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Managed motorways all lane running
Demonstration of meeting safety objective report

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Sign-off / approval sheet

Signature	For	Sign-Off Statement
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Name: Max Brown Date:14/08/2013 Signature:	MM-ALR Design Workstream (NetServ Project Sponsor)	I endorse confirmation that: • the scope and content of the attached deliverable are correct and fit for purpose given the current stage of the project. • the attached deliverable complies with the requirements of the relevant Work Instructions for Project Safety Risk Management.
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Name: Dave Stones Date: 14/08/2013 Signature:	Traffic Management (MM-ALR Senior User)	I accept that in relation to the project operating regime the scope and content of the attached deliverable are correct and fit for purpose given the current stage of the project.
Name: Brian Barton Date: 14/08/2013 Signature:	Network Services (Managed Motorways Group Manager)	I approve that in relation to project safety: • the scope and content of the attached deliverable are correct and fit for purpose given the current stage of the project • the attached deliverable complies with the requirements of the relevant Work Instructions for Project Safety Risk Management.
Name: Mike Wilson Date: 15/08/2013 Signature:	MM-ALR Senior Responsible Owner	I approve that in relation to project safety: • the attached Project Safety Deliverable complies with the requirements of the relevant Work Instructions for Project Safety Risk Management.

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Executive summary

Introduction

This report describes the approach taken and the outcomes achieved from the work undertaken to demonstrate the achievement of the safety objective for managed motorways all lane running (MM-ALR).

A generic safety objective has been agreed for MM-ALR as defined in chapter 1.3.

The purpose of this document is to demonstrate that for MM-ALR the safety objectives are likely to be achieved. A qualitative review of the highest risk 'existing' motorway hazards and the 'new' hazards introduced by MM-ALR has been used, supported by a semi-quantitative assessment of the risk from these hazards.

Conclusion

With regard to the safety objective for all road users this report demonstrates that MM-ALR is likely to meet the safety objective and takes account of:

- A reduction in risk for a significant number (14) of the highest scoring existing motorway hazards (19), due to a controlled environment being provided through a combination of regularly spaced mandatory speed signals, speed enforcement, and full CCTV coverage
- One highest scoring (i.e. E08/S08 and above) new MM hazard is introduced, hazard 'H152 - Vehicle recovered from emergency refuge area (ERA)' (E08)
- One high-scoring existing hazard increases in risk, hazard 'H135 - Vehicle stops in running lane – off peak' (increases from E07.81 to E08.31)
- The impact of the new highest scoring hazard and increase to one existing highest scoring hazard is expected to be countered by the decrease in risk of existing highest scoring hazards
- Calculations show that the total score for 'after' represents approximately a reduction of risk of 18% when compared with the safety baseline.

With regard to meeting the safety objective for specific users, this report demonstrates that MM-ALR reduces the risk of a number of existing hazards, increases a number of existing hazards and introduces a number of new hazards for these groups. On balance it can be shown that for each of the following road user groups considered in this report, the safety objective is likely to be achieved:

Users

- Pedestrians
- Motorcyclists
- HGV drivers
- Disabled drivers or passengers

- Private recovery organisations
- Emergency services

Workers

- On road resources (ORR) (inc. the Traffic Officer Service (TOS) and National Vehicle Recovery Manager (NVRM))
- Maintenance workers

With regard to maintenance workers, since the publication of IAN161/12, improvements have been identified leading to a reduction in the frequency of maintenance activities. Thus it can be demonstrated that the safety objective is likely to be achieved and the risk managed so far as is reasonably practicable (SFAIRP). Further work has also be carried out in assessing risk to ORR, especially in relation to TOS procedures and activities undertaken by the NVRM, finalisation of this work is at an advanced stage and indications are that the risk to this worker group can be managed SFAIRP.

Validation of the outcomes of the hazard assessment associated with MM-ALR will be monitored and validated upon the implementation of schemes.

1 Introduction

1.1 Background

In January 2009 the Government announced that hard shoulder running (HSR) would be extended to some of the busiest parts of the Highways Agency's major road network and this initiated the managed motorways (MM) programme. The MM concept built upon the success of the M42 active traffic management pilot (M42 MM) scheme. IAN 111/09 "Managed motorways implementation guidance – hard shoulder running" [2] and IAN112/08 "Managed motorways implementation guidance – Through junction hard shoulder running" [3] provide designers with guidance on the implementation of managed motorways with dynamic hard shoulder running and the option for including through junction hard shoulder running.

Further knowledge and experience of operating managed motorways schemes indicated that there was scope to further reduce capital and operating costs, whilst meeting congestion objectives and not reducing safety performance compared to the safety baseline.

Managed motorways all lane running (MM-ALR) [1] has been developed by the Highways Agency to enable a reduction in the amount of infrastructure necessary for a managed motorway scheme, resulting in significant cost savings without a reduction in safety. Permanent conversion of the hard shoulder to a running lane along with the ability to dynamically control mandatory speed limits is a key aspect of MM-ALR. This removes the complex operating regime of opening and closing a dynamic hard shoulder.

1.2 MM-ALR key challenges

MM–ALR is described in Design Manual for Roads and Bridges (DMRB) IAN 161/13 "Managed motorway all lane running" [1]. The outline design for MM is shown in Figure 1-1. Key features include:

a. The hard shoulder on the main line is permanently converted to a controlled running lane. This includes the main line intra-junction subject to assessment
b. Refuge areas provided at a maximum of 2500m intervals. Refuge areas may either be bespoke facilities (an emergency refuge area (ERA)) or converted from an existing facility, for example a wide load bay, a motorway service area (MSA), the hard shoulder on an exit slip/link road or hard shoulder intra-junction where through junction running (TJR) is not provided
c. Variable mandatory speed limits (VMSL)
d. Above lane specific signalling only provided at the 'gateway signals and VMS' location, where necessary at intermediate locations and where the number of running lanes exceed four. At all other signal locations, verge mounted carriageway signalling must be provided

e. Driver information, including mandatory speed limits, are provided at intervals not less than 600m (relaxed on short links) and not exceeding 1500m
f. Queue protection system
g. Full low-light pan-tilt-zoom (PTZ) CCTV coverage
h. Emergency roadside telephones (ERT) are only provided in refuge areas (however not provided in MSA or on slip roads)
i. A central reserve rigid concrete barrier (RCB) contributing to the provision of low maintenance central reserve should be provided on all MM-ALR schemes in accordance with TD 19 unless the road worker safety objective can be met by alternative mitigations.

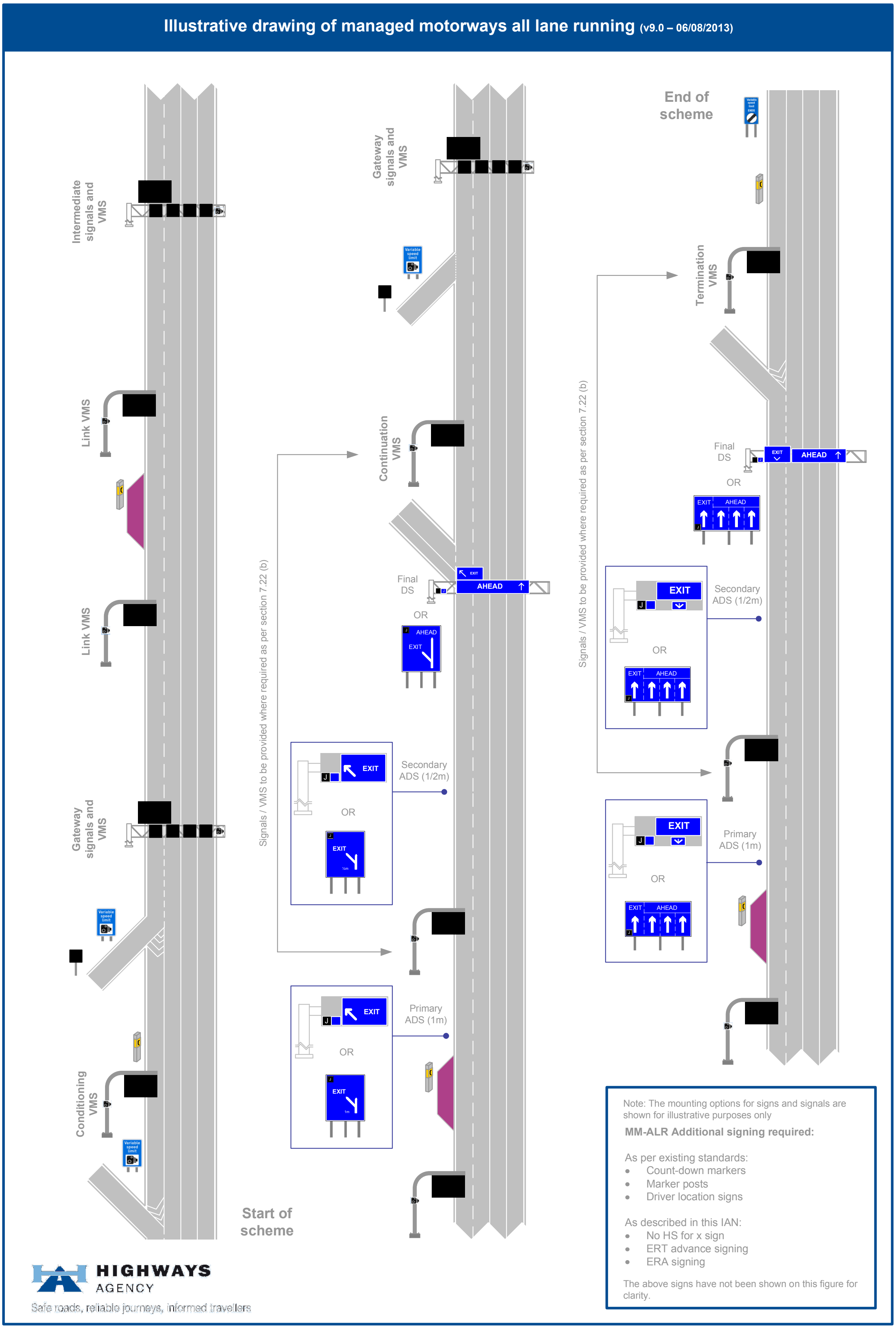

Figure 1-1: Illustrative drawing of managed motorways all lane running

There are a number of key differences between MM-ALR (IAN161/13) and the MM-HSR (IAN111/09) design [1] [2]. These are presented in Table 1-1.

IAN 111/09 compliant MM scheme	IAN 161/13 compliant MM scheme
Dynamic use of the hard shoulder with opening and closing of the hard shoulder for congestion management.	Permanent conversion of the hard shoulder into a running lane, including through junction running.
Driver information provided through: • Portal gantries positioned at a nominal spacing of 800m, capable of providing above lane specific signalling and supporting information (VMS)	Driver information provided through: • Portal gantries positioned near the start of each link, capable of providing above lane specific signalling and supporting information (VMS); and • Single VMS at a maximum spacing of 1500m capable of providing the same types of information but using pictograms, wickets etc. • Supplementary above lane specific signalling may be provided on longer links
ERA at nominal 800m spacing – usually associated with gantries.	Refuges at up to 2500m intervals.
Overhead direction signs mounted on gantries and cantilevers.	Cantilever/post mounted signs. Portal gantry mounted direction signs only used to aid clarity in immediate vicinity of junctions or where complexity of road layout indicates that overhead direction signs provide greater clarity.

Table 1-1: Key differences between an IAN 111/09 compliant MM scheme and the 'MM–ALR' design

The challenges for MM-ALR include:

- Road user safety
- Road worker safety
- Adequate guidance that produces the required level of compliant driver behaviour
- Operating and maintenance regimes (including managing emergencies)
- Mitigations for top scoring hazards
- Managing incidents

1.3 Safety baseline and objectives for MM-ALR

A generic safety baseline and generic safety objectives have been agreed for MM-ALR schemes.

1.3.1 Safety baseline

Validated STATS19 personal injury accident (PIA) data covering the scheme extent, including entry and exit slips is used to determine the road user safety baseline. The road user safety baseline used to demonstrate meeting the safety objective must be the number (averaged per annum) of all fatal and weighted injury (FWI) casualties and the rate of FWIs per billion vehicle miles per annum averaged for the three years prior to the installation of any element of MM-ALR.

> FWI is defined as: (number of fatalities) + 0.1 x (number of serious casualties) + 0.01 x (number of slight casualties).

If more than 50% of the main line carriageway by length has motorway incident detection and automatic signalling (MIDAS) installed, the road user safety baseline must be based on the recorded accident rate before installation of MIDAS. If this information is not available or older than 5 years, the current three year average rate must be increased by 10% to account for MIDAS. It is generally accepted that MIDAS reduces accident rates by between 9% and 13%, therefore an addition of 10% must be used for this purpose.

1.3.2 Road user safety objective

A MM-ALR scheme will satisfy the road user safety objective if it is demonstrated for a period of three years after becoming fully operational that:

- The average number of FWI casualties per year is no worse than the safety baseline
- The rate of FWIs per billion vehicle miles per annum is no worse than the safety baseline
- For each link, no population (e.g. car drivers, pedestrians, HGV drivers and motorcyclists) is disproportionately adversely affected in terms of safety and risk to each population remains tolerable. (Where different forms of managed motorways are proposed on opposing carriageways, for example, controlled motorways and MM-ALR, then the road user benefits should be considered per link per carriageway)

1.3.3 Road worker safety objective

There is no numerical objective or target for road worker accidents on MM-ALR schemes and the risk must be managed in accordance with the so far as is reasonably practicable (SFAIRP) principle. The Highways Agency's “Aiming for Zero (AfZ)” strategy must be applied for further positive action to reduce the risk to road workers during maintenance and operation. One part of the strategy aims to eliminate all fatalities and serious injuries to road workers maintaining the Highways Agency’s road network.

1.4 Document purpose

The purpose of this document is to demonstrate that the safety objectives for MM-ALR are likely to be achieved. A qualitative review of the highest risk ‘existing’ motorway hazards and the 'new' hazards introduced by MM-ALR, supported by a semi-quantitative assessment of the risk from these hazards, has been used to show this.

1.5 Document scope

This document considers the generic design of MM-ALR only. Application of MM-ALR for individual schemes will require a scheme based hazard assessment.

1.6 Document structure

The content of the document is as follows:

- **Chapter 1**: Introduction - background to MM-ALR, safety baseline and objectives, purpose and scope of document
- **Chapter 2**: Methodology – describes the approach used to demonstrate the meeting of the safety objective
- **Chapter 3**: Hazard log preparation, assumptions and background studies – describes modifications to the managed motorways hazard log; assumptions; background studies
- **Chapter 4**: Hazard log scoring - demonstration of meeting the safety objective for all users – presents the impact of introducing MM-ALR on the highest risk hazards
- **Chapter 5**: Demonstration of meeting the safety objective for specific users – presents the impact of introducing MM-ALR on the highest risk and relevant hazards to each road user group
- **Chapter 6**: Conclusions and recommendations – summarises whether the safety objective can be met
- **Chapter 7**: References
- **Appendices**: Glossary of terms and abbreviations, medium scoring hazards, risk assessment methodology, 'Controlled environment' paper and hazard log scoring verification workshops.

2 Methodology

This chapter summarises the methodology for demonstrating the meeting of the safety objective.

2.1 Methodology for demonstrating meeting of safety objective (for all users)

The (generic) methodology is documented in IAN 139/11 [4]. The foundation for the demonstration of meeting the safety objective is the risk assessment methodology which is documented in Appendix C.

The demonstration involves a qualitative and semi-quantitative risk comparison of MM-ALR with the safety baseline (a D3M without implementation of any element of managed motorways, i.e. without MIDAS).

The flowchart in Figure 2-1 summarises the process followed:

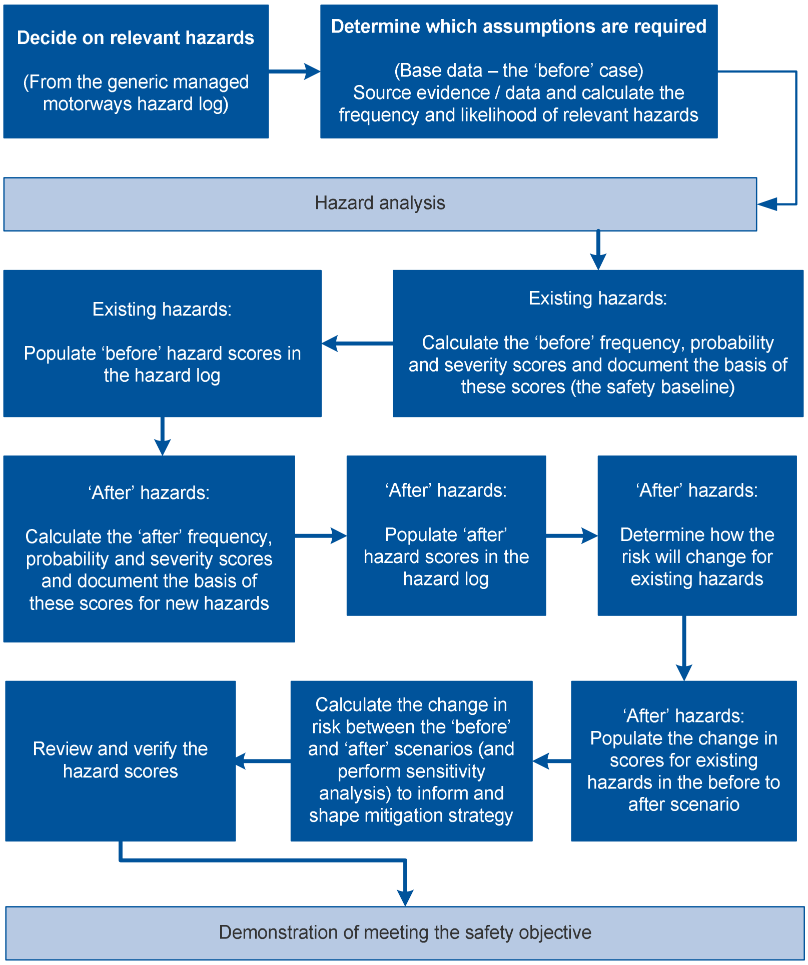

Figure 2-1: Process for demonstrating meeting of safety objective

2.2 Methodology for assessment of safety impact for specific road user groups

In addition to considering the impact of the scheme on the safety of all road users (in line with the demonstration of meeting the safety objective) chapter 5 of this document considers the safety impact of the scheme for the following specific user groups:

Users

- Pedestrians
- Motorcyclists
- HGV drivers
- Disabled drivers or passengers
- Private recovery organisations
- Emergency services

Workers

- **On road resources (ORR) (inc. the Traffic Officer Service (TOS) and National Vehicle Recovery Manager (NVRM))**
- **Maintenance workers**

It is necessary to understand how the implementation of MM-ALR affects workers, including maintenance workers (chapter 1.3) and ORR (shown in **bold** above), as they have separate safety objectives. The NVRM is included in this analysis due to the direct employment by the Highways Agency and the statuary obligation to meet the objective for this worker group.

In summary, the methodology involved the following steps:

- The MM-ALR hazard log was examined for all hazards relevant to the specific user group in question
- The 'before and after' scores (i.e. the difference between MM-ALR and the baseline) were reviewed for a specific user group

Finally the hazards with the largest contributing scores were examined to see whether the safety of that specific user group was improved, or not. This was done by:

- Checking whether the highest risk hazards that are relevant to the baseline have a different risk under MM-ALR
- Checking whether this is sufficient to counterbalance the risk of any new hazards introduced by MM-ALR

The conclusion for each user group is presented as a qualitative proposition. The hazard assessment is not suited to a quantitative approach as noted in chapter 2.3 below.

2.3 Use of quantitative assessments to support qualitative risk comparison

The demonstration of meeting the safety objective is based upon a qualitative risk comparison; a semi-quantitative consideration of the risk change based upon the outputs of the hazard log review has also been included. Care must be taken not to assume that the numerical output represents a higher degree of precision than is possible given the limited accuracy and availability of input data. To avoid such misinterpretation, this document uses the numerical calculations as a tool for guiding the construction of a qualitative argument.

2.4 Project safety risk management

The Highways Agency implements a safety management approach called project safety risk management for all its MM schemes (IAN 139/11) [4].

Highways Agency projects have traditionally used a prescriptive approach to demonstrating safety, relying on adherence to detailed standards. These standards are based on research, pilot activities and many years of experience, thus capturing the necessary risk mitigation properties. However, this approach is becoming less appropriate for the more complex and innovative systems now being installed and the need has been recognised for more formal safety management on highways projects.

The approach, developed from the management of safety on the M42 MM scheme, provides a framework for managing road user and road worker risk so that an appropriate level of safety management is applied. This approach takes into account the size and complexity of the project to determine, amongst other factors, an appropriate safety baseline and safety objectives.

GD04/12 [10] provides a framework for safety risk assessment and control and updates and clarifies requirements and guidance for addressing safety risks. A key requirement of this standard is that appropriate safety risk assessment, evaluation and management is undertaken to inform all activities, projects and decisions. This includes ensuring that the safety risk impacts for different populations that the Agency has a responsibility for, along with their safety risk exposure and safety risk tolerance, are taken into account.

Populations considered in GD04/12 include:

- Workers: People directly employed by the Agency and who work on the strategic road network (SRN), e.g. Traffic Officers; people in a contractual relationship with the Agency, including NVRM operatives, all workers engaged in traffic management activities and incident support services, and any other activities where live traffic is present, (such as persons carrying out survey and inspection work)
- Users: includes road users, the police and emergency services and non-motorised ‘users’ such as equestrians, cyclists and pedestrians, as well as those others not in a contractual relationship with the Agency, such as privately contracted vehicle recovery and vehicle repair providers

- Other parties: third parties includes any person or persons who could be affected by the SRN, but who are neither using it, nor working on it, i.e. living or working adjacent to the SRN, using other (non-Agency) transport networks that intersect with the SRN (e.g. local roads, railways) and those who are living or working in properties owned by the Agency.

The approach set out in GD04/12 allows safety risk tolerance, balancing judgments, and benefits versus costs to be examined, while taking account of available budgets and other duties when considering safety measures. This is consistent with Health and Safety Executive (HSE) guidance for 'sensible safety risk management', which seeks to ensure that workers and the public are properly protected, and understand their responsibilities, while providing an overall balance of benefit and safety risk. This includes the concept of 'trade off', whereby an increase in the safety risk from one hazard can be balanced by a commensurate decrease in the safety risk of another hazard. Furthermore, where individual safety risk controls result in a safety benefit to one population, the outcome for other populations must be that they are not disproportionately adversely affected in safety terms and the residual safety risk to a negatively affected population must always at least remain within tolerable parameters.

GD04/12 also requires that documentation is kept which evidences the decision making process for hazard and risk assessments and the identification and implementation of risk mitigation measures.

3 Hazard log preparation, assumptions and background studies

To carry out the hazard assessment of MM-ALR the existing generic MM hazard log was used as a starting point. However, the hazard log relates to hazards that are appropriate to MM-HSR involving the dynamic opening and closing of the hard shoulder. As MM-ALR does not feature this, it was necessary to make a number of modifications to the existing set of hazards. Either:

- Hazards were removed
- Existing hazards were modified
- Hazards were added

IAN161/13 utilises lane referencing of lane 1, lane 2 etc. IAN111/09 uses references starting with lane below signal (LBS), the hazard log has been developed from that of an HSR scheme and so the LBS reference remains from those hazards relating to HSR. Lane references for MM-ALR hazards revert back to those used in IAN161/13.

3.1 Removed hazards

The hazards removed from the hazard log are presented in Table 3-1.

Hazard	Description	Comment
H3	Aborting or pausing LBS1 sequence half way	Associated with dynamic HSR
H4	Blanking of one gantry when LBS1 open to traffic indicates sudden local closure of LBS1	Associated with dynamic HSR
H5	Closing sequence overtakes vehicles in LBS1, requiring them to move out of LBS1 unnecessarily	Associated with dynamic HSR
H15	Driver observance of red X changes on rest of network	Associated with the use of red lane control on dynamic HSR
H16	Driver on LBS1 fails to exit and continues on LBS1 through junction	Hazard associated with the presence or otherwise of dynamic HSR through a junction
H17	Driver stays on LBS1 when it is closing	Associated with dynamic HSR
H18	Drivers assume that LBS1 is open immediately after section	Associated with dynamic HSR
H19	Drivers assume they can use LBS1 on rest of	Associated with dynamic HSR

Hazard	Description	Comment
	network	
H20	Drivers enter LBS1 too early when LBS1 being opened	Associated with dynamic HSR
H26	Excessive opening and closing of LBS1	Associated with dynamic HSR
H35	Incident occurs in opened section of LBS1 during opening sequence	Associated with dynamic HSR
H44	LBS1 closed too early	Associated with dynamic HSR
H45	LBS1 closed too late	Associated with dynamic HSR
H46	LBS1 opened before required	Associated with dynamic HSR
H47	LBS1 opened too late (after traffic flow has broken down)	Associated with dynamic HSR
H49	LGVs, HGVs or other wide vehicles avoid using LBS1 due to narrowing effect of red studs	Associated with dynamic HSR
H50	Limping vehicles in LBS1 (when open)	Associated with dynamic HSR
H56	Motorcycle stopped on LBS1 as LBS1 opens	Associated with dynamic HSR
H61	Object in LBS1 causes impediment to traffic - causes drivers to take avoiding action when opening	Associated with dynamic HSR
H63	Opening sequence is faster than the traffic	Associated with dynamic HSR
H64	Operator closes LBS1 following an incident on main carriageway, diverting traffic toward incident	Associated with dynamic HSR
H71	Pedestrians on LBS1 while opening LBS1	Associated with dynamic HSR
H75	Power failure of several/all gantries during LBS1 running effectively indicates sudden closure of LBS1	Associated with dynamic HSR
H86	Slow traffic in LBS2 passed by faster traffic on LBS1	Associated with dynamic HSR
H107	Vehicle accelerates into LBS1 immediately after last red X	Associated with dynamic HSR
H125	Vehicle stopped on LBS1 as LBS1 opens	Associated with dynamic HSR
H128	Vehicle stops in LBS1 when LBS1 open	Equivalent to vehicle stopping in Lane 1 of main carriageway (i.e.

Hazard	Description	Comment
		now forms part of H155 Vehicle stops in running lane – peak and H135 Vehicle stops in running lane – off peak)

Table 3-1: Hazards removed from the generic managed motorways hazard log

3.2 Modified and new hazards

The hazards that were either modified, or in the case of H135 added to the hazard log are presented in Table 3-2. The hazard reference refers to the original hazard log developed for HSR schemes, following a review of the hazard log for MM-ALR, changes made to reflect the variation in the concept required alterations to hazard reference and descriptions. The revised hazard references are taken forward in the rest of the report and are the references utilised in the generic hazard log.

Hazard ref	Original description	Revised hazard ref	Revised description	Comments
H6	Collision with workers doing maintenance from ERAs/verge	H136	Collision with workers doing maintenance on verge	Changed to enable hazard assessment based on the assumed use of temporary traffic management for these activities.
H8	Debris in running lane	H137	Debris in running lane (being hit or causing unsafe manoeuvre)	Changed to more accurately describe the hazard
H10	Driver falls asleep	H138	Driver fatigued - unable to perceive hazards effectively	Changed to more accurately describe the hazard
H24	Excessive lane changing caused by use of LBS1 for hard shoulder running	H139	Excessive lane changing caused by availability of an additional lane	No hard shoulder in MM-ALR
H27	Excessively slow moving vehicle in running lane (excluding hard shoulder LBS1)	H140	Excessively slow moving vehicle in running lane	No hard shoulder in MM-ALR
H33	HGV-LGV-Bus exits ERA when LBS1 is open	H141	HGV-LGV-Bus exits ERA	No hard shoulder in MM-ALR

Hazard ref	Original description	Revised hazard ref	Revised description	Comments
H43	Large vehicle does not completely enter hard shoulder -LBS1when stopping	H142	Large vehicle does not completely clear the running lane when stopping on hard shoulder (D3M) or verge (MM-ALR)	Changed to reflect different nature of this hazard from 'before' to 'after'
H55	Motorcycle stopped in LBS1 when closed	H143	Motorcycle stopped next to running lanes (D3M = hard shoulder, MM-ALR = verge)	Changed to reflect different nature of this hazard from 'before' to 'after'
H57	Motorcycle uses LBS1 to pass slow moving or stationary traffic	H144	Motorcycle uses hard shoulder to pass slow moving or stationary traffic	Changed to indicate that this now only applies 'before' i.e. on D3M
H60	Motorcyclists crossing line between hard shoulder (LBS1) and LBS2	H145	Motorcyclists crosses rumble strips	Changed to reflect different nature of this hazard from 'before' to 'after'
H72	Pedestrians walking along the hard shoulder/LBS1 (when LBS1 is closed)	H146	Pedestrians walking along the hard shoulder (applies to D3M only)	Changed to indicate that this now only applies 'before' i.e. on D3M
H73	Pedestrians walking on verge when LBS1 is open	H147	Pedestrians walking in lane 1 (applies to MM-ALR only)	Changed to indicate that this now only applies 'after' i.e. on MM-ALR
H81	Roadworks - short term static on hard shoulder/LBS1	H148	Roadworks - short term static on hard shoulder	Changed to indicate that this now only applies 'before' i.e. on D3M
H109	Vehicle drifts off carriageway	H149	Vehicle drifts off carriageway (i.e. leaving the carriageway as a result of road environment)	Changed to more accurately describe the hazard
H114	Vehicle in ERA obtrudes onto LBS1	H150	Vehicle in ERA (or verge) obtrudes into lane 1 (applies only to MM-ALR)	Changed to indicate that this now only applies 'after' i.e. on MM-ALR

Hazard ref	Original description	Revised hazard ref	Revised description	Comments
H117	Vehicle not fully in control when trying to stop on LBS1	H151	Vehicle not fully in control when trying to stop on hard shoulder (D3M) or verge (MM-ALR)	Changed to reflect different nature of this hazard from 'before' to 'after'
H119	Vehicle recovered from ERA when LBS1 is open	H152	Vehicle recovered from ERA	Changed to reflect different nature of this hazard from 'before' to 'after'
H124	Vehicle reversing up the hard shoulder (LBS1)	H153	Vehicle reversing up hard shoulder (D3M) or lane 1 (MM-ALR)	Changed to reflect different nature of this hazard from 'before' to 'after'
H127	Vehicle stopped on the hard shoulder (LBS1) when it is closed	H154	Vehicle stopped on hard shoulder (D3M) or verge (MM-ALR)	Changed to reflect different nature of this hazard from 'before' to 'after'
H129	Vehicle stops in running lane	H155	Vehicle stops in running lane - peak	This hazard was split into two hazards: H155 for peak and H135 for off-peak as the risk is different for each
H129	Vehicle stops in running lane	H135	Vehicle stops in running lane - off-peak	This hazard was split into two hazards: H155 for peak and H135 for off-peak as the risk is different for each

Table 3-2: Hazards modified or added to the generic managed motorways hazard log for MM-ALR

In assessing the hazards associated with MM-ALR it was identified that one of the most critical hazards to assess was, "Vehicle stops in running lane". It was concluded that the nature of this hazard is different between peak (congested) conditions and off-peak (uncongested). That is, during congested conditions it is more likely that when the vehicle stops it will be noticed by drivers of following vehicles and queues will form. This is less likely to happen off-peak. This assessment is detailed further in chapter 3.4.

3.3 Assumptions

A number of assumptions have been used within the hazard log to calculate the hazard safety risk scores. Key assumptions relating to the highest scoring hazards (E08/S08 and above) within the generic hazard log are presented in Table 3-3.

Assumption	Description	Value	Comments
A4	Average duration for a breakdown (minutes)	50	TRL unpublished report PR/TT/069/98 states a range from 43 to 60 minutes
A22	Number of breakdowns per day per motorway mile	1.56	Assume a breakdown rate of 12 per million vehicle mile (from calculation of vehicle stoppage rates). (130,000*12)/1000000 = 1.56 breakdowns per day per motorway mile
A23	Number of comfort stops and vehicle checks per day per motorway mile	7.8	Data from M1, M42 and M25 gives a range of 3:1, 5:1 and 10:1 respectively (M1 data is newest data, M25 is oldest; assume newer data is more representative as likely to reflect campaigns to reduce hard shoulder stoppages). Assume a rate of about 5 times as many as breakdowns.
A25	Number of lane closures per day per motorway mile	0.22	Data collected from the M3 and M4 suggests values of between 0.13 and 0.30. Data collected for M42 MM suggests 0.22. Assume this figure.
A37	Percentage of breakdowns that cannot be fixed on site and require towing	25%	General assumption - RAC data seems to confirm this
A38	Percentage of breakdowns that fail to reach a refuge	50%	Significant data analysis including RAC data suggests that at least half of all breakdowns could reach a refuge.
A52	Percentage of traffic volume during off-peak periods	80%	Based on actual figures from first MM-ALR schemes
A53	Percentage of traffic volume during peak periods	20%	Based on actual figures from first MM-ALR schemes

Assumption	Description	Value	Comments
A71	Vehicles per day per motorway mile	130,000	Based on flows recorded on links on the M3 and M4

Table 3-3: Key Assumptions used in the hazard log for MM-ALR

3.4 Vehicle stops in running lane

Vehicle stops in running lane is a key hazard within the hazard assessment, and therefore needs to be risk scored as accurately as possible.

3.4.1 Understanding this hazard on dual 3-lane motorways

Initial consideration of the STATS19 (i.e. verified by the Police/DfT) personal injury accident and casualty data collected on D3M links (2006-2010) [6] indicates that the associated accident (Vehicle parked in running lane) represents the following proportions of all accidents and casualties by severity on D3M links:

- 1.6% of all fatal and serious accidents
- 1.6% of all killed and seriously injured casualties

The KSI ratio (the proportion of all personal injury accidents/casualties that are fatal/serious accidents/casualties) for "Vehicle parked in running lane" are:

	MM-ALR	D3M
Accidents	0.21	0.13
Casualties	0.15	0.10

Table 3-4: KSIs for vehicles parked in a running lane

That is, "Vehicle parked in running lane" have a higher severity of accident/casualty when compared with the average for D3M links.

The table below provides information about the proportion of these accidents that occur during peak and off-peak and the KSI ratios peak and off-peak.

	Proportion (All accidents)	Number of KSI	Proportion of KSI accidents	KSI ratio - Accidents
Peak	0.34	16	0.39	0.24
Off-peak	0.66	25	0.61	0.19

Table 3-5: Proportions of accident occurance

The key facts obtained from the above analysis are:

- They are more likely to happen off-peak rather than peak
- The KSI ratio off-peak is less than the KSI ratio peak.

3.4.2 Determining the hazard frequency

The frequency of lane closures is used as a proxy to estimate the frequency with which vehicles might be forced to stop suddenly.

From chapter 3.3 Assumptions, A25 the ‘number of lane closures per day per motorway mile’ is assumed to be 0.22. Therefore the number of lane closures per year = 0.22*365 = 80.3 (rounded to 80).

Analysis of the command and control data for the M4 had identified that the daily profile for the frequency of these causes is as shown in Figure 3-1.

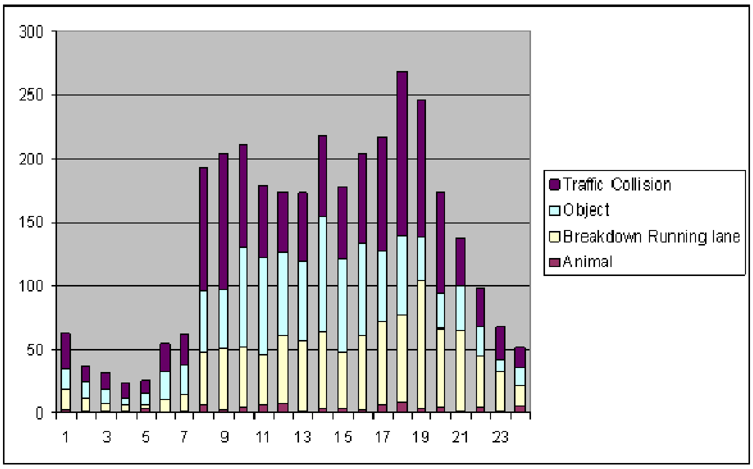

Figure 3-1: Frequency of causes leading to vehicle parked in carriageway (no. of incidents across hours in day)

From this it can be assumed that the frequency of the underlying hazard is proportional to flow (as the above plot mirrors the flow profile on the M4).

	Assuming 20% of flow during the peak	**In terms of frequency index (Appendix C)**
Peak	16	4.20
Off-Peak	64	4.81

Table 3-6: Frequency of underlying hazards

If however, the hazard is scored as a state, the ‘Frequency’ is as follows for the off-peak:

Number of occurrences: 64, assume present for 1 hour each = 64 hours per year which equates to frequency index score (see Appendix C) closest to 4.0 (probable).

3.4.3 Determining the hazard probability

The occurrence of this hazard does not always result in a collision. For example, in the case of a vehicle fault, the vehicle does not usually stop suddenly, so drivers immediately behind have time to react having been warned by vehicle break lights or manoeuvre. The following vehicle will be warned by observing vehicle brake lights, which may be supplemented by the use of hazard lights. Analysis of breakdowns in live lanes and resulting injury accidents suggests that the rate of a vehicle stopped in a live lane being hit such that an injury accident occurs is about 1 in 1,000. This suggests a probability figure of 1.0 (remote).

As noted above there are more vehicle parked in carriageway accidents off-peak than peak (1.56 as many). Assuming that the frequency is proportional to flow, then it is likely that the hazard probability off-peak is higher than that peak: Assuming that it is 1 for peak, the off-peak probability is 2.35 times higher.

However, the probability scores use a logarithmic scale. A score of 1.5 represents 3 times the probability score 1.

Therefore the hazard probability for peak and off-peak can be different by 0.5.

Assume:

- Peak probability value of 1.0
- Off-peak probability value of 1.5

3.4.4 Determining the hazard severity

A vehicle stopped in a running lane is one of the most common causes of collisions on the motorway where there is a high speed differential.

The KSI ratio off-peak is lower than the KSI ratio peak. However, it is still of the same order. Therefore, assume that there is no difference with regard to the hazard severity off-peak. Comparing the KSI ratios with D3M accidents as a whole the severity of vehicle parked in carriageway accidents is 60% greater. This suggests a higher than average severity index of 1.5, but not 2 (as the difference in severity does not justify this value).

	Frequency	Probability	Severity	Risk score
Peak	4.20	1.0	1.5	**E06.7**
Off-peak (if hazard is considered an Event)	4.81	1.5	1.5	**E07.81**
Off-peak (if hazard is considered a State)	4.0	1.5	1.5	**S07.0**

Table 3-7: Hazard scoring for hazard 'Vehicle stops in running lane' during peak and off peak time

Given the difference in score when treating this hazard an Event or State, the decision has been taken to consider this hazard as an Event in all subsequent calculations.

3.4.5 Reality check

The ‘peak’ risk component of this hazard represents 0.1% of the baseline D3M risk and the ‘off-peak’ component 1.4% of the baseline D3M risk. Data from D3M links (see chapter 3.4.1 indicates that combined they represent about 1.6% of all KSI accidents. Therefore, the calculated values are in line with actual KSI accident data.

3.4.6 Change in risk with MM-ALR

Hazard ‘H155 - Vehicle stops in running lane – peak’ and hazard ‘H135 - Vehicle stops in running lane – off peak’ increase by an estimated 216% with MM-ALR, roughly a three-fold increase in risk. This is due to more vehicle stops in running lanes as there is no hard shoulder available and not all vehicles will be able to reach a refuge area.

Figure 3-2 shows the expected number of live (i.e. running) lane stops. MM-ALR is expected to eliminate illegal stops currently taking place on the hard shoulder. Of the expected number of vehicle breakdowns that currently occur on a hard shoulder it is estimated that 50% are able to reach a refuge area. Ten percent of the remaining 50% are expected to stop on the verge as a proportion of MM-ALR schemes will not have any safety barrier. Under MM-ALR we therefore expect about 0.35 breakdowns per day per carriageway mile in a live (i.e. running lane). This is around three times the current D3M rate for live lane stoppages.

	Number: Per day per carriageway mile*	**% of stops relative to D3M**	Comment
Total stops in existing situation (dual 3-lane motorway (D3M))	**4.68 stops on the hard shoulder and in a live lane**	**100%**	12 breakdowns per million vehicle miles Illegal stops at a rate of 5x the breakdown rate
Removal of illegal stops with MM-ALR and removal of hard shoulder: leaves breakdowns	**0.78 breakdowns**	**16.7%**	
Removal of breakdowns that can continue to a refuge area under MM-ALR (50% reduction)	**0.39 breakdowns not reaching refuge**	**8.3%**	Breakdowns retaining motive power (supported by RAC figures)
Removal of breakdowns that can pull into the verge (10% reduction)	**0.35 breakdowns in a live lane**	**7.5%**	Generic hazard log assumes 10% of vehicles that cannot reach refuge area pull into the verge: takes account of safety barrier in the verge

* Based on an average daily single direction flow of 65,000 vehicles

Figure 3-2: Managed motorways all lane running (MM-ALR) live lane breakdowns flowchart

In addition MM-ALR gives the ability to set signals to protect an incident (50mph and incident warnings for an unconfirmed report, and then lane specific closures once the location is verified), and with more CCTV a quicker ability to verify the location of the stopped vehicle. This mitigates the risk for each vehicle stopped in a live lane.

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4 Hazard log scoring

4.1 Population of the hazard log

To populate the hazard log for MM-ALR a list of assumptions was first produced as noted in chapter 3.3.

Once the assumptions had been determined individual risk assessments for each hazard in the hazard log were carried out, using the methodology described in Appendix C and the project safety risk management work instructions, IAN 139/11 [4]. An example of application of this methodology is presented in chapter 3.4 (i.e. the assessment of the hazard 'Vehicle stops in running lane').

Following the publication of the M42 MM three year safety review [5] greater assurance is now available that a scheme conforming to IAN 111/09 [2] can achieve considerable safety benefits. As highlighted in chapter 1.3 there are differences between MM-ALR and IAN 111/09. However, there are key elements in common most notably mandatory speed control and enforcement. Hazards that are impacted by these should see a considerable improvement in safety risk.

4.2 Analysis of hazards – evidence gathering and assessment

MM-ALR introduces a number of changes to the layout and technology provision on the motorway. Intuitively, the changes to the physical layout (most notably the permanent conversion of the hard shoulder to a running lane) are likely to lead to a reduction in safety. However, the provision of an extra lane will delay and reduce the length of periods of congestion (which in turn may reduce the conditions that lead to accidents). The provision of technology (mandatory signals, VMS and MIDAS) are anticipated to lead to a reduction in risk. In order for MM-ALR to achieve its safety objective the increases in safety risk that may be introduced by the change in road layout need to be balanced by the provision of technology providing a safe driving environment.

In order to collect evidence to support the hazard analysis a number of studies have been undertaken. Two of these studies have direct relevance to this report. One considers the impact of road layout changes the other considers the safety impact of the technology. These reports are:

- All-purpose trunk roads (APTR)/D3M analysis and hazard assessment [6] – referred to as the APTR report
- Provision of adequate guidance review [8] – referred to as the adequate guidance report.

The APTR report collects evidence from existing roads in order to better understand the likely safety implications of the road layout component of MM-ALR.

The adequate guidance report considers amongst other issues whether or not the technology elements of MM-ALR are adequate for maintaining a good level of compliance by drivers.

The details of the implications of the APTR report and the adequate guidance report are discussed in the MM-ALR generic safety report [7]. Briefly, the implications of these reports are:

- The APTR report suggests that the road layout of MM-ALR (without the controlled environment i.e. D4M with MIDAS) is likely to lead to an increase in safety risk of the order of 9%.
- The adequate guidance suggests that the environment of MM-ALR (mandatory signals, VMS and MIDAS) is likely to lead to a level of driver compliance (i.e. responding as appropriate to signs and signals). However, evidence is still being collected and until this evidence is available, the full benefits as highlighted in the M42 MM three year safety review [5] cannot be relied upon. This has been taken account in the hazard assessment.

4.3 Verification of hazard log scores

A hazard log workshop was held on 1st February 2012, during which a group of experts reviewed the scoring of each hazard, in order to verify the proposed changes for the after scenario. A second workshop took place on 29th February 2012 looking specifically at maintenance worker hazards. The results of that workshop are reported in chapter 5.3.5.

As part of the update to IAN161 and the associated safety documentation a workshop took place on 18th March 2013 to discuss amendments to hazard scores based upon changes to the IAN161 document. This version of the report identifies those changes agreed at the workshop. In addition, further changes to hazard log scores have been made based on work undertaken for MRPB.

4.4 Key hazards

4.4.1 Overview

The scoring exercise and the hazard log structure enables the hazards that pose the greatest risk to be targeted. The highest risk hazards were considered to be those:

- With a ‘before’ or ‘after’ risk score of 8.0 or more

With respect to the existing risk and before the implementation of MM-ALR, existing motorway hazards with a score of 8.0 or more account for 89% of the existing risk. Similarly, existing hazards (before implementation of MM-ALR) with a score of 7.5 or more account for 95% of the existing risk and hazards with a score of 7.0 or more account for 99% of the existing risk (see Appendix B).

In total new hazards resulting from the implementation of the scheme are expected to add approximately 4% (as identified in the generic hazard log) to the existing risk (these hazards are associated with the operation of the ERAs). Therefore, to match or better the safety baseline the risk associated with existing hazards must decrease by more than 4% as a result of the scheme.

4.4.2 Assessment of 'MM-ALR' against the baseline

The hazard analysis work leads to the conclusion that MM-ALR is likely to be safer than the baseline and takes account of:

- A reduction in risk for a significant number (14) of the highest scoring existing motorway hazards (19), due to a controlled environment being provided through a combination of regularly spaced mandatory speed signals, speed enforcement, and full CCTV coverage
- One highest scoring (i.e. E08/S08 and above) new MM hazard is introduced, hazard 'H152 - Vehicle recovered from emergency refuge area (ERA)' (E08)
- One high-scoring existing hazard increases in risk, hazard 'H135 - Vehicle stops in running lane – off peak' (increases from E07.81 to E08.31)
- The impact of the new highest scoring hazard and increase to one existing highest scoring hazard is expected to be countered by the decrease in risk of existing highest scoring hazards
- Calculations show that the total score for 'after' represents approximately a reduction of risk of 18% when compared with the safety baseline.

This analysis suggests that MM-ALR is likely to meet its overall safety objectives. This is shown in Figure 4-1. (For clarity, only the highest scoring hazards on MM-ALR are listed in the table on the right of this figure).

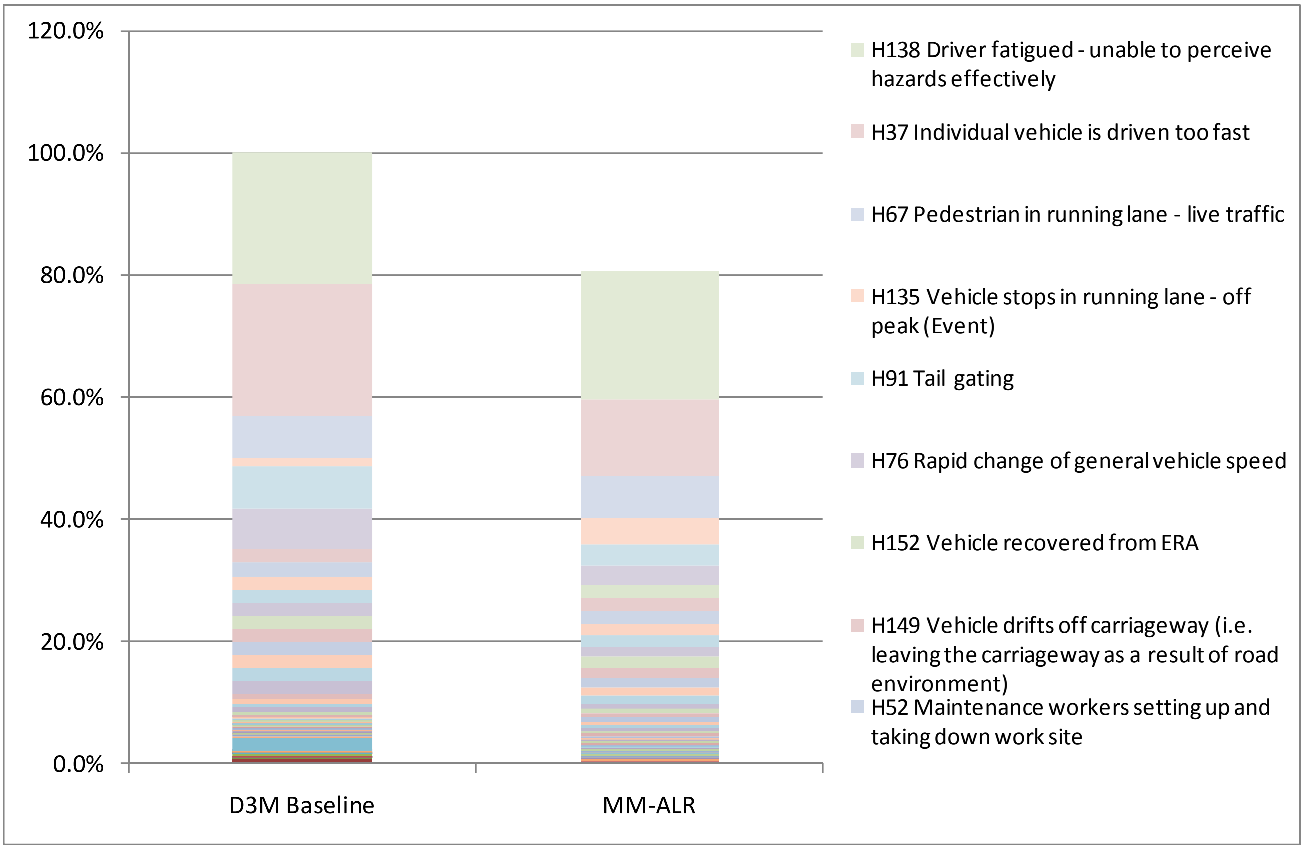

Figure 4-1: Comparison of safety risk for D3M baseline and MM-ALR

4.4.3 Notes on assessment methodology

Despite the use of numbers the risk score is at best semi-quantitative and does not provide an absolute measure of risk. The methodology is designed to place each hazard into one of a number of bands so that it can be seen clearly which hazards are considered to present the greatest risk.

This approach also facilitates the calculation of risk changes that a project brings about, thus enabling an assessment to be made as to whether a project has achieved its safety objective. To complete such an assessment each hazard must be reviewed and the impact that the project has on its score considered. By adding together the impact of all such risk changes, the overall change in risk that the project brings is calculated.

However, the use of semi-quantitative approach means that undue weight should not be placed on the quoted change in risk as it is only indicative of the change in risk for the scheme as a whole.

5 Demonstration of meeting the safety objective for specific users

5.1 High scoring hazards

The highest scoring hazards are listed below (S08/E08 and above). These drive the hazard analysis summarised in chapter 4 and represent approximately 89% of the total baseline risk. When reviewing Table 5-1 'percentage (%) change in safety risk':

- '0' means no change in risk
- 'Green' means a reduction in risk
- 'Red' means an increase in risk

Also, 'controlled environment' is considered to include the setting of mandatory speed limits, MIDAS and an appropriate compliance strategy through enforcement. This is detailed further in Appendix D.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H138	Driver fatigued - unable to perceive hazards effectively	Event	E09.00	E08.99	-3	Some benefit during peak of the controlled environment.
H37	Individual vehicle is driven too fast	State	S09.00	S08.77	-42	Considerable benefit from the controlled environment during the peak but also benefit off-peak (compliance with national speed limit).
H67	Pedestrian in running lane - live traffic	Event	E08.50	E08.50	0	Benefit from the controlled environment. However more instances due to increase in live lane breakdowns
H135	Vehicle stops in running lane - off-peak (Event)	Event	E07.81	E08.31	216	. See section 3.4
H91	Tail gating	State	S08.50	S08.20	-49	Considerable benefit from the controlled environment

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
						during the peak
H76	Rapid change of general vehicle speed	Event	E08.50	E08.16	-54	Considerable benefit from the controlled environment during the peak
H152	Vehicle recovered from ERA	Event		E08.00		MM introduced hazard
H149	Vehicle drifts off carriageway (i.e. leaving the carriageway as a result of road environment)	Event	E08.00	E08.00	0	Although traffic is travelling closer to the edge of the carriageway, most of this traffic will be during peak and will be subject to a controlled environment
H52	Maintenance workers setting up and taking down work site	State	S08.00	S08.00	0	Although there is benefit from the controlled environment (setting of signals during set-up and taking-down), the number of times TM is used is expected to increase
H89	Sudden weaving at exit point	Event	E08.00	E07.93	-15	Some benefit from controlled environment
H54	Motorcycles filter through traffic	Event	E08.00	E07.91	-19	Benefit from controlled environment. Smoother traffic travelling at higher speeds - less need to filter through
H13	Driver loses control of vehicle	Event	E08.00	E07.90	-21	Some benefit from controlled environment
H120	Vehicle rejoins running lane	Event	E08.00	E07.90	-21	Non-emergency stops are effectively eliminated and most remaining stops will be in refuge areas
H121	Vehicle reversing	Event	E08.00	E07.90	-21	Some benefit from controlled environment

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
	along exit slip					
H103	Unsafe lane changing	Event	E08.00	E07.83	-33	Some benefit from controlled environment
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08.00	E07.80	-37	More prominent signals can be used to reduce this risk
H112	Vehicle enters main carriageway unsafely	Event	E08.00	E07.80	-37	Some benefit from controlled environment based upon optimum provision as outlined through an overrun assessment
H95	TO/ISUO in running lane	Event	E08.00	E07.60	-60	Considerable benefit from the controlled environment and the use of rolling road-blocks
H154	Vehicle stopped on hard shoulder (D3M) or verge (MM-ALR)	State	S08.00	S06.50	-97	Effectively eliminated. Non emergency stops are reduced and most remaining stops will be in refuge areas

Table 5-1: Change in risk score for higher risk hazards

5.2 Medium scoring hazards

A table of medium scoring hazards (E07.5/S07.5 and E07/S07) is presented in Appendix B. These represent about 10% of the baseline risk.

5.3 Hazards related to specific populations

In addition to considering the impact of the scheme on the safety of all road users, the initial hazard log work has considered the safety impact of the scheme for the following specific user groups:

User

- Pedestrians
- Motorcyclists
- HGV drivers
- Disabled drivers or passengers
- Private recovery organisations
- Emergency services

Worker

- On road resources (ORR)
- Maintenance workers

5.3.1 Pedestrians

The pedestrian related hazards are listed in Table 5-2 below in descending after safety risk score.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H67	Pedestrian in running lane - live traffic	Event	E08.50	E08.50	0	Benefit from the controlled environment. However more instances due to increase in live lane breakdowns
H69	Pedestrians in a running lane - stationary-slow moving traffic	State	S07.50	S07.40	-21	Benefit from the controlled environment
H147	Pedestrians walking in lane 1 (applies to MM-ALR only)	State		S07.00		MM introduced hazard
H68	Pedestrian on slip road	State	S07.00	S07.00	0	No change expected
H48	Legal-illegal pedestrian(s) in path of vehicles in ERA	Event		E06.50		MM introduced hazard
H74	Person on off-side	State		S06.5		MM introduced

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
	of vehicle in ERA					hazard
H146	Pedestrians walking along the hard shoulder (applies to D3M only)	State	S06.50	S00.00	Eliminated	Eliminated. No hard shoulder under MM-ALR

Table 5-2: Change in risk score for pedestrian related hazards

The risk from the highest scoring hazard ‘H67 - Pedestrian in running lane - live traffic’ (E08.5) is expected to remain the same. For MM-ALR more vehicle breakdowns (and consequently also more pedestrians) are expected to occur in live lanes. However, there will be increased monitoring to detect vehicles stopped in a live lane and MIDAS will be available to protect a stopped vehicle, if a queue develops, which will provide significant benefit during congested periods. In addition, lane signals and VMS signs can be used to protect a vehicle stopped in a running lane and any pedestrians in the vicinity of that vehicle.

The second highest scoring hazard (H69, S07.5), which reduces in risk under MM-ALR, is an order of magnitude greater in risk than the new hazards introduced with MM-ALR (H147, S07.0; H48, E06.5; H74, S06.5). One hazard (H146, S06.5) is eliminated with the implementation of MM-ALR. The significant reduction in risk to hazard H69 is likely to dominate the total risk for pedestrians. It can be concluded that the safety objective is likely be met for pedestrians for MM-ALR schemes.

5.3.2 Motorcyclists

The motorcyclist related hazards are listed in Table 5-3 below in descending after safety risk score.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H54	Motorcycles filter through traffic	Event	E08.00	E07.91	-19	Benefit from controlled environment. Smoother traffic travelling at higher speeds - less need to filter through
H58	Motorcyclist cross wind buffering	State	S06.50	S06.50	0	Running of MM-ALR will not create a change in the risk associated with this hazard.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H59	Motorcyclist falls off crossing line on entry to ERA	Event		E06.50		MM introduced hazard
H145	Motorcyclists crosses rumble strips	Event	E05.50	E05.50	0	Running of MM-ALR will not create a change in the risk associated with this hazard
H143	Motorcycle stopped next to running lanes (D3M = hard shoulder, MM-ALR = verge)	State	S07.00	S05.50	-97	Non emergency stops are effectively eliminated as there is no hard shoulder to stop on under MM-ALR. Most remaining stops will be in refuge areas. Only some stops may occur in verge under MM-ALR.
H144	Motorcycle uses hard shoulder to pass slow moving or stationary traffic	State	S06.00	S00.00	Eliminated	Eliminated. No hard shoulder under MM-ALR

Table 5-3: Change in risk score for motorcyclist related hazards

The highest risk hazard affected by MM-ALR is 'H54 - Motorcycles filter through traffic' and the risk for this is expected to reduce. This is because MM-ALR will introduce a smoother regulated flow of traffic, reducing the need for motorcyclists to filter through traffic.

With the score for this hazard over an order of magnitude greater in risk than the new hazard introduced with MM-ALR (H59, E06.5), the significant reduction in risk to hazard H54 is likely to dominate the total risk for motorcyclists. It can be concluded that the safety objective is likely to be met for motorcyclists for MM-ALR schemes.

5.3.3 HGV drivers

The HGV driver related hazards are listed in Table 5-4 below in descending 'after' safety risk score.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H141	HGV-LGV-Bus exits ERA	Event		E07.50		MM introduced hazard
H142	Large vehicle does	State	S04.50	S04.20	-50	Hard shoulder will

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
	not completely clear the running lane when stopping on hard shoulder (D3M) or verge (MM-ALR)					become a permanent full time running lane, reducing the occurrences of HGVs stopping, as only verge will be available, and only in some locations.

Table 5-4: Change in risk score for HGV driver related hazards

The highest risk new hazard affecting large vehicles is 'H141 - HGV-LGV-Bus exits ERA' which is scored as an E07.50. Larger vehicles will find it harder to exit from an ERA during ALR due to their slow acceleration. However monitoring on the M42 MM scheme has identified no significant problems with large vehicles leaving ERAs. In addition there are established procedures to assist vehicles to exit from ERAs. Mitigation measures have been identified to reduce this risk.

HGV drivers are a subset of all users and therefore will benefit from the overall risk reduction in existing motorway hazards. The new hazard is not considered to significantly increase the overall risk associated with HGVs; the risk is expected to decrease as a result of the improvement in hazards relating to all vehicle types.

As it can be demonstrated that the safety objective for all vehicles is likely to be met (see chapter 4) it is likely that the safety objective for HGVs and other large vehicles can also be met.

5.3.4 On road resources (ORR)

The ORR) related hazards are listed in Table 5-5 below in descending after safety risk score.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08.00	E07.80	-37	More robust and more frequent signalling: controlled environment perception for motorists; but more live lane breakdowns.
H95	TO/ISUO in running lane	Event	E08.00	E07.60	-60	More robust and more frequent signalling to protect TO/ISUO
H62	On-road resources work	State	S07.50	S07.40	-21	More robust and more frequent signalling to

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
	unprotected					protect ORR
H94	TO arrives, but has difficulty containing the scene	Event	E07.00	E06.90	-21	More robust and more frequent signalling to protect TO/ISUO
H96	TOs behave hazardously at an incident	Event	E06.50	E06.50	0	No change expected
H34	Incident management - rolling block	Event	E06.00	E06.50	216	Lack of hard shoulder for stoppages from which to commence incident management means rolling road block will be required more often under MM-ALR
H22	Emergency staff - TO etc on foot at scene of an incident	State	S06.00	S06.00	0	Expect more live lane breakdowns. Better protection of each incident
H101	Unable to set signs and signals to protect incidents	State	S06.00	S06.00	0	ORR do not rely wholly on signs and signals for protection
H83	Signals change while TO/ emergency services are still on motorway	Event	E06.00	E05.90	-21	CCTV available for operators to check whether there is still attendance at incident
H66	Operator fails to set signals to protect incident in timely manner	State	S05.50	S05.40	-21	CCTV for operators to confirm incident location
H84	Signals set in wrong place (i.e. are not protecting the incident)	State	S04.00	S03.9	-21	CCTV for operators to confirm incident location
H82	Short duration stops / debris removal by TO /	State	S07.00	S00.00	Eliminated	As for H34, rolling road block required in all circumstances.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
	maintenance workers					Therefore, this hazard is eliminated.

Table 5-5: Change in risk score for on road resources related hazards

The hazard log, in representing hazards to road users and workers does not identify all the risks the ORR is exposed to in undertaking their roles and duties. (It is not the intent of the hazard log to identify task related risks). The traffic officer service (TOS) are finalising the development of detailed working procedures for operating MM-ALR that have been based on the experience of operating existing sections of motorway and APTR with ALR. These procedures seek to reduce the risks to the TOS to be as low as reasonably practicable. It is noted that the TO (and all ORR) are not reliant on the setting of signs and signals (in response to an incident) to close a lane and to establish a safe place to work. The TOS (and all ORR) will secure the scene of the incident by the positioning of TO vehicles and the establishment of emergency traffic management (ETM).

MM-ALR is expected to reduce the risk for ORR for the highest risk hazards 'H95 - TO/ISUO in running lane' (E08) and 'H11 Driver ignores closed lane(s) signals that are protecting an incident' (E08) through a more controlled environment and the use of mandatory signals. In addition there is expected to be also a small benefit if vehicles utilise ERAs. 'H62 - On road resources work unprotected' (S07.5) is also expected to improve as mandatory signals and message signs can be used to protect ORR and inform motorists of their presence. Short duration stops and debris removal by TO/maintenance workers (H82) is eliminated under MM-ALR. This work, as well as other work, will now require a rolling road block, which is why the risk of hazard H34 is expected to increase.

As noted above work has also be carried out in assessing risk in relation to TOS procedures, finalisation of this work is at an advanced stage and indications are that the risk to this worker group can be managed SFAIRP. Activities undertaken by the NVRM are covered in chapter 5.3.7 which concludes that the risk to this group can also be managed SFAIRP.

5.3.5 Maintenance workers

The maintenance workers related hazards are listed in Table 5-6 below in descending after safety risk score. The scores presented in Table 5-6 that are classed as 'high scoring' hazards (as per section 5.1) were considered at the hazard log scoring verification workshop that took place on 1st February 2012. These were subsequently reviewed at a further 'maintenance hazards only' workshop which took place on 29th February 2012.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H52	Maintenance workers setting	State	S08.00	S08.00	0	Benefit from the controlled environment

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
	up and taking down work site					(setting of signals during set-up and taking-down), but number of times TM is used is expected to increase.
H79	Roadworks - long term static	State	S07.50	S07.50	0	No change in risk
H80	Roadworks - short term static	State	S06.50	S06.80	99	Increase in equipment contributes to increased number of activities.
H51	Maintenance workers in carriageway	Event	E06.00	E06.00	0	No change in risk
H136	Collision with workers doing maintenance on verge	State	S06.50	S00.00	Eliminated	Eliminated. This will not occur without TM and rolling road block
H148	Roadworks - short term static on hard shoulder	State	S07.50	S00.00	Eliminated	No hard shoulder under MM-ALR. Therefore hazard is eliminated
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07.00	S00.00	Eliminated	Eliminated. This will not occur without TM and rolling road block

Table 5-6: Change in risk score for hazards realting to maintenance workers

One of the highest risk hazards ‘H52 - Maintenance workers setting up and taking down work site’ (S08.0) is expected to be no worse compared to the baseline. Likewise, hazard ‘H79 - Roadworks - long term static’ (S07.5) is expected not to change with the implementation of MM-ALR.

Hazard ‘H80 - Roadworks – short term static’ (S06.5) is expected to increase, due to the lack of a hard shoulder from which to commence short term roadworks. Therefore, maintenance activities that were grouped under hazard ‘H148 - Roadworks - short term static on hard shoulder’ are now included under H80.

‘H82 - Short duration stops / debris removal by TO / maintenance workers’ (S07.0) is eliminated, due to the running of all lanes under MM-ALR. Short term stops are not possible, as there is no hard shoulder to stop on, from which to collect debris etc. This risk transfers to 'H34 - Incident management – rolling block'.

From the above initial hazard analysis it can be concluded that the safety objective is likely to be achieved and that the risk is managed SFAIRP. This is a significant change from the position of IAN 161/12 which stated it 'cannot be concluded that the safety objective is likely to be achieved or that the risk is managed SFAIRP'. This change in stance is a result of changes to key assumptions now used within the analysis following further work which has been completed since the publication of IAN 161/12. This work has focussed on mitigating and managing the following key maintenance hazards:

- H52 Maintenance workers setting up and taking down work site
- H80 Roadworks - short term static

These hazards were chosen as they are the ones that are likely to be most influenced by the implementation of MM-ALR and are two of the three highest scoring maintenance related hazards. The main drivers behind the risk relating to these hazards are:

- An increase in frequency of maintenance activities
- The risk associated with setting up and taking down work sites (method and exposure), in particular without a hard shoulder

Mitigation measures to manage the above since the publication of IAN 161/12 have been further assessed. The following section provides a synopsis of the resultant changes/new assumptions following this work, along with additional work which is ongoing to further reduce the risk to road workers (maintainers). It is split into two sections:

- Mandatory – mitigation measures which must be implemented as standard within scheme designs to help ensure the safety objective is met. There is strong evidence to show that the implementation of these mitigation measures will provide tangible benefits to road workers (maintainers).
- Future development – work currently being undertaken by the Highways Agency which should provide further safety benefits (achievement of the road worker safety objective was not dependent upon AfZ).

Mandatory:

The items below are mitigation measures which have been progressed since the publication of IAN161/12, the revised analysis for road workers (maintainers) assumes that these are provided as standard within the design.

1. Rigid concrete barrier (RCB): IAN 161/13 mandates the use of the RCB, unless the road worker safety objective can be met by alternative mitigations. RCB provides numerous benefits, the key one for road workers (maintainers) is the elimination of central reserve steel barrier repairs which are 'category 1' defects that would result in

the need for urgent short-term roadworks (reactive maintenance) and biennial tensioning. This has a direct impact on mitigate hazards H80 and H52 (taking account of minimal maintenance interventions required for RCB).

Road user safety benefits including elimination of cross over accidents can also be realised through the installation of RCB.

2. Remote access to technology equipment: This is being delivered by the Highways Agency at a programme level and is outside of schemes control. This work is being delivered in two phases. Phase 1 will provide remote access to road side controllers that control signs (VMS) and signals through a dedicated PC located within each of the seven RCCs. This phase was completed in spring 2013. Phase 2 will provide access through secure connections accessed by any PC at any location and will extend remote access to other technology equipment e.g. CCTV / MIDAS. This is scheduled for completion by the end of 2015.

   Maintainers cannot visit the roadside to undertake short duration stops to diagnose issues through the interrogation of the roadside controllers without the need for traffic management. Remote access will mitigate this by allowing the remote diagnosis of faults and remote resets. This will reduce the number of maintenance interventions required, hence helping to mitigate hazards H80 and H52.

3. Rationalisation of maintenance interventions: Due to the requirement for traffic management to undertake almost all maintenance activities, maintainers will be required to rationalise all planned maintenance interventions. Unplanned maintenance interventions should be combined with planned works where suitable; the risk based approach mandated in the asset support contracts (ASC) will facilitate this objective. It should be noted that this will be rationalisation of activities over what is undertaken in the existing situation.

   The rationalisation of works will help to reduce the risks associated with setting up and taking down roadwork sites (H52) resulting in fewer instances of short term roadworks (H80), thus reducing the risk to road workers (maintainers).

4. Remote control traffic management signs and fixed taper points: Remote control traffic management signs should be used in conjunction with fixed taper points, in line with the draft Highways Agency guidance for temporary traffic management (TTM) deployment on MM-ALR schemes. This will help to mitigate hazard H52, by removing the need for road workers (maintainers) or their vehicles to be present in a live lane to install advance traffic management signs. This mitigation measure is anticipated to provide significant benefit, it aligns with Highways Agency AfZ objectives and therefore must be incorporated into MM-ALR schemes.

5. Implementation of mandatory 40mph speed limit while temporary traffic management is being established or removed.

Future developments:

Various AfZ projects are currently being undertaken with the aim of reducing the hazards faced by road workers (maintainers). These projects are not currently critical to the achievement of the road worker safety objective, however they are anticipated to provide significant benefits to road workers (maintainers). The following AfZ projects are deemed to be relevant to MM-ALR schemes:

- Elimination of all offside wicket signs for relaxed traffic management
- Use of high level vehicle mounted VMS signs to supplement the permanent VMS
- Reducing risk associated with use of impact protection vehicles
- Use of VMS/lane signals as temporary mandatory speed limit terminal and repeater signs removing need for fixed plate signs – inclusion of this project within the MM-ALR remit is being considered with the consideration that VMS/lane signals will show a speed restriction in addition to a wicket sign for MM-ALR in advance of road works
- Use of VMS to convey information – it is intended that the VMS in MM-ALR will sign TTM. A trial is underway on the M4 to test the effectiveness of using VMS to displaying TTM closures, rather than ground level plate signing. Discussions with the Department for Transport (DfT) may be required dependent upon the results of this testing.

In addition, the Highways Agency is also undertaking work to mitigate/manage risk to road workers (maintainers), through an assessment based on the 'ERIC' principle as described in figure 5-1.

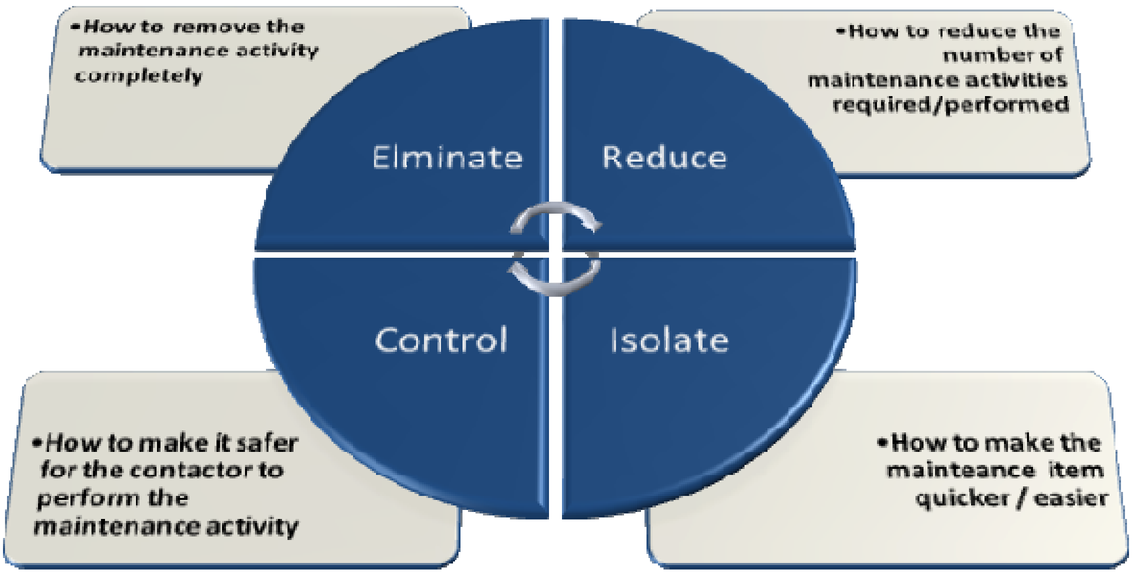

Figure 5-1: The principles of an 'ERIC' assessment

This principle looks at reducing the need for maintenance by considering what maintenance can be eliminated or reduced. A number of potential areas have already been identified e.g. RCB virtually eliminates reactive maintenance associated with barrier strikes; rationalisation of works reduces the number of maintenance interventions performed. The Highway Agency's MM-ALR Meeting the Road Worker Safety Objective Task and Finish group has undertaken further review of an ERIC assessment to reduce maintenance activities that reside at Highways Agency programme level. The following programme issues are being addressed:

- Removal of fog sensors – this would not seem viable due to their interdependency on associated equipment. A review of reported faults to identify poorly functioning equipment, though the benefits offered by fog detectors seems to be limited
- Increasing time to fix faults – analysis is on-going and will be taking account of a risk based approach to repair times, an update to technology management and maintenance manual (TMMM) [9] is an expected outcome of this task
- Review of cleaning requirements for technology
- Review of statutory electrical testing requirements and test periods for mechanical equipment

The work noted above, alongside AfZ projects is ongoing and is anticipated to provide further safety benefits upon completion.

The above projects primarily provide benefits to road workers (maintainers) by reducing the risk associated with hazards H52 and H80 as they aim to eliminate/reduce the need for a maintenance operative to work in a live lane. Mandatory speed restrictions on the approach to TTM are also expected to help control/reduce the severity of an incident should one occur.

Summary:

It can be concluded at this stage that the safety objective is likely to be achieved and that the risk is managed SFAIRP. There are indications that the hazards and risks identified can be either eliminated or mitigated so as to be as low as reasonably practicable resulting in the residual risk associated with the operations and maintenance of the MM-ALR layout being no more onerous than for a D3M layout.

5.3.6 Emergency services

The emergency services related hazards are listed in Table 5-7 below in descending 'after' safety risk score.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08.00	E07.80	-37	More robust and more frequent signalling: controlled environment perception for motorists; but more live lane breakdowns.
H87	Speed differential between emergency services and general traffic	Event	E06.50	E06.50	0	No change in risk
H34	Incident management - rolling block	Event	E06.00	E06.50	216	Lack of hard shoulder for stoppages from which to commence incident management means rolling road block will be required more often under MM-ALR
H22	Emergency staff - TO etc on foot at scene of an incident	State	S06.00	S06.00	0	Expect more live lane breakdowns. Better protection of each incident
H101	Unable to set signs and signals to protect incidents	State	S06.00	S06.00	0	Do not rely wholly on signs and signals for protection
H83	Signals change while TO/ emergency services are still on motorway	Event	E06.00	E05.90	-21	CCTV available for operators to check whether there is still attendance at incident
H66	Operator fails to set signals to protect incident in timely manner	State	S05.50	S05.40	-21	CCTV to inform operators where exactly incident is, to improve signal setting time
H84	Signals set in wrong place (i.e. are not protecting the incident)	State	S04.00	S03.90	-21	CCTV for operators to confirm incident location

Table 5-7: Change in risk score for emergency services related hazards

For the highest risk hazard ‘H11 - Driver ignores closed lane(s) signals that are protecting an incident’ (E08.0) the risk is expected to decrease. It should be noted that although there is likely to be an increase in live lane breakdowns the emergency services are not reliant on the setting of signs and signals to close a lane to establish a safe place to work. The emergency services will secure the scene of the incident by the positioning of vehicles and the establishment of emergency traffic management (ETM).

Hazard 'H87 - Speed differential between emergency services and general traffic' is not expected to change with the introduction of MM-ALR.

The risk associated with hazard 'H34 - Incident management – rolling block' will increase due to the use of the hard shoulder as a running lane, therefore mandating the use of rolling road blocks to deal with debris / incidents etc.

The safety objective for emergency services is therefore likely to be achieved.

5.3.7 Private recovery organisations

The hazard log does not contain a specific set of hazards for breakdown services and recovery operators. Therefore the change in risk from the implementation of MM-ALR cannot be assessed on the same hazard by hazard basis as the individual user groups covered in the previous sections. However, when driving on the motorway recovery operators benefit from the same reduction in safety risk as all road users. When at the scene of an incident they benefit from the same reduction in risk as ORRs and emergency services. In addition, the main hazards affecting breakdown services and recovery operators are hazards relating to working on broken down vehicles on the hard shoulder or in ERAs. Safety for breakdown services and recovery operators is expected to remain unchanged or possibly improve slightly as work can be undertaken in ERAs, which offer better protection than the hard shoulder as would be used on D3M schemes. Monitoring on the M42 MM scheme has shown that exiting ERAs can be done safely.

In relation to work being carried out by the NVRM and the statutory removal of vehicles from live lanes, this will only be undertaken behind the protection of ETM or TO/emergency services vehicles and so the risk can be managed SFAIRP.

In addition, for work taking place on the main carriageway, protection is increased through the use of mandatory signs and VMS with pictograms.

It is considered that the safety objective is likely to be achieved for breakdown services and recovery operators.

5.3.8 Disabled drivers or passengers

The hazard log does not contain a specific set of hazards for disabled drivers or passengers as they are covered by hazards covering all users. Therefore, the change in risk from the implementation of MM-ALR cannot be assessed on the same hazard by hazard basis as the individual user groups covered in the previous sections. However, a qualitative review has been undertaken of the change in risk for disabled drivers or passengers.

The main hazards affecting disabled drivers or passengers are generic existing motorway hazards affecting all drivers.

The situations that are likely to affect disabled persons differently from other road users are those in which their vehicle breaks down or is involved in a minor incident. Whereas able-bodied occupants may leave their vehicles and seek a place of refuge (e.g. beyond the safety barrier), a disabled occupant may find it difficult to leave the vehicle.

Compared with the baseline, there are several reasons why a disabled occupant is likely to be better off under MM-ALR if their vehicle breaks down. These are:

- Better ability to protect the vehicle through the setting of message signs and signals
- The RCC operator is better able to observe what is happening and send a TO patrol to provide assistance
- In many cases, it will be possible to move the vehicle (either by the driver, or using the TO patrol vehicle to move it) to the nearest place of refuge

Overall the safety objective is likely to be achieved for disabled drivers or passengers.

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6 Conclusions and recommendations

6.1 Demonstration of meeting safety objective for all users

With regard to the safety objective for all users this report demonstrates that MM-ALR schemes are likely to meet the safety objective and takes account of:

- A reduction in risk for a significant number (14) of the highest scoring existing motorway hazards (19), due to a controlled environment being provided through a combination of regularly spaced mandatory speed signals, speed enforcement, and full CCTV coverage
- One highest scoring (i.e. E08/S08 and above) new MM hazard is introduced, hazard 'H152 - Vehicle recovered from emergency refuge area (ERA)' (E08)
- One high-scoring existing hazard increases in risk, hazard 'H135 - Vehicle stops in running lane – off peak' (increases from E07.81 to E08.31)
- The impact of the new highest scoring hazard and increase to one existing highest scoring hazard is expected to be countered by the decrease in risk of existing highest scoring hazards
- Calculations show that the total score for 'after' represents approximately a reduction of risk of 18% when compared with the safety baseline.

6.2 Demonstration of meeting safety objective for specific users

The qualitative risk comparison for specific road user groups presented in this report shows that MM-ALR reduces the risk of a number of existing hazards for these groups but also increases the risk of some hazards and introduces a number of new hazards. On balance it can be shown that for each of the following user groups considered in this report the safety objective is likely to be achieved.

Users

- Pedestrians
- Motorcyclists
- HGV drivers
- Disabled drivers or passengers
- Private recovery organisations
- Emergency services

Workers

- On road resources (ORR)
- Maintenance workers

With regard to maintenance workers, since the publication of IAN161/12, improvements have been identified leading to a reduction in the frequency of maintenance activities. Key measures include the implementation of RCB and remotely operated traffic management signs. Thus it can be demonstrated that the safety objective is likely to be achieved and the risk managed SFAIRP. Further work has also be carried out in assessing risk to ORR, especially in relation to TOS procedures and activities undertaken by the NVRM, finalisation of this work is at an advanced stage and indications are that the risk to this worker group can be managed SFAIRP.

Validation of the outcomes of the hazard assessment associated with MM-ALR will be monitored and validated upon the implementation of schemes.

7 References

[1]	Interim Advice Note 161/13, Managed motorways all lane running
[2]	Interim Advice Note 111/09, Managed Motorway implementation guidance – Hard shoulder running
[3]	Interim Advice Note 112/08, Managed Motorways Implementation Guidance – Through Junction Hard Shoulder Running
[4]	Interim Advice Note 139/11, Managed Motorways Project Safety Risk Work Instructions
[5]	M42 MM Monitoring and Evaluation, Three Year Safety Review, HCG, January 2011
[6]	All-Purpose Trunk Roads (APTR)/Dual 3-lane Motorway (D3M) Analysis and Hazard Assessment, 1039092/ATA/035
[7]	MM-ALR Generic Safety Report, 1039092/GSR/016
[8]	MM-ALR Provision of Adequate Guidance Review, 1039092/AGR/042
[9]	Technology management and maintenance manual (TMMM), January 2013
[10]	GD04/12 Standard for safety risk assessment on the strategic road network

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Appendix A: Glossary of terms and abbreviations

Acronym	Description
APTR	All purpose trunk road
ATM	Active traffic management
CCTV	Closed circuit television
CDM	Construction (Design & Management)
D3M	Dual 3-lane motorway
DMRB	Design Manual for Roads and Bridges
ERA	Emergency refuge area
ERT	Emergency roadside telephone
FWI	Fatal and weighted injury
HGV	Heavy goods vehicle
HSR	Hard shoulder running
KSI	Killed, seriously injured
LGV	Large goods vehicle
LBS	Lane below signal
MIDAS	Motorway incident detection and automatic signalling
MM	Managed motorways
MM-ALR	Managed motorways all lane running
MM-HSR	Managed motorways – hard shoulder running
MSA	Motorway service area
NetServ	Highways Agency, Network Services Directorate
ORR	On road resource
PCF	Project control framework
PIA	Personal injury accident
PSCRG	Project safety control review group
PTZ	Pan-tilt-zoom
RCB	Rigid concrete barrier
RCC	Regional control centre

Acronym	Description
SFAIRP	So far as is reasonably practicable
TJR	Through junction running
TOS	Traffic officer service
VMS	Variable message sign
VMSL	Variable mandatory speed limit

Appendix B: Medium scoring hazards

Further to Table 5-1, the table below contains the medium scoring hazards (E07.5/S07.5 and E07/S07). The hazards scoring E07/S07 and above represent 99% of the existing scheme risk. When reviewing the table 'percentage (%) change in safety risk':

- '0' means no change in risk
- 'Green' means a reduction in risk
- 'Red' means an increase in risk

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H141	HGV-LGV-Bus exits ERA	Event		E07.50		MM introduced hazard
H79	Roadworks - long term static	State	S07.50	S07.50	0	No change expected
H113	Vehicle exits ERA	Event		E07.50		MM introduced hazard
H110	Vehicle drifts out of lane	Event	E07.50	E07.43	-15	More lanes available for motorists and better controlled environment, decreasing the likelihood of hazard
H62	On-road resources work unprotected	State	S07.50	S07.40	-21	More robust and more frequent signalling to protect ORR
H69	Pedestrians in a running lane - stationary-slow moving traffic	State	S07.50	S07.40	-21	Benefit from the controlled environment
H137	Debris in running lane (being hit or causing unsafe manoeuvre)	State	S07.50	S07.23	-47	More lanes, so evasive action will be easier

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H147	Pedestrians walking in lane 1 (applies to MM-ALR only)	State		S07.00		MM introduced hazard
H116	Vehicle misjudges entry to ERA	Event		E07.00		MM introduced hazard
H126	Vehicle stopped on slip road (off or on slip)	Event	E07.00	E07.10	26	As there is no hard shoulder under MM-ALR, it is possible that a vehicle may limp to the slip road and then stop
H122	Vehicle reversing back to exit slip	Event	E07.00	E07.06	15	An increase in risk off-peak as all lanes are running lanes under MM-ALR
H32	Health deterioration of vehicle occupant	Event	E07.00	E07.05	13	Potential increase in risk as more live lane stops as a result of health deterioration of vehicle occupant
H42	Lane(s) closed, but driver unable to leave lane and stops	Event	E07.00	E07.00	0	No change expected
H68	Pedestrian on slip road	State	S07.00	S07.00	0	No change expected
H150	Vehicle in ERA (or verge) obtrudes into lane 1 (applies only to MM-ALR)	State		S07.00		MM introduced hazard
H131	Vehicle suddenly decelerates at end of on slip road	Event	E07.00	E07.00	0	No change expected

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H36	Incidents or congestion caused in other lanes or carriageway due to rubber necking	State	S07.00	S06.90	-21	Some benefit from controlled environment
H94	TO arrives, but has difficulty containing the scene	Event	E07.00	E06.90	-21	More robust and more frequent signalling to protect TO/ISUO
H123	Vehicle reversing up entry slip	Event	E07.00	E06.90	-21	Less congestion expected under MM-ALR, so less need for motorists to reverse back up entry slip.
H104	Unsafe lane changing in the slip road (both off and on slips)	Event	E07.00	E06.86	-28	Good lane discipline with controlled environment and less congestion.
H2	Abnormal loads - notifiable	Event	E07.00	E06.80	-37	Better signalling to advise motorists of the presence of abnormal loads
H77	Reduced visibility due to weather conditions	State	S07.00	S06.80	-37	Signals can be set to warn/inform motorists and will be more visible

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H99	TOs/emergency services not despatched in a timely manner	Event	E07.00	E06.80	-37	CCTV to inform operators where exactly incident is, to improve despatch time
H102	Undertaking	Event	E07.00	E06.80	-37	More lanes available, so less need for undertaking. During peak times smoother and more even traffic flows reduce need for undertaking.
H80	Roadworks - short term static	State	S06.50	S06.80	99	Increase in equipment contributes to increased number of activities.
H118	Vehicle on the main carriageway decelerates suddenly	Event	E07.00	E06.70	-50	Benefit from controlled environment; signals can be set automatically in response to queues (one of the main reasons why a vehicle might need to decelerate suddenly)
H30	Group of vehicles drive too fast (in relation to variable speed limit or national speed limit)	State	S07.00	S06.70	-50	Benefit from controlled environment

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H143	Motorcycle stopped next to running lanes (D3M = hard shoulder, MM-ALR = verge)	State	S07.00	S05.50	-97	Non emergency stops are effectively eliminated as there is no hard shoulder to stop on under MM-ALR. Most remaining stops will be in refuge areas. Only some stops may occur in verge under MM-ALR.
H148	Roadworks - short term static on hard shoulder	State	S07.50	S00.00	Eliminated	No hard shoulder under MM-ALR Therefore hazard is eliminated
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07.00	S00.00	Eliminated	Eliminated. This will not occur without TM and rolling road block
H153	Vehicle reversing up hard shoulder (D3M) or lane 1 (MM-ALR)	Event	E07.00	E05.50	-97	Effectively eliminated, as hard shoulder does not exist for MM-ALR – very undesirable to reverse up a live lane.

Table B-1: Change in risk score for medium scoring hazards

Appendix C: Risk assessment methodology

The risk assessment methodology is based on deriving safety risk scores for each hazard by adding together individual parameters.

Hazards are categorised as either an ‘Event’ or a ‘State’.

An Event (E) is a hazard which occurs momentarily, e.g. a vehicle carries out a high-risk lane change. Usually it is not meaningful to talk of how long such a hazard exists for. It is more relevant to understand how often this event occurs.

A State (S) hazard is one which is present for a period of time e.g. vehicle stopped on hard shoulder – the longer it is present, the greater the risk. Such hazards will have a measurable duration and can persist for long periods. Therefore it is important to understand how long the state exists (as well as how often it occurs).

Event hazard risk scores are evaluated by adding together a score for each of the following three factors:

- The rate at which the hazard is expected to occur
- The probability that the hazard causes an incident
- The severity of the incident

State hazard risk scores are evaluated by adding together a score for each of the following three factors:

- The likelihood that the hazardous state is present
- The rate at which incidents occur if the hazardous state is present
- The severity of the incident, which is the same as for event hazards

Therefore, risk scores for both Event and State hazards consist of three parameters as shown in Figure C-1 below. The individual scores for the three parameters are then added together to give an overall risk score for that hazard. However, the risk ‘score’ is based on a logarithmic scale, which is explained in more detail below.

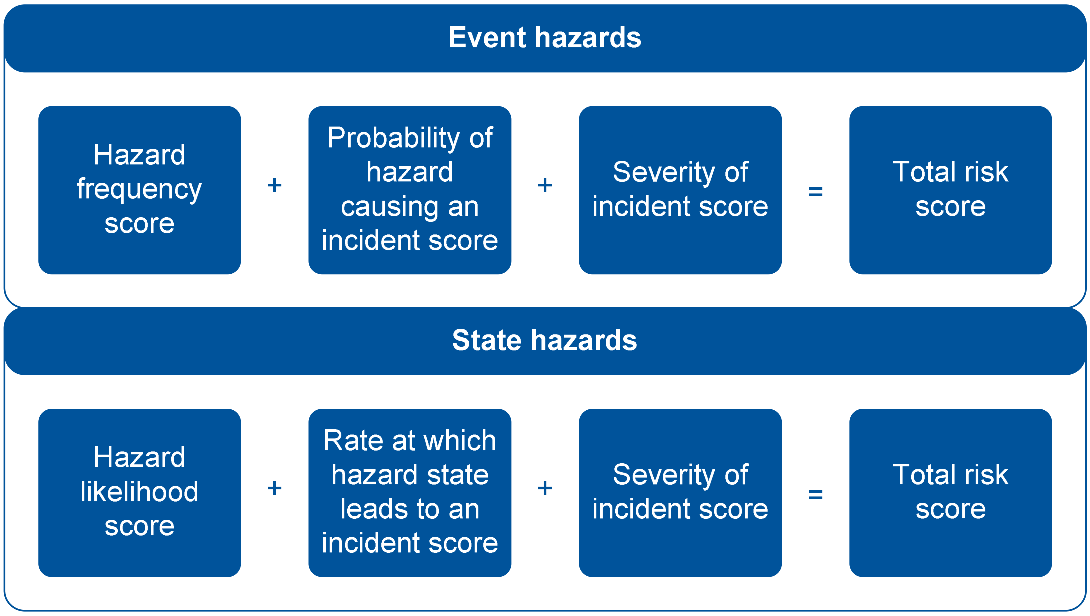

Figure C-1: Risk score components

C.1 Index values used for event frequency and state likelihood

The values that are actually entered into the hazard log database for these parameters are known as 'Index Values'. These can be explained by looking at the frequency and likelihood parameters.

Event Frequency

The index values used for an Event frequency are shown in Table C-1.

Frequency Classification	Nominal Value: Occurrences/year/mile	Index Value
Very frequent	1000	6.0
	316	5.5
Frequent	100	5.0
	31.6	4.5
Probable	10	4.0
	3.16	3.5
Occasional	1	3.0
	0.316	2.5
Remote	0.1	2.0
	0.0316	1.5
Improbable	0.01	1.0
	0.00316	0.5
Incredible	0.001	0.0

Table C-1: Frequency classifications and index values

So if a State hazard is expected to occur 100 times a year on a mile of motorway (of the scheme), the value that is entered in the database is 5.0. However, if it occurs 10 times a year an index value of 4.0 is entered.

This 'logarithmic' scale of scoring is used to cover the necessary range of values and then present them in a manageable form. An increase of 1 in a score therefore represents a factor of 10 increase in the risk.

Therefore if an Event hazard has the following index values for each of its parameters;

- Frequency index value = 5.0,
- Probability index value =1.0
- Severity index value = 1.0

Its overall score is E07.00

State Likelihood

The index values used for State hazard likelihoods are shown in Table C-2.

Likelihood Classification	Interpretation	Index Value
Very frequent	At least 1 occurrence present at any one time per Motorway mile.	6.0
	Present 115 days per year per Motorway mile	5.5
Frequent	Present 36.5 days per year per Motorway mile	5.0
	Present 11.5 days per year per Motorway mile	4.5
Probable	Present 3.65 days per year per Motorway mile	4.0
	Present 1.15 days per year per Motorway mile	3.5
Occasional	Present 9 hours per year per Motorway mile	3.0
	Present 3 hours per year per Motorway mile	2.5
Remote	Present 50 minutes per year per Motorway mile	2.0
	Present 15 minutes per year per Motorway mile	1.5
Improbable	Present 5 minutes per year per Motorway mile	1.0
	Present 90 seconds per year per Motorway mile	0.5
Incredible	Present 30 seconds per year per Motorway mile	0.0

Table C-2: Likelihood classification of State hazards and index values

So if an Event hazard is expected to be present 9 hours per year on a mile of motorway (of the scheme), the value that is entered in the database is 3.0. However, if it occurs 11.5 days per year, an index value of 5.0 is entered.

If a State hazard has the following index values for each of its parameters;

- Likelihood index value = 4.0
- Rate index value = 1.0
- Severity index value = 2.0

Its overall score is S07.00

The index values used for the other parameter are defined in the following subsections.

C.2 Index values used for event probability and state rate

The values used for Event probability and State rate are presented in Table C-3.

Probability that an Event/State causes collisions			
Classification	Events	Value	States
	If this hazard occurs then:		This hazard, if present, will:
Certain	A collision is certain	4	Definitely causes a collision
Probable	A collision is probable	3	Frequently causes a collision
Occasional	A collision will occasionally happen	2	Occasionally causes a collision
Remote	There is a remote chance of a collision	1	Infrequently causes a collision
Improbable	A collision is improbable	0	Rarely causes a collision

Table C-3: Event/State collision probability rates

C.3 Index values used for severity

The values used for severity for both Event and State hazards are presented in the Table C-4

Severity Classification	Interpretation	Index Value	Person outside of vehicle	Stationary Vehicle	Motorcycle	Car	Large Vehicle (LHV, HGV, Bus)
Severe	The proportion of collisions that are fatal is expected to be higher than average by at least a factor of 10	2.0	Involved	Involved	Involved	Speed differential approx 60 mph	Speed differential approx 50 mph
Higher than average	The proportion of fatal collisions is expected to be higher than average by a factor between 3 and 10	1.5	No involvement	No involvement	No involvement	Speed differential approx 50 mph	Speed differential approx 40 mph
Average	The distribution of collisions (i.e. ratio of damage-only to fatal) is expected to be similar to the highway average	1.0	No involvement	No involvement	No involvement	Speed differential approx 40 mph	Speed differential approx 30 mph
Lower than average	The proportion of fatal collisions is expected to be lower than average by a factor between 3 and 10	0.5	No involvement	No involvement	No involvement	Speed differential approx 30 mph	Speed differential approx 20 mph
Minor	The proportion of collisions that are fatal is expected to be lower than average by at least a factor of 10	0.0	No involvement	No involvement	No involvement	Speed differential < 20 mph	Speed differential < 10 mph

Table C-4: Event/State Collision Severity rates

C.4 Index values used for 'after' scoring values

Hazard 'after' scores identify a variance in risk from the original 'before' score for the 'steady state' (operation) of the managed motorway scheme.

Increase in risk

No change

Decrease in risk

After scoring values	
Value	**% (+/-)**
+0.5	216% increase in risk (tripling of risk)
+0.4	150% increase in risk
+0.3	100% increase in risk (doubling of risk)
+0.2	60% increase in risk
+0.1	25% increase in risk
0.0	No change in risk
-0.1	20% decrease in risk
-0.2	35% decrease in risk
-0.3	50% decrease in risk (risk halved)
-0.4	60% decrease in risk
-0.5	70% decrease in risk

Table C-5: 'After' scoring index values

Appendix D: Controlled environment

Introduction

Operation of a high speed road in a way that supports reliable journeys, through the effective management of congestion and planned / unplanned incidents, in a safe and sustainable manner depends primarily on appropriate driver behaviour. This behaviour can be achieved through the implementation of an intuitive network of roadside signs and signals along with enforcement measures that in combination create a ‘controlled environment’ (a toolkit of mitigations and provisions). This paper seeks to define what constitutes a controlled environment and considers what influences the behaviours that achieve successful outcomes.

Outcomes

Key objectives of the Highways Agency are to achieve safe roads, reliable journeys and informed travellers. There are three fundamental outcomes that define and enable measurable evaluation of the success of managed motorways:

- Compliant Driver Behaviour
- Journey Time Reliability
- Maintenance of Safety

To demonstrate success, the outcomes required or anticipated from a scheme must be identified. The causes of the behaviours can then be considered together with effective means of achieving these; through mitigation measures and other provisions. These measures and provisions together constitute the ‘controlled environment’.

A ‘controlled environment’

Driver information is provided through the effective operation of appropriate infrastructure and technology. A controlled environment provides the driver (road user) with the right (i.e. relevant, timely and accurate) information, at the right location at the right time; thereby promoting appropriate and intuitive driver behaviour (through situational awareness)[1]. Road users will travel through a scheme in an environment where information is highly visible and they perceive that their behaviour is being monitored.

The change in driver behaviour

Accidents are generally associated with a number of common causation factors including speeding, weaving (injudicious lane changing), inappropriate headways (tailgating) and fatigue. Therefore it is essential that a scheme identifies the environment that result in the behaviour that can cause these accidents and introduces appropriate mitigation to reduce the level of risk of hazards being realised to an acceptable / manageable level. A relatively

[1] The controlled environment concept applies to any section of road 24/7 (i.e. in peak and off peak periods).

small number of hazards make up a significant proportion of the overall level of risk on a scheme[2]. The introduction of a controlled environment will influence the behaviour of road users, which will also provide benefits for road workers due to an improved level of compliant driver behaviour.

The controlled environment through effective operation of appropriate infrastructure and technology promotes compliance from a typical road user in response to:

- The threat / risk that non compliance will be 'captured' and result in financial penalty and implications on driving licence (e.g. points or ban / suspension).
- An intuitive response to education: drivers are taught and pass their driving test on the understanding that compliance with mandatory signs and signals is required. This is supported by a general cultural propensity to obey rules.
- Public perception - compliance is understood, by many, to be beneficial in terms of journey reliability, reduction in driver stress and a perception of 'fairness'. In general, drivers are not disadvantaged when compared to others using the same section of road at the same time.

The Managed Motorways Controlled Environment

The appropriate application of infrastructure and technology, coupled with appropriate operational regimes lead to the desired outcomes being achieved. The significant hazards are listed in Table E-1 along with the measures which impact upon them. The majority of significant hazards are mitigated by more than one measure. The key measures that make up a controlled environment are summarised as follows:

Operations:

- Appropriate information, provided at suitable intervals and visible to road users – 'right place, right time, right message'. This ensures drivers have limited opportunity to forget key information before being reminded of the required behaviour.
- Education and encouragement enable driver comprehension of the information and the reasons for its provision. This supports and encourages behavioural change.
- Enforcement - The perception that motorists will be prosecuted for non-compliance with the signs and signals on display.
- The ability of Regional Control Centres (RCC) to monitor the highway and implementation of Traffic Officer procedures can assist in developing driver 'confidence' on route availability.
- A high level of compliance can be achieved through the implementation of an appropriate signalling regime designed to meet the operational requirements. To achieve compliance only a relatively small percentage of drivers on a congested section of road need to obey the information displayed - following drivers are 'forced' to comply[3].

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[2] The 17 highest road user scoring hazards, excluding road worker hazards, make up 84% of the overall risk.

[3] A figure has not been defined within this paper as robust data and further analysis is yet to be completed.

Infrastructure:

- Advanced Direction Signs which are visible and display clear information ensure that motorists move into the correct lane at an appropriate time.
- The use of overhead gantries and cantilevers, at appropriate spacing, provides an environment that encourages the required behaviour.
- The provision of Emergency Refuge Areas (ERAs) and Emergency Roadside Telephones (ERTs) give motorists a place of refuge should they need to stop in an emergency.
- Fixed traffic enforcement signs provide a warning to motorists and encourage compliant driver behaviour.
- Lining and studs provide clear information so that drivers understand the status of the carriageway.

Technology:

- Displaying appropriate information for road users on Variable Message Signs (VMS) e.g.: lane closure information, appropriate mandatory speed limit and carriageway status. These signs are supported by a system of inductive loops which form part of the Motorway Incident Detection and Automated Signalling (MIDAS) system (queue protection) and the controlled motorway system which automatically sets speed limits in response to traffic conditions.
- Lane signalling on gantries which display appropriate (mandatory) speeds or lane closure information.
- The provision of enforcement cameras along with non-live cameras help to achieve compliance with displayed speed limits.
- A visible and comprehensive CCTV system, may also influence and modify behaviours. This monitoring capability enables reactive and efficient planned and un-planned incident management.

Maintaining the controlled environment

Evaluating the success of the M42 Managed Motorways Pilot has been an important element in developing an understanding of the constituent features of the controlled environment. The evidence from the M42 Pilot demonstrates a high level of driver compliance and suggests a high level of intuitive 'situational awareness'. The Pilot showed that, through the creation of a visible controlled environment, a substantial decrease in both the frequency and severity of accidents can be achieved.

With the provision of increasingly less technology and infrastructure on schemes, it will perhaps become more challenging to optimise and maintain the concept of a controlled environment.

Therefore it is important that the deployment of infrastructure and technology (not only at the road side but increasingly through the use of in-vehicle systems) continues to result in motorists who concentrate on the information provided as they react and behave as necessary through a section of the network. This will ensure that the provision of accurate, suitable and relevant information, together with the perceived threat of prosecution for non-compliance and the education and encouragement of drivers will enable managed motorway schemes to continue to achieve congestion and safety benefits.

	Measures to enable a Controlled Environment		
Hazard (Approximate % of overall scheme risk)	**Operational**	**Infrastructure**	**Technology**
Driver fatigued – unable to perceive hazards effectively (24%)	- Information displayed in timely manner - Appropriate signalling regime to meet operational requirements	- Lining and stud provision - Enhanced visual environment	- Signals on verge mounted VMS and overhead gantries
Individual vehicle is driven too fast (14%)	- Education – driver understanding of information - Encouragement – changing behaviour on the road - Suitable and relevant information - Information displayed in timely manner - Customer perception - Visibility of information - Perceived enforcement (surveillance / 'being watched') - Appropriate signalling regime to meet operational requirements	- Gantries - Cantilevers - Fixed plate enforcement signs - Enhanced visual environment	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras - Inductive loops (MIDAS)
Vehicle stops in running lane – (off peak in MM-ALR) (8%)	- Suitable and relevant information - Traffic Officer procedures and ability to monitor	- Additional lane (no hard shoulder) - Gantries - Fixed plate enforcement signs - ERAs with ERTs	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Inductive loops (MIDAS)
Pedestrian in running lane – live traffic (6%)	- Suitable and relevant information - Traffic Officer and RCC ability to monitor	- ERAs with ERTs	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV
Rapid change of general vehicle speed (4%)	- Education - driver understanding of information - Suitable and relevant information - Information displayed in timely manner - Visibility of information - Perceived enforcement	- Gantries - Cantilevers - Additional lane (no hard shoulder) - Fixed plate enforcement signs	- Signals on verge mounted - VMS and overhead gantries - Enforcement cameras - Inductive loops (MIDAS)

	Measures to enable a Controlled Environment		
Hazard (Approximate % of overall scheme risk)	**Operational**	**Infrastructure**	**Technology**
	(surveillance / 'being watched') - Traffic Officer procedures and RCC ability to monitor - Appropriate signalling regime to meet operational requirements		
Tailgating (4%)	- Education - driver understanding of information - Encouragement – changing behaviour on the road - Suitable and relevant information - Customer perception - Perceived enforcement (surveillance / 'being watched') - Appropriate signalling regime to meet operational requirements	- Additional lane (no hard shoulder) - Enhanced visual environment	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras - Inductive loops (MIDAS)
Vehicle stops in running lane - Peak (4%)	- Education - driver understanding of information - Encouragement – changing behaviour on the road - Suitable and relevant information - Information displayed in timely manner - Visibility of information - Appropriate signalling regime to meet operational requirements	- Gantries - Additional lane (no hard shoulder) - Fixed plate enforcement signs - Lining and stud provision - ERAs with ERTs	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Inductive loops (MIDAS)
Vehicle drifts off carriageway (2%)	- Encouragement – changing behaviour on the road - Suitable and relevant information - Information displayed in timely manner	- Gantries - Cantilevers - Lining and stud provision - Safety barriers - Enhanced visual environment	- Signals on verge mounted VMS and overhead gantries
Sudden weaving at exit point (2%)	- Suitable and relevant information - Information displayed in timely manner - Visibility of information - Appropriate signalling regime to meet operational requirements	- Advanced Direction Signs - Lining and stud provision	- Comprehensive CCTV - Inductive loops (MIDAS)

	Measures to enable a Controlled Environment		
Hazard (Approximate % of overall scheme risk)	**Operational**	**Infrastructure**	**Technology**
Motorcycles filter through traffic (2%)	- Education – driver understanding of information - Encouragement – changing behaviour on the road - Suitable and relevant information - Information displayed in timely manner - Perceived enforcement (surveillance / 'being watched')	- Gantries - Additional lane (no hard shoulder)	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras
Driver loses control of vehicle (2%)	- Education - driver understanding of information - Encouragement – changing behaviour on the road - Suitable and relevant information - Information displayed in timely manner - Visibility of information - Appropriate signalling regime to meet operational requirements	- Gantries - Additional lane (no hard shoulder) - Fixed plate enforcement signs - Lining and stud provision - Safety barriers - Enhanced visual environment	- Signals on verge mounted VMS and overhead gantries
Vehicle rejoins running lane (2%)	- Visibility of information - Appropriate signalling regime to meet operational requirements	- ERAs with ERTs - Additional lane (no hard shoulder)	- Signals on verge mounted VMS and overhead gantries
Vehicle reversing along exit slip (2%)	- Visibility of information - Perceived enforcement (surveillance / 'being watched')	- Fixed plate enforcement signs - Lining and stud provision	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras
Unsafe lane changing (2%)	- Education – driver understanding of information - Information displayed in timely manner - Customer perception - Perceived enforcement (surveillance / 'being watched') - Appropriate signalling regime to meet operational requirements	- Advanced Direction Signs - Additional lane (no hard shoulder) - Lining and stud provision	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras - Inductive loops (MIDAS)

	Measures to enable a Controlled Environment		
Hazard (Approximate % of overall scheme risk)	**Operational**	**Infrastructure**	**Technology**
Vehicle enters main carriageway unsafely (2%)	- Education – driver understanding of information - Suitable and relevant information - Visibility of information - Appropriate signalling regime to meet operational requirements	- Fixed plate enforcement signs - Lining and stud provision	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras
Driver ignores closed lane(s) signals that are protecting an incident (2%)	- Suitable and relevant information - Customer perception - Visibility of information - Appropriate signalling regime to meet operational requirements	- Gantries - Cantilevers - Fixed plate enforcement signs	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras
Vehicle recovered from ERA (2%)	- Traffic Officer procedures and RCC ability to monitor - Appropriate signalling regime to meet operational requirements	- ERAs with ERTs	- Comprehensive CCTV - Signals on verge mounted VMS and overhead gantries

Table E-1: Key hazards and mitigations

HIGHWAYS AGENCY
Safe roads, reliable journeys, informed travellers

Appendix E: Hazard log scoring verification workshops

The hazard scores presented in this report were verified at a workshop which took place on 1st February 2012 and attended by:

Andrew Alcorn, Highways Agency
Max Brown, Highways Agency
Martin Lynch, Highways Agency
Brian Barton, Highways Agency
Andrew Page-Dove, Highways Agency
Mike Wilson, Highways Agency
Alex Bywaters, Highways Agency
Lucy Wickham, Mouchel
Ryszard Gorell, Mouchel
Helen Parkyns, IBI Group
Adam Simpson, IBI Group
Sarah Garland, Highways Agency
Iain Candlish, WSP (CDM Co-ordinator)

A further workshop took place on 29th February 2012 to discuss progress on managing maintenance worker safety risk. This workshop was attended by:

Andrew Alcorn, Highways Agency
Martin Lynch, Highways Agency (in part)
Malcolm Wilkinson, Highways Agency
Alex Bywaters, Highways Agency
Gareth Tyler, IBI Group
Lucy Wickham, Mouchel
Ryszard Gorell, Mouchel

As part of this update to IAN161 and the associated safety documentation a hazard workshop took place on 18th March 2013, this was attended by:

Andrew Alcorn, Highways Agency
Andrew Page-Dove, Highways Agency
Iain Candlish, WSP (CDM Co-ordinator)
Tom Grahamslaw, Mouchel
Axel Kappeler, Mouchel

Adam Simpson, IBI Group
Alexis Pope, URS
Daniel Thomas-Keeping, Mouchel
Ian Canaway, Mouchel