Smart motorways all lane running
Generic safety report

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Executive summary

Introduction

This document is the generic safety report for smart motorways all lane running (ALR). The purpose of this document is to demonstrate that the appropriate level of safety management has been undertaken to assess the expected safety performance for the implementation of ALR.

The key safety challenges for ALR are:

- 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

Conclusion

The information presented in this report demonstrates that:

A safety objective has been set for ALR schemes and is likely to be achieved

A generic safety baseline and generic safety objectives have been agreed for ALR schemes. These cover road users and road workers.

Road user safety baseline:

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

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

For the purposes of this report, the safety baseline assumes prior to the implementation of any element of smart motorways (including motorway incident detection and automatic signalling (MIDAS)).

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

Road worker safety:

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.

The methodology used to demonstrate whether the safety objective can be achieved is based on the methodology used successfully for the M42 J3a to J7 Active Traffic Management Pilot scheme and Birmingham Box Smart Motorways Phase 1&2 (BBSM1&2) schemes. Results from the "M42 monitoring and evaluation three year safety review" [2] have been used to provide some evidential basis for the likely safety performance of the ALR generic scheme. Further evidence has been provided from a review of the safety performance of the all purpose trunk road (APTR) network [7] and a review of the likely impact of ALR on driver compliance and understanding [8]. Finally, initial results from monitoring of the first ALR schemes on the M25 have been taken into account.

Achieving the safety objective:

The "GD04 assessment report" [5] (based on the use of a generic ALR hazard log) shows that the safety objective for road users is likely to be achieved 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 closed circuit television (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 E8.00 to E8.03.

- 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.

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 achieving the safety objective is likely to be achieved for car drivers, pedestrians, motorcyclists, HGV drivers, emergency services, private recovery organisations, and disabled drivers or passengers.

With regard to maintenance workers, since the publication of IAN161/12, improvements have been identified leading to a reduction in the frequency of maintenance activities. Thus it can be demonstrated with greater confidence that the safety objective is likely to be achieved and the risk managed so far as is reasonably practicable. The Highway Agency’s ALR Meeting the Road Worker Safety Objective Task and Finish group has undertaken further review of an ERIC assessment to reduce maintenance activities that reside at Highways England programme level. This work has been reflected in the development of the road worker safety assessment tool.

Further work has also been 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.

An appropriate Safety Management Process has been selected for ALR and has been applied

- ALR has been classified as ‘Type B’. This represents a ‘medium’ level of safety management
- The assessment has been carried out by persons with the required level of competency.

Hazards are well managed

- An appropriate risk assessment methodology consistent with the M42 Active Traffic Management (ATM) pilot scheme and BB 1&2 schemes, IAN139/11 [6], and GD04/12 [9] has been used
- The ALR generic hazard log has been used as the starting point to develop a list of hazards applicable to ALR
- All identified scheme hazards have then been assessed and the risk level they present has been determined
- Evidence has been used where relevant to support the hazard assessment
- A list of appropriate safety requirements has been produced.

Summary

It can be concluded from the information summarised in this generic safety report that the objective to “demonstrate that the appropriate level of safety management has been undertaken to assess the expected safety outcome for the implementation of ALR” has been met. For road workers it can be demonstrated that the safety objective of SFAIRP can be achieved.

1 Introduction

1.1 Background

Smart motorway all lane running (ALR) [1] has been developed by Highways England to enable a reduction in the amount of infrastructure necessary for 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.

Varying safety studies have been undertaken on each traffic management element to determine their impact on the safety of the motorway network. When establishing the impact of smart motorways on safety a number of items need to be defined:

- Safety baseline – against which the safety objective will be measured
- Safety objective – the level of safety that the scheme is aiming to achieve
- Level of safety benefit / impact achievable and mitigation measures required.

This report summarises the safety impact (beneficial and detrimental) of one version of smart motorways known as ALR.

1.2 Overview of ALR design

ALR is described in Design Manual for Roads and Bridges (DMRB) IAN 161/15 “Smart Motorways – 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 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 (VMS)’ location, where necessary at intermediate locations and where the number of running lanes exceed four. At all other signal locations, verge mounted carriageway signalling must be provided

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

f. Queue protection system

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

h. Emergency roadside telephones (ERT) are only provided in refuge areas (however not provided in MSA or on slip roads)
i. A central reserve rigid concrete barrier (RCB) shall be provided on all ALR schemes in accordance with TD 19 unless the road worker safety objective can be met by alternative mitigations.

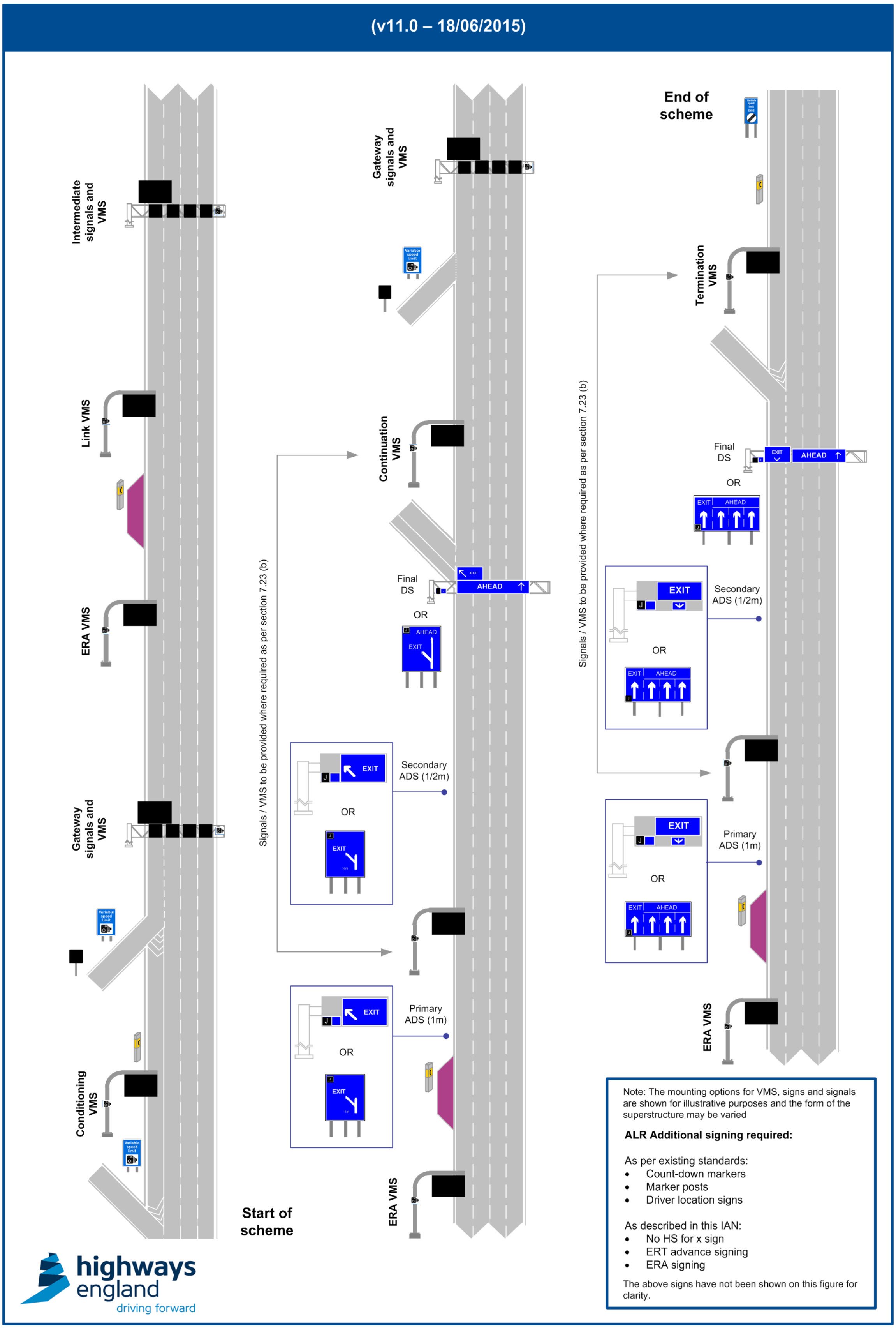

Figure 1-1: Illustrative drawing of ALR

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

1.2.1 Tolerable risk

The level of risk that would be deemed to be tolerable for a package of measures such as ALR depends on a number of factors, which are discussed below.

1.2.2 Overall level of risk

The Road Traffic Act places a duty on highway authorities to consider the safety performance of their network, while the Highways Act places a duty to maintain the public highway. For a well performing motorway network Highways England must as a minimum maintain the current level of safety. Highways England also needs to consider different populations of road users and check that 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. In addition, Highways England seeks to reduce the absolute number of casualties on its network to support the strategic framework for road safety, so needs to look for risk reduction opportunities across the network.

1.2.3 Balancing risk

In general for smart motorways as long as Highways England lowers or maintains the global level of risk for road users they may allow the risk from some hazards to increase provided this increase in risk is considered tolerable (i.e. the globally at least equivalent concept (GALE)). This was accepted as a requirement on the M42 Active Traffic Management (ATM) pilot scheme and is also supported in GD04/12. So if an increase in the risk from one hazard can be balanced by a commensurate decrease in the risk of another hazard, then this has been deemed tolerable. However such a balancing process will always require some caution, so that the decrease in the second risk will need to be larger than the increase in the first – i.e. over time risk as a whole will decrease so as to ensure the appropriate balance is always achieved.

1.2.4 Not reducing risk

Risk reduction normally involves expenditure and effort and there may be different risk reduction options that require different levels of cost and the effort. It is common practice to review the cost benefit of the different options and select those that show the optimum cost benefit. That said this cannot be done in isolation as other factors need to be taken into account, such as the tolerable level of risks. In some cases a minimum degree of risk reduction might be considered necessary to meet the long term safety aims. Also risk tolerability may require that a minimum degree of risk reduction for a particular hazard is deemed appropriate.

1.2.5 Good practice

Where good practice exists in risk reduction then there is a duty of care obligation to apply this good practice. Whilst approaches and initiatives introduced by pilot or trial schemes, e.g. the hard shoulder CCTV detection system used on the M42 ATM Pilot scheme, may not be considered to be sustainable practice, they do set a potential benchmark against which any future scheme should be evaluated. Other elements of smart motorways e.g. RCB have become good practice so a decision not to implement them would require significant review and justification.

1.2.6 Allowing total risk to increase

While not common, allowing an increase in total risk has occurred in other transport sectors in the past; where non-safety benefits of the risk increase have significantly outweighed the safety disadvantages. Where such risk increases have occurred very substantial research has been undertaken to determine both the increase in risk and the benefits gained so as to be certain that the balance is appropriate. For example, no night time use of train horns on pedestrian footpath crossings increases risk to pedestrians, but it reduces the noise pollution and nuisance to neighbours[1].

System effects, versus local benefits. There may be occasions when risk mitigation has wider effects than just the scheme being considered. In these cases the safety benefits should only be evaluated for the scheme. The wider system benefits cannot be used to justify the tolerable risk criteria for the scheme. That said, the system benefits or disadvantage should be considered in making a risk mitigation decision. For example, implementing a unique layout for a road junction may have safety benefits locally but create disadvantages regionally.

1.2.7 Deciding on tolerable risk

The level of risk deemed tolerable for a scheme may therefore need to take into account a number of criteria:

- A maximum level of risk that is deemed tolerable for the section of road. This might consist of a percentage of the overall network or regional risk or an absolute criterion in terms of road users fatal and weighted injury (FWI) casualties
- Levels of performance for risk mitigation systems that are deemed to be a minimum for the duty of care to be met
- Good practice that is available for mitigating the risk
- The cost benefit of different options for risk mitigation, as long as they deliver a risk level lower than the maximum tolerable risk and meet the minimum performance requirements

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[1] The extensive research on this subject is available on the web site of the Rail Safety and Standards Board (RSSB).

- The overall effects of the actions taken. For example, a national campaign to reduce stoppages on the hard shoulder would have benefits to the whole network, not just a dynamic hard shoulder scheme. While the network effects should not be taken into account in cost benefit for the scheme they may help show that Highways England has adequately considered / discharged its duty of care.

1.3 Use of statistics

In compiling this generic safety report the use relevant statistical information was used when assessing the level of safety achievable. The outputs of statistical analyses presented in previous safety reports have been incorporated where relevant. A degree of caution should therefore be used when interpreting the figures presented within this report. When using these figures no additional statistical analysis has been undertaken nor has any verification of the calculations been sought. Where used, these figures are referenced back to the source document. Whilst the figures are useful in establishing the quantitative impact on safety it should be noted that the degree of confidence in each of the figures will vary due to differences in the quality of data used and also the period over which the data was collected.

The figures quoted should therefore be considered a guide as to what the likely safety improvement will be through the introduction of ALR. In reality the actual safety improvement achieved by ALR is dependent on the existing environment, and as such the safety improvement achieved may be more or less than the figures presented in this generic safety report.

1.4 Assumptions

The detailed design of an ALR scheme is dependent on the characteristics of the stretch of motorway under consideration. Topography, number of junctions, distance between junctions, width of hard shoulder, clearance to structures, drainage construction are a few of the existing motorway characteristics that influence the design specification of any proposed smart motorways scheme. Similarly the characteristics of the existing motorway will also affect the level of safety performance delivered by a scheme.

Each stretch of motorway needs to be considered separately when defining the details of an ALR scheme including:

- An analysis of main carriageway and merge/diverging traffic flows – in order to determine the optimum traffic solution for the stretch of motorway over the design life of the scheme
- An analysis of the features of each location to determine the most appropriate operational speed

This report is based on the following key assumptions:

- Highways England accepted principle of globally at least equivalent (GALE) as a way of measuring the safety performance of a managed motorway improvement scheme for road users
- The GALE principle has also been applied to specific links of the network. Applying the GALE principle to each link means that it is not acceptable to balance an increased risk for one link by reducing it in another
- No road user (e.g. car drivers, pedestrians, HGV drivers and motorcyclists) is disproportionately adversely affected in terms of safety and risk to each population remains tolerable
- Highways England accepts that risk to workers must be managed so far as is reasonably practicable (SFAIRP) – as required under the Health and Safety at Work, etc Act (1974). This includes, for example, traffic officers and maintainers[2] but not private vehicle recovery operators (who are licensed road users)
- Highways England accepts that they may trade off the safety benefits of one smart motorways element against the safety disadvantages of another element within a scheme (e.g. smart motorways with through junction running (TJR)) so as to achieve the overall operational benefit
- The safety report requirements will need to be reviewed and updated to state all the principles that will need to be applied in order that the safety of the schemes is achieved. A project will still be required to demonstrate that the overall effects of changes / mitigations and operating principles are acceptable: to make sure that the sum of many small changes does not equal a major negative change to the safety that will be delivered.

1.5 Document structure

This report is structured as follows:

- **Chapter 1:** Introduction - details the background, purpose and scope of this report
- **Chapter 2:** Contributing factors - explores the existing mandatory and Highways England processes and procedures that contribute to the delivery of safety on a scheme. These include road safety audits (RSA) and the Construction (Design & Management) Regulations 2007 (CDM 2007)
- **Chapter 3:** Achieving the safety objectives - sets out the approach to demonstrating that the safety objective can be achieved
- **Chapter 4:** Has the safety objective been agreed and is it likely to be achieved? - sets out the safety objective and safety baseline for ALR, the methodology used to

[2] The term As Low As Reasonably Practicable (ALARP) is applied particularly where risk can, in principle, be quantified. Because of this link to quantification, ALARP rather than SFAIRP is the term generally applied in a number of sectors – including Highways – when discussing risk management and risk philosophy.

demonstrate that the safety objective can be achieved, and the demonstration that the safety objective is likely to be achieved

- **Chapter 5:** Has a safety management process been followed? – describes how an appropriate safety management system (SMS) has been selected and applied, and shows that the project has been resourced with competent people for the safety work, a robust safety approvals process is in place, there are plans in place to monitor project safety performance, and that the safety report will be handed over to Highways England for operation and maintenance
- **Chapter 6:** Have hazards been well managed? – demonstrates that an appropriate risk assessment methodology, hazard log and set of hazards have been applied, all scheme hazards have been analysed, and how project safety requirements will be identified to meet the project design
- **Chapter 7:** Conclusions
- **Chapter 8:** References
- **Appendices:** Glossary of terms and abbreviations, goal-structured notation (GSN) for ALR safety report, risk assessment methodology.

2 Contributing factors

2.1 Existing processes and procedures

The purpose of this chapter is to present the processes and procedures that are currently in place that are intended to support the implementation of 'safe' schemes on the Highways England network. These are presented to demonstrate that the safety risk associated with a scheme is considered at a number of stages during the development of a scheme. Whether implicitly or explicitly, they drive the need to develop appropriate safety objectives (and baselines) for smart motorways schemes.

2.1.1 Road safety audits

According to DMRB HD19/03, RSA is defined as:

> *"The evaluation of Highway Improvement Schemes during design and at the end of construction (preferably before the scheme is open to traffic) to identify potential road safety problems that may affect any users of the highway and to suggest measures to eliminate or mitigate those problems. The audit process includes the accident monitoring of Highway Improvement Schemes to identify any road safety problems that may occur after opening. This Stage 4 Audit will include the analysis and reporting of 12 and 36 months of completed personal injury accident data from when the scheme became operational."*

The audit comprises four stages:

> Stage 1: Completion of preliminary design
>
> Stage 2: Completion of detailed design
>
> Stage 3: Completion of construction
>
> Stage 4: Monitoring

The implication of applying the RSA process is that individually, each scheme will deliver a certain level of safety performance. This depends upon the type of scheme implemented, for example whether or not it is a safety or a congestion management scheme.

2.1.2 Construction (design and management) regulations 2007

The CDM 2007 came into force on 6 April 2007. The CDM Regulations aim to ensure that construction projects are safe to build, safe to use and safe to maintain.

In the context of smart motorways schemes, CDM provides a framework by which worker safety (both during construction and subsequent maintenance) can be maintained. Central to CDM is the concept of managing risk SFAIRP.

2.1.3 Project safety risk management

Highways England implements a safety management approach called project safety risk management for all its smart motorways schemes (GD04/12 [9] and IAN 139/11) [6].

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

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

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’.

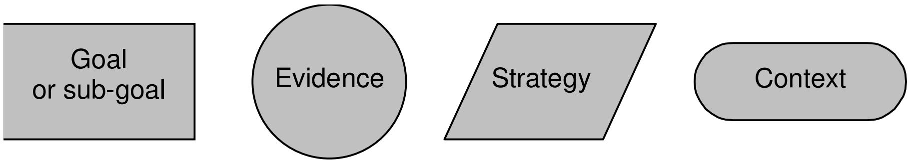
GD04/12 also requires that documentation is kept which evidences the decision making process for hazard and risk assessments and the identification and implementation of risk mitigation measures.

3 Achieving the safety objectives

The purpose of this document is to evaluate whether ALR, based on existing evidence, is likely to achieve the safety objectives that have been agreed by Highways England.

3.1 Goal-structured notation (GSN)

Goal-structured notation (GSN) has been used to structure the safety arguments in a graphical manner. A GSN diagram shows how goals are broken down into sub-goals and eventually supported by evidence, whilst making clear the strategies adopted to meet the goals and the context in which goals are stated. These four entities are depicted by the following shapes.



The GSN diagram for ALR is supplied as Appendix B of this document. Colour is used to denote progress with goals as shown in Figure 3-1.

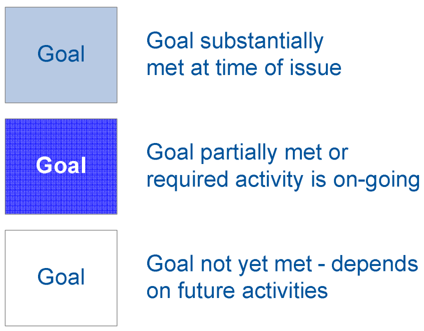


Figure 3-1: Key to progress with GSN goals

Figure 3-2 shows an extract from the GSN diagram. It identifies three main strands to the safety argument, which are considered in chapters 4, 5 and 6.

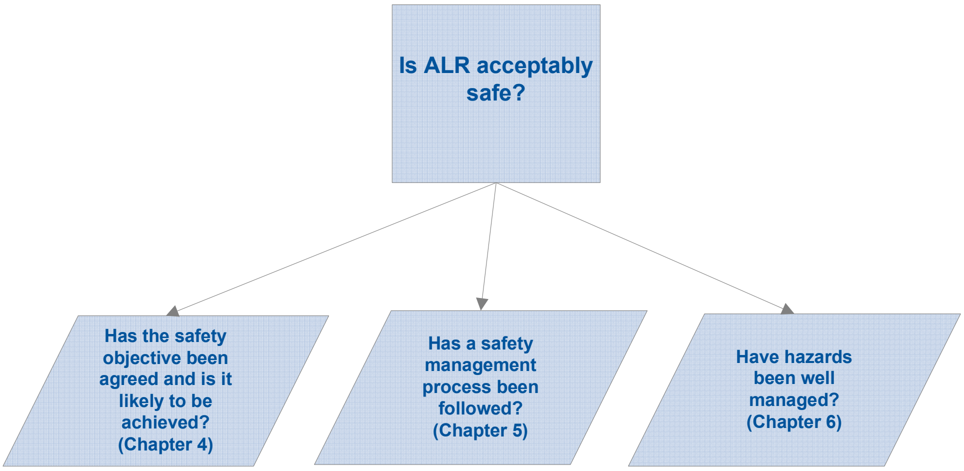


Figure 3-2: Three strategies are followed to demonstrate that ALR is acceptably safe

3.2 Link with other safety documents

There are three documents that should be read in conjunction with this document:

- GD04 assessment report [5] provides a safety risk assessment of a generic ALR motorway
- ALR provision of adequate guidance review [8] provides information about whether or not ALR will provide enough guidance to drivers so that the safety benefits of a controlled environment can be achieved
- APTR/D3M analysis and hazard assessment report [7] a document collecting evidence supporting the hazard assessment. In particular, this report provides evidence of the safety performance of multi-lane high speed roads on the APTR network which do not have a hard shoulder.

4 Has the safety objective been agreed and is it likely to be achieved?

This chapter demonstrates that:

- The safety baseline for the project has been agreed
- The safety objectives have been agreed for both road users and road workers
- Achievement of the safety objectives can be demonstrated.

The structure of the argument is illustrated in the GSN diagram in Figure 4-1 below.

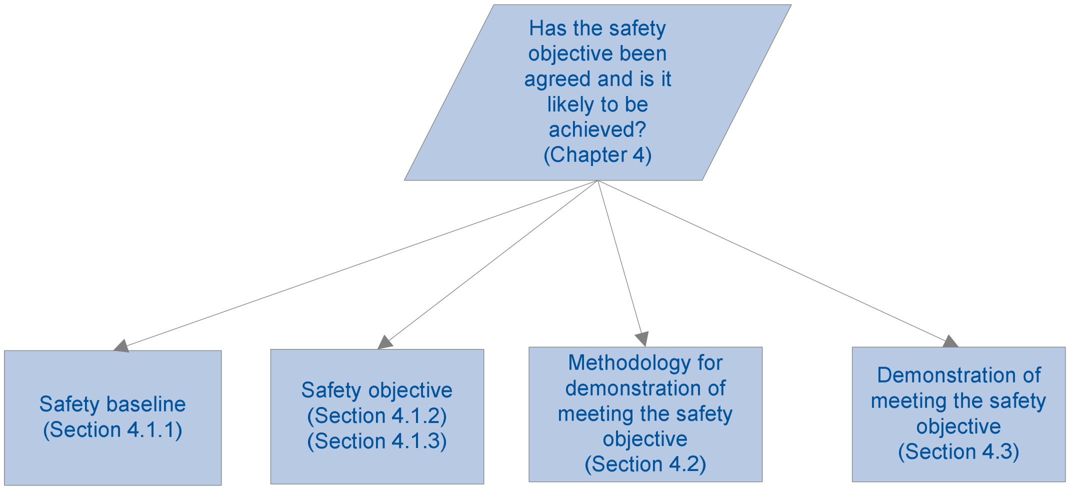


Figure 4-1: Extract of GSN diagram showing how it is demonstrated that a safety objective has been agreed and is likely to be achieved

4.1 Safety baseline and objectives for ALR

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

4.1.1 Safety baseline

Validated STATS19 personal injury collision (PIC) data covering the scheme extent, including entry and exit slips must be 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).

4.1.2 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 more than the safety baseline
- The rate of FWIs per billion vehicle miles per annum is no more 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 and ALR, then the road user benefits should be considered per link per carriageway)

4.1.3 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 SFAIRP principle. This is a legal requirement. Highways England's 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.

4.2 Methodology for demonstrating meeting of safety objective

This sub-section summarises the methodology for demonstrating the meeting of the safety objective. It initially considers meeting the safety objective for all users and then considers the impact on specific user groups.

4.2.1 Meeting of safety objective (for all users)

The (generic) methodology is documented in IAN 139/11 [6]. 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 4-2 summarises the process followed:

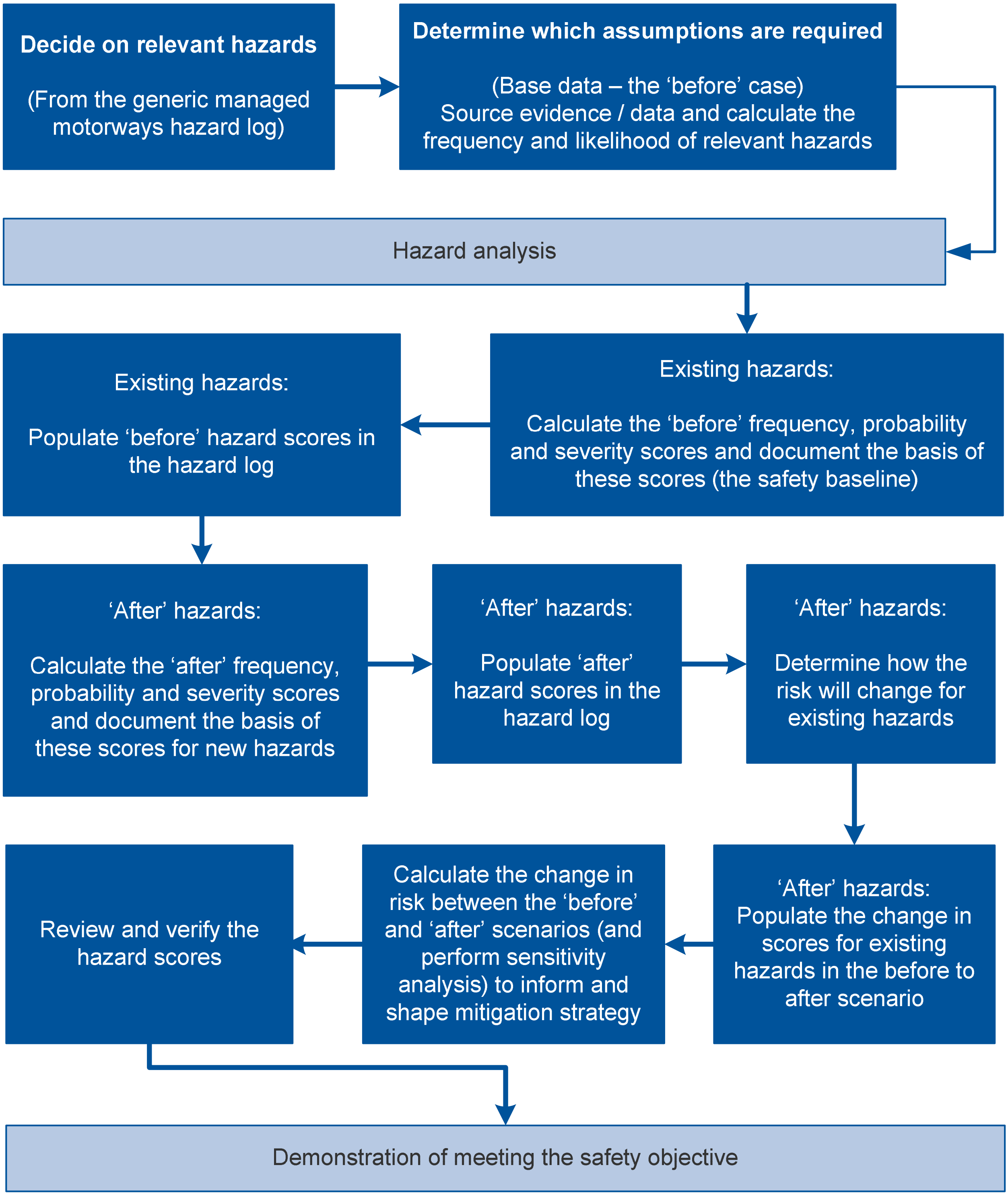


Figure 4-2 Process for demonstrating meeting of safety objective

4.2.2 Assessment of safety impact for specific road user groups

This report considers the impact of the scheme on the safety of all road users, analysis of the impact upon specific road user groups has been detailed in the GD04 assessment report [5], covering the following groups:

Users

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

Workers

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

There is a separate safety objective for road workers (see section 4.1.3), ORR and maintenance workers (shown in **bold**), so it is necessary to particularly focus on and understand how the implementation of ALR will affect these two user groups. The NVRM is included in this analysis due to the direct employment by Highways England and the statutory 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 specific user group in question
- The 'before and after' scores (i.e. the difference between ALR and the baseline) were reviewed as they could be different for a specific user group.

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

- Checking whether the highest risk hazards that are relevant to the baseline have a different risk under 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. The hazard assessment is not suited to a quantitative approach as explained in chapter 4.2.3 below.

4.2.3 Use of quantitative assessments

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.

4.3 Demonstration of meeting the safety objective

4.3.1 Achievement of safety objective for all road users

The GD04 assessment report [5] demonstrates that the design 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 recovered 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 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.

Further details are provided in the GD04 assessment report [5].

4.3.2 Achievement of safety objective for specific road user groups

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 road user groups considered (car drivers, motorcyclists, HGV drivers, emergency services, private recovery organisations, and disabled drivers or passengers), the safety objective is likely to be achieved because the reduction in risk for the existing motorway hazards outweighs the increase in risk from the introduction of new hazards related to ALR.

4.3.3 Achievement of safety objective for specific road worker groups

With regard to maintenance workers, since the publication of IAN161/12, improvements have been identified leading to a reduction in the frequency of maintenance activities. The safety objective can be achieved, with the risk managed SFAIRP.

The traffic officer service (TOS) have developed detailed working procedures for operating ALR that have been based on the experience of operating existing sections of motorway (including those where hard shoulder running is in operation) and APTR with ALR. These procedures seek to reduce the risks to the TOS to be as low as reasonably practicable. Thus it can be demonstrated that the safety objective is likely to be achieved and the risk managed SFAIRP. Further details are provided in the GD04 assessment report [5].

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5 Has a safety management process been followed?

This chapter demonstrates that:

- An appropriate safety management system (SMS) has been selected and applied
- The project has been resourced with competent people to carry out the safety work
- A robust safety approvals process is in place.

The structure of the argument is illustrated in the GSN diagram in Figure 5-1 below.

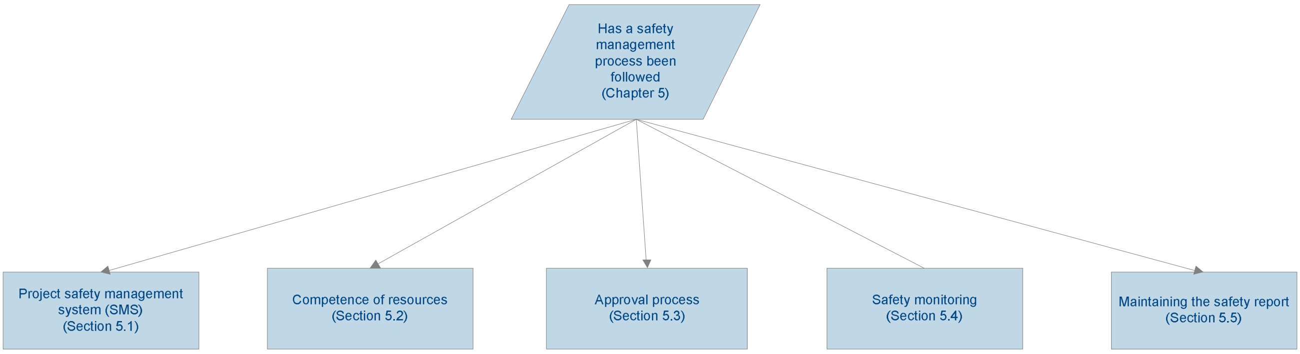

Figure 5-1: Extract of GSN diagram showing how it is demonstrated that an appropriate and robust safety management process has been followed

5.1 Project safety management system

5.1.1 Selection of project safety management system

IAN139/11 [6] describes the process by which the SMS is selected for a smart motorway project. It advises that the default position for all smart motorways projects is that they will require at least a Type B SMS. For ALR the assessment agrees with the advice provided by Highways England that smart motorways schemes require a Type B SMS. Table 5-1 provides a summary.

Table 5-1: Reasoning for classification decisions for ALR

Feature	Results for project
1. Stakeholder interest	**Type C.** A number of key stakeholders are involved Key stakeholders include: – Highways England Network Delivery and Development (NDD) and Customer Operations – Traffic officer service – Maintenance operatives – Police – Emergency services (e.g. fire service, ambulance) – Vehicle recovery organisations

Feature	Results for project
2. Operational experience	**Type B.** Experience of controlled all lanes running (CALR) has been achieved on short sections of existing motorway – usually where there is some form of constraint, i.e. hard shoulder discontinuity on M25 controlled motorways links. Multi-lane running without a hard shoulder exists on some A-roads (for example sections of the A3, A23 and A45) and some sections of motorway (for example M6 J7-8E). The controlled motorways element of the design has also been used on the M25, M42 ATM pilot scheme and BB1&2 schemes. There is now some experience of ALR operation from the M25 schemes that opened in 2014.
3. Technology	**Type B.** The technology is used on several sections of motorway, e.g. M25 J10 to J16, M42 and BB1&2 schemes.
4. Standards and legislation	**Type B.** Design requirements for ALR are available through IAN 161/15
5. Impact on Organisation	**Type B/C.** The role of control centres will need to be expanded to cover the operation of this regime (although this is not considered to be as significant for ALR as it would be for HSR – no hard shoulder opening checks). At a local level changes are expected to be required and training/briefings will be required for relevant staff to inform them of the change. The impact on Highways England as a whole is not considered to be Type C as much of the impact on procedures has already occurred as a result of the M42 ATM pilot and BB1&2 schemes. Therefore, potentially high impact on a local level, but medium impact on Highways England as a whole.
6. Project Scale	**Type B.** Moderate lengths of the Highways England motorway network are likely to be affected.

5.2 Competence of resources

The work presented in this document has been carried out by the same team that carried out the hazard assessment work on the following Highways England projects:

- M42 ATM Pilot scheme
- BB1&2 schemes

This team has competency consistent with the guidance contained in the remit for organisation and governance - National Safety Control Review Group (NSCRG) and project safety control review group (PSCRG) as well as GD 04/12.

5.3 Approval process

The work presented in this document has been subject to an appropriate internal approvals process, as well as review by appropriate Highways England specialists.

5.4 Safety monitoring

Highways England commissioned a project to monitor and evaluate the impact of the first ALR scheme, the M25 J23 to J27. It was crucial that the performance of the scheme was accurately assessed in order to:

- Review the safety performance during the initial period of operation
- Better understand the change in risk to road users and to road workers
- Quantify and provide evidence of the benefits of the concept
- Provide evidence to help improve the concept of operation and the design requirements.

In addition scheme specific data has been collected for the ALR scheme, M25 J5 to J6. Additional scheme specific data will be collected as future ALR schemes become operational. This will be collated an analysed for scheme specific optimisation as well as to support the generic concept of operation and design requirement.

The main results of the early monitoring are included as evidence in this generic safety report.

5.5 Maintaining the safety report

The generic safety report will be updated each time Interim Advice Note 161 is updated. It will also be updated if there is a significant change in the operation of ALR which requires an update to the safety assessment.

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6 Have hazards been well managed?

This chapter demonstrates that:

- An appropriate risk assessment methodology, hazard log and set of hazards have been applied
- All scheme hazards have been analysed
- Safety requirements have been defined.

The structure of the argument is illustrated in the GSN diagram in Figure 6-1 below.

Figure 6-1: Extract of GSN diagram showing how it is demonstrated that hazards have been well managed

6.1 Risk assessment methodology, hazard log and set of hazards

6.1.1 Generic methodology

The risk assessment methodology applied is based on the methodology used for the M42 ATM Pilot and BB1&2 schemes and is described in IAN 139/11 [6].

From that generic ALR hazard log, a list of specific hazards and their scores has been developed for ALR and documented in the GD04 assessment report [5]. Hazards were categorised as 'Event' or 'State' hazards, each hazard consisting of three parameters as detailed in Figure 6-2. The individual scores for the three parameters are then added together to give an overall risk score for that hazard (e.g. E09 or S08).

For existing hazards, i.e. those hazards that exist both before and after the implementation of the scheme, changes in risk as a result of the scheme implementation are simply added to or taken away from the numeric part of the risk score. For example, if the before risk for a hazard is scored as E08 and the reduction in risk is 0.2, the after score is E07.8.

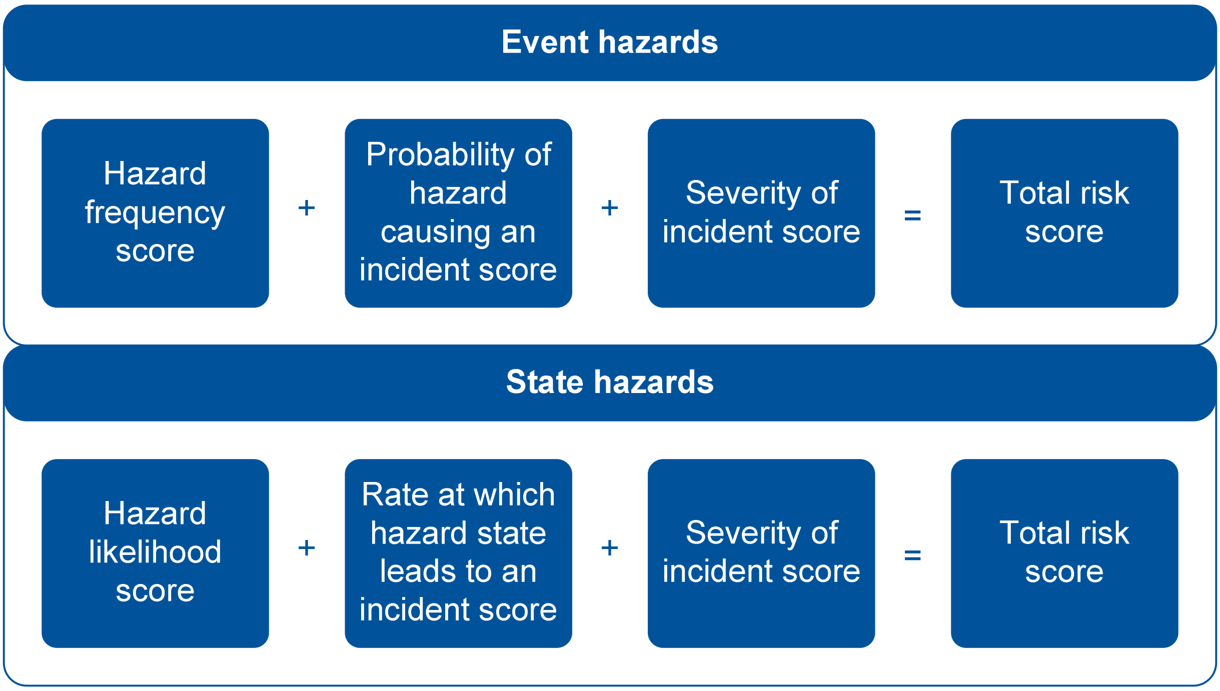


Figure 6-2: Calculation of Event and State hazard risk scores

Appendix C provides more details on the risk assessment methodology.

6.1.2 Use of M42 ATM Pilot scheme monitoring results

To provide an evidential basis for scoring the changes in risk that may result from the scheme reference was made to the monitoring results obtained from the M42 ATM Pilot scheme [2] (the number of accidents has decreased from an average of 5.08 a month to 2.25 a month; the Accident Severity Ratio has improved by 56% and the Casualty Severity Ratio has improved by 64% indicating that the remaining accidents are resulting in less severe casualties). This was justified on the basis that the proposed scheme shared a number of significant characteristics with the M42 ATM pilot scheme most notably the presence of a controlled environment.

6.1.3 Use of M25 ALR scheme monitoring results

- Monitoring is being carried out for the first ALR schemes that have become 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 require further analysis. However, some important results are emerging which have been considered in updating the generic ALR hazard log. Actual live lane stoppage numbers are comparable to the predicted numbers
- Considerable amount of non-emergency stops in ERAs especially from HGVs
- At times driver compliance with Red X lane closure signals was poor particularly at times of high traffic flow

6.2 Analysis of hazards – evidence gathering and assessment

In order to collect evidence to support the hazard analysis a number of studies have been undertaken. Two of these studies have direct relevance to this report. These are:

- APTR/D3M analysis and hazard assessment [7] – referred to as the APTR report
- Provision of adequate guidance review [8] – referred to the adequate guidance report.

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

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

6.2.1 All-Purpose Trunk Roads (APTR)/Dual 3-lane Motorway (D3M) analysis and hazard assessment

The APTR report summarised the results of a number of strands of work intended to provide an understanding of the safety challenges involved and to gain a level of assurance of how ALR design would be expected to perform in terms of safety.

Three distinct elements of work were undertaken:

- Analysis of accident and casualty data collected from the D3M (which have hard shoulders) and multi-lane APTR (which do not). The purpose of this analysis was to establish the safety implications of converting the hard shoulder to a running lane without any further mitigation. That is, what is the underlying safety risk associated with the ALR road layout
- Detailed analysis of some of the more significant safety hazards has been undertaken using the accident and casualty data described above. The purpose of this was to ensure that the safety implications of these are as fully understood as possible
- A hazard assessment was undertaken with respect to ALR. This formed the basis of the hazard assessment presented in the GD04 assessment report [5].

Analysis of accident and casualty data3 collected from all the D3M and multi-lane APTR in England indicated that 3-lane APTRs have a rate4 of KSI accidents that is approximately 9% higher than that encountered on the D3M network. With regard to KSI casualties, the rate is approximately 5% higher. These rates take into account the impact of MIDAS queue protection and are therefore measured against a baseline of a D3M without MIDAS.

The implication of the above result is to constrain the possible safety impact of ALR to less than 9% greater than the baseline. This is because the ALR layout shares many of the

[3] Personal Injury Accident (2005-2009 validated Stats19) data from the entire Highways England D3M, 2-lane and 3-lane APTR road network was used in the analysis. The data was restricted to those occurring on links between junctions as 2-lane and 3-lane APTRs have at grade junctions while the D3Ms do not.

[4] per Million Vehicle Mile

characteristics of 3-lane APTRs (i.e. no hard shoulder and lay-bys / refuge areas at a maximum of 2.5km intervals).

Detailed analysis of some of the more significant safety hazards concluded that in comparison with D3M links, multi-lane APTR links are characterised by:

- A four to five fold increase in the frequency of vehicle parked in main carriageway accidents
- An increase in the frequency of accidents involving vehicles leaving the carriageway
- No increase in the frequency of fatigue related accidents
- An increase in frequency of pedestrian accident
- No increase in the frequency of debris related accidents
- An increase in the frequency of accidents involving a motorcycle.

The analysis concluded it is likely that the frequency of vehicle parked in main carriageway and vehicles leaving the carriageway accidents are related to the loss of the hard shoulder. However, it is likely that most of the increase in the frequency of pedestrian accidents is due to different levels of access to the road. The reason for the increase in frequency of motorcycle accidents is less clear and may be due to a number of factors including differences in geometrical standards between the two types of road.

In addition to the above, a more detailed analysis was also undertaken on three sections of roads which are known to have three lanes without a hard shoulder or substantial hard strip.

The three specific sections are:-

- A3 – Stoke Interchange to Stratford Bridge
- A23 – M23 Junction 11 to Handcross
- A46 – Junction with A249/B4115 to Junction with A45.

The analysis of the accident and casualty data collected from the three selected APTR links suggests that 3-lane APTR links are capable of performing at a level of safety comparable with D3M links with similar geometry.

The APTR report provided a basis for understanding how key hazards could be impacted by the layout of ALR and this has been carried through to the hazard assessment. A particular detailed assessment has been undertaken of the safety risk associated with vehicle parked in main carriageway accidents (i.e. accidents involving vehicles that breakdown in the carriageway).

6.2.2 Provision of adequate guidance review

The adequate guidance report considered the following question:

> *Is an adequate level of information (guidance) provided to the road user so that he understands how he is expected to behave within the new ALR environment?*

It considered a number of sources of information and concluded that:

- Evidence from existing HSR schemes (M42 ATM Pilot and BB1&2) shows a high level of compliance

- Existing HSR schemes provide more reliable journeys encouraging compliance
- Evidence from existing HSR schemes (M42 ATM and BB1&2) shows MM creates a controlled environment.

The report also noted that:

- The level of speed compliance on the M42 ATM Pilot and Birmingham Box Phase 1 (BB1) schemes has significantly supported the safe and successful operation of the schemes
- Controlling the speed and behaviour of traffic has enabled the realisation of traffic benefits. In order to achieve a similar level of compliance on an ALR scheme a comprehensive compliance strategy and education campaign will need to be in place
- ALR scheme will provide additional capacity and help to alleviate any congestion on the section. The additional capacity should result in a higher probability of free driving conditions and therefore there is likely to be less inclination for a driver to change lanes or speed to gain an advantage over other traffic. In addition, if the majority of road users travel at the speed limits then it limits the ability of a minority of road users to speed
- The introduction of more reliable journeys is a key consideration for the driving public as surveys have indicated that 'not knowing' the time a journey is going to take is a major frustration. Therefore making journey times reliable day in, day out – even if the average journey time increases by a small percentage – is a key benefit that the existing HSR schemes (i.e. M42 ATM pilot scheme) has delivered to road users
- ALR will introduce a reduced level of infrastructure when compared to an IAN 111/09 scheme. Through their whole design the existing HSR (IAN 111/09) schemes have encouraged compliance. Through the introduction of additional capacity on an ALR designed scheme there will be a higher probability of free driving conditions than previous and drivers will be encouraged to comply
- The concept of a controlled environment was to some extent related to the amount of infrastructure and technology introduced through the existing HSR (IAN 111/09) [3] schemes. This level of infrastructure and technology will be reduced with an ALR scheme with no fixed hard shoulder cameras and fewer opportunities to provide information. However, there will be full CCTV coverage and information will be located at spacing which manages the amount of time a driver cannot see the next signal/variable message sign
- ALR will increase the spacing of signalling, and a significant amount of it will come from the verge (the VMS) rather than overhead for all lanes. Signalling will be regularly spaced and the design of the ALR schemes will result in good forward visibility before the next signal. The location of signs and signals will need to meet a number of design requirements to appropriate provision of information.

In conclusion the adequate guidance report suggests that the environment of ALR (mandatory signals, VMS and MIDAS) is likely to lead to a level of driver compliance (i.e. responding as appropriate to signs and signals). This has subsequently been confirmed through a transport research laboratory (TRL) trial and has been taken account of in the hazard assessment.

6.2.3 High risk hazards

This section provides information about how the highest risk hazards (those that have a score of S08/E08 and above) are impacted by ALR. Further details can be found in the GD04 assessment report [5]

The highest scoring hazards drive the hazard analysis summarised in chapter 4 and represent approximately 92% of the total baseline risk.

Table 6-1 presents the change in safety risk for hazards with the greatest risk score:

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

Table 6-1: Change in safety risk for hazards with the greatest risk score

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

Hazard	Description	Type	Before safety risk	After safety risk	% change in safety risk	Comments
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.
H52	Maintenance workers setting up and taking down work site	State	S08.00	S08.00	0	Although there is benefit from the controlled environment (setting of signals during set-up and taking-down), the number of times TM is used is expected to increase
H89	Sudden weaving at exit point	Event	E08.00	E07.93	-15	Some benefit from controlled environment
H54	Motorcycles filter through traffic	Event	E08.00	E07.91	-19	Benefit from controlled environment. Smoother traffic travelling at higher speeds - less need to filter through
H13	Driver loses control of vehicle	Event	E08.00	E07.90	-21	Some benefit from controlled environment
H120	Vehicle rejoins running lane	Event	E08.00	E07.90	-21	Non-emergency stops are effectively eliminated and most remaining stops will be in refuge areas
H121	Vehicle reversing 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

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
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
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

Presented below is a discussion of the highest scoring hazards (i.e. those with a score of greater than E08/S08).

The two highest scoring hazards, 'H138 - Driver fatigued – unable to perceive hazards effectively' (E09) and 'H37 - Individual vehicle is driven too fast' (S09) are applicable to the existing motorway and also post implementation. The M42 ATM pilot monitoring report [2] suggests that there could be a slight reduction in risk and this has been taken into account within the analysis.

However, 'H37 - Individual vehicle is driven too fast' is expected to reduce significantly in risk post implementation because a controlled environment is provided through a combination of regularly spaced mandatory signals, perceived speed enforcement, and the perceived monitoring by PTZ CCTV cameras.

No change in risk is expected for 'H138 – Driver fatigued – unable to perceive hazards effectively'. There is no benefit from the implementation of ALR expected especially off peak when the signs and signals are off.

No change in risk is expected for 'H67 - Pedestrian in running lane - live traffic'. Although there will be an increase in vehicles stopping in live traffic with the absence of the hard shoulder this will be mitigated by better and quicker protection of all incidents in live lanes therefore no change in risk has been noted for this hazard.

Hazard 'H135 - "Vehicle stops in running lane – off-peak' is likely to see a substantial increase in safety risk. Although ERAs and other refuge areas will help to minimise the number of vehicles stopping in a running lane an increase in frequency is still expected. Vehicles stopped in a running lane will be better protected through the use of signals once the location is verified. An increase in risk is anticipated reflecting a substantial increase in the frequency of vehicles stopping in a running lane.

The risk from 'H76 - Rapid change of general vehicle speed' and 'H91 - Tail gating' are expected to reduce significantly mainly due to the increased capacity provided by ALR and the controlled environment provided by regularly spaced signals and MIDAS congestion algorithm.

The frequency of 'H52 - Maintenance workers setting up and taking down work site' is expected to remain the same under ALR. Although there will be additional equipment implemented as part of ALR along with the removal of the hard shoulder, a number of mitigation options to reduce the risk to maintainers will be included e.g. RCB. This is detailed further in the DMSO report [5].

One new high scoring hazard is introduced: 'H113 - Vehicle exits ERA'.

6.2.4 Lower risk hazards

The scoring and analysis of lower risk hazards is covered in the GD04 assessment report [5].

6.3 Safety requirements

The hazard assessment has generated/confirmed a number of safety requirements. These are presented in Table 6-2.

Table 6-2: Safety Requirements for ALR schemes

Reference	Responsible	Safety Requirement
'Strategic' Safety Requirements		
Situational awareness / creation and maintenance of a 'controlled environment'		
SR-01	Highways England/ Design	Signal sequencing rules must facilitate the required signalling outcomes in response to manual or automatic primary signal settings, and be appropriate for the signal / message sign spacing and operating speed.

SR-02	Design	For the prevailing traffic conditions, motorists shall be given clear instruction on which lane(s) to use. These instructions must facilitate vehicle movements (from lane to lane) in a controlled and safe manner.
SR-03	Design	Variable mandatory speed control must be provided.
SR-04	Design	An automatic queue protection system (e.g. MIDAS) to alert both operators and road users of changes in traffic conditions must be provided.
SR-05	Design/Operator	An enforcement strategy must be implemented to ensure creation and maintenance of a 'controlled' environment.
SR-06	Other	A monitoring strategy must be in place to enable the creation and maintenance of the required network and safety performance data
SR-07	Other	Stakeholder engagement must be designed to facilitate and support effective education and encouragement of road users.
'Tactical' Safety Requirements		
Maintenance:		
SR-10	Design	All equipment must be designed to eliminate or minimise the need for maintenance and reduce the exposure for road workers SFAIRP (So Far As Reasonably Practicable). This includes the inclusion of rigid concrete barrier in the central reserve.
SR-11	Design	Roadside equipment requiring maintenance should, where practicable, be clustered and an appropriate access strategy put in place minimising the need for temporary traffic management in live lanes.
SR-12	Maintainer	Maintenance contractors must be trained and competent in the appropriate maintenance procedures.
SR-13	Maintainer	Winter treatment must include all designated refuge areas.
SR-14	Highways England/ Design	Faults that impact on the safe and efficient operation of the system shall be defined and response / repair times incorporated into relevant contracts in accordance with their impact.
SR-15	Maintainer	Sightlines must be effectively maintained to signs and signals.
SR-16	Design	Equipment/procedures should be included with the aim of eliminating the need for carriageway crossings by road workers.

Scheme Operation		
SR-20	Operator	Procedures and guidance must be appropriate and effective for safe operation.
SR-21	Operator	Traffic Officers must be trained and competent to work in accordance with the latest national procedures and the operational procedures and guidance provided within the ALR manual.
		Operators must be trained in the ALR scheme procedures. They must also be competent in carrying out the procedures and guidance.
SR-22	Operator	Operators must have instantaneous access to the current procedures and guidance at all relevant workstations.
SR-23	Operator	The interfaces with emergency services must be effective and must allow them to carry out their functions.
SR-24	Operator	Procedures shall use a consistent lane referencing system across a scheme.
SR-25	Operator/Maintainer	A system must be established to operationally manage the access and actions of maintenance personnel.
Technology		
SR-30	Design	Software/hardware must be in accordance with Highways England standards.
SR-31	Design	Software development procedures and testing must be in accordance with Highways England standards.
SR-32	Design	All site and system data must be maintained under strict version control.
SR-33	Maintainer	After maintenance activity has been carried out on the technology system and / or equipment, tests shall be carried out to re-commission them to the 'as-built' / as-commissioned.
SR-34	Design	Full CCTV camera coverage must be provided of the carriageway (including refuge areas). The coverage must be such that an operator can interpret correctly the nature of each incident within the designed viewing range at all times of day and night, and in all ambient lighting levels whether the carriageway is lit or not, as they will be used to confirm the location of incidents on the main carriageway. To achieve this, at the extreme of the required coverage and maximum zoom, a 1.75m target should represent a minimum of 5% of screen height.

Infrastructure		
SR-40	Design	Fixed signage must be provided directing motorists to ERTs (not including signage for pedestrians on marker posts which will not be provided on ALR schemes).
SR-42	Design	Safety barrier must only be installed where necessary, i.e. gaps should not be necessarily closed.

7 Conclusions

This document is the generic safety report for ALR. The purpose of the document is to demonstrate that the appropriate level of safety management has been undertaken to assess the expected safety outcome for the implementation of ALR.

The information presented in this report demonstrates that:

A safety objective has been set for the scheme and is likely to be achieved

- A safety objective has been set for ALR for road users and road workers
- The safety baseline for the scheme has been set as “a D3M before implementation of MIDAS queue protection”
- A robust methodology has been used to demonstrate whether the safety objective is likely to be achieved. The methodology is based on the methodology used for the M42 ATM pilot and BB1&2 schemes (the foundation for the demonstration of meeting the safety objective is the risk assessment methodology which is documented in IAN139/11 [6])
- The demonstration of meeting safety objective based on the use of a scheme specific hazard log
- For individual populations, including road workers, the relevant safety objectives are likely to be achieved.

An appropriate safety management process has been selected for the project and has been applied

- An appropriate SMS has been selected and applied in accordance with Highways England PSRM work instructions, IAN139/111 [6] ALR has been classified as ‘Type B’
- The project has been resourced with competent people to carry out the safety work
- A robust safety approvals process is in place to approve safety documents, in particular for key safety documents.

Hazards are well managed

- An appropriate risk assessment methodology consistent with IAN139/11 [6], and GD04/12 [9] has been used
- The ALR generic hazard log has been used as the starting point to develop a list of hazards applicable to ALR
- All identified scheme hazards have been assessed and the risk level they present has been determined
- Project safety requirements have been developed/confirmed to manage the risk from ALR hazards.

It can be concluded from the information summarised in this generic safety report that the objective to “demonstrate that the appropriate level of safety management has been undertaken to assess the expected safety outcome for the implementation of ALR" has been met. For road workers (maintenance and ORR) it can be demonstrated that the safety objective of SFAIRP can be achieved.

8 References

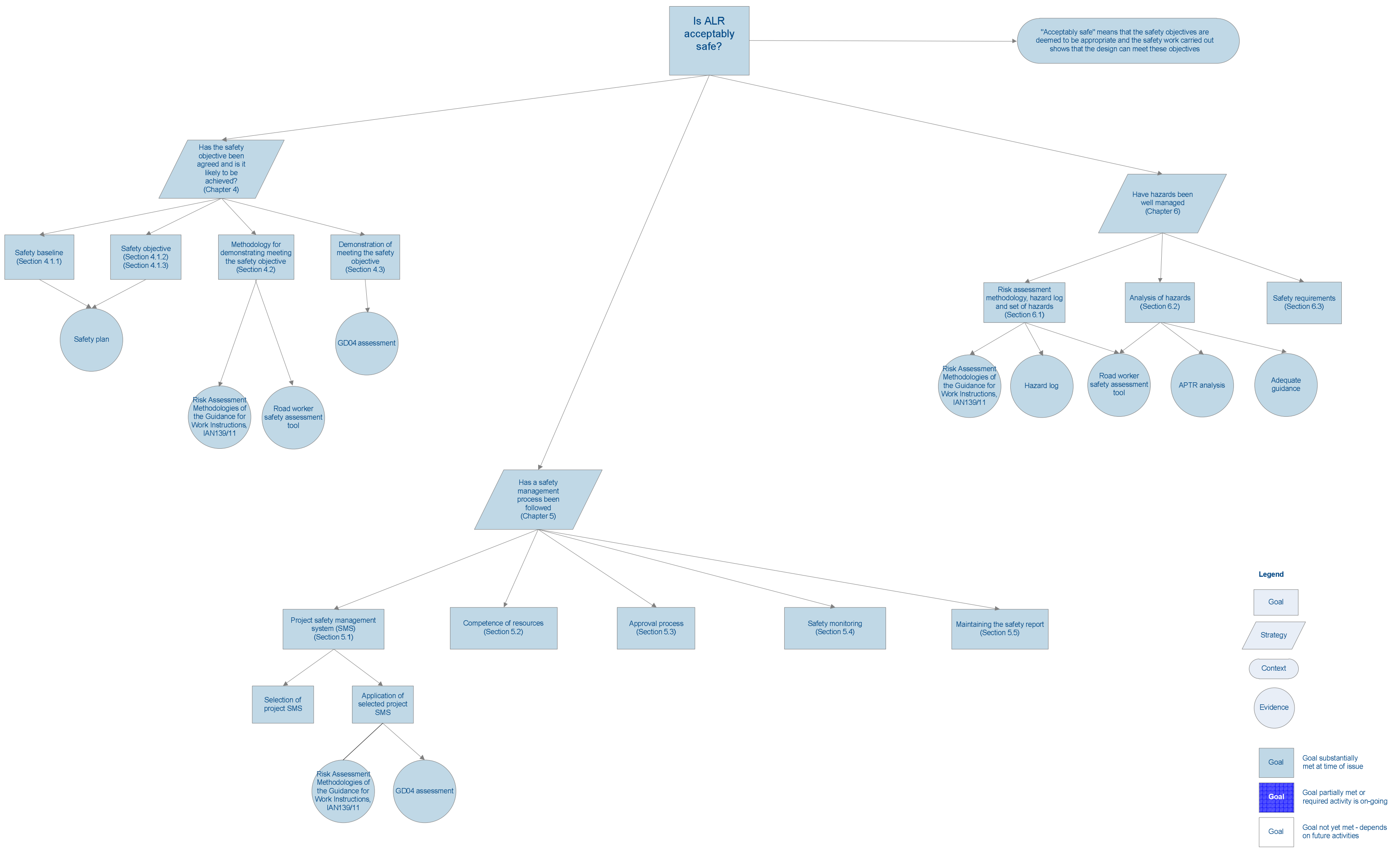
[1]	Interim Advice Note 161/15, Smart Motorways
[2]	M42 MM Monitoring and Evaluation, Three Year Safety Review, HCG, January 2011
[3]	Interim Advice Note 111/09, Managed Motorways implementation guidance – Hard shoulder running
[4]	Interim Advice Note 112/08, Managed Motorways Implementation Guidance – Through Junction Hard Shoulder Running
[5]	ALR GD04 Assessment Report, 1065017-WP017-DOC005
[6]	Interim Advice Note 139/11, Managed Motorways Project Safety Risk Work Instructions
[7]	All-Purpose Trunk Roads (APTR)/Dual 3-lane Motorway (D3M) Analysis and Hazard Assessment, 1039092/ATA/035
[8]	MM-ALR Provision of Adequate Guidance Review, 1039092/AGR/042
[9]	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
BB1&2	Birmingham Box Phases 1 and 2
CALR	Controlled all lanes running
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
GALE	Globally at least equivalent
GSN	Goal-structured notation
HGV	Heavy goods vehicle
HSR	Hard shoulder running
KSI	Killed, seriously injured
LGV	Large goods vehicle
MIDAS	Motorway incident detection and automatic signalling
MSA	Motorway service area
NDD	Highways England, Network Delivery and Development
NSCRG	National safety control review group
ORR	On road resource
PCF	Project control framework
PIA	Personal injury accident
PSCRG	Project safety control review group
PSRM	Project safety risk management
PTZ	Pan-tilt-zoom
RCB	Rigid concrete barrier

Acronym	Description
RSA	Road safety audit
SFAIRP	So far as is reasonably practicable
SMS	Safety management system
TJR	Through junction running
TOS	Traffic officer service
VMS	Variable message sign
VMSL	Variable mandatory speed limit

Appendix B: GSN diagram for the ALR safety report



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.

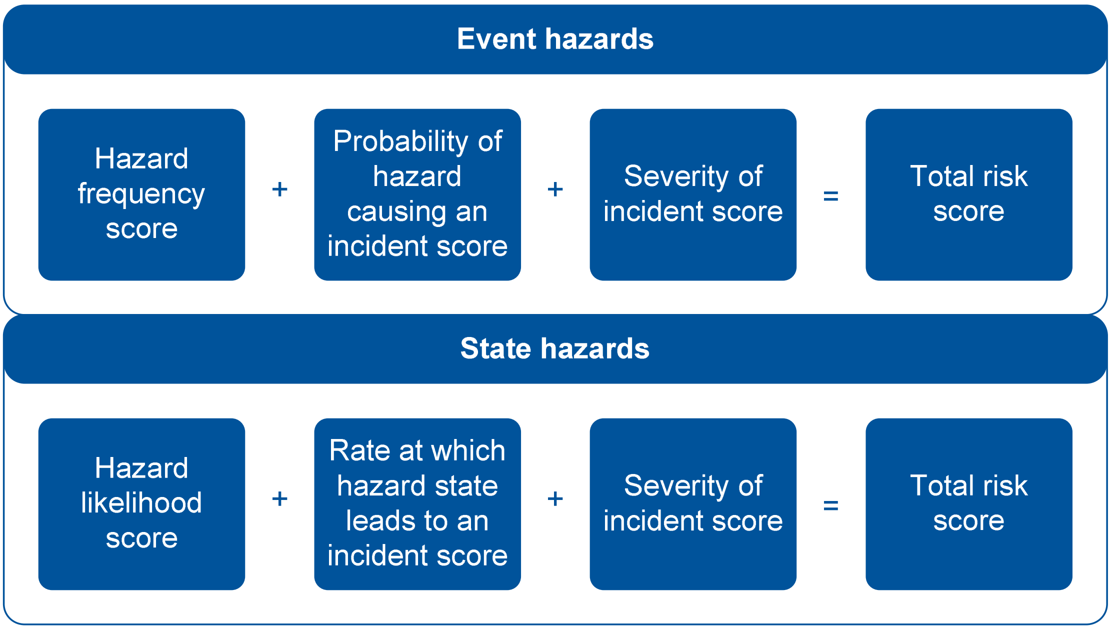


Figure C-1: Risk score components

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

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

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

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

Its overall score is 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.

Table C-4: Event/State collision severity rates

Severity Classification	Interpretation	Index Value	Person outside of vehicle	Stationary Vehicle	Motorcycle	Car	Large Vehicle (HGV, LGV, 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

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 smart motorways scheme, see Table C-5.

Table C-5: 'After' scoring index values

	After scoring values	
	Value	**% (+/-)**
Increase in risk	+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
No change	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
Decrease in risk	-0.5	70% decrease in risk