HIGHWAYS AGENCY

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Managed Motorways – All Lanes Running

Demonstration of Meeting Safety Objective Report

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Reviewer List

Name	Role
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Approvals Sheet for Managed Motorways – All Lanes Running Demonstration of Meeting Safety Objective Report

Signature	For	Sign-Off Statement
Name: Lucy Wickham Date: 23/03/2012 Signature:	MM-ALR Project Consultant (Project Director)	I confirm that: • the scope and content of the attached deliverable are correct and compiled with reasonable skill and care • the attached deliverable complies with the requirements of the relevant Work Instructions for Project Safety Risk Management, in as far as is reasonably practicable.
Name: Max Brown Date: 23/03/2012 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.
Name: Andrew Page-Dove Date: 23/03/2012 Signature:	Network Delivery & Development (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: Andrew Page-Dove Date: 23/03/2012 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: Martin Lynch Date: 23/03/2012 Signature:	Network Services (Safe Roads & Casualty Reduction 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: 23/03/2012 Signature:	MM-ALR Senior Responsible Owner	I approve that in relation to project safety & the PCF: • 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 lanes running (MM-ALR).

A generic safety objective has been agreed for MM-ALR as defined in IAN 161 [1].

The objective of this document is to demonstrate that for MM-ALR the safety objective is 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 quantitative assessment of the risk from these hazards.

Conclusions

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

- A reduction in risk for a significant number (15) of the highest scoring existing motorway hazards (20), due to a controlled environment being provided through a combination of regularly spaced mandatory speed signals, speed enforcement, and comprehensive CCTV coverage
- One highest scoring new MM hazard is introduced (E08/S08 and above) is introduced (Vehicle recovered from Emergency Refuge Area (ERA))
- Three high-scoring existing hazards increase in risk
- The impact of the new hazards is expected to be countered by the decrease in risk of existing highest scoring hazards
- Anti-log calculations show that the total score for 'after' represents approximately a reduction of risk of 15% when compared with the safety baseline (no Motorway Incident Detection And Signalling (MIDAS)).

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 for these groups and introduces a number of new hazards. 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:

- Pedestrians,
- Motorcyclists,
- HGV Drivers
- On Road Resources (ORR),
- Emergency Services,
- Recovery Organisations, and
- Disabled drivers or passengers.

With regard to Maintenance Workers, improvements are required in the frequency and implementation of maintenance activities before it can be concluded that the safety objective is likely to be achieved or that the risk is managed SFAIRP. However 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 risks associated with the operations and maintenance of the MM-ALR layout being no more onerous than for a D3M layout.

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 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 and safety objectives.

A new design Managed Motorway – All Lanes Running (MM-ALR) [1] has been developed by the Highways Agency which will enable a reduction in the amount of infrastructure necessary for a managed motorway scheme, resulting in significant cost savings. Permanent conversion of the hard shoulder to a running lane along with the ability to dynamically control mandatory speed limits across all lanes is a key aspect of MM-ALR. This will remove the complex operating regime of opening and closing a dynamic hard shoulder.

1.2 MM-ALR key challenges

MM–ALR is as described in DMRB IAN 161 "Managed Motorway – All Lanes Running" [1]. The outline design for managed motorways 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.
c. Variable mandatory speed limits (VMSL)
d. Lane specific signalling only provided at the 'gateway signals and VMS' location and where necessary at intermediate locations. At all other signal locations, verge mounted carriageway signalling must be provided
e. Driver information, including mandatory speed limits, are provided at intervals not less than 600m and not exceeding 1500m.
f. Queue protection system
g. Comprehensive low-light pan-tilt-zoom (PTZ) CCTV coverage
h. Emergency roadside telephones (ERTs) are only provided in all dedicated refuge areas (except MSAs), e.g. ERAs, intra-junction (where Though Junction Running is not required and a suitable hard shoulder is present).
i. No non-essential infrastructure or technology.
j. The avoidance wherever practicable the positioning of infrastructure in the central reserve.

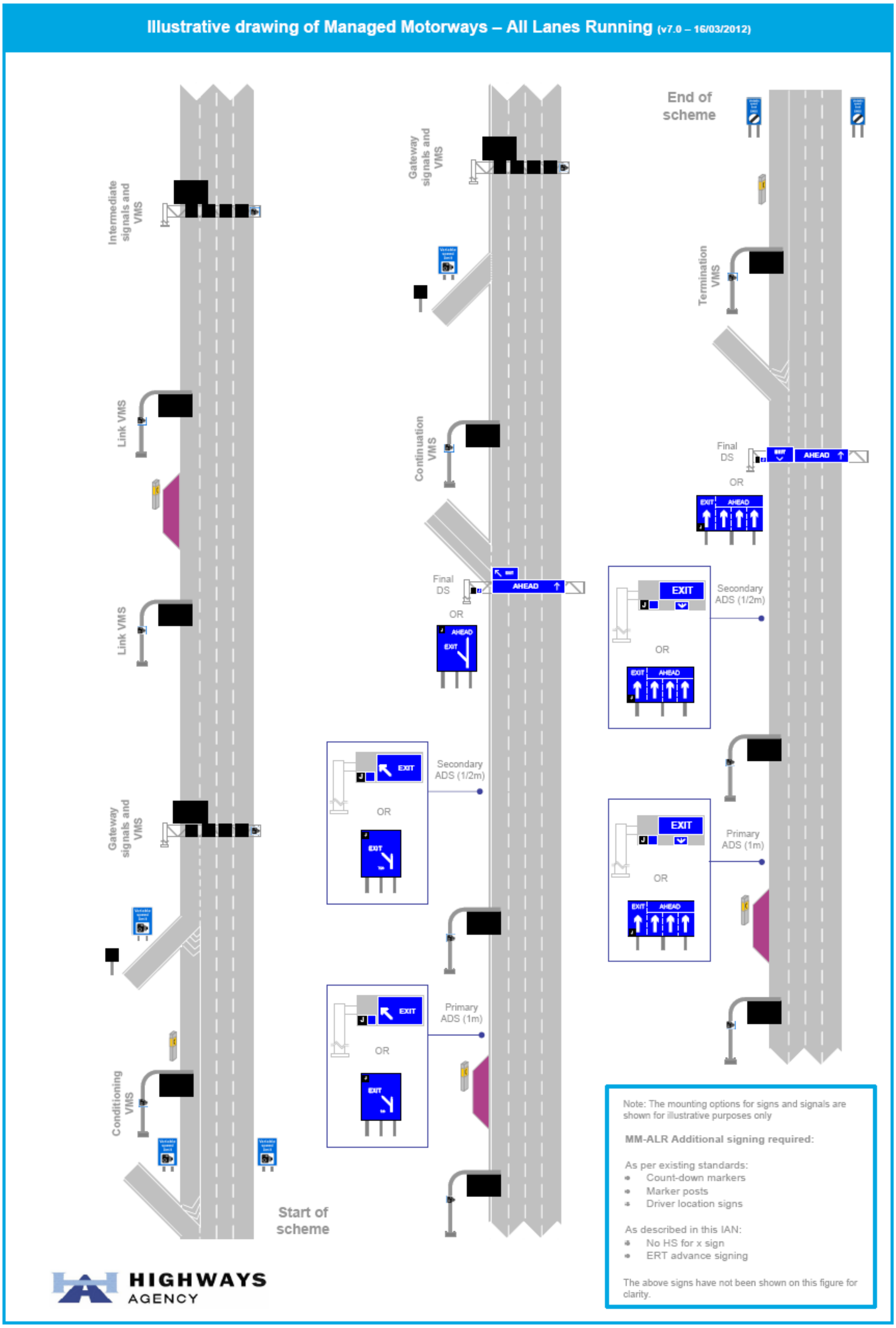

Figure 1-1: Illustrative drawing of Managed Motorways – All lanes running

There are a number of key differences between MM-ALR and the Managed Motorways Hard Shoulder Running (MM-HSR) design [2] [3] . These are presented in Table 1-1.

IAN 111/09 compliant MM scheme	MM-ALR
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.
Driver information provided through: • Gantries positioned at a nominal spacing of 800m, capable of providing lane specific signalling (AMI) and supporting information (MS4)	Driver information provided through: • Signals positioned near the start of each link, capable of providing above lane specific signalling (AMI) and supporting information (MS4); and • Single variable message signs at a maximum spacing of 1500m capable of providing the same types of information but using pictograms, wickets etc. • Additional above lane specific signalling may be provided on longer links
Emergency refuge areas (ERAs) at nominal 800m spacing – usually associated with gantries.	Refuges at up to 2500m intervals.
Overhead direction signs mounted on gantries and cantilevers.	Verge mounted signs. Overhead 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 key challenges for this MM-ALR relate to:

- Adequate Guidance
- Road user safety is maintained across all groups
- Road Worker Safety
- Operating and Maintenance Regimes
- Mitigations for top scoring hazards

1.3 Safety baseline and objectives for MM-ALR

A generic safety baseline and generic safety objectives have been agreed for MM-ALR schemes, as define in IAN 161 [1].

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 system and automatic signalling (MIDAS) installed, the road user safety baseline must be based on the recorded accident rate before installation of MIDAS or, 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.

For the purposes of this report, the safety baseline assumes prior to the implementation of any element of managed motorways.

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 Fatal and Weighted Injuries (FWI) casualties per year is no more than the safety baseline, and
- the rate of FWIs per billion vehicle miles per annum is no more than the safety baseline,
- no population (e.g. car drivers, pedestrians, HGV drivers and motorcyclists) is adversely affected in terms of safety.

1.3.3 Road worker safety

There is no numerical objective or target for road worker accidents on MM-ALR schemes and the risk must be managed in accordance with SFAIRP (So Far As Is Reasonably Practicable). The Highways Agency's “Aiming for Zero” 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 objective is 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 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:** Background to MM-ALR, safety objectives, purpose and scope for document;
- **Chapter 2:** Methodology – describes the approach used to demonstrate the meeting of the safety objective;
- **Chapter 3:** Modifications to the Managed Motorways Hazard log; Assumptions; background studies
- **Chapter 4:** 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 is likely to be met
- **Chapter 7:** References
- **Appendices**: Glossary of Terms and Abbreviations, Medium scoring hazards, Overview of Risk Assessment Methodology, Implications of M42 MM three year safety review and Hazard log scoring verification workshop attendance.

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 based on the methodology used successfully for the M42 MM and Birmingham Box Managed Motorways Phase 1&2 (BBMM1&2) Schemes. It is also documented in IAN 139 [4]. The foundation for the demonstration of meeting the safety objective is the risk assessment methodology which is documented in Appendix C.

The Demonstration involved a qualitative and 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:

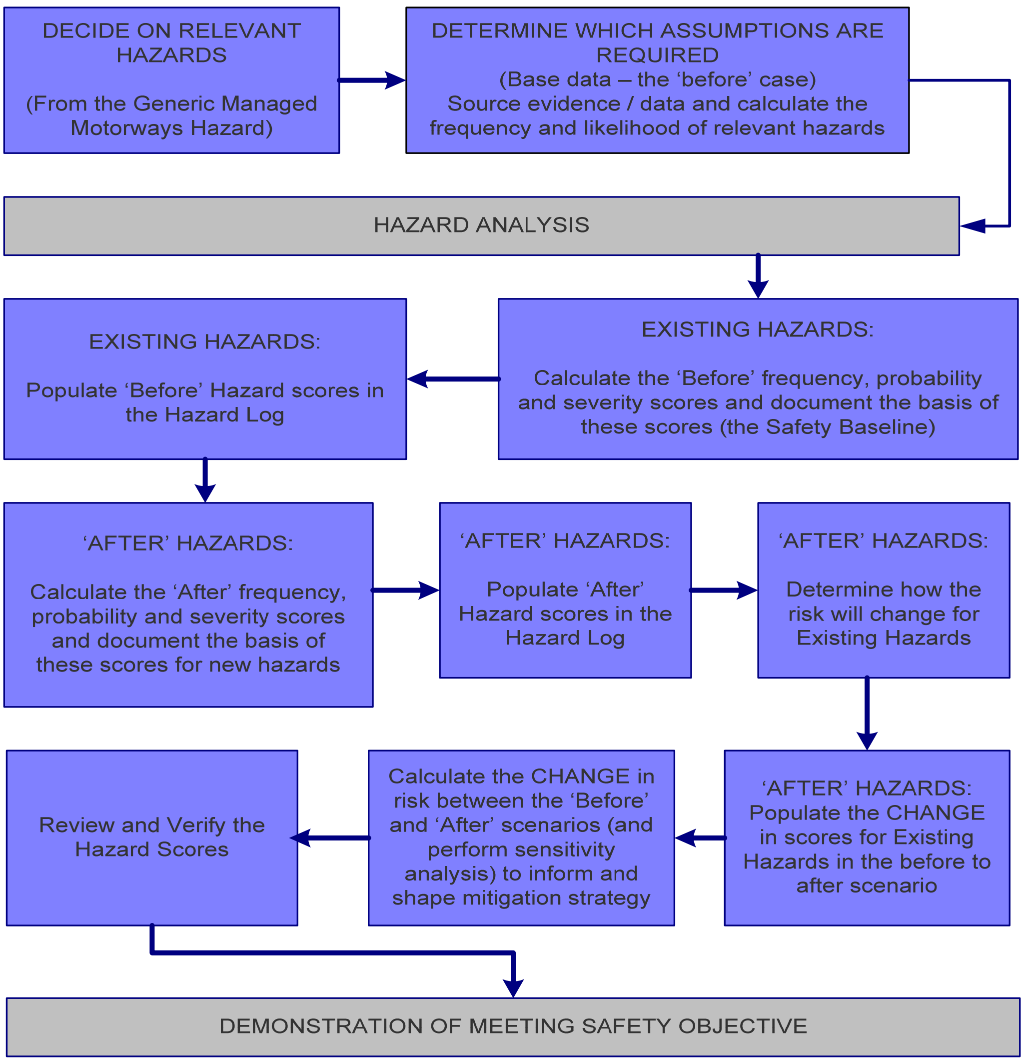

Figure 2-2 Process for demonstrating meeting of safety objective

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:

- Pedestrians
- Motorcyclists
- HGV Drivers
- **On Road Resources (ORR)**
- **Maintenance Workers**
- Emergency Services
- Recovery Organisations
- Disabled Drivers or Passengers

This approach is required as the Highways Agency does not seek to improve safety for one user group at the expense of another.

There is a separate safety objective for road workers (Chapter 1.3), ORR and maintainers (shown in bold above), so it is necessary to particularly focus on and understand how the implementation of MM-ALR will affect these two user groups.

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 as they could be different 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.

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 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 Impact on M42 MM Three Year Safety Review and Value Engineering

The hazard log has been updated to reflect the benefits of MM demonstrated on the M42 MM Scheme [5]. It is expected that the Value Engineering will reduce to some extent the amount of benefit achieved but not beyond that of the safety objective for road users for MM-ALR, and this is reflected in the "change with MM-ALR" scores.

3 Hazard log preparation, assumptions and background studies

In order to carry out the hazard assessment of MM-ALR, the existing generic MM hazard log was used as a starting point. However, that 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; or
- Hazards were added.

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 (Hard Shoulder Running)
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 network	Associated with dynamic HSR
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

Hazard	Description	Comment
H49	LGVs, HGVs or other wide vehicles avoid using LBS1 due to narrowing effect of red studs	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. now forms part of H129 “Vehicle stops in running lane”)

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 and H136 added to the hazard log are presented in table 3-2.

Hazard	Original Description	Revised Description	Comments
H6	Collision with workers doing maintenance from ERAs/verge	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	Debris in running lane (being hit or causing unsafe manoeuvre)	Changed to more accurately describe the hazard
H10	Driver falls asleep	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	Excessive lane changing caused by availability of an additional lane	No LBS1 (Lane Below Signal 1) or hard shoulder in MM-ALR
H27	Excessively slow moving vehicle in running lane (excluding hard shoulder LBS1)	Excessively slow moving vehicle in running lane	No LBS1or hard shoulder in MM-ALR
H33	HGV-LGV-Bus exits ERA when LBS1 is open	HGV-LGV-Bus exits ERA	No LBS1 or hard shoulder in MM-ALR
H43	Large vehicle does not completely enter hard shoulder - LBS1when stopping	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	Motorcycle stopped next to running lanes (D3M = Hard Shoulder, MM-ALR = verge)	Changed to reflect different nature of this hazard from 'before' to 'after'

Hazard	Original Description	Revised Description	Comments
H57	Motorcycle uses LBS1 to pass slow moving or stationary traffic	Motorcycle uses Lane 1 to pass slow moving or stationary traffic	Changed to reflect different nature of this hazard from 'before' to 'after'
H60	Motorcyclists crossing line between hard shoulder (LBS1) and LBS2	Motorcyclists crosses rumble strips	
H72	Pedestrians walking along the hard shoulder/LBS1 (when LBS1 is closed)	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	Pedestrians walking on verge	
H81	Roadworks - short term static on hard shoulder/LBS1	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	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	Vehicle in ERA / Verge obtrudes onto LBS1 (D3M) or Lane 1 (MM-ALR)	Changed to reflect different nature of this hazard from 'before' to 'after'
H117	Vehicle not fully in control when trying to stop on LBS1	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	Vehicle recovered from ERA	Changed to reflect different nature of this hazard from 'before' to 'after'
H124	Vehicle reversing up the hard shoulder (LBS1)	Vehicle reversing up hard shoulder (D3M) or LBS1 (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	Vehicle stopped on Hard Shoulder (D3M) or verge (MM-ALR)	Changed to reflect different nature of this hazard from 'before' to 'after'

Hazard	Original Description	Revised Description	Comments
H129	Vehicle stops in running lane	Vehicle stops in running lane - Peak	See below
H135		Vehicle Stops in Running Lane - Off Peak (State)	See below
H136		Vehicle Stops in Running Lane - Off Peak (Event)	See below

Table 3-2: Hazards removed from the generic managed motorways hazard log

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 the drivers of a following vehicle and queues will forms. This is less likely to happen off-peak.

In addition, although the hazard is considered an Event, in the off-peak it can also be considered a State. For this reason the off-peak component is entered as an Event or State in the hazard log. However, it should be noted that in carrying out the hazard assessment it is only assessed as either an Event or State. i.e. the assessment is carried out twice with either all the risk assumed to be a State and then with all the risk associated with this hazard as an Event.

3.3 Assumptions

A number of assumptions have been used within the hazard log to calculate the hazard safety risk scores. The key assumptions are presented in Table 3-3.

Assumption	Description	Value	Comments
A1	Amount of debris collected by MAC per day per motorway mile	0.3	Based on MAC data from M3, M4 and M42
A3	Average duration an illegal pedestrian present per occurrence (minutes)	60	This is a figure that has been used consistently across MM schemes.
A4	Average Duration for a Breakdown (minutes)	50	Based on data from "Analysis of M42 Hard Shoulder Stoppage Data" used for M42 ATM pilot. This gives an average duration of 45 minutes for a breakdown. Operational data for the M1 (Safety on Hard Shoulders on D2

Assumption	Description	Value	Comments
			and D3 motorways) TRL unpublished report gives a similar figure.
A5	Average duration for a stop	10	In order to calculate the average duration of a stop, estimated that comfort stops are 10 times as frequent as breakdowns. The average duration of a breakdown is 50 minutes and the average duration of a comfort stop is 5 minutes (50+ 50)/11 = 10 minutes (rounded up)
A8	Average length of time multiple lane closures occur	60	Data on this hazard is difficult to come by so 1 hour (60 minutes) is assumed. Note: Assumption used for one Hazard that is typically low scoring.
A10	Average Vehicle Occupancy Rate	1.6	http://www.dft.gov.uk/pgr/statistics/datatablespublications/personal/focuspt/2005/
A11	Carriageway Lengths	6km	Typical length of a D3M section.
A12	Current Emergency Roadside Telephone spacing	1.5km	DMRB TA 73/97
A18	Maximum length of time debris present before being removed	120 minutes	Conservative assumption
A20	Number of authorised stops on hard shoulder (LBS1) per day per motorway mile	0.5	From 'Command and Control' data for the M3, the authorised stops per day per motorway mile estimated to be 0.58. Summary of hard shoulder occupancy and accidental rates (M25) states the number of authorised stops on the M42 as 4 per day. That implies about 0.4 per day per motorway mile. 0.5 assumed.
A21	Number of Breakdowns During Peak Periods per day per motorway mile	0.93	Breakdown rate calculated as 12 per million vehicle mile. Vehicles per day = 130,000. Assume 60% of this travels during the peak = .13*.6*12 =0.93

Assumption	Description	Value	Comments
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	15.6	Assume a rate of about 10 as much 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 ATM pilot suggests 0.22. Assume this figure.
A29	Number of stops on LBS1 per day per motorway mile During Off-peak Periods (Comfort Stops, Vehicle Checks and Breakdowns) - before Implementation	7	Breakdowns per day peak = 0.63, comfort stops = 6.3 (i.e. 10 times breakdown rate) This assumes 40% of flow off-peak
A30	Number of stops on the hard shoulder (LBS1) during peak periods (Comfort Stops, Vehicle Checks and Breakdowns) per day per motorway mile - Before Implementation	10.2	Breakdowns per day peak = 0.93, comfort stops = 9.3 (i.e. 10 times breakdown rate) This assumes 60% of flow off-peak
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 an ERA	50	Assumes that vehicle can coast a certain distance before stopping
A39	Percentage of breakdowns that stop on central reserve	1	There is limited data available to support this assumption. We therefore pessimistically assume that 1% of breakdowns stop on the central reserve.

Assumption	Description	Value	Comments
A40	Percentage of broken down vehicles that limp before stopping	50	No data is available for this assumption. However, we assume that 50% of breakdowns allow the driver to limp for some period of time before coming to a stop.
A42	Percentage of Drivers not using the hard shoulder to accelerate after stopping	50	The M42 ATM Monitoring Report (ATM Safety Monitoring: First set of 4-Lane MVSL Results (42690/DOC/0056) section 2.8.4) estimates that during 3 lane running 50% of vehicles stopping to use LBS1 do not gain speed before entering the main carriageway.
A43	Percentage of drivers that break down in a running lane and get out to inspect their vehicle	100	Pessimistic assumption that all drivers will get out and have a look.
A44	Percentage of drivers that will pass under a Red X	1	Data for the M42 states that this is likely to be approximately 1% (Mitigation Plans for Red X Non Compliance - Sept 2007).
A45	Percentage of lane closures that involve more than one lane	30	D0010 (section 4.1.4) states that on the M42 ATM Pilot, there were 2.3 lane closures per day of which 0.46 were multiple lane closures. Therefore, 20% of lane closures involve more than one lane. Command and Control data from M3/M4 implies 30%. This figure is used
A48	Percentage of road that is slip road	16	Assume slip roads are 300m long. Main carriageway = 6km. Total road length = 6+1.2 = 7.2. Percentage slip road = 1.2/7.2 = 16%
A51	Percentage of Traffic on Main Carriageway that is Large Vehicles (Over 5.2m long)	13	Data collected from the M3 and M4 (MIDAS) suggests values of about 13%.
A52	Percentage of Traffic Volume during off-peak periods	0.4	This is a figure that has been used consistently across the schemes.

Assumption	Description	Value	Comments
A53	Percentage of Traffic Volume during peak periods	0.6	This is a figure that has been used consistently across the schemes.
A57	Percentage of vehicles that have caravans/trailers	1	Assume 1%
A58	Percentage of vehicles which are motorcyclists	0.5	Figure consistent with M3/M4
A63	Total amount of time authorised vehicles stop on hard shoulder (LBS1) per day per motorway mile	7.5	Taking A20 (0.5 stops per day per motorway mile) and 15 minutes per stop - suggests 7.5 minutes per day.
A64	Total amount of time maintenance vehicle stops on hard shoulder (LBS1) per day per motorway mile	7.5	Assume that the vast majority of authorised stops are maintenance related
A65	Total Amount of Time that Vehicles Stop on the hard shoulder per day per motorway mile	156 minutes	Total number of Breakdowns per day = 1.56 (A22) and Total number of Comfort stops and Vehicle Checks = 15.60 (A23). Per day total = 17.12. Length of Breakdown 50 minutes (A4) and Length of time of Comfort stop 5 minutes (S1) = 1.56*50 + 5*15.60 = 156 minute
A70	Total number of stops per day per motorway mile (Breakdowns, Comfort Stops and Vehicle Safety Checks)	17.16	Total number of Breakdowns per day = 1.56 (A22) and Total number of Comfort stops and Vehicle Checks = 15.60 (A23). Per day total = 17.16.
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) [8] 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:

- Accidents = 0.21
- Casualties = 0.15

In comparison for D3M links:

- Accidents = 0.13
- Casualties = 0.10

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

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.

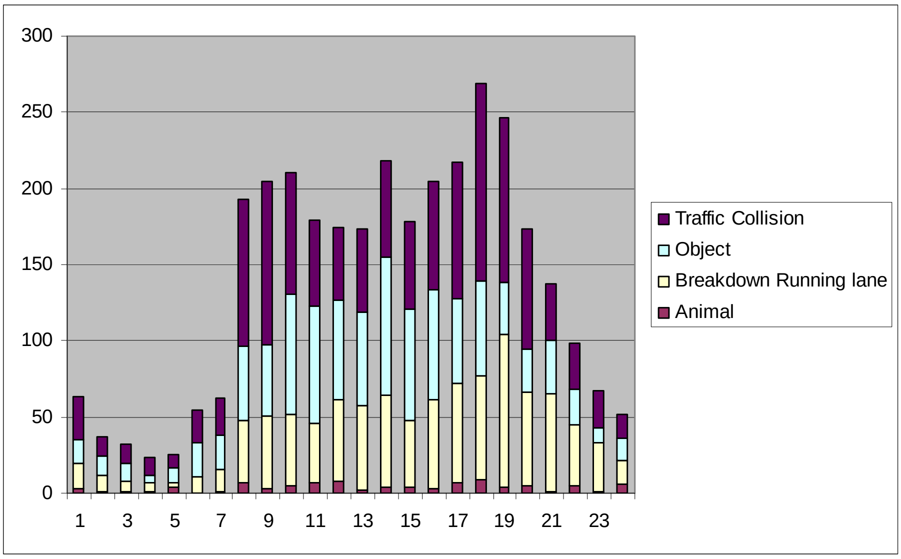

Figure 3-1: Frequency of causes leading to vehicle parked in carriageway

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 60% of the flow during the peak, the frequency of the underlying hazard is:

- Peak: 48
- Off Peak: 32

In terms of Frequency index (see Appendix C), this equates to:

- Peak: 4.68
- Off Peak: 4.51

If however, the hazard is scored as a State, the 'Frequency' is as follows for the off-peak:

Number of occurrences: 32, Assume present for 1 hour each = 32 hours per year which equates to frequency index score (see Appendix C) closest to 3.5 (between probable and occasional)

3.4.3 Determining the hazard probability

This hazard is not always considered to 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. The following vehicle will be warned by observing vehicle brake lights, which may be supplemented by the use of hazard lights. Assumed to be Occasional (2.0)

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 1.5
- Off Peak Probability value of 2

3.4.4 Determining the hazard severity

This hazard 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, 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)

The above calculations suggest the following risk scores for this hazard:

- Peak : E4.68+1.5+1.5 = 7.68
- Off Peak (if hazard is considered an Event) : E4.51+2+1.5 = 8.01
- Off Peak (if hazard is considered a State) : S3.5+2+1.5 = 7.00

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 1.01% of the baseline D3M risk and the 'off-peak' component 2.16% of the baseline D3M risk. Data from D3M links (see Section 3.4.1 indicates that they combined represent about 1.6% of all KSI accidents. Therefore, the calculated values are slightly higher than reality, but appropriate for use within the hazard log.

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. These assumptions were derived from various sources of data.

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, Interim Advice Note IAN 139/11 [4] . An example of application of this methodology is presented in Chapter 3.4 (i.e. the assessment of ‘vehicle stops in running lane’).

As noted previously (Section 3.2) a number of changes were made to the generic managed motorways hazard log. In addition the off-peak component of “Vehicle stops in running lane” was treated as an Event. Therefore, hazard H135 has not been used.

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 (see Appendix D). 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 more than 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 others considers the safety impact of the technology. These reports are:

- All-Purpose Trunk Roads (APTR)/Dual 3-lane Motorway (D3M) Analysis and Hazard Assessment [8] – referred to as the “APTR” report
- Provision of Adequate Guidance Review [10] – referred to 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 [9] 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. The attendance of this workshop is presented in Appendix E. 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.

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 94% of the existing risk and hazards with a score of 7.0 or more account for 98% of the existing risk (see Appendix B).

In total new hazards resulting from the implementation of the scheme are expected to add approximately 4% 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 it is likely to be safer than baseline due to:

- A reduction in risk for a significant number (15) of the highest scoring existing motorway hazards (20), due to a controlled environment being provided through a combination of regularly spaced mandatory speed signals, speed enforcement, and comprehensive CCTV coverage
- One highest scoring new MM hazard is introduced (E08/S08 and above) is introduced (Vehicle recovered from ERA)
- Three high-scoring existing hazards increase in risk
- The impact of the new hazards is expected to be countered by the decrease in risk of existing highest scoring hazards
- Anti-log calculations show that the total score for 'after' represents approximately a reduction of risk of 15% when compared with the safety baseline (no MIDAS).

This analysis suggests that MM-ALR is likely to meet its overall safety objective. 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.)

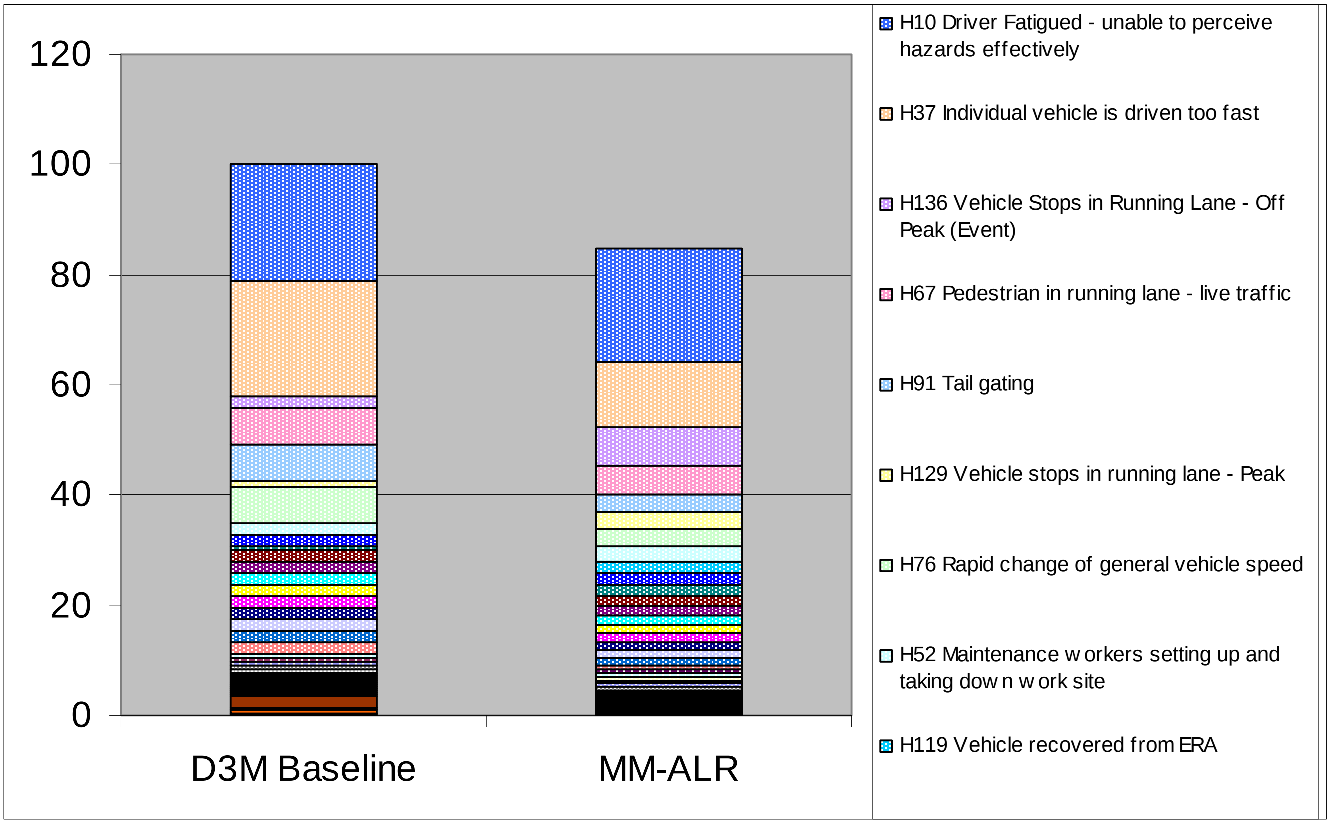

Figure 4-1: Comparison of safety risk for D3M Baseline and MM-ALR

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 '%age change in Safety Risk":

- '0' means no change in risk
- 'Green' means a reduction in risk
- 'Red' means an increase in risk
- 'New' means that the hazard is introduced by MM-ALR.

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

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
H10	Driver Fatigued - unable to perceive hazards effectively	Event	E09	E08.98	-2.718	Some benefit during peak of the controlled environment.
H37	Individual vehicle is driven too fast	State	S09	S08.75	-42.72	Considerable benefit from the controlled environment during the peak.
H136	Vehicle Stops in Running Lane - Off Peak (Event)	Event	E08.01	E08.50	216.2	The number of lane closures per day per motorway mile is 0.22. However, the breakdown rate is 1.56. Assuming that all the breakdowns happen in carriageway. This would imply that the risk of this hazard is 7 times its original rate. However, it is assumed that 50% of vehicle breakdowns will be able to make it to an ERA, dropping the risk to 3.5 times higher. Add in some benefit from setting signals the now rate is assumed to be at least 3 times the original rate or an increase of more than 200%

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
H67	Pedestrian in running lane - live traffic	Event	E08.5	E08.4	-20.56	Benefit from the controlled environment.
H91	Tail gating	State	S08.5	S08.20	-49.38	Considerable benefit from the controlled environment during the peak
H129	Vehicle stops in running lane - Peak	Event	E07.68	E08.17	214.06	See H136 above
H76	Rapid change of general vehicle speed	Event	E08.5	E08.15	-54.36	Considerable benefit from the controlled environment during the peak
H52	Maintenance workers setting up and taking down work site	State	S08	S08.1	25.892	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 likely to increase.
H109	Vehicle drifts off carriageway (i.e. leaving the carriageway as a result of Road Environment)	Event	E08	E08	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,
H119	Vehicle recovered from ERA when Lane 1 is open	Event	E00	E08	NEW	New hazard
H89	Sudden weaving at exit point	Event	E08	E07.92	-15.42	Some benefit from Controlled Environment
H54	Motorcycles filter through traffic	Event	E08	E07.91	-18.51	Some benefit from Controlled Environment
H13	Driver loses control of vehicle	Event	E08	E07.9	-20.56	Some benefit from Controlled Environment
H120	Vehicle rejoins running lane	Event	E08	E07.9	-20.56	Trivia stops are reduced and most remaining stops will be in ERAs.
H121	Vehicle reversing along exit slip	Event	E08	E07.9	-20.56	Some benefit from Controlled Environment
H103	Unsafe lane changing	Event	E08	E07.82	-32.81	Some benefit from Controlled Environment

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08	E07.8	-36.9	More prominent signals can be used to reduce this risk
H112	Vehicle enters main carriageway unsafely	Event	E08	E07.79	-37.41	Some benefit from Controlled Environment
H95	TO/ISUO in running lane	Event	E08	E07.6	-60.18	Considerable benefit from the controlled environment and the use of rolling road-blocks
H127	Vehicle stopped on Hard Shoulder (D3M) or verge (MM-ALR)	State	S08	S00	-100	Effectively Eliminated. Trivial stops are reduced and most remaining stops will be in ERAs.

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

5.2 Medium scoring hazards

A table of medium scoring hazards is presented in Appendix B. These represent about 9% 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:

- Pedestrians
- Motorcyclists
- HGV Drivers
- On Road Resources (ORR)
- Maintenance Workers[1]
- Emergency Services
- Recovery Organisations
- Disabled Drivers or Passengers

[1] Currently there is no numerical objective or target for Road Worker accidents on MM projects and the risk is managed in accordance with So Far As Is Reasonably Practicable. The Highways Agency's "Aiming for Zero" strategy is intended to be a catalyst for further positive action to reduce the risk to Road Workers. One part of the strategy aims to eliminate all fatalities and serious injuries to Road Workers maintaining the Highways Agency's road network.

This is important not only for ORR and Maintenance Workers, but for all specific user groups as the Highways Agency has tried to ensure safety for one user group is not improved at the expense of another.

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	%age change in Safety Risk	Comments
H67	Pedestrian in running lane - live traffic	Event	E08.5	E08.4	-20.56	Benefit from the controlled environment.
H69	Pedestrians in a running lane - stationary-slow moving traffic	State	S07.5	S07.4	-20.56	Benefit from the controlled environment.
H73	Pedestrians walking on verge	State	S07	S07.1	25.892	Hard shoulder in use, therefore pedestrians closer to traffic
H68	Pedestrian on slip road	State	S07	S07	0	Running of MM-ALR will not create a change in the risk associated with this hazard.
H48	Legal-illegal pedestrian(s) in path of vehicles in ERA	Event	E00	E06.5	NEW	Running of MM-ALR will not create a change in the risk associated with this hazard.
H72	Pedestrians walking along the hard shoulder (Applies to D3M only)	State	S06.5	S00	Eliminated	Eliminated due to running of hard shoulder permanently and full time.

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 reduce. 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, AMI (mandatory) signals and MS4s signs can be used to protect a vehicle stopped in a running lane and any pedestrians in the vicinity of that vehicle.

With the highest scoring hazard (H67, E08.5) over an order of magnitude greater in risk than the new hazards introduced with MM-ALR (H48, E06.5), the significant reduction in risk to this hazard is likely to dominate the total risk for pedestrians. Therefore overall the safety objective is likely to be met for pedestrians for MM-ALR schemes.

5.3.2 Motorcyclists

The hazard analysis reveals that road users in general have a reduced safety risk of 17%. That is when hazards applicable to road users are analysed in isolation from the safety risk to road workers and others, the risk to road users in general is expected to be 17% less than the baseline.

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	%age change in Safety Risk	Comments
H54	Motorcycles filter through traffic	Event	E08	E07.91	-18.51	Smoother traffic travelling at higher speeds - less need to filter through
H58	Motorcyclist cross wind buffering	State	S06.5	S06.5	0	Running of MM-ALR will not create a change in the risk associated with this hazard.
H59	Motorcyclist falls off crossing line on entry to ERA	Event	E00	E06.5	NEW	Running of MM-ALR will not create a change in the risk associated with this hazard.
H60	Motorcyclists crosses rumble strips	Event	E05.5	E05.5	0	Running of MM-ALR will not create a change in the risk associated with this hazard.
H55	Motorcycle stopped next to running lanes (D3M = Hard Shoulder, MM-ALR = verge)	State	S07	S00	Eliminated	Eliminated due to running of hard shoulder permanently and full time.
H57	Motorcycle uses Lane 1 to pass slow moving or stationary traffic	State	S06	S00	Eliminated	Eliminated due to running of hard shoulder permanently and full time.

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 weave.

With the 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 this hazard is likely to dominate the total risk for motorcyclists. Therefore overall the safety objective is likely to be met for motorcyclists for MM-ALR schemes.

5.3.3 HGV Drivers

The HGV drivers related hazards are listed in Table 5-4 below in descending After Safety Risk Score.

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
H33	HGV-LGV-Bus exits ERA	Event	E00	E07.5	NEW	New hazard introduced as a result of ERAs being deployed on MM-ALR
H43	Large vehicle does not completely clear the running lane when stopping on Hard Shoulder (D3M) or Verge (MM2)	State	S04.5	S04.2	-49.88	Hard shoulder will become a permenant 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 ‘H33 HGV-LGV-Bus exits ERA which is scored as an E7.5. 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 not found 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.

As the majority of hazards that apply to all vehicles apply similarly to large vehicles, we can expect large vehicles to also benefit in a similar way from risk reduction in many existing motorway hazards as all vehicles. Due to this, 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 can 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 On Road Resources (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	%age change in Safety Risk	Comments
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08	E07.8	-36.9	More robust and more frequent signalling,- controlled environment perception for motorists.
H95	TO/ISUO in running lane	Event	E08	E07.6	-60.18	More robust and more frequent signalling to protect TO/ISUO
H62	On-road resources work unprotected	State	S07.5	S07.4	-20.56	More robust and more frequent signalling to protect TO/ISUO
H94	TO arrives, but has difficulty containing the scene	Event	E07	E06.9	-20.56	More robust and more frequent signalling to protect TO/ISUO
H99	TOs/emergency services not despatched in a timely manner	Event	E07	E06.8	-36.9	CCTV to inform operators where exactly incident is, to improve despatch time
H96	TOs behave hazardously at an incident	Event	E06.5	E06.5	0	No change expected
H98	TOs/emergency services despatched but cannot reach scene	Event	E06	E06	-4.263	Small benefit derived from signals being set to facilitate TO/emergency services reaching incident
H101	Unable to set signs and signals to protect incidents	State	S06	S06	-4.263	Small benefit from perception of controlled environment, regardless whether

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
						signals set
H83	Signals change while TO/ emergency services are still on motorway	Event	E06	E05.9	-20.56	CCTV available for operators to check whether there is still attendance at incident
H97	TOs/ emergency services go to wrong location (incident)	Event	E06	E05.9	-20.56	CCTV for operators to confirm incident location
H66	Operator fails to set signals to protect incident in timely manner	State	S05.5	S05.4	-20.56	CCTV for operators to confirm incident location
H34	Incident management - rolling block	Event	E05	E05.2	58.489	Lack of the hard shoulder for stoppages from which to commence incident management – rolling road block required in all circumstances
H84	Signals set in wrong place (i.e. are not protecting the incident)	State	S02	S01.9	-20.56	CCTV for operators to confirm incident location
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07	S00	Eliminated	As for H34, rolling road block required in all circumstances

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

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 can be parked in 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.

Therefore, the safety objective is likely to be achieved for ORR.

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	%age change in Safety Risk	Comments
H52	Maintenance workers setting up and taking down work site	State	S08	S08.1	25.892	More robust signalling, and a more controlled environment to protect maintenance workers
H80	Roadworks - short term static	State	S07.5	S07.99	214.06	All roadworks will commence from a rolling road block, so risk will increase.
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08	E07.8	-36.9	More robust signalling and controlled environment
H79	Roadworks - long term static	State	S07.5	S07.5	0	No change in risk
H51	Maintenance workers in carriageway	Event	E06	E06	-2.842	More robust signalling and controlled environment
H101	Unable to set signs and signals to protect incidents	State	S06	S06	-4.263	Small benefit from perception of controlled environment, regardless whether signals set
H34	Incident management - rolling block	Event	E05	E05.2	58.489	Lack of the hard shoulder for stoppages from which to commence incident management – rolling road block required in all circumstances

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
H84	Signals set in wrong place (i.e. are not protecting the incident)	State	S02	S01.9	-20.56	CCTV for operators to confirm incident location
H6	Collision with workers doing maintenance on verge	State	S06.5	S00	-100	Effectively eliminated due to lack of hard shoulder. This will not occur without full TM and RRB
H81	Roadworks - short term static on hard shoulder	State	S07.5	S00	Eliminated	No hard shoulder available, so hazard eliminated
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07	S00	Eliminated	No hard shoulder available, so hazard eliminated

Table 5-6 Change in risk score for motorcyclist related hazards

One of the highest risk hazards 'H52 - Maintenance workers setting up and taking down work site' (S08.0) is expected to increase compared to the baseline. There is more equipment to maintain compared to the baseline; however there will be no hard shoulder available from which to maintain this equipment. This will therefore result in lane closures.

H80 'Roadworks – short term static' (S07.5) is also 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 'H81 Roadworks - short term static on hard shoulder' are now included under H80.

'H79 - Roadworks - long term static', (S07.5) hazards, is expected to reduce in risk, as the approach to roadworks will be better signalled (mandatory signals will operate upstream when traffic queues to pass through roadworks) and speed compliance is expected to be better therefore reducing the likelihood of incidents.

H11 'Driver ignores closed lane(s) signals that are protecting an incident' (E08) is expected to decrease, through a more controlled environment and the use of mandatory signals. In addition there is expected to be also a small benefit if vehicles can be parked in ERAs.

'H82 - Short duration stops / debris removal by TO / maintenance workers' (S07.5) 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 within, from which to collect debris etc.

From the above initial analysis, it cannot be concluded that the safety objective is likely to be achieved or that the risk is managed SFAIRP.

In order to better understand the hazards associated with maintenance workers a more detailed analysis was undertaken. This analysis was based on a detailed understanding of the maintenance activities that are likely to take place on a D3M without MIDAS and MM-ALR. The analysis concentrated on the following key maintenance hazards:

- H6 Collision with workers doing maintenance on verge
- H52 Maintenance workers setting up and taking down work site
- H80 Roadworks - short term static
- H81 Roadworks - short term static on hard shoulder

These hazards were chosen for further analysis as they are the ones that are likely to be most influenced by the implementation of MM-ALR. This group also contains the two maintenance related hazards with the highest risk scores (H52 and H80), which are also anticipated to increase in risk.

This more detailed analysis revealed that the after safety risk associated with these hazards was less than originally anticipated. However, the before safety risk was also lower. Therefore it was anticipated that the safety risk associated with this group of hazards increases by 70%. However, this was based on an assumption that each of the activities identified is carried out in isolation.

The more detailed analysis confirmed that the main drivers behind the increase in risk were:

- An increase in frequency of maintenance activities
- The risks associated with setting up and taking down work sites (method and exposure)

In order to mitigate/manage the increase in risk a number of activities are currently underway addressing the two issues identified above.

With regard to the first issue, an assessment is underway based on the ‘ERIC’ principle as described in figure 5-1.

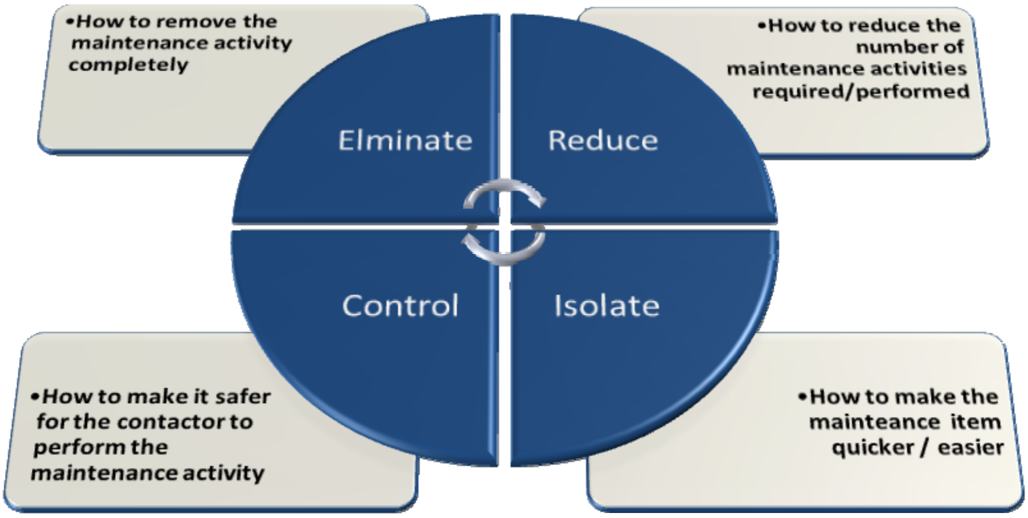

Figure 5-1 The principles of an 'ERIC' assessment

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. In addition, given the risks associated with setting up and taking down work sites, rationalising planned maintenance works will mean less instances of short term roadworks, thus reducing the increase in risk still further. Finally, benefit would also be gained from reducing the frequency of unplanned maintenance (for example, the replacement of a central reserve steel barrier with a concrete barrier will eliminated a large number of 'category 1' defects that would result in the need for urgent short-term roadworks).

With regard to the safety risk associated with setting up and taking down of work sites a number of innovations are being considered these include:

- Fixed taper positions
- Use of VMS to replace fixed signing in the central reserve
- Remotely operated signs in the central reserve
- Use of crash-cushion vehicles.

These changes are intended to make the setting up and taking down of work sites safer (as they will involve fewer crossings of the carriageway to set up signs) and quicker (reducing exposure to risk).

In order to understand the magnitude of the changes that would be required to bring the level of safety risk associated with MM-ALR back to a level comparable with D3M a sensitivity analysis has been undertaken. This analysis considered a number of combinations of changes. One such combination considered the impact of replacing a steel central reserve barrier with a concrete barrier and reducing the number of short-term roadworks by carrying out some activities at the same time. If it assumed that the provision of concrete barrier reduces the number of category 1 defects per year per mile of motorway and the number of short-term roadworks can be reduced by a third (by combining maintenance activities) then the level of safety risk from maintenance can be shown to be similar to that before the implementation of MM-ALR.

The improvements are required in the frequency and implementation of maintenance activities. Although it cannot be concluded at this stage that the safety objective is likely to be achieved or 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 risks 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	%age change in Safety Risk	Comments
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08	E07.8	-36.9	More robust and more frequent signalling,- controlled environment perception for motorists
H87	Speed differential between emergency services and general traffic	Event	E06.5	E06.5	0	No change in this hazard
H22	Emergency staff - TO etc on foot at scene of an incident	State	S06	S06	-4.263	Small benefit derived from signals being set
H101	Unable to set signs and signals to protect incidents	State	S06	S06	-4.263	Small benefit from perception of controlled environment, regardless whether signals set
H83	Signals change while TO/ emergency services are still on motorway	Event	E06	E05.9	-20.56	CCTV available for operators to check whether there is still attendance at incident
H66	Operator fails to	State	S05.5	S05.4	-20.56	CCTV to inform

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
	set signals to protect incident in timely manner					operators where exactly incident is, to improve signal setting time
H34	Incident management - rolling block	Event	E05	E05.2	58.489	Lack of the hard shoulder for stoppages from which to commence incident management – rolling road block required in all circumstances
H84	Signals set in wrong place (i.e. are not protecting the incident)	State	S02	S01.9	-20.56	CCTV for operators to confirm incident location
H99	TOs/emergency services not despatched in a timely manner	Event	E07	E06.9	-36.80	CCTV to inform operators where exactly incident is, to improve despatch time 0

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

For the highest risk hazard 'H11 - TOs/emergency services not despatched in a timely manner' (E07.0) the risk is expected to decrease. CCTV makes it easier to find an incident, so TOs / emergency services ca be despatched more accurately.

The highest scoring hazard affecting the risk to Emergency Services personnel is 'H22 - Emergency staff -TO etc on foot at scene of an incident' (S06). This hazard is expected to improve for MM-ALR schemes because the increased control will provide a safer environment around the scene of an incident (protection of the incident with mandatory signals supported by message signs to inform drivers of incident ahead, lane diverts and controlled environment).

The risk associated with 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 Recovery Organisations

The emergency services related hazards are listed in Table 5-8 below in descending After Safety Risk Score.

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08	E07.8	-36.9	More robust and more frequent signalling,- controlled environment perception for motorists
H22	Emergency staff - TO etc on foot at scene of an incident	State	S06	S06	-4.263	Small benefit derived from signals being set
H83	Signals change while TO/ emergency services are still on motorway	Event	E06	E05.9	-20.56	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	S05.5	S05.4	-20.56	CCTV to inform operators where exactly incident is, to improve signal setting time
H34	Incident management - rolling block	Event	E05	E05.2	58.489	Lack of the hard shoulder for stoppages from which to commence incident management – rolling road block required in all circumstances
H84	Signals set in wrong place (i.e. are not protecting the incident)	State	S02	S01.9	-20.56	CCTV for operators to confirm incident location

Table 5-8 Change in risk score for emergency services related hazards

The Hazard Log does not contain a specific set of hazards for breakdown services and recovery operators as they are suitably 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 breakdown services and recovery operators.

The main hazards affecting breakdown services and recovery operators are generic existing motorway hazards affecting all drivers and 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 for exiting ERAs on no occasion was there assessed to be a serious risk of collision.

In addition, for work taking place on the main carriageway, protection is increased through the use of mandatory signs and MS4s with pictograms.

The safety objective for breakdown services and recovery operators is therefore likely to be achieved.

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 suitably 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 only situations that are likely to affect disabled persons differently from other road users are those in which their vehicles break down or are 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 ERA, which is a safe place to stop

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

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 due to:

- A reduction in risk for a significant number (15) of the highest scoring existing motorway hazards (20 in total) due to a controlled environment being provided through a combination of operationally regularly spaced mandatory speed signals, perceived speed enforcement, and the 'perceived' monitoring by a large number of CCTV cameras

- No very high scoring new MM hazards (E09/S09) are introduced (highest scoring new MM hazard is E08)

- Hence the impact of the new hazards is expected to be countered by the decrease in risk of existing highest scoring hazards

The main safety challenges for the design on this section, which are not expected to prevent the safety objective being achieved, include:

- The hard shoulder being used as a running lane, full time, and permanently.

- Minimising the impact of the Value Engineering on the safety and operation of the section.

- Four high scoring hazards (out of 20) increasing in risk.

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 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.

- Pedestrians

- Motorcyclists

- HGV Drivers

- On Road Resources (ORR)

- Emergency Services
- Recovery Organisations
- Disabled drivers or passengers

With regard to Maintenance Workers, improvements are required in the frequency and implementation of maintenance activities before it can be concluded that the safety objective is likely to be achieved or that the risk is managed SFAIRP. However 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 risks associated with the operations and maintenance of the MM-ALR layout being no more onerous than for a D3M layout.

7 References

[1]	Interim Advice Note 161/12, Managed Motorway - All lanes 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]	1039092, MM-ALR Demonstration of Meeting the Safety Objective Report
[7]	Interim Advice Note 139/11 Managed Motorways Project Safety Risk Work. Instructions.
[8]	All-Purpose Trunk Roads (APTR)/Dual 3-lane Motorway (D3M) Analysis and Hazard Assessment, 1039092/ATA/035
[9]	MM-ALR Generic Safety Report, 1039092/GSR/016
[10]	MM-ALR Provision of Adequate Guidance Review, 1039092/AGR/042

Appendix A: Glossary of terms and abbreviations

Acronym	Description
AM	Access Management
APTR	All Purpose Trunk Road
ATM	Active Traffic Management
BB3MM	Birmingham Box Phase 3 Managed Motorways
BBMM1&2	Birmingham Box Managed Motorways Phases 1 and 2
CCTV	Closed Circuit Television
CDM	Construction (Design & Management)
CM	Controlled Motorway
D3M	Dual 3-lane Motorway
DHS	Dynamic Hard Shoulder
DMRB	Design Manual for Roads and Bridges
ERA	Emergency Refuge Area
ERT	Emergency Roadside Telephone
FWI	Fatal and Weighted Injury
GALE	Globally At Least Equivalent
GSN	Goal Structured Notation
HA	Highways Agency
HGV	Heavy Goods Vehicle
HSR	Hard Shoulder Running
KSI	Killed, Seriously Injured
LGV	Large Goods Vehicle
LBS	Lane Below Signal
MAC	Managing Agent Contractor
MHS	Maintenance Hard Standings
MIDAS	Motorway Incident Detection and Automatic Signalling
MM	Managed Motorways
MM-ALR	Managed Motorways – All Lanes Running
MM-HSR	Managed Motorways – Hard Shoulder Running
MS4	Motorway Signal Mark 4
MSA	Motorway Service Area
NDD	Highways Agency, Network Delivery and Development
NetServ	Highways Agency, Network Services Directorate
NSCRG	National Safety Control Review Group
OGC	Office of Government Commerce
ORR	On Road Resource
PCF	Product Control Framework
PIA	Personal Injury Accident
POPE	Post Opening Project Evaluation

Acronym	Description
PSA	Public Service Agreement
PSCRG	Project Safety Control Review Group
PSRM	Project Safety Risk Management
PTZ	Pan-Tilt-Zoom
RCC	Regional Control Centre
RSA	Road Safety Audit
SFAIRP	So Far As Is Reasonably Practicable
SGAR	Stage Gate Assessment Review
SME	Small Medium Enterprise
SMS	Safety Management System
SRO	Senior Responsible Owner
TechMAC	Technology Managing Agent Contractor
TJR	Through Junction Running
TOS	Traffic Officer Service
TP	Triple Package
TMD	Highways Agency, Traffic Management Directorate
VMS	Variable Message Sign
VMSL	Variable Mandatory Speed Limit

Appendix B: Medium scoring hazards

Further to Table 3-1, the table below contains the medium scoring hazards (E07.5 / S07.5 and E07 / S07). The hazards scoring E07/S07 and above represent 98% of the existing scheme risk. When reviewing the table the following points should be considered:

1. Decreases in hazard risk score are highlighted in green
2. Increases in hazard risk score are highlighted in red.
3. 'Eliminated' means that the risk has been eliminated.
4. 'New' means the hazard is new to MM-ALR

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
H80	Roadworks - short term static	State	S07.5	S07.99	214.06	All roadworks will commence from a rolling road block, so risk will increase.
H33	HGV-LGV-Bus exits ERA when LBS1 is open	Event	E00	E07.5	NEW	New hazard introduced as a result of ERAs being deployed on MM-ALR
H79	Roadworks - long term static	State	S07.5	S07.5	0	No change expected
H113	Vehicle exits ERA when Lane 1 is open to traffic	Event	E00	E07.5	0	New hazard introduced as a result of ERAs being deployed on MM-ALR
H110	Vehicle drifts out of lane	Event	E07.5	E07.42	-15.42	More lanes available for motorists, decreasing the likelihood of hazard
H62	On-road resources work unprotected	State	S07.5	S07.4	-20.56	More robust and more frequent signalling and CCTV for operators to confirm signals are set.

H69	Pedestrians in a running lane - stationary-slow moving traffic	State	S07.5	S07.4	-20.56	Slight benefit from the signals
H8	Debris in running lane (being hit or causing unsafe manoeuvre)	State	S07.5	S07.22	-46.63	More lanes, so evasive action will be easier.
H73	Pedestrians walking on verge	State	S07	S07.1	25.892	Verge will be next to live carriageway – no hard shoulder available to distance pedestrians from traffic
H116	Vehicle misjudges entry to ERA	Event	E00	E07.1	25.892	Vehicles will enter ERA from live carriageway – no hard shoulder available to alter course
H126	Vehicle stopped on slip road (off or on slip)	Event	E07	E07.1	25.892	More likely to occur, as hard shoulder no longer exists.
H122	Vehicle reversing back to exit slip	Event	E07	E07.05	14.622	More likely to occur, as hard shoulder no longer exists , so there is nowhere for motorists to stop. This may therefore become more tempting
H32	Health deterioration of vehicle occupant	Event	E07	E07.05	12.946	Less areas within which motorists can stop in the case of health deterioration
H42	Lane(s) closed, but driver unable to leave lane and stops	Event	E07	E07	0	No change expected
H68	Pedestrian on slip road	State	S07	S07	0	No change expected

H114	Vehicle in ERA / Verge obtrudes onto LBS1 (D3M) or Lane 1 (MM-ALR)	State	S00	S07	0	New hazard introduced as a result of ERAs being deployed on MM-ALR
H131	Vehicle suddenly decelerates at end of on slip road	Event	E07	E07	0	No change expected
H36	Incidents or congestion caused in other lanes or carriageway due to rubber necking	State	S07	S06.9	-20.56	Some benefit from Controlled Environment
H94	TO arrives, but has difficulty containing the scene	Event	E07	E06.9	-20.56	Some benefit from Controlled Environment
H123	Vehicle reversing up entry slip	Event	E07	E06.9	-20.56	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	E06.85	-27.67	Some benefit from Controlled Environment
H2	Abnormal loads - notifiable	Event	E07	E06.8	-36.9	Better signalling to asvise motorists of the presence of abnormal loads
H77	Reduced visibility due to weather conditions	State	S07	S06.8	-36.9	Better signalling to asvise motorists and reduce speeds
H99	TOs/emergency services not despatched in a timely manner	Event	E07	E06.8	-36.9	CCTV to inform operators where exactly incident is, to improve despatch time
H102	Undertaking	Event	E07	E06.8	-36.9	More lanes available, so less need for undertaking
H118	Vehicle on the main carriageway decelerates suddenly	Event	E07	E06.7	-49.88	Benefit from the controlled environment; signals can be

						set automatically
H30	Group of vehicles drive too fast (in relation to set/not set speed limit)	State	S07	S06.69	-50.28	Benefit from controlled environment
H55	Motorcycle stopped next to running lanes (D3M = Hard Shoulder, MM2 = verge)	State	S07	S00	Eliminated	No hard shoulder available, so hazard eliminated
H81	Roadworks - short term static on hard shoulder	State	S07.5	S00	Eliminated	No hard shoulder available, so hazard eliminated
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07	S00	Eliminated	No hard shoulder available, so hazard eliminated
H124	Vehicle reversing up Hardshoulder (D3M) or Lane 1 (MM-ALR)	Event	E07	E00	-100	Effectively eliminated, as hard shoulder does not exist fro MM-ALR – very undesirable to reverse up a live lane.

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'.

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 AC.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 AC.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 AC.2.

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	0.01	2.0
	0.00316	1.5
Improbable	0.001	1.0
	0.000316	0.5
Incredible	0.0001	0.0

Table AC.2: Frequency classifications and Index Values

So if an Event 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 E7.0

State Likelihood
The index values used for State Hazard likelihoods are shown in Table AC.3.

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 AC.3: Example of 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 S7.0

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 AC.4.

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 AC.4: 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 AC.5

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 AC.5: Event/State severity scores

Appendix D: Implications of M42 MM three year safety review

D1. Consideration of the Results

The first 36 months of validated Personal Injury Accident (PIA) data during 4-Lane Variable Mandatory Speed Limits (4L VMSL) is available from the M42 MM scheme. Overall there has been a reduction in the number and severity of PIAs during the first 36 months of 4L VMSL operations compared to 3L VMSL and No VSL.

- On average 2.25 PIAs per month with 4L VMSL compared to 3.17 and 5.08 in the 3L VMSL and No VSL cases respectively
- This represents a 56% reduction between No VSL and 4L VMSL
- PIAs which have occurred during HSR were all slight in severity
- The PIA severity index has fallen to 0.07 with 4L VMSL compared to 0.16 with 3L VMSL and No VSL

The number of rear end shunts and single vehicles PIAs per year has dropped significantly with 4L VMSL compared to No VSL, side impacts are unchanged.

The headline PIA figures can be analysed in a number of different ways to represent the reduction in safety risk. This is shown in Table E1. This suggests a 60% reduction in safety risk compared to the baseline is a reasonable representation.

Table D1: Analysis of PIA figures - 60% reduction in risk

	No VSL	4L VMSL	Percentage reduction
PIA rate per month	5.08	2.25	- 56%
PIA rate per month per billion vehicle miles travelled	116	48	- 59%
PIA rate per month * severity ratio	0.81	0.18	- 78%
PIA rate per month Weighted	7.5	2.6	- 66%

Note: Weighted: Fatal 10; Severe 3; Slight 1

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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