
2. This type of variability occurs when Queue Protection momentarily deactivates (due to a decrease in density) and the ‘gap’ is filled either by a Congestion Setting 50mph or by the signal sequencing rules which set 50mph limits. If this occurs, an algorithm called CoMo40 allows Congestion Settings to set 50mph limits to alleviate this issue to some extent.
3. This type of variability is also very common and is caused by Queue Protection triggering momentarily. When this is seen repeatedly at a single vehicle detector site it is indicative of a fault.

END OF Annex J

ANNEX K SM ALGORITHMS

There are three algorithms within the SM system that set VMSL:

- The HIOCC Algorithm;
- The CM Algorithm; and
- The LFS Alerts Algorithm.

The first two algorithms set signals and messages automatically in response to traffic conditions. The third generates an alert within the RCC which begins the hard shoulder opening or closing process. Opening the hard shoulder causes 60mph speed limits to be set on the link. The following process describes how LFS thresholds are used by the system:

- Traffic uses the SM scheme;
- Vehicle detector sites (e.g. MIDAS loops) detect the presence, speed and length of individual vehicles;
- The system records minute-by-minute flow and calculates 15 minute rolling average flow values for each section of the scheme assigned as a DHS section;
- Total flow is calculated across all lanes;
- Once flow crosses the LFS Rising threshold for that particular section, an alert is generated and indicator displayed in the RCC, known as the LFS indicator. This is intended to act as a prompt for the RCC staff to then begin the hard shoulder opening process for that section;
- Once flow drops below the LFS Falling threshold for the section the LFS indicator is cancelled.
- This is intended to act as prompt for the RCC staff to then begin the hard shoulder closing process.

In the figures below, blue boxes indicate steps in the process and white boxes indicate the inputs/outputs.

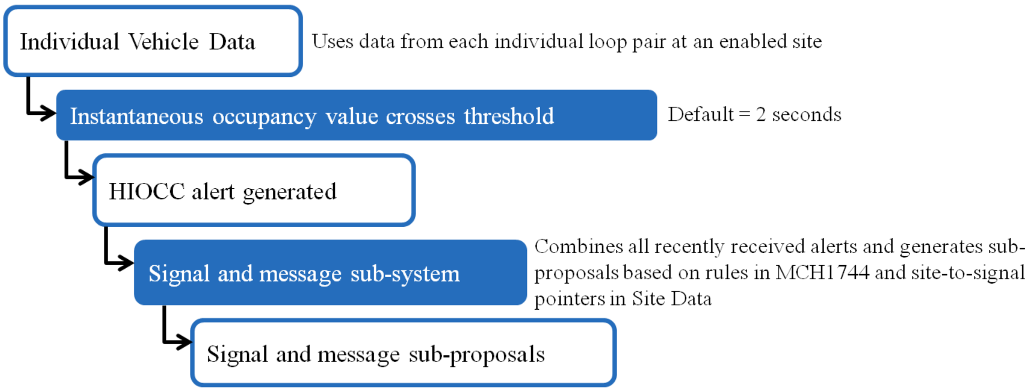


Figure 16: The HIOCC Algorithm

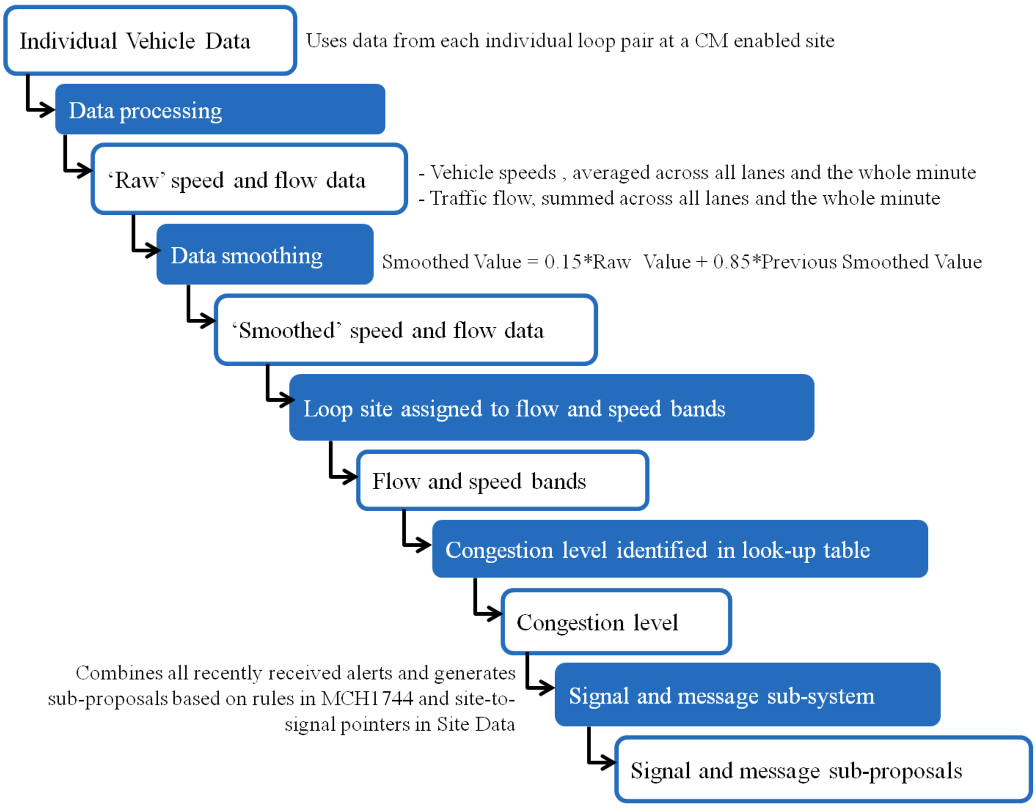


Figure 17: The CM Algorithm

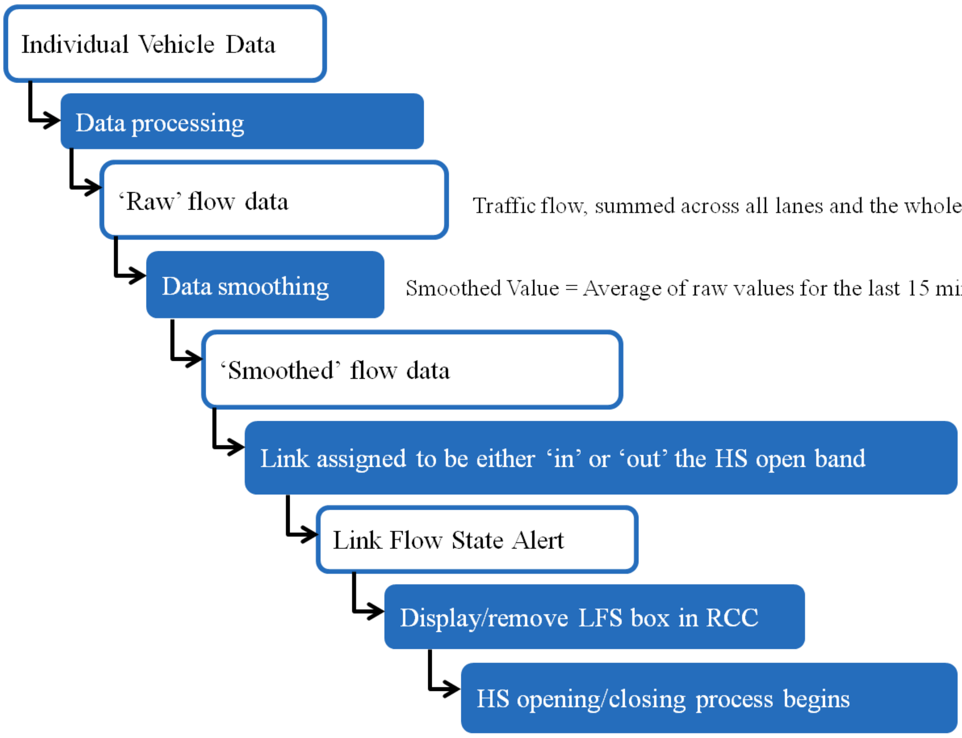


Figure 18: The LFS Alert Algorithm

The two diagrams below provide additional insight into how the algorithms interact with SM system as a whole. Both present a relevant sub-set of the components that make up an SM system and present the flow of data throughout the system at different instances. Figure 19 presents the flow of data within the SM system when a new version of the region's site data is loaded, particularly focussing on the parameters used by the algorithms. Figure 20 presents the flow of data within the SM system, from the vehicle detectors detecting speed and flow to the congestion settings being displayed.

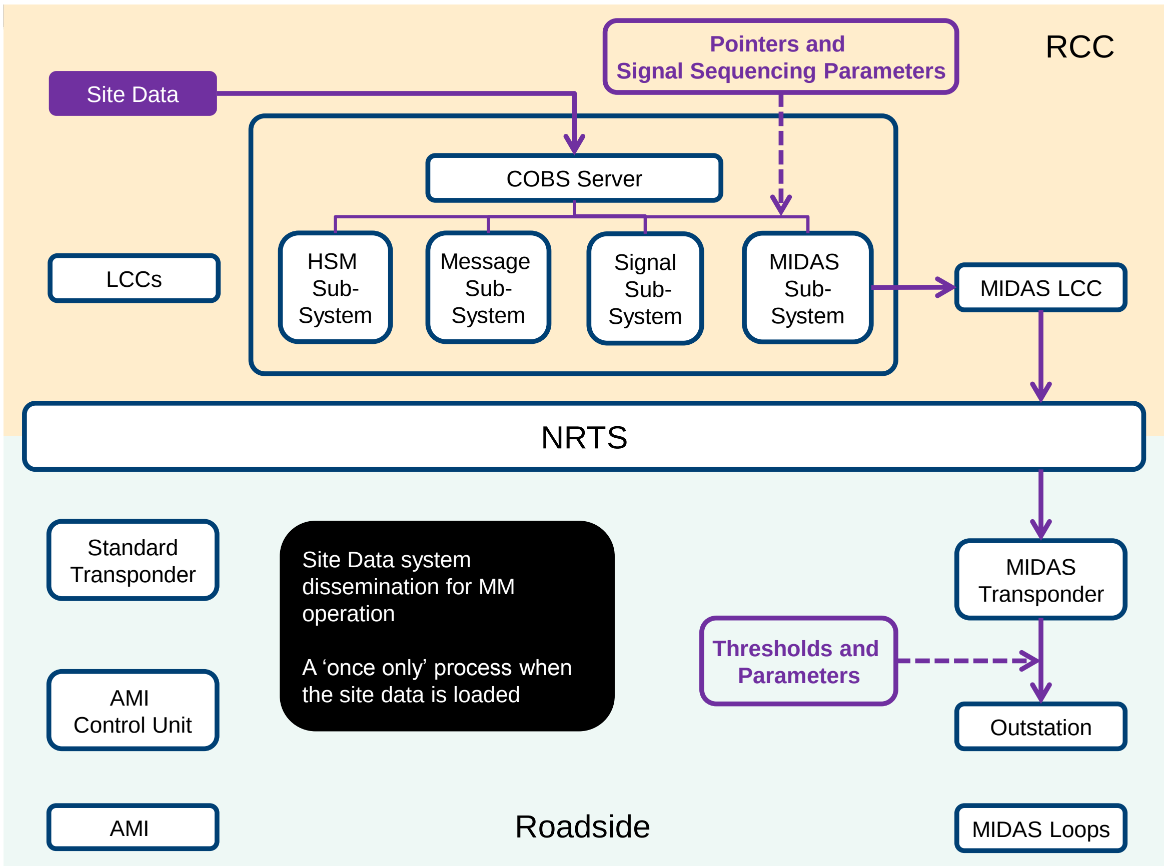


Figure 19: Data flow diagram: site data load

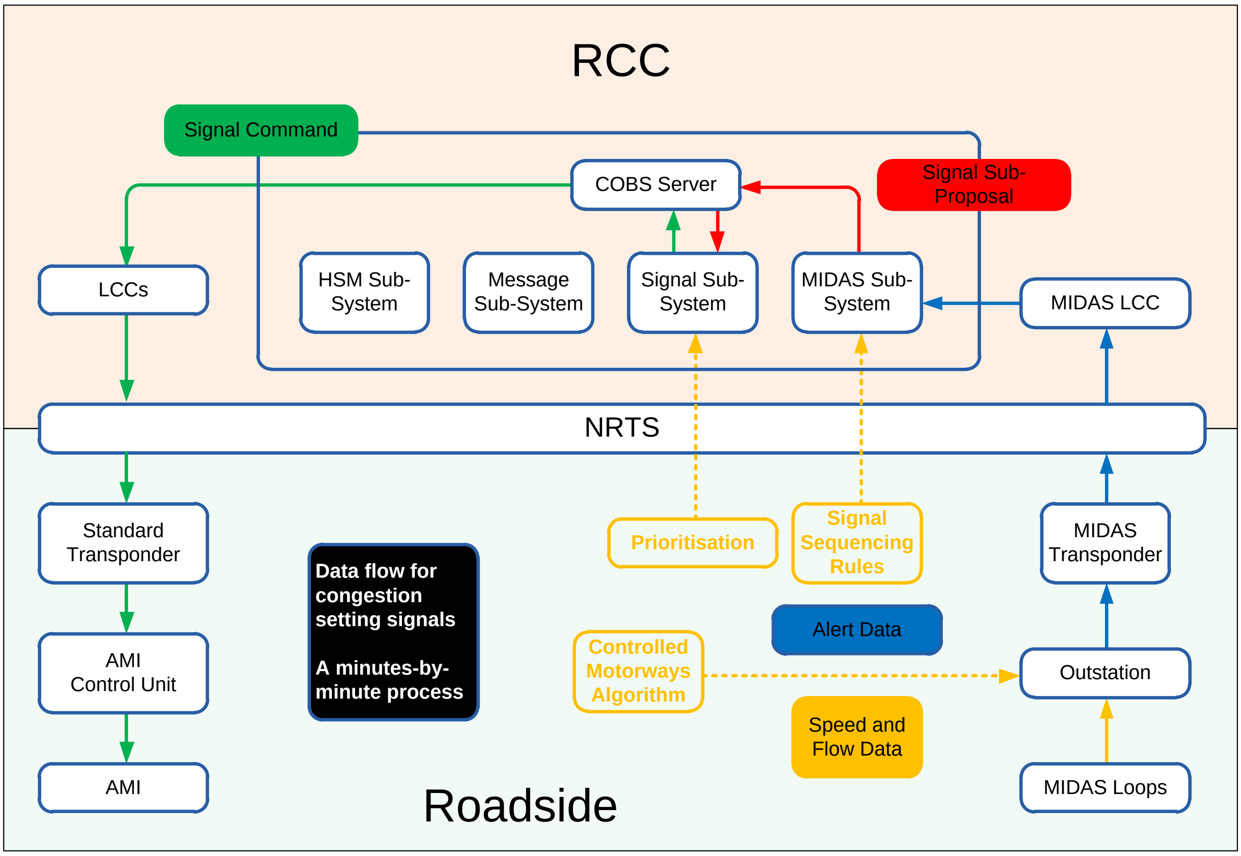


Figure 20: Data flow diagram: congestion settings

END OF Annex K

END OF SPECIFICATION