Smart motorways all lane running GD04 assessment report

1065017-WP017-DOC005

August 2015

building great relationships

Working on behalf of Highways England

Document control

Document title	Smart motorway all lane running: GD04 assessment report
Author	Ryszard Gorell / Tom Grahamslaw and Axel Kappeler
Owner	Max Brown
Distribution	For review and acceptance
Document status	For Issue

Record of issue

Version	Date	Description	Author
0.1	02 March 2012	First draft	Ryszard Gorell
0.2	05 March 2012	Second draft	Amendments by A Alcorn
1.0	23 March 2012	Final	Max Brown
1.1	16 April 2013	Draft update	Tom Grahamslaw
1.2	22 July 2013	Draft second update	Tom Grahamslaw
2.0	16 August 2013	Final	Tom Grahamslaw
3.0	30 December 2014	ALR update draft	Axel Kappeler
3.1	18 August 2015	Change to Highways England and finalisation	Ryan Bridger
3.2	19 August 2015	Final	Lucy Wickham

Reviewer list

Name	Role
Joanna Goulding	Professional and Technical Solutions Directorate, Safety and Risk & Governance Team Leader
Max Brown	Professional and Technical Solutions Directorate, Smart Roads Team Leader, Project Sponsor
Iain Candlish	Smart Motorways Programme CDM Advisor
National Safety Control Review Group (NSCRG)	ALR safety governance

Approvals

Name	Signature	Title	Date of Issue	Version
Freda Rashdi	[signature]	Senior responsible owner (SRO)	17/11/15	3.2

This page is intentionally left blank.

Table of contents

Executive summary

Introduction

This report describes the approach taken and the outcomes achieved from conducting a safety risk assessment in accordance with GD04/12 'Standard for safety risk assessment on the strategic road network' of the smart motorways all lane running (ALR) concept including the demonstration of achievement of the safety objective for ALR. A generic safety objective has been agreed for ALR as defined in chapter 3.

The purpose of this document is to demonstrate that for ALR the safety objectives are likely to be achieved. A qualitative review of the highest risk 'existing' motorway hazards and the 'new' hazards introduced by ALR has been used, supported by a semi-quantitative assessment of the risk from these hazards. Initial results from monitoring of the first ALR schemes on the M25 have been taken into account.

Conclusion

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

- A reduction in risk for a significant number (11) of the highest scoring existing motorway hazards (17), due to a controlled environment being provided through a combination of regularly spaced mandatory speed signals, speed enforcement, and full CCTV coverage
- One highest scoring (i.e. E08/S08 and above) new ALR hazard is introduced, hazard 'H113 - Vehicle exits emergency refuge area (ERA)' (E08)
- Two high-scoring existing hazards increase in risk, hazard 'H135 - Vehicle stops in running lane – off peak' (increases from E07.81 to E08.31) and 'H149 – Vehicle drifts off carriageway (i.e. leaving the carriageway as a result of road environment) which increases from E08.00 to E08.03.
- The impact of the new highest scoring hazard and increase to the two existing highest scoring hazards is expected to be countered by the decrease in risk of existing highest scoring hazards
- Calculations show that the total score for 'after' represents approximately a reduction of risk of 18% when compared with the safety baseline.

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

Users

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

- Private recovery organisations
- Emergency services

Workers

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

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

The outcomes of the hazard assessment associated with ALR will be monitored and validated following implementation of schemes.

1 Determine the scope

1.1 Background to introducing ALR

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

In April 2014, the first ALR schemes opened on the M25 between J23 and J25 and between J5 and J7. A further section between J25 and J27 was opened in November 2015.

1.2 Overview ALR design

ALR is described in Design Manual for Roads and Bridges (DMRB) IAN 161/15 “Smart motorway all lane running” [1]. The outline design for ALR 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 site-specific assessment

b. Refuge areas provided at a maximum of 2500m intervals. Refuge areas may either be bespoke facilities (an emergency refuge area (ERA)) or converted from an existing facility, for example a wide load bay, a motorway service area (MSA), the hard shoulder on an exit slip/link road or hard shoulder intra-junction where there is no through junction running

c. Variable mandatory speed limits (VMSL)

d. Above lane specific signalling only provided at the ‘gateway signals and variable message sign’ location, where necessary at intermediate locations and where the number of running lanes exceeds four. At all other signal locations, verge mounted carriageway signalling must be provided

e. Driver information, including mandatory speed limits, are provided at intervals not less than 600m (relaxed on short links) and not exceeding 1500m

f. Queue protection system

g. Full low-light pan-tilt-zoom (PTZ) CCTV coverage

h. Emergency roadside telephones (ERT) are only provided in refuge areas (however not provided in MSA or on slip roads)

i. A central reserve rigid concrete barrier (RCB) shall be provided on all ALR schemes in accordance with TD 19 unless the road worker safety objective can be met by alternative mitigations.

j. Remote access (remote monitoring) to technology equipment

k. Remotely operating temporary traffic management signs

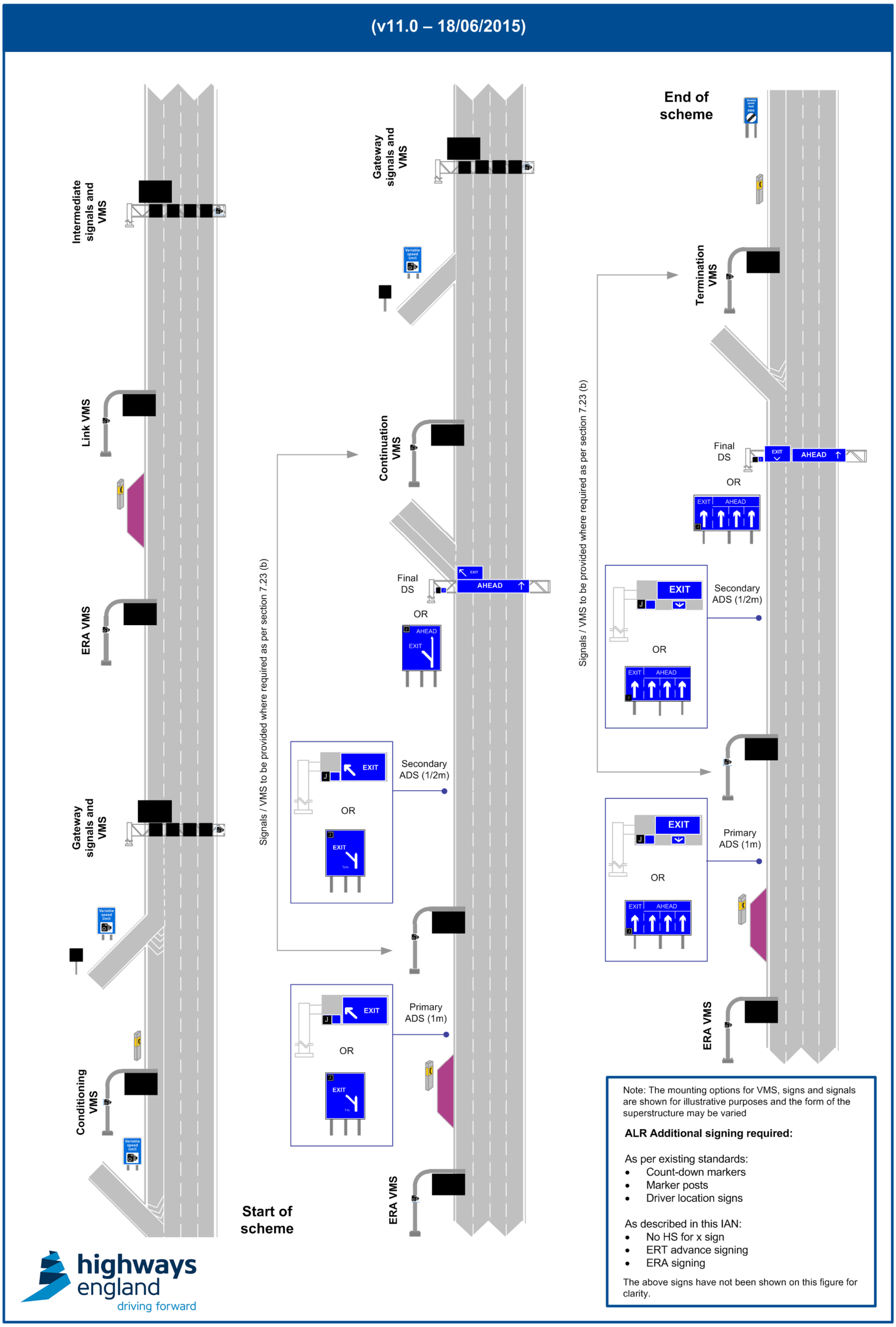


Figure 1-1: Illustrative drawing of smart motorways all lane running

1.3 ALR key safety challenges

The key safety challenges for ALR include:

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

1.4 Document purpose

The purpose of this document is to demonstrate that the safety objectives for ALR are likely to be achieved. A qualitative review of the highest risk 'existing' motorway hazards and the 'new' hazards introduced by ALR, supported by a semi-quantitative assessment of the risk from these hazards, has been used to demonstrate this. Initial results from monitoring of the first ALR schemes on the M25 have been taken into account.

1.5 Document scope

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

1.6 Document structure

The content of the document follows the structure (stages) of the safety risk management process set out in GD04 and is as follows:

- **Chapter 1**: Determine the scope (stage 1) – summarises the background to introducing ALR, overview ALR design, key safety challenges for ALR, purpose and scope of document
- **Chapter 2**: Identify the hazards (stage 2) – describes the approach used to identify hazards for populations affected by the operation of ALR
- **Chapter 3**: Identify relevant criteria for populations (stage 3) – sets out the safety baseline and objectives for the identified populations
- **Chapter 4**: Consider existing risk exposure for each population (stage 4) - provides an overview of current risk exposure for the identified populations
- **Chapter 5**: Risk analysis, assessment and evaluation (stage 5) – presents the results of the risk assessments for the identified populations and summarises whether the safety objective can be met
- **Chapter 6**: Consideration of mitigation measures

  - Risk control decisions (stage 6) – summarises key risk control measures
  - Document safety risk decision in a safety risk report (stage 7) – provides an introduction to the generic ALR safety report
- **Chapter 7**: Maintaining the GD04 assessment
  - Handover of safety risk report to operators (stage 8) – sets out how this GD04 assessment, the generic ALR safety report and other relevant documents are communicated and cascaded to those who require the information
  - Update and refresh the safety risk report when change proposed (stage 9) – provides a summary of updates and changes that have been made to this GD04 assessment and the safety report since the last version
  - Monitor and review safety risk report assumptions (stage 10) – provides a summary of safety monitoring arrangements and results
- **Chapter 6**: Conclusions and recommendations
- **Chapter 7**: References
- **Appendices**: Glossary of terms and abbreviations, medium scoring hazards, risk assessment methodology, 'Controlled environment' paper

2 Identify the hazards

This chapter summarises the methodology used for identifying hazards, assessing their risk and demonstrating meeting of the safety objective.

2.1 Project safety risk management

Highways England implements a comprehensive safety management approach on all its (smart motorway) schemes (IAN 139/11) [4].

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

The approach, developed from the management of safety on the M42 Active Traffic Management (ATM) pilot scheme, provided a framework for managing road user and road worker risk so that an appropriate level of safety management is applied. It takes into account the size and complexity of the project to determine, amongst other factors, an appropriate safety baseline and safety objectives.

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

Populations considered in GD04/12 include:

- Workers: People directly employed by the Agency and who work on the strategic road network (SRN), e.g. Traffic Officers; people in a contractual relationship with the Agency, including NVRM operatives, all workers engaged in traffic management activities and incident support services, and any other activities where live traffic is present, (such as persons carrying out survey and inspection work)
- Users: includes road users, the police and emergency services and non-motorised 'users' such as equestrians, cyclists and pedestrians, as well as those others not in a contractual relationship with the Agency, such as privately contracted vehicle recovery and vehicle repair providers
- Other parties: third parties includes any person or persons who could be affected by the SRN, but who are neither using it, nor working on it, i.e. living or working adjacent to the SRN, using other (non-Agency) transport networks that intersect with the SRN (e.g. local roads, railways) and those who are living or working in properties owned by the Agency.

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

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

2.2 Updating the ALR hazard log

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

- Hazards relating to the dynamic opening and closing of the hard shoulder were removed
- Existing hazards were modified where necessary
- New hazards were added as required

Since the publication of IAN 161/13 the following three hazards have been added to the generic ALR hazard log based on the experience of operating the first ALR schemes on the M25:

Table 2-1: New hazards added to the ALR generic hazard log

Hazard ID	Hazard Description	Event/ State	f	P	s	Before Risk	Change with ALR	ALR Risk	Notes
H156	TOs access incident through traffic (Peak)	Event	4.5	0	1	E5.5	+0.1	E5.6	Risk may increase slightly as TOs have to access more live lane incidents
H157	Emergency services access incident through traffic (Peak)	Event	3	0.5	1	E4.5	+0.1	E4.6	Risk may increase slightly as emergency services have to access more live lane incidents

Hazard ID	Hazard Description	Event/ State	f	P	s	Before Risk	Change with ALR	ALR Risk	Notes
H158	TOs/ Emergency Services access incident via reverse flow	Event	1	2	2	E5	+0.2	E5.2	Risk may increase as reverse flow procedure is expected to be used more frequently with ALR

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

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

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

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

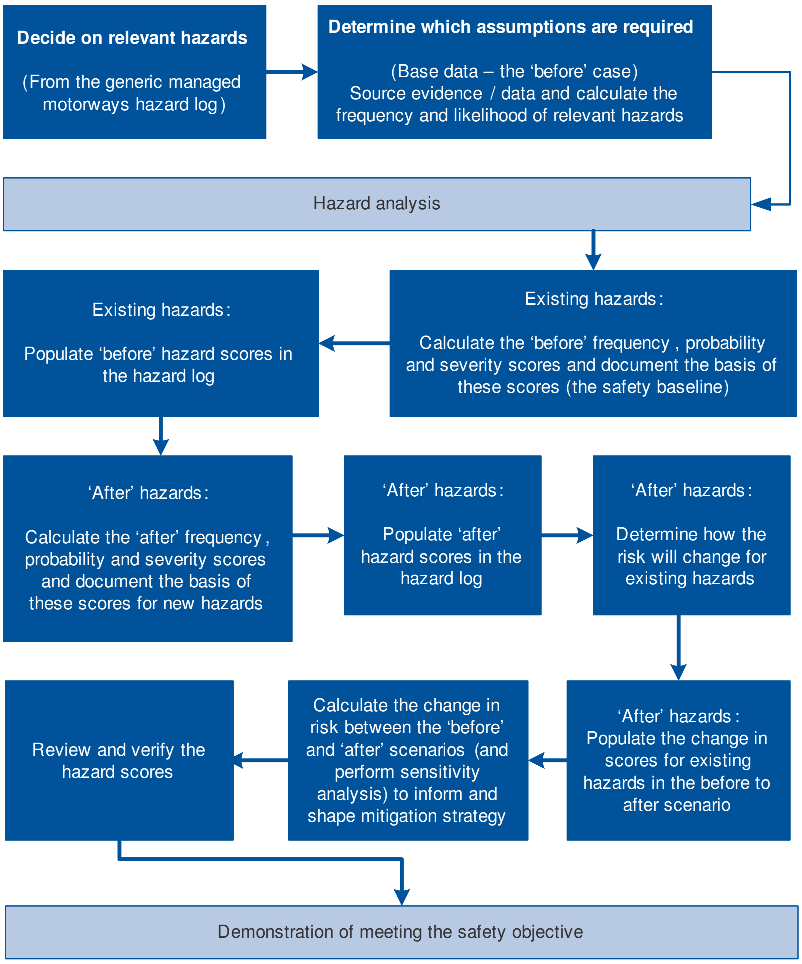


Figure 2-1: Process for demonstrating meeting of safety objective

2.4 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, the risk assessment methodology considers the safety impact of ALR for the following specific user groups:

Users

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

Workers

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

It is necessary to understand how the implementation of ALR affects workers, including maintenance workers and ORR, as they have separate safety objectives. The NVRM is included in this analysis due to their direct employment by Highways England and the statuary obligation to meet the objective for this worker group.

In summary, the methodology involved the following steps:

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

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 ALR
- Checking whether this is sufficient to counterbalance the risk of any new hazards introduced by ALR

The conclusion for each user group is presented as a qualitative proposition supported by semi-quantitative analysis. The hazard assessment is not suited to a quantitative approach as noted in chapter 2.5 below.

2.5 Use of quantitative assessments to support qualitative risk comparison

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

Despite the use of numbers the risk score is only 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.

3 Identify relevant criteria for populations

A generic safety baseline and generic safety objectives have been agreed for ALR schemes. However, each ALR scheme will need to use scheme specific data to determine its specific safety baseline.

3.1 **Safety baseline**

Validated STATS19 personal injury collision 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 the safety objective has been met shall 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 ALR (including motorway incident detection and automatic signalling (MIDAS) queue protection) and prior to the start of construction.

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

3.1.1 Road user safety objective

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

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

3.1.2 Road worker safety objective

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

4 Consider existing risk exposure for each population

4.1 Road users

Highways England's Safety Risk Model (SRM) contains historic road user casualty numbers. These are show in Table 4-1.

Table 4-1: Road user casualties on Highways England motorways

	2011	2012	2013	Total	Average per year
Fatalities	90	78	87	255	85
Serious injuries	654	577	596	1827	609
Slight injuries	8,008	7,556	7,154	2,2718	7,573

From these figures the average annual FWI for road users can be calculated as 221.63 per year (collective road user risk).

In addition, Highways England's 'Standard for safety risk assessment on the strategic road network' GD04/12 [10] puts the annual risk of death to individual road users at 1 in 320,000 for motorways.

Figure**Error! Reference source not found.** 5-1 shows a comparison of the safety risk for all users for D3M baseline (existing risk exposure) compared to the expected level of safety risk following the implementation of ALR. Most of the risk, both for the D3M baseline and for ALR, is to road users.

4.2 Traffic Officers

Highways England's SRM contains historic casualty numbers for TOS. These are show in Table 4-2. Main figures are for motorways only. Figures in brackets are for motorways plus 'unknown' road type.

Table 4-2: TOS casualties on Highways England motorways

	2011	2012	2013	Total	Average per year
Fatalities	0 (0)	1 (1)	0 (0)	1 (1)	0.33 (0.3)

	2011	2012	2013	Total	Average per year
Serious injuries	2 (3)	4 (5)	9 (10)	15 (18)	5 (6)
Slight injuries	38 (46)	22 (25)	14 (17)	74 (88)	24.67 (29.33)

From these figures the average annual FWI for TOS can be calculated as 1.08 (1.23) per year (collective risk for traffic officers).

Figure 5-5 shows a comparison of the existing safety risk for TOS compared to the expected level of safety risk following the implementation of ALR.

4.3 Maintainers

Highways England's SRM contains historic casualty numbers for Highways England's supply chain which covers road workers, construction workers and maintenance workers. Supply chain casualties are show in Table 4-3. Main figures are for motorways only. Figures in brackets are for motorways plus 'unknown' road type.

Table 4-3: Supply chain casualties on Highways England motorways

	2011	2012	2013	Total	Average per year
Fatalities	0 (0)	0 (1)	0 (0)	0 (1)	0 (0.33)
Serious injuries	2 (8)	3 (11)	2 (8)	7 (27)	2.33 (9)
Slight injuries	38 (139)	42 (117)	27 (65)	107 (321)	35.67(107)

From these figures the average annual FWI for Highways England's supply chain can be calculated as 0.59 (2.30) casualties per year (collective risk for maintainers).

4.4 Vehicle stops in running lane

One of the most critical hazards to assess for road users is, "Vehicle stops in running lane". Therefore this hazard needs to be risk scored as accurately as possible in order to understand the existing risk exposure. It was concluded that the nature of this hazard is different between peak (congested) conditions and off-peak (uncongested). That is, during congested conditions it is more likely that when the vehicle stops it will be noticed by drivers of following vehicles and queues will form. This is less likely to happen off-peak.

4.4.1 Understanding this hazard on dual 3-lane motorways

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

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

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

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

	ALR	D3M
Accidents	0.21	0.13
Casualties	0.15	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.

Table 4-5: Proportions of accident occurance

	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.

4.4.2 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 5.1 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 4-1.

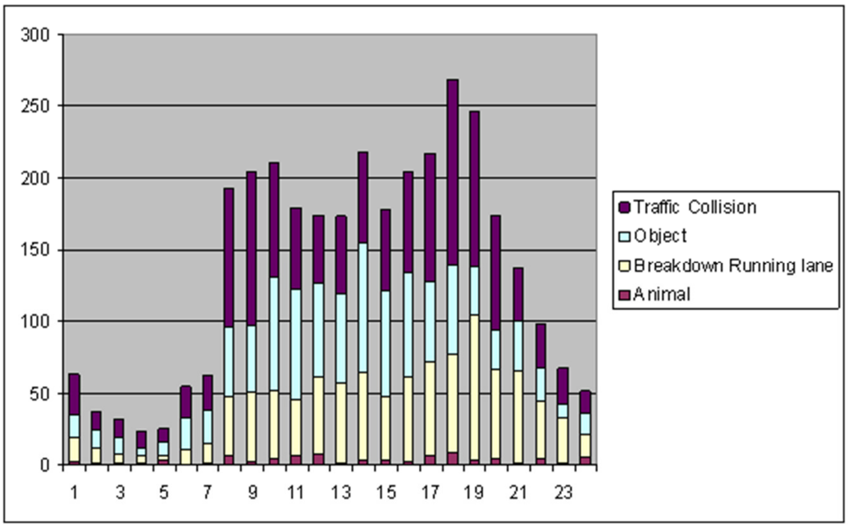


Figure 4-1: Frequency of causes leading to vehicle parked in carriageway (no. of incidents across hours in day)

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

Table 4-6: Frequency of underlying hazards

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

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

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

4.4.3 Determining the hazard probability

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

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

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

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

Assume:

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

4.4.4 Determining the hazard severity

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

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

Table 4-7: Hazard scoring for hazard 'Vehicle stops in running lane' during peak and off peak time

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

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

4.4.5 Reality check

The 'peak' risk component of this hazard represents 0.1% of the baseline D3M risk and the 'off-peak' component 1.4% of the baseline D3M risk. Data from D3M links (see chapter 4.4.1) indicates that combined they represent about 1.6% of all KSI accidents. Therefore, the calculated values are in line with actual KSI accident data.

5 Risk analysis, assessment and evaluation

5.1 Key assumptions

A number of key assumptions have been used within the hazard log to calculate the hazard safety risk scores. Key assumptions relating to the highest scoring hazards (E08/S08 and above) within the generic hazard log are presented in Table 5-1.

Table 5-1: Key assumptions used in the hazard log for ALR

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

Assumption	Description	Value	Comments
A53	Percentage of traffic volume during peak periods	20%	Based on actual figures from first MM-ALR schemes
A71	Vehicles per day per motorway mile	130,000	Based on flows recorded on links on the M3 and M4

5.2 Population of the hazard log

Once the assumptions had been determined, individual risk assessments for each hazard in the hazard log were carried out using the methodology described in Appendix C and the project safety risk management work instructions, IAN 139/11 [4]. An example of application of this methodology is presented in chapter 4.4 (i.e. the assessment of the hazard 'Vehicle stops in running lane').

Following the publication of the M42 smart motorways three year safety review [5], greater assurance is available that a scheme conforming to IAN 111/09 [2] can achieve considerable safety benefits; key elements in common are most notably mandatory speed control and enforcement. Hazards that are impacted by these should see a considerable improvement in safety risk.

Monitoring is being carried out of the first ALR schemes that became operational on parts of the M25 in 2014. Results are only preliminary at this stage due to the short time that ALR has been operational and therefore require further analysis. However, some important results are emerging which have been considered in updating the generic ALR hazard log.

5.3 Analysis of hazards – evidence gathering and assessment

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, variable message sign (VMS) and MIDAS) are anticipated to lead to a reduction in risk. In order for ALR to achieve its safety objective the increases in safety risk that may be introduced by the change in road layout need to be balanced by the provision of technology providing a safe driving environment.

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

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

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

The adequate guidance report considers amongst other issues whether or not the technology elements of 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 ALR generic safety report [7]. Briefly, the implications of these reports are:

- The APTR report suggests that the road layout of 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 review suggests that the environment of ALR (mandatory signals, VMS and MIDAS) is likely to lead to an adequate level of driver compliance (i.e. responding as appropriate to signs and signals). However, evidence is still being collected through continued monitoring of the operation of the first ALR schemes and until this validated evidence is available, the full benefits highlighted in the M42 ATM pilot three year safety review [5] cannot be fully relied upon. This has been taken account in the hazard assessment.

5.4 Risk assessment for all road users

The scoring exercise and the hazard log structure enables the hazards that pose the greatest risk to be targeted and to consider appropriate mitigations. 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 before implementation of ALR, motorway hazards with a score of 8.0 or more account for 92% of the existing risk. Similarly, existing hazards (before implementation of ALR) with a score of 7.5 or more account for 95% of the existing risk and hazards with a score of 7.0 or more account for 99% of the existing risk (see Appendix B).

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

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

- A reduction in risk for a significant number (11) of the highest scoring existing motorway hazards (17). This is due to a controlled environment being provided through a combination of regularly spaced mandatory speed signals, speed enforcement, and full CCTV coverage.
- One highest scoring (i.e. E08/S08 and above) new ALR hazard is introduced, hazard ‘H113 - Vehicle exits ERA’ (E08)
- Two high-scoring existing hazards increases in risk, hazard ‘H135 - Vehicle stops in running lane – off peak’ (increases from E07.81 to E08.31) and ‘H149 – Vehicle drifts

off carriageway (i.e. leaving the carriageway as a result of road environment)' which increases from E08.00 to E08.03.

- The impact of the new highest scoring hazard and increase to one existing highest scoring hazard is expected to be countered by the decrease in risk of existing highest scoring hazards

Calculations show that the total score for 'after' represents approximately a reduction of risk of 18% when compared with the safety baseline.

This analysis suggests that ALR is likely to meet its overall safety objectives. This is shown in Figure 5-1. (For clarity, only the highest scoring hazards on ALR are listed in the table on the right of this figure).

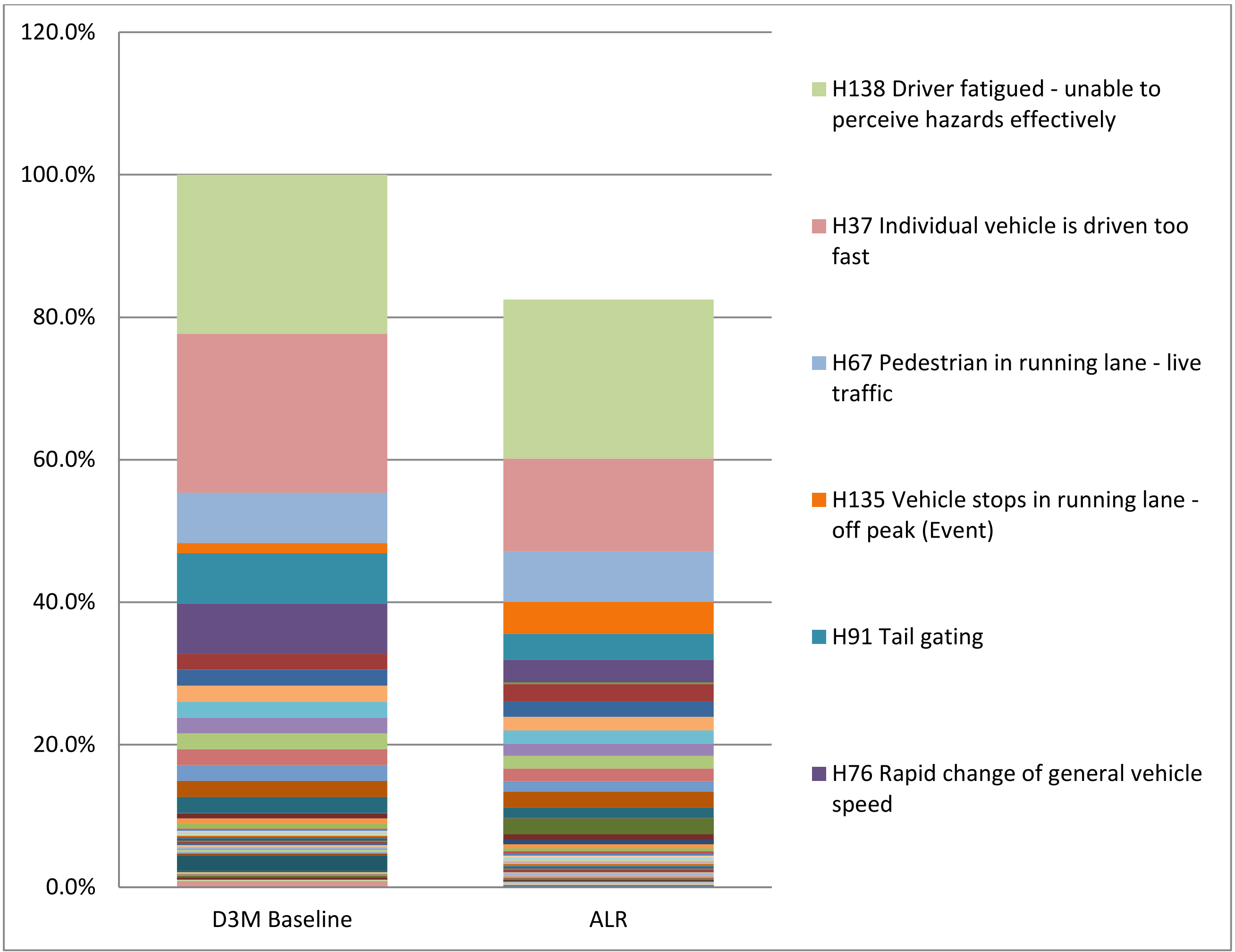


Figure 5-1: Comparison of safety risk for D3M baseline and ALR

The highest scoring hazards are listed below (S08/E08 and above) in Table 5-2. When reviewing Table 5-2 'percentage (%) change in safety risk':

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

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

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

Table 5-2: Change in risk score for high risk hazards

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H138	Driver fatigued - unable to perceive hazards effectively	Event	E09.00	E09.00	0	No change. No benefit from ALR especially off peak when signs and signals are off.
H37	Individual vehicle is driven too fast	State	S09.00	S08.77	-42	Considerable benefit from the controlled environment during the peak but also benefit off-peak (compliance with national speed limit).
H67	Pedestrian in running lane - live traffic	Event	E08.50	E08.50	0	Benefit from the controlled environment. However more instances due to increase in live lane breakdowns
H135	Vehicle stops in running lane - off-peak (Event)	Event	E07.81	E08.31	216	An increase in risk is anticipated reflecting a substantial increase in the frequency of vehicles stopping in a running lane
H91	Tail gating	State	S08.50	S08.20	-49	Considerable benefit from the controlled environment during the peak
H76	Rapid change of general vehicle speed	Event	E08.50	E08.16	-54	Considerable benefit from the controlled environment during the peak
H149	Vehicle drifts off carriageway (i.e. leaving the carriageway as a result of road environment)	Event	E08.00	E08.03	6	Traffic travelling closer to the edge of the carriageway, but better controlled environment during peak. Shallower angle of impact if near side barrier is hit from lane 1. Typically lower speed in lane 1.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H52	Maintenance workers setting up and taking down work site	State	S08.00	S08.00	0	Although there is benefit from the controlled environment (setting of signals during set-up and taking-down), the number of times Traffic Management (TM) is used is expected to increase
H89	Sudden weaving at exit point	Event	E08.00	E07.93	-15	Some benefit from controlled environment
H54	Motorcycles filter through traffic	Event	E08.00	E07.91	-19	Benefit from controlled environment. Smoother traffic travelling at higher speeds - less need to filter through
H13	Driver loses control of vehicle	Event	E08.00	E07.90	-21	Some benefit from controlled environment
H120	Vehicle rejoins running lane	Event	E08.00	E07.90	-21	Non-emergency stops are effectively eliminated and most remaining stops will be in refuge areas
H121	Vehicle reversing along exit slip	Event	E08.00	E07.90	-21	Some benefit from controlled environment
H103	Unsafe lane changing	Event	E08.00	E07.83	-33	Some benefit from controlled environment
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08.00	E08.00	0	More robust and more frequent signalling: controlled environment perception for motorists; but more live lane breakdowns and monitoring of first ALR schemes shows lack of driver compliance with Red X signals
H112	Vehicle enters main carriageway unsafely	Event	E08.00	E07.80	-37	Some benefit from controlled environment based upon optimum provision as outlined through an overrun assessment

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H154	Vehicle stopped on hard shoulder (D3M) or verge (MM-ALR)	State	S08.00	S06.50	-97	Effectively eliminated. Non emergency stops are reduced and most remaining stops will be in refuge areas
H113	Vehicle exits ERA	Event		E08.00		ALR introduced hazard

5.4.1 Vehicle stops in running lane

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

Figure 5-2 shows the expected number of live (i.e. running) lane stops. ALR is expected to eliminate illegal stops currently taking place on the hard shoulder. Of the expected number of vehicle breakdowns that currently occur on a hard shoulder it is estimated that 50% are able to reach a refuge area. Ten percent of the remaining 50% are expected to stop on the verge as a proportion of ALR schemes will not have any safety barrier. Under ALR we therefore expect about 0.35 breakdowns per day per carriageway mile in a live (i.e. running lane). This is around three times greater than the current D3M rate for live lane stoppages.

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

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

Figure 5-2: ALR live lane breakdowns flowchart

Less than 1 in 10 vehicles (7.5%) that we see currently stopping on the hard or in a live lane of a D3M carriageway are expected to stop in a live lane in an ALR scenario.

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

Monitoring of the first ALR schemes on the M25 has confirmed that actual live lane stoppage numbers are comparable to those predicted (see Figure 5-3). This shows that since ALR operation started on the whole section M25 J23-27 since 7 November 2014 until 25 May 2015 (January 2015 has been excluded from this analysis due to issues with data)).

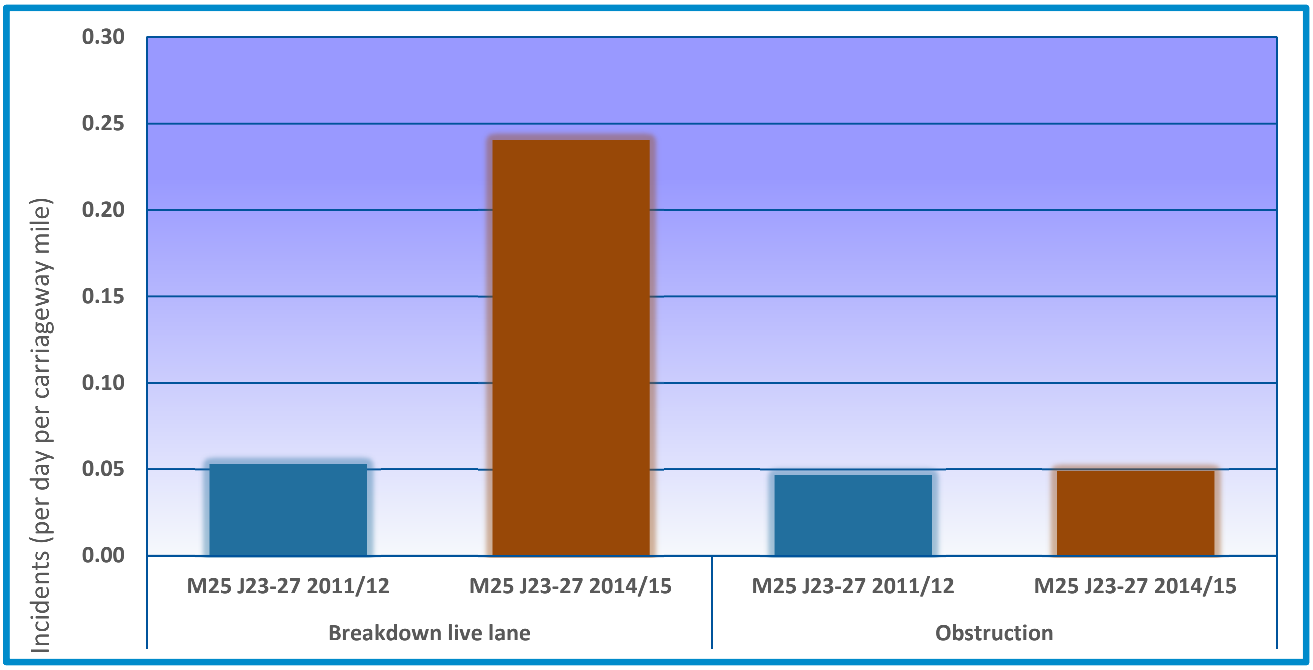


Figure 5-3: M25 J23-27 ALR live lane breakdowns and obstructions

5.5 Risk assessment for pedestrians

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

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

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

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H146	Pedestrians walking along the hard shoulder (applies to D3M only)	State	S06.50	S00.00	Eliminated	Eliminated. No hard shoulder under ALR
H147	Pedestrians walking in lane 1 (applies to ALR only)	State		S05.80		ALR introduced hazard

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

The second highest scoring hazard (H69, S07.5), which reduces in risk under ALR, is an order of magnitude greater in risk than the new hazards introduced with ALR (H48, E06.5; H74, S06.5; H147, S05.80). One hazard (H146, S06.5) is eliminated with the implementation of ALR. The significant reduction in risk to hazard H69 is likely to dominate the total risk for pedestrians. It can be concluded that the safety objective is likely be met for pedestrians for ALR schemes.

This is shown in Figure 5-4. (For clarity, only the highest scoring hazards on ALR are listed in the table on the right of this figure).

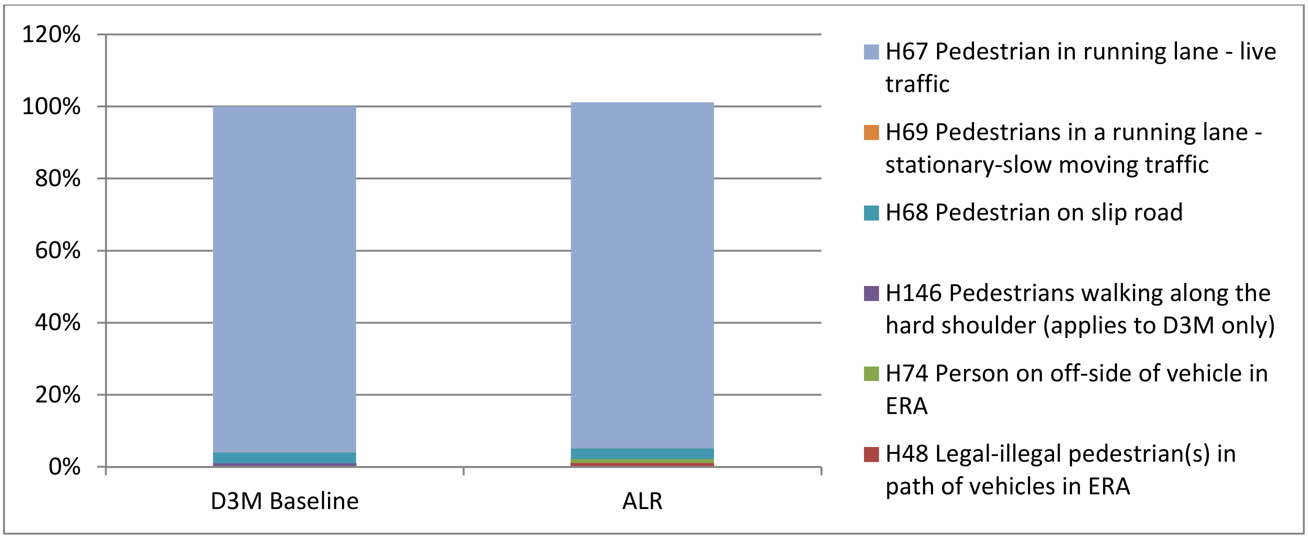


Figure 5-4: Comparison of pedestrian safety risk for D3M baseline and ALR

5.6 Risk assessment for motorcyclists

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

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

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H54	Motorcycles filter through traffic	Event	E08.00	E07.91	-19	Benefit from controlled environment. Smoother traffic travelling at higher speeds - less need to filter through
H58	Motorcyclist cross wind buffering	State	S06.50	S06.50	0	Running of ALR will not create a change in the risk associated with this hazard.
H59	Motorcyclist falls off crossing line on entry to ERA	Event		E06.50		ALR introduced hazard
H145	Motorcyclists crosses rumble strips	Event	E05.50	E05.50	0	Running of ALR will not create a change in the risk associated with this hazard
H143	Motorcycle stopped next to running lanes (D3M = hard shoulder, ALR = verge)	State	S07.00	S05.50	-97	Non emergency stops are effectively eliminated as there is no hard shoulder to stop on under ALR. Most remaining stops will be in refuge areas. Only some stops may occur in verge under ALR.
H144	Motorcycle uses hard shoulder to pass slow moving or stationary traffic	State	S06.00	S00.00	Eliminated	Eliminated. No hard shoulder under ALR

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

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

5.7 Risk assessment for HGV drivers

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

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

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H141	HGV-LGV-Bus exits ERA	Event		E07.50		ALR introduced hazard. Initial monitoring of first ALR schemes has shown considerable amount of non-emergency stops in ERAs
H142	Large vehicle does not completely clear the running lane when stopping on hard shoulder (D3M) or verge (ALR)	State	S04.50	S04.20	-50	Hard shoulder will become a permanent full time running lane, reducing the occurrences of HGVs stopping, as only verge will be available, and only in some locations.

The highest risk new hazard affecting large vehicles is 'H141 - HGV-LGV-Bus exits ERA' which is scored as an E07.50. Larger vehicles will find it harder to exit from an ERA during ALR due to their slow acceleration. However monitoring on the M42 scheme has identified no significant problems with large vehicles leaving ERAs. In addition there are established procedures to assist vehicles to exit from ERAs. Mitigation measures have been identified to reduce this risk. Initial monitoring of the first ALR schemes has shown considerable amount of non-emergency stops in ERAs. Further monitoring and analysis is required to assess whether the risk from this hazard should be changed.

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

As it can be demonstrated that the safety objective for all vehicles is likely to be met (see section 5.4) it is likely that the safety objective for HGVs and other large vehicles can also be met.

5.8 Risk assessment for disabled drivers or passengers

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

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

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

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

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

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

5.9 Risk assessment for private recovery organisations

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

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

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

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

5.10 Risk assessment for emergency services

The emergency services related hazards are listed in Table 5-6 below in descending 'after' safety risk score.

Table 5-6: Change in risk score for emergency services related hazards

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08.00	E08.00	0	More robust and more frequent signalling: controlled environment perception for motorists; but more live lane breakdowns and monitoring of first ALR schemes shows lack of driver compliance with Red X signals.
H87	Speed differential between emergency services and general traffic	Event	E06.50	E06.50	0	No change in risk
H34	Incident management - rolling block	Event	E06.50	E06.91	158	Lack of hard shoulder for stoppages from which to commence incident management means rolling road block will be required more often under ALR
H22	Emergency staff - TO etc on foot at scene of an incident	State	S06.00	S06.00	0	Expect more live lane breakdowns. Better protection of each incident
H101	Unable to set signs and signals to protect incidents	State	S06.00	S06.00	0	Do not rely wholly on signs and signals for protection
H83	Signals change while TO/ emergency services are still on motorway	Event	E06.00	E05.90	-21	CCTV available for operators to check whether there is still attendance at incident
H66	Operator fails to set signals to protect incident in timely manner	State	S05.50	S05.40	-21	CCTV to inform operators where exactly incident is, to improve signal setting time
H84	Signals set in wrong place (i.e. are not	State	S04.00	S03.90	-21	CCTV for operators to confirm incident location

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
	protecting the incident)					

For the highest risk hazard 'H11 - Driver ignores closed lane(s) signals that are protecting an incident' (E08.0) the risk is expected to remain unchanged. Emergency services are not reliant on the setting of signs and signals to close a lane to establish a safe place to work. They will secure the scene of the incident by the positioning of vehicles and the establishment of ETM. However, with the introduction of ALR the number of live lane breakdowns is expected to increase. Monitoring of the first ALR schemes that started operating on parts of the M25 in 2014 showed that the increase in the number of live lane stops is in line with assumptions. Initial monitoring also showed that at times driver compliance with Red X lane closure signals was poor particularly at times of high traffic flow.

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

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

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

5.11 Risk assessment for on road resources (ORR)

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

Table 5-7: Change in risk score for on road resources related hazards

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08.00	E08.00	0	More robust and more frequent signalling: controlled environment perception for motorists; but more live lane breakdowns and monitoring of first ALR schemes shows lack of driver compliance with Red X signals.
H94	TO arrives, but has difficulty containing the scene	Event	E07.00	E06.90	-21	More robust and more frequent signalling to protect TO

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H96	TOs behave hazardously at an incident	Event	E06.50	E06.50	0	No change expected
H34	Incident management - rolling block	Event	E06.50	E06.91	158	Lack of hard shoulder for stoppages from which to commence incident management means rolling road block will be required more often under ALR
H22	Emergency staff -TO etc on foot at scene of an incident	State	S06.00	S06.00	0	Expect more live lane breakdowns. Better protection of each incident
H101	Unable to set signs and signals to protect incidents	State	S06.00	S06.00	0	ORR do not rely wholly on signs and signals for protection
H83	Signals change while TO/ emergency services are still on motorway	Event	E06.00	E05.90	-21	CCTV available for operators to check whether there is still attendance at incident
H66	Operator fails to set signals to protect incident in timely manner	State	S05.50	S05.40	-21	CCTV for operators to confirm incident location
H84	Signals set in wrong place (i.e. are not protecting the incident)	State	S04.00	S03.9	-21	CCTV for operators to confirm incident location
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07.00	S00.00	Eliminated	As for H34, rolling road block required in all circumstances. Therefore, this hazard is eliminated.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H95	TO/maintainer in running lane	Event	E06.50	E00.00	Eliminated	Safer working environment. Assumption Rolling Road block must be used for all causes of this hazard supported by signals.

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

'H62 - On road resources work unprotected' (S07.5) is also expected to improve as mandatory signals and message signs can be used to protect ORR and inform motorists of their presence. Short duration stops and debris removal by TO/maintenance workers (H82) and TO/maintenance stops in the running lane are eliminated under ALR. This work, as well as other work, will now require a rolling road block, which is why the risk of hazard H34 is expected to increase.

As noted above work has also be carried out in assessing risk in relation to TOS procedures, which indicates that the risk to this worker group can be managed SFAIRP. Activities undertaken by the NVRM are covered in chapter 5.9 which concludes that the risk to this group can also be managed SFAIRP.

This is shown in Figure 5-5. (For clarity, only the highest scoring hazards on ALR are listed in the table on the right of this figure).

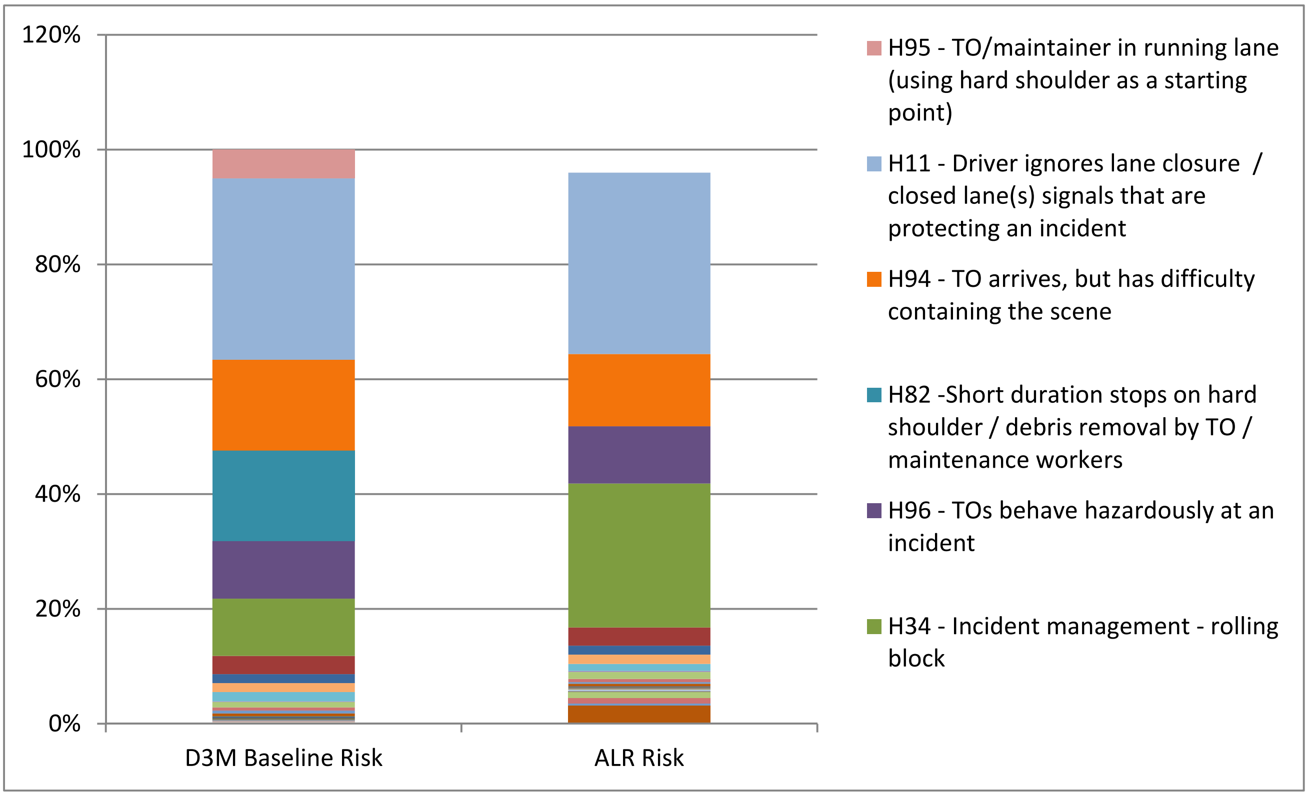


Figure 5-5: Comparison of safety risk for D3M baseline and ALR

5.12 Risk assessment for maintenance workers

The maintenance workers related hazards are listed in Table 5-8 below in descending after safety risk score order.

Table 5-8: Change in risk score for hazards relating to maintenance workers

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H52	Maintenance workers setting up and taking down work site	State	S08.00	S08.00	0	Benefit from the controlled environment (setting of signals during set-up and taking-down), but number of times TM is used is expected to increase.
H79	Roadworks - long term static	State	S07.50	S07.50	0	No change in risk
H80	Roadworks - short term static	State	S06.50	S06.80	99	Increase in equipment contributes to increased number of activities.
H51	Maintenance workers in carriageway	Event	E06.00	E06.00	0	No change in risk
H136	Collision with workers doing maintenance on verge	State	S06.50	S00.00	Eliminated	Eliminated. This will not occur without TM and rolling road block
H148	Roadworks - short term static on hard shoulder	State	S07.50	S00.00	Eliminated	No hard shoulder under MM-ALR. Therefore hazard is eliminated
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07.00	S00.00	Eliminated	Eliminated. This will not occur without TM and rolling road block

One of the highest risk hazards 'H52 - Maintenance workers setting up and taking down work site' (S08.0) is expected to be no worse compared to the baseline. Likewise, hazard 'H79 - Roadworks - long term static' (S07.5) is not expected to change with the implementation of ALR. However, the use of remote access to technology should reduce the number of visits required to the roadside, and hence the number of times TM is set up. The risk is also reduced through the use of remotely operated Temporary Traffic Management (TTM) signs.

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

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

From the above initial hazard analysis it can be concluded that the safety objective is likely to be achieved and that the risk is managed SFAIRP.

6 Consideration of mitigation measures

6.1 Risk control decisions

6.1.1 Road Users

Key mitigation features specified within the Design Manual for Roads and Bridges (DMRB) IAN 161/13 “Managed Motorway – All lanes running” are outlined in section 1.2 of the safety report. It has been shown in section 5.4 that the safety objective for road users can be met with these design features.

In addition the following risk control measures are being taken forward by Highways England:

- Single vehicle detection (SVD) is currently being trialled on the M62. This could improve incident response times by shortening the time taken to detect an incident and setting variable message signs and signals to protect vehicles in a live lane.
- More campaigns for driver education to encourage compliance with signals, in particular red X, encouraging drivers to make sure their vehicle is road worthy before entering the motorway, and to follow safety guidance when driving within ALR schemes.
- Automatic red X enforcement should driver education not reduce red X non-compliance sufficiently.
- Use of turn around points to reduce response times to incidents.

6.1.2 Road workers

6.1.2.1 Traffic officers

With the risk control measures outlined in section 1.2 it has been shown in section 5.11 that the safety objective for road workers (traffic officers) can be met. In addition, the Operating Smart Motorways engagement with core responders was formed through a national Steering Group with supporting Task and Finish Groups to define and agree a single national approach to the operation of ALR schemes. This provides efficient routine operation and sets out a uniform approach to incident management. The Terms of Reference for the Operating Smart Motorways engagement have been updated so that it continues in parallel with the smart motorways programme. Following programme level engagement each scheme will engage locally with stakeholders, including local authorities and emergency services. The Operating Smart Motorways engagement will continue to work to improve the incident response of core responders on ALR, as well as consider improvements for their safety.

The campaigns for driver education and the development of automatic red X enforcement should also provide safety benefits for traffic officers. This will be through a combination of minimising the number of incidents traffic officers have to attend in live lanes (for example reducing the number of vehicles running out of fuel), as well as reducing their risk when working in a live lane.

6.1.2.2 Maintenance workers

With the risk control measures outlined in section 1.2 it has been shown in section 5.12 that the safety objective for road workers (maintainers) can be met. Various AfZ projects are currently being undertaken with the aim of further reducing the risk from hazards faced by road workers (maintainers). These projects are not currently critical to the achievement of the road worker safety objective, however they are anticipated to provide significant benefits to road workers (maintainers). The following AfZ projects are deemed to be relevant to ALR schemes:

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

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

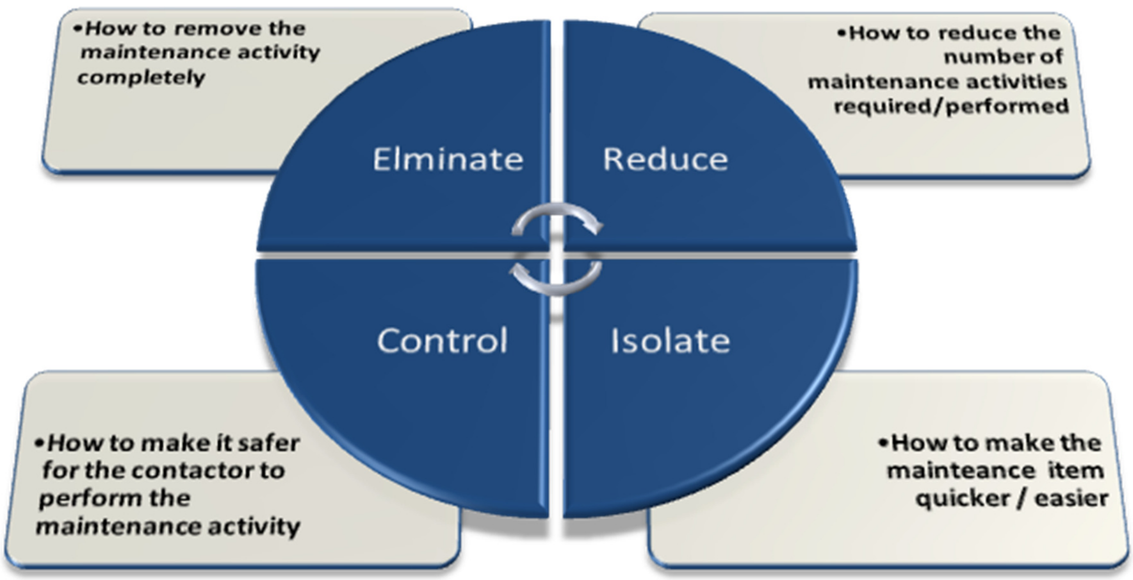


Figure 6-1: The principles of an 'ERIC' assessment

This principle looks at reducing the need for maintenance by considering what maintenance can be eliminated or reduced. Highway England's ALR Meeting the Road Worker Safety Objective Task and Finish group has undertaken further review of an ERIC assessment of maintenance activities that reside at Highways England programme level. The following programme issues are being addressed:

- Removal of fog sensors – this would not seem viable due to their interdependency on associated equipment. A review of reported faults to identify poorly functioning equipment, though the benefits offered by fog detectors seems to be limited

- Increasing time to fix faults – analysis is on-going and will be taking account of a risk based approach to repair times, an update to technology management and maintenance manual (TMMM) [9] is an expected outcome of this task

- Review of cleaning requirements for technology

- Review of statutory electrical testing requirements and test periods for mechanical equipment

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

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

6.2 Document safety risk decision in a safety risk report

In addition to the GD04 assessment documented in this report, the work is summarised in the ALR generic safety report.

7 Maintaining the GD04 assessment

7.1 Handover of safety risk report to operators

The GD04 assessment documented in this report along with the ALR generic safety report assess a generic ALR scheme. Specific schemes will need to carry out their own assessments and produce their own scheme specific evidence demonstrating that the scheme is acceptably safe to operate and maintain. It is these scheme specific reports that are handed over to the operators and maintainers such as Customer Operations and NDD. The generic safety documentation will be made available to schemes by Highways England as a reference and starting point for the scheme specific risk assessments.

7.2 Update and refresh the safety risk report when change proposed

Any change proposed to IAN161 will lead to a review and update of related safety reports, including this document. The availability of validated monitoring evidence from ALR schemes will also necessitate a review of these assessments.

7.3 Monitor and review safety risk report assumptions

Each ALR scheme is required to produce a Plan for Monitoring Operations. Monitoring is being carried out of the first ALR schemes that went into operation on parts of the M25 in 2014. Results are only preliminary at this stage due to the short time that ALR has been operational and require further analysis and consideration before they are used as evidence. Feedback from individual scheme monitoring will be collated at programme level and used to review the associated safety risk reports for ALR, including this one.

8 Conclusions and recommendations

8.1 Demonstration of meeting safety objective for all users

In respect of the safety objective for all users, this report demonstrates that ALR schemes are likely to meet the safety objective and takes account of:

- A reduction in risk for a significant number (11) of the highest scoring existing motorway hazards (14), due to a controlled environment being provided through a combination of regularly spaced mandatory speed signals, speed enforcement, and full CCTV coverage
- One highest scoring (i.e. E08/S08 and above) new ALR hazard is introduced, hazard 'H113 - Vehicle exits ERA' (E08)
- Two high-scoring existing hazards increase in risk, hazard 'H135 - Vehicle stops in running lane – off peak' (increases from E07.81 to E08.31) and 'H149 – Vehicle drifts off carriageway (i.e. leaving the carriageway as a result of road environment)' which increases from E08.00 to E08.03)
- The impact of the new highest scoring hazard and increase to two existing highest scoring hazards is expected to be countered by the decrease in risk of existing highest scoring hazards
- Calculations show that the total score for 'after' represents approximately a reduction of risk of 18% when compared with the safety baseline.

8.2 Demonstration of meeting safety objective for specific users

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

Users

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

Workers

- On road resources (ORR)
- Maintenance workers

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

Preliminary results from initial monitoring of the first ALR schemes on the M25 show that ALR performs broadly in line with expectations. Issues for further analysis include significant driver non-compliance with Red X lane closure signals and non-emergency use of ERAs particularly by HGVs.

9 References

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

Appendix A: Glossary of terms and abbreviations

Acronym	Description
ALR	All lane running
APTR	All purpose trunk road
ATM	Active traffic management
CCTV	Closed circuit television
CDM	Construction (Design & Management)
D3M	Dual 3-lane motorway
DMRB	Design Manual for Roads and Bridges
ERA	Emergency refuge area
ERT	Emergency roadside telephone
FWI	Fatal and weighted injury
HGV	Heavy goods vehicle
KSI	Killed, seriously injured
LGV	Large goods vehicle
LBS	Lane below signal
MIDAS	Motorway incident detection and automatic signalling
MSA	Motorway service area
ORR	On road resource
PTZ	Pan-tilt-zoom
RCB	Rigid concrete barrier
RCC	Regional control centre
SFAIRP	So far as is reasonably practicable
TJR	Through junction running
TOS	Traffic officer service
VMS	Variable message sign
VMSL	Variable mandatory speed limit

Appendix B: Medium scoring hazards

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

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

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

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H141	HGV-LGV-Bus exits ERA	Event		E07.50		ALR introduced hazard
H79	Roadworks - long term static	State	S07.50	S07.50	0	No change expected
H113	Vehicle exits ERA	Event		E07.50		ALR introduced hazard
H110	Vehicle drifts out of lane	Event	E07.50	E07.43	-15	More lanes available for motorists and better controlled environment, decreasing the likelihood of hazard
H137	Debris in running lane (being hit or causing unsafe manoeuvre)	State	S07.50	S07.23	-47	More lanes, so evasive action will be easier
H116	Vehicle misjudges entry to ERA	Event		E07.00		ALR introduced hazard
H126	Vehicle stopped on slip road (off or on slip)	Event	E07.00	E07.10	26	As there is no hard shoulder under ALR, it is possible that a vehicle may limp to the slip road and then stop

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H122	Vehicle reversing back to exit slip	Event	E07.00	E07.06	15	An increase in risk off-peak as all lanes are running lanes under ALR
H32	Health deterioration of vehicle occupant	Event	E07.00	E07.05	13	Potential increase in risk as more live lane stops as a result of health deterioration of vehicle occupant
H42	Lane(s) closed, but driver unable to leave lane and stops	Event	E07.00	E07.00	0	No change expected
H68	Pedestrian on slip road	State	S07.00	S07.00	0	No change expected
H150	Vehicle in ERA (or verge) obtrudes into lane 1 (applies only to ALR)	State		S07.00		ALR introduced hazard
H131	Vehicle suddenly decelerates at end of on slip road	Event	E07.00	E07.00	0	No change expected
H36	Incidents or congestion caused in other lanes or carriageway due to rubber necking	State	S07.00	S06.90	-21	Some benefit from controlled environment
H94	TO arrives, but has difficulty containing the scene	Event	E07.00	E06.90	-21	More robust and more frequent signalling to protect TO
H123	Vehicle reversing up entry slip	Event	E07.00	E06.90	-21	Less congestion expected under ALR, so less need for motorists to reverse back up entry slip.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H104	Unsafe lane changing in the slip road (both off and on slips)	Event	E07.00	E06.86	-28	Good lane discipline with controlled environment and less congestion.
H2	Abnormal loads - notifiable	Event	E07.00	E06.80	-37	Better signalling to advise motorists of the presence of abnormal loads
H77	Reduced visibility due to weather conditions	State	S07.00	S06.80	-37	Signals can be set to warn/inform motorists and will be more visible
H99	TOs/emergency services not despatched in a timely manner	Event	E07.00	E06.80	-37	CCTV to inform operators where exactly incident is, to improve despatch time
H102	Undertaking	Event	E07.00	E06.80	-37	More lanes available, so less need for undertaking. During peak times smoother and more even traffic flows reduce need for undertaking.
H80	Roadworks - short term static	State	S06.50	S06.80	99	Increase in equipment contributes to increased number of activities.

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H118	Vehicle on the main carriageway decelerates suddenly	Event	E07.00	E06.70	-50	Benefit from controlled environment; signals can be set automatically in response to queues (one of the main reasons why a vehicle might need to decelerate suddenly)
H30	Group of vehicles drive too fast (in relation to variable speed limit or national speed limit)	State	S07.00	S06.70	-50	Benefit from controlled environment
H143	Motorcycle stopped next to running lanes (D3M = hard shoulder, ALR = verge)	State	S07.00	S05.50	-97	Non emergency stops are effectively eliminated as there is no hard shoulder to stop on under ALR. Most remaining stops will be in refuge areas. Only some stops may occur in verge under ALR.
H148	Roadworks - short term static on hard shoulder	State	S07.50	S00.00	Eliminated	No hard shoulder under ALR Therefore hazard is eliminated
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07.00	S00.00	Eliminated	Eliminated. This will not occur without TM and rolling road block

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
H153	Vehicle reversing up hard shoulder (D3M) or lane 1 (ALR)	Event	E07.00	E05.50	-97	Effectively eliminated, as hard shoulder does not exist for 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'.

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

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

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

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

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

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

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

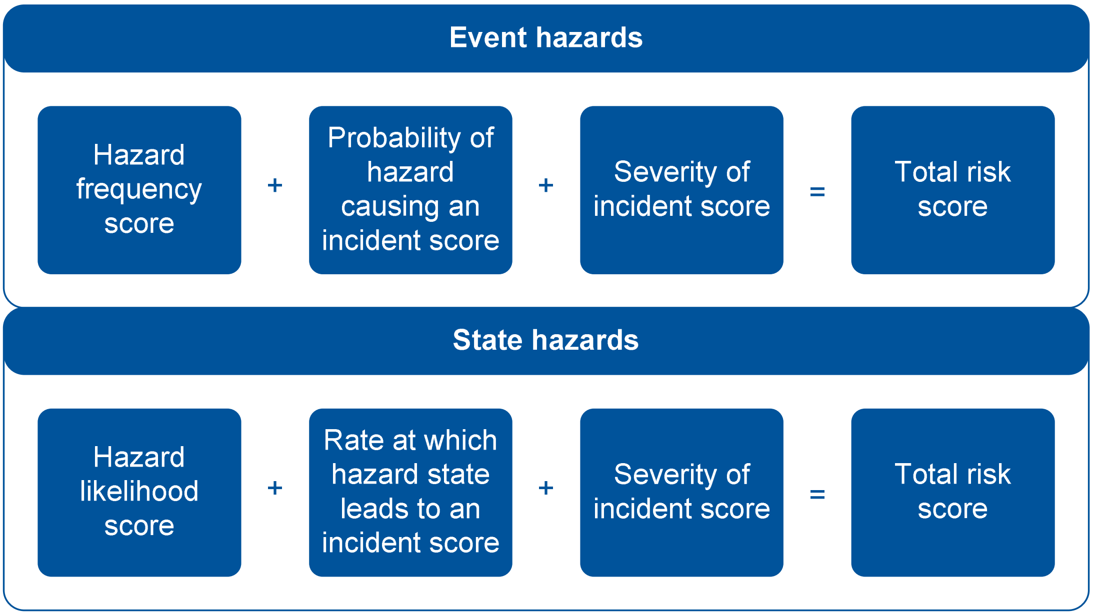


Figure C-1: Risk score components

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

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

Event Frequency

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

Table C-1: Frequency classifications and index values

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

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

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

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

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

Its overall score is E07.00

State Likelihood

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

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

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

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

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

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

Its overall score is S07.00

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

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

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

Table C-3: Event/State collision probability rates

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

C.3 Index values used for severity

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

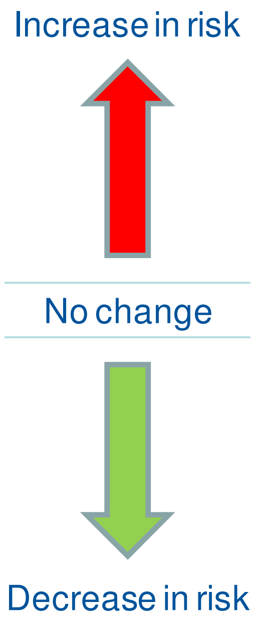
Severity Classification	Interpretation	Index Value	Person outside of vehicle	Stationary Vehicle	Motorcycle	Car	Large Vehicle (LHV, HGV, Bus)
Severe	The proportion of collisions that are fatal is expected to be higher than average by at least a factor of 10	2.0	Involved	Involved	Involved	Speed differential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

Table C-4: Event/State collision severity rates

C.4 Index values used for ‘after’ scoring values

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

Table C-5: ‘After’ scoring index values



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

Appendix D: Controlled environment

Introduction

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

Outcomes

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

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

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

A 'controlled environment'

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

The change in driver behaviour

Accidents are generally associated with a number of common causation factors including speeding, weaving (injudicious lane changing), inappropriate headways (tailgating) and fatigue. Therefore it is essential that a scheme identifies the environment that result in the behaviour that can cause these accidents and introduces appropriate mitigation to reduce the level of risk of hazards being realised to an acceptable / manageable level. A relatively small number of hazards make up a significant proportion of the overall level of risk on a scheme[2]. The introduction of a controlled environment will influence the behaviour of road

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

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

users, which will also provide benefits for road workers due to an improved level of compliant driver behaviour.

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

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

The Smart Motorway Controlled Environment

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

Operations:

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

Infrastructure:

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

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

Technology:

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

Maintaining the controlled environment

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

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

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

Table E-1: Key hazards and mitigations

	Measures to enable a Controlled Environment		
Hazard (Approximate % of overall scheme risk)	**Operational**	**Infrastructure**	**Technology**
Driver fatigued – unable to perceive hazards effectively (22%)	- Information displayed in timely manner - Appropriate signalling regime to meet operational requirements	- Lining and stud provision - Enhanced visual environment	- Signals on verge mounted VMS and overhead gantries
Individual vehicle is driven too fast (13%)	- Education – driver understanding of information - Encouragement – changing behaviour on the road - Suitable and relevant information - Information displayed in timely manner - Customer perception - Visibility of information - Perceived enforcement (surveillance / 'being watched') - Appropriate signalling regime to meet operational requirements	- Gantries - Cantilevers - Fixed plate enforcement signs - Enhanced visual environment	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras - Inductive loops (MIDAS)
Vehicle stops in running lane – (off peak in ALR) (4.5%)	- Suitable and relevant information - Traffic Officer procedures and ability to monitor	- Additional lane (no hard shoulder) - Gantries - Fixed plate enforcement signs - ERAs with ERTs	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Inductive loops (MIDAS)
Pedestrian in running lane – live traffic (7%)	- Suitable and relevant information - Traffic Officer and RCC ability to monitor	- ERAs with ERTs	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV
Rapid change of general vehicle speed (3%)	- Education - driver understanding of information - Suitable and relevant information - Information displayed in timely manner - Visibility of information - Perceived enforcement (surveillance / 'being watched') - Traffic Officer procedures and RCC ability to monitor - Appropriate signalling regime to meet operational requirements	- Gantries - Cantilevers - Additional lane (no hard shoulder) - Fixed plate enforcement signs	- Signals on verge mounted - VMS and overhead gantries - Enforcement cameras - Inductive loops (MIDAS)

	Measures to enable a Controlled Environment		
Hazard (Approximate % of overall scheme risk)	**Operational**	**Infrastructure**	**Technology**
Tailgating (3%)	- Education - driver understanding of information - Encouragement – changing behaviour on the road - Suitable and relevant information - Customer perception - Perceived enforcement (surveillance / 'being watched') - Appropriate signalling regime to meet operational requirements	- Additional lane (no hard shoulder) - Enhanced visual environment	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras - Inductive loops (MIDAS)
Vehicle drifts off carriageway (2%)	- Encouragement – changing behaviour on the road - Suitable and relevant information - Information displayed in timely manner	- Gantries - Cantilevers - Lining and stud provision - Safety barriers - Enhanced visual environment	- Signals on verge mounted VMS and overhead gantries
Sudden weaving at exit point (2%)	- Suitable and relevant information - Information displayed in timely manner - Visibility of information - Appropriate signalling regime to meet operational requirements	- Advanced Direction Signs - Lining and stud provision	- Comprehensive CCTV - Inductive loops (MIDAS)
Motorcycles filter through traffic (2%)	- Education – driver understanding of information - Encouragement – changing behaviour on the road - Suitable and relevant information - Information displayed in timely manner - Perceived enforcement (surveillance / 'being watched')	- Gantries - Additional lane (no hard shoulder)	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras
Driver loses control of vehicle (2%)	- Education - driver understanding of information - Encouragement – changing behaviour on the road - Suitable and relevant information - Information displayed in timely manner	- Gantries - Additional lane (no hard shoulder) - Fixed plate enforcement signs - Lining and stud provision - Safety barriers	- Signals on verge mounted VMS and overhead gantries

	Measures to enable a Controlled Environment		
Hazard (Approximate % of overall scheme risk)	**Operational**	**Infrastructure**	**Technology**
	- Visibility of information - Appropriate signalling regime to meet operational requirements	- Enhanced visual environment	
Vehicle rejoins running lane (2%)	- Visibility of information - Appropriate signalling regime to meet operational requirements	- ERAs with ERTs - Additional lane (no hard shoulder)	- Signals on verge mounted VMS and overhead gantries
Unsafe lane changing (1.5%)	- Education – driver understanding of information - Information displayed in timely manner - Customer perception - Perceived enforcement (surveillance / 'being watched') - Appropriate signalling regime to meet operational requirements	- Advanced Direction Signs - Additional lane (no hard shoulder) - Lining and stud provision	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras - Inductive loops (MIDAS)
Vehicle enters main carriageway unsafely (2%)	- Education – driver understanding of information - Suitable and relevant information - Visibility of information - Appropriate signalling regime to meet operational requirements	- Fixed plate enforcement signs - Lining and stud provision	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras
Driver ignores closed lane(s) signals that are protecting an incident (2%)	- Suitable and relevant information - Customer perception - Visibility of information - Appropriate signalling regime to meet operational requirements	- Gantries - Cantilevers - Fixed plate enforcement signs	- Signals on verge mounted VMS and overhead gantries - Comprehensive CCTV - Enforcement cameras