Guidance on the Preparation of Risk Assessments within Railway Safety Cases

Synopsis
This document provides guidance on how the risk assessments that support and are described within Railway Safety Cases (RSCs) can be prepared and maintained to meet the criteria specified in GA/GN6509 Issue 2.

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# Guidance on the Preparation of Risk Assessments within Railway Safety Cases

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Part A

A1 Issue Record

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This document will be updated when necessary by distribution of a complete replacement.

A2 Implementation of this document

The publication date of this document is 1 June 2002.

This document does not supersede any other Railway Group Guidance Notes.

A3 Responsibilities

Railway Group Guidance Notes are non-mandatory documents providing helpful information relating to the control of hazards and often set out a suggested approach, which may be appropriate for Railway Group* members to follow.

* The Railway Group comprises Railtrack PLC (in Railway Administration), Railway Safety, and the train and station operators who hold Railway Safety Cases for operation on or related to infrastructure controlled by Railtrack.

Railtrack PLC (in Railway Administration) is known as Railtrack.

A4 Health and safety responsibilities

In issuing this document, Railway Safety makes no warranties, express or implied, that compliance with all or any document published by Railway Safety is sufficient on its own to ensure safe systems of work or operation. Each user is reminded of its own responsibilities to ensure health and safety at work and its individual duties under health and safety legislation.

A5 Technical content

The technical content of this document has been approved by:

Controller, Safety Strategy & Risk, Railway Safety

Enquires to be directed to Railway Safety – Tel: 020 7904 7518

A6 Supply

Controlled and uncontrolled copies of this document may be obtained from the Industry Safety Liaison Dept, Railway Safety, Evergreen House, 160 Euston Road, London NW1 2DX.
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Part B

B1 Purpose

B1.1 To give guidance on how the risk assessments that support and are described within Railway Safety Cases (RSCs) can be prepared and maintained to meet the criteria specified by the Health & Safety Executive [1]. The guidance is designed to help ensure:

a) a consistent and robust approach is taken to the risk assessments

b) use is made of recent developments in railway risk assessments and risk management such as the safety risk model (SRM) developed by Railway Safety

c) risk is reduced to a level that is as low as reasonably practicable (ALARP) via a practical and effective ALARP demonstration.

B1.2 The development of risk assessments within RSCs and the railway industry generally is an ongoing process. In carrying out a risk assessment for an RSC it is possible that a duty holder will:

a) develop or refine the methodologies outlined in this guidance note

b) make improvements to the risk assessment templates, or

c) identify new hazardous events and precursors not considered within the current version of the SRM.

B1.3 In such cases Railway Safety recognise that it would be beneficial for the changes to be considered for inclusion in future versions of the guidance note, risk assessment templates and SRM. Details of such enhancements and any other feedback on this guidance note or the SRM should be sent to Railway Safety at the address given in Section A6, marked for the attention of the Head of Risk Assessment.

B2 Application of this document

To whom the guidance applies

B2.1 This document applies to potential train and station operators preparing RSCs for assessment by Railtrack PLC (in Railway Administration) (known as Railtrack) and Railway Safety and for acceptance by the Health & Safety Executive (HSE). It also applies to train and station operators with an already accepted RSC who are required to revise and update their RSC as part of the three-year review process.

This document also contains guidance that is applicable to the duty holders of the following categories of Railway Safety Case:

a) infrastructure controller

b) station operator

c) train operator (passenger, freight and infrastructure maintenance companies).

Documents supported by this Guidance Note

B2.2 None

B3 Definitions

ALARP demonstration
A process for demonstrating that the collective risk from a duty holder’s operation has been reduced to a level that is as low as reasonably practicable (ALARP).
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 Collective risk
The average number of fatalities or equivalent fatalities per year that would be expected to occur from a hazardous event, or group of hazardous events.

 Consequences
The number of fatalities, major injuries and minor injuries resulting from the occurrence of a particular hazardous event outcome.

 Control measures
The measures (hardware systems and equipment or procedural) that are put in place to prevent or minimise the frequency at which precursors (cause) and (consequence) occur or to mitigate the consequences following the occurrence of a hazardous event.

 Duty holder
The holder of a Railway Safety Case accepted by the HSE.

 Equivalent fatalities
An overall measure of safety harm, taking account of injury and fatalities. Equivalent fatalities make allowance for the potential impact of major injuries and minor injuries when carrying out cost benefit analyses. Ten major injuries and 200 minor injuries are both considered equal to one equivalent fatality.

 Fatality
Death within one year of the causal incident.

 Frequency
The frequency of an event is the number of times an event occurs over a specified period of time eg number of events/year.

 Hazardous event
A hazardous event is an event that has the potential to lead directly to death or injury eg derailment, collision or fire.

 Individual risk
The probability of fatality per year to which an individual is exposed from the operation of the railway.

 Major injuries
Injuries to passengers, staff or members of the public as defined in the Reporting of Injuries, Diseases, and Dangerous Occurrences Regulations 1995 (RIDDOR 1995). This includes injuries such as fractures, amputations, loss of sight or an injury resulting in admittance to hospital for a period of more than 24 hours.

 Minor injuries
Injuries to passengers, staff or members of the public which are not major injuries. Shock or trauma due to witnessing an accident or a near miss is not classified as a minor injury within the RIDDOR 1995, but it has been included as a minor injury in the SRM.

 Outcomes
The range of scenarios that could arise following the occurrence of a hazardous event.

 Precursor (cause)
A system failure, sub-system failure, component failure, human error or operational condition which could individually or in combination with other precursors (cause) result in the occurrence of a hazardous event eg broken rail, signal passed at danger (SPAD) or dragging brakes are precursors to the hazardous events derailment, collision and fire respectively.
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Precursor (consequence)
A system failure, sub-system failure, component failure, human error, physical effect or operational condition which could individually or in combination with other precursors (consequences) result in significantly different outcomes following a hazardous event. For instance, following a train derailment there could be a bridge collapse onto a train, a fire or a toxic goods release. Precursors (consequence) can be considered to be the escalation factors that give rise to increased consequence outcomes following the occurrence of a hazardous event.

Probability
The likelihood of an event occurring over a specified period of time or on demand (when an individual component or system is called upon to operate).

Regular traveller
A regular traveller is a regular user of the railway who is considered to be in the most exposed passenger group when estimating individual passenger risk. It is assumed typically that a regular traveller on average makes 500 journeys/year (2 journeys/day, 5 days/week for 50 weeks/year).

Residual risk
Residual risk relates to the level of risk remaining when the current risk control measures and their degree of effectiveness are taken into account.

Risk contribution
This is a term used in the SRM analysis software and relates to the reduction in the total collective risk estimate for a hazardous event if the frequency or probability of a precursor (cause), precursor (consequence) or group of precursors was reduced to zero.

Societal risk
The frequency of accidents leading to multiple fatalities resulting from the operation of the railway.

Train
Any self powered vehicle, or vehicles hauled by a self powered vehicle, with flanged wheels on guiding rails.

List of acronyms
ALARP As Low as Reasonably Practicable
HSC Health and Safety Commission
HSE Health and Safety Executive
RIDDOR Reporting of Injuries, Diseases, and Dangerous Occurrences Regulations
RPB Risk Profile Bulletin
RSC Railway Safety Case
R2P2 Reducing Risks, Protecting People [9]
SMIS Safety Management Information System
SMS Safety Management System
SPAD Signal Passed at Danger
SRM Safety Risk Model
VPF Value of Preventing a Fatality

B4 Background
B4.1 The safe operation of the railways in England, Wales and Scotland is dependent on successfully managing the interfaces between the infrastructure controllers, train and station operating companies and infrastructure maintenance contractors.
that operate on the railway. To ensure that safety is established and managed as an inherent part of the operation of trains on Railtrack controlled infrastructure, each organisation including the infrastructure controllers, is required to develop and maintain an RSC as defined in the Railways Safety Case Regulations 2000 (RSC Regulations 2000) [2].

Each RSC is assessed and accepted by the HSE and is also required to be assessed by both Railtrack and Railway Safety. Both of these organisations make a recommendation as to whether an RSC should or should not be accepted.

B4.2 In this context a train means any self powered vehicle, or vehicles hauled by a self powered vehicle, with flanged wheels on guiding rails. This includes vehicles defined in Railway Group Standards (RGS) as on-track machines (OTM), road-rail vehicles (RRV) and rail-mounted maintenance machines (RMMM), and applies both inside and outside of Rule Book Section Tii/Tiv Possessions.

An RSC is required to clearly identify:

a) the nature and extent of the operations to be undertaken
b) the safety risk associated with these operations
c) the procedures and arrangements by which the risk is controlled
d) the organisation in place for implementing these procedures and arrangements.

B4.3 The minimum content of an RSC is defined in the RSC Regulations 2000 and in particular, Schedule 1 of these regulations and its supporting guidance. Further guidance on the content of RSCs is provided as follows:

a) For acceptance of an RSC by HSE, acceptance criteria published on the HSE web site www.hse.gov.uk/railway/criteria [1].

b) For assessment of a train or station operators RSC by Railway Safety, assessment criteria are provided in GA/GN6509 Guidance on Assessment by Railway Safety of Train and Station Operators’ Railway Safety Cases [3].

c) For assessment of an infrastructure controllers RSC by Railway Safety, assessment criteria are provided in GA/GN6508 Guidance on Assessment by Railway Safety of Railtrack’s Railway Safety Cases [4].

B4.4 This guidance note considers:

a) the legislative requirements for risk assessment
b) what safety risk assessment is
c) the purposes of risk assessment
d) possible risk assessment methods for use in safety cases including the consideration of the definition of ‘suitable and sufficient’
e) criteria for assessing the results of risk assessments in terms of individual risk and risk being ALARP
f) the type of risk assessment information to be recorded in the safety case document.

B4.5 The guidance note does not include details of how to develop the safety management system section of an RSC on the basis of the findings of the risk assessment. Such details may be included in future guidance notes.
It should be noted that this guidance refers only to the assessment of safety risk, i.e., the identification and quantification of the risk associated with events that can lead to injury or death to people from the operation or maintenance of the railway. Methodologies associated with occupational health issues, economic (production loss) and environmental risk assessment are not addressed.

The risk assessment methods described in this guidance note are possible risk assessment methods for use by a duty holder that, if followed, would produce a risk assessment that is suitable and sufficient in the context of the assessment criteria given in the documents listed in paragraph B4.3 above. The proposed methods are not mandatory. A duty holder can use other methods or adapt the proposed methods as required, providing the level of analysis and reporting provides a risk assessment to an equivalent standard.

The risk assessment proposed methods are broadly consistent with the principles, methods and practices outlined in the Engineering Safety Management ‘Yellow Book’ [5].

The requirements for risk assessment in the context of RSCs are described within the following legislation.

**Health and Safety at Work etc Act 1974**

The requirement to undertake risk assessment originates from the Health and Safety at Work, etc Act 1974 [6] which places general duties on employers to employees and non-employees, including members of the public, to provide a safe and healthy workplace and working environment, safe systems of work, safe plant and equipment, and adequate information, instruction, training and supervision ‘so far as is reasonably practicable’.

**Management of Health and Safety at Work Regulations 1999**

The Management of Health and Safety at Work Regulations 1999 [7] state that ‘Every employer shall make a suitable and sufficient assessment of:

a) the risks to the health and safety of his employees to which they are exposed whilst they are at work, and

b) the risks to the health and safety of persons not in his employment arising out of or in connection with the conduct by him of his undertaking.’

‘Suitable and sufficient’ is not defined in the regulations but practical examples are given in the guidance to the regulations.

**Railways (Safety Case) Regulations 2000**

The RSC Regulations 2000 [2] are made under the Health and Safety at Work etc Act, 1974 [6]. The regulations apply to all railway operators, that is infrastructure controllers and train and station operators. They require railway operators to prepare a comprehensive safety case, covering the health and safety of staff, contractors, passengers and the public, and to secure HSE acceptance of that safety case. The Office of the Rail Regulator (ORR) will not grant a licence to a railway operator without there being an accepted safety case or an exemption in place.
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B5.5 A safety case serves two main purposes:

a) To give confidence that the operator has the ability, commitment and resources to assess properly and control effectively the risk to the health and safety of staff, contractors, passengers and the public, and

b) To provide a comprehensive core document, with links to other more specific documents, rules and procedures, against which management, auditors and HSE can check that the accepted risk control measures and the health and safety management systems (SMS) have been properly put into place and continue to operate in the way originally intended.

B5.6 The supporting guidance to Schedule 1 of the RSC Regulations 2000 states ‘Risk assessment is essential in order to identify the measures which are necessary to meet health and safety obligations and to reduce risks to as low as reasonably practicable’ and ‘A risk assessment should identify the risk control measures already in place, assess their effectiveness, and evaluate the risk remaining. The process then involves considering what additional control measures are needed to reduce risks to a level that is as low as reasonably practicable’.

B6 What is safety risk assessment?

B6.1 Risk in the context of safety is a measure of the average number of injuries, fatalities or equivalent fatalities that could occur per year as a result of the construction, operation, maintenance, alteration, renewal, decommissioning and demolition of a system. It can be calculated as the product of how often an event is likely to occur per year (the event frequency) and the consequences (injuries, fatalities or equivalent fatalities) that could arise should an event occur ie:

\[
\text{Frequency of a hazardous event} \\
\text{eg events/year} \\
x \\
\text{The consequences given the event occurs} \\
\text{eg expected equivalent fatalities/event} \\
= \\
\text{Collective Risk} \\
\text{eg expected equivalent fatalities/year}
\]
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To demonstrate what this looks like in practice, some example results of a risk assessment for a series of hazardous events are shown in Table B6.1 below.

<table>
<thead>
<tr>
<th>Hazardous event description</th>
<th>Frequency (Events/Year)</th>
<th>Consequences (No of equiv. Fats/event)</th>
<th>Collective risk (Equiv. Fats/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Collision between two trains</td>
<td>1.8</td>
<td>3.32</td>
<td>5.8</td>
</tr>
<tr>
<td>2 Collision of train with object on line - no derailment</td>
<td>49.7</td>
<td>0.006</td>
<td>0.3</td>
</tr>
<tr>
<td>3 Collision between two trains in station</td>
<td>6.0</td>
<td>0.025</td>
<td>0.15</td>
</tr>
<tr>
<td>4 Collision with buffer stops</td>
<td>40.9</td>
<td>0.029</td>
<td>1.2</td>
</tr>
<tr>
<td>5 Train collision with road vehicle on level crossings</td>
<td>21.5</td>
<td>0.28</td>
<td>6.1</td>
</tr>
<tr>
<td>6 Train derailment</td>
<td>14.3</td>
<td>0.30</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Total collective risk from these 6 hazardous events = 17.9

Table B6.1: Example risk assessment results

A risk assessment is a systematic and structured process for:

a) identifying the hazardous events which have the potential to cause injury or death to individuals (in the context of a railway operation this means passengers, workers and members of the public) who are directly or indirectly exposed to the operation and maintenance of a system

b) identifying the precursors (cause) i.e. the component, sub-system or system failures, physical effects, human error failures or operational conditions, which can result in the occurrence of each hazardous event

c) identifying the control measures that are in place to control or limit the occurrence of each precursor (cause) that cannot be eliminated

d) estimating the frequency at which each cause precursor and hazardous event can occur

e) estimating the consequences in terms of injuries and fatalities that could occur for the different outcomes that may follow the occurrence of a hazardous event. This would include identifying the control measures that are in place to control or limit:

i) the occurrence of each precursor (consequence) that cannot be eliminated, and

ii) the consequences of the hazardous event.

f) estimating the overall risk associated with each hazardous event

g) estimating the individual risk associated with exposed group(s), as defined in section B12 below

h) where necessary, identifying the additional control measures required to ensure that risk is ALARP

i) providing clear and comprehensive documentary evidence of the methodologies, assumptions, data, judgements and interpretations used in the development of the risk assessment and the analysis of its results.
B7 Purposes of a risk assessment in an RSC

B7.1 The main purposes of a risk assessment in an RSC are to:

a) meet the requirements of health & safety legislation as described in section B5 above

b) help ensure that company managers and staff identify and understand all aspects of the risk associated with their operation (the possible hazardous events, causes, control measures and consequences that can influence their operation)

c) provide confidence that a system can be operated safely given the equipment, facilities, safety management system and operating strategy in place

d) identify, understand and control the interfaces with other companies and related operations that can affect the safe operation of a system

e) assist in the identification of new control measures that could be used to reduce risk

f) assess the change in risk which could result from a change in the operating strategy or following alterations/renewal of a system

g) enable resources to be directed effectively to achieve the maximum risk reduction

h) enable a company to demonstrate that the level of risk associated with its operation is controlled to a level that is ALARP

i) provide a basis for continuous safety review and improvement.

j) Provide an input into the development of wider industry controls and standards.

B7.2 Most risk assessments, particularly for hazardous events of low frequency with potentially high consequences, require a level of risk quantification or ranking. However, it should be emphasised that it is the qualitative aspects of the risk assessment, and the dissemination of this information throughout a company that provides significant potential benefit from the risk assessment, in terms of:

a) improved awareness of such events,

b) the ways in which failures can be prevented, controlled or managed, and

c) the consideration of additional control measures.

B7.3 All risk assessments contain uncertainties and therefore their results can only be used as a guide to the level of risk within the bounds of the uncertainty, see section B13 (below). The results of such assessments should therefore only be used as an input into decision making and should not be the sole basis for making a decision.

B8 Risk assessment methods

Introduction

B8.1 In the context of an RSC, risk assessment is based on the assessment of the risk resulting from hazardous events which can occur as a result of the duty holder’s operations which have the potential to lead to fatalities, major injuries or minor injuries to passengers, staff or members of the public.
B8.2 The quantitative elements of the risk assessment process defined within this guidance note are designed to produce a suitable and sufficient risk assessment in terms of estimating:

a) the overall collective risk associated with the duty holder’s operation in terms of expected equivalent fatalities/year

b) the risk contribution for each hazardous event (expressed in equivalent fatalities/year) to enable the highest contributors to risk to be identified, the risk reduction to be prioritised, and to provide an input to ALARP assessments (see section B12.11 to B12.21 and Appendix F)

c) the risk contribution of individual precursors or groups of precursors to enable the highest contributors to risk to be identified, the risk reduction to be prioritised, and to provide an input to ALARP assessments (see section B12.11 to B12.21 and Appendix F)

d) the individual risk in terms of fatalities/year for the individuals most exposed to the duty holder’s operations to determine if the level of risk associated with the duty holder’s operation is in the intolerable, tolerable or broadly acceptable region.

Selection of methodology to use

B8.3 The Management of Health & Safety at Work Regulations 1999 and the RSC Regulations 2000 make reference to the need for a risk assessment to be suitable and sufficient depending on the nature of the undertaking and the type and extent of the hazardous events and risk that exist. The definition of what constitutes ‘suitable and sufficient’ has, historically, been very difficult to establish owing to the wide range and scales of operation such risk assessments have been applied to. However, for the purposes of this guidance it is considered worthwhile considering some criteria for judging what constitutes ‘suitable and sufficient’.

B8.4 To do this it is suggested that, before undertaking a risk assessment, a high level review of the duty holder’s operation is undertaken to determine:

a) Whether there is potential for fatalities to occur as a result of the duty holder’s operations.

b) If there is potential for fatalities:

   i) whether the operations being considered are similar to the type of operations considered within the Railway Safety SRM as described and summarised in the risk profile bulletin (RPB) [8]. This would include passenger train operating companies, freight train operating companies, Railtrack and station operators

   ii) whether there is experience of the operations being considered but the particular operations are not incorporated within the SRM eg RRVs operated by infrastructure maintenance companies, or

   iii) whether it is a new operation for which there is little or no operating experience which can be drawn on directly when undertaking the risk assessment.
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B8.5 The level and type of risk assessment that could be carried for each case [B8.4 (a), (b), (bii) and (biii)] is shown diagrammatically in Figure B8.5 and is described as follows:

a) No potential for fatalities - the minimum level of risk assessment should be:

i) a high level hazardous event identification process

ii) a qualitative high level risk ranking approach

iii) the consideration of additional controls measures in relation to providing confidence that risk is ALARP.

Such an approach may be applicable to some workplace risk assessments. However due to the potential for fatalities within the range of operations and tasks undertaken on the railway it is unlikely that this level of risk assessment would be considered suitable and sufficient for RSC risk assessment.

An outline methodology for a qualitative high level risk ranking approach is described in Appendix B paragraphs 2.3 to 2.9.

If a potential for fatalities is identified at any stage during this risk assessment process, a more detailed risk assessment methodology as described in B8.5 (b) to (d) will be required.

b) Potential for fatalities – similar to existing operation where the type of activity is covered by the SRM, i.e. passenger train operating companies, freight train operating companies, Railtrack and station operators, the minimum level of risk assessment should be:

i) a detailed hazardous event identification with the information from the SRM used as the initial basis for the RSC risk assessment, modified to take account of the specific factors applicable to the operation such as new or different hazardous events, causes or consequences and individual potentially high risk locations. It is not acceptable to reproduce the information from the RPB within the safety case without the specific factors applicable to the operation being considered

ii) a quantified risk assessment using the information from the SRM (described in the RPB) as the basis of the analysis but modified to account for the characteristics of the operation being considered

iii) an identification of control measures with links to the safety management system described in the RSC

iv) an assessment of individual risk and comparison with the individual risk targets

v) a demonstration that collective risk has been reduced to a level that is as low as reasonably practicable including recognition of the potential for multiple fatality incidents.

A proposed methodology for an RSC risk assessment based on the use of information from the SRM is described in detail in Appendix A.
c) Potential for fatalities – similar to existing operation where the type of operation is not covered by the SRM eg RRVs operated by infrastructure maintenance companies, the minimum level of risk assessment should be:

   i) a detailed hazard identification
   ii) a semi-quantitative risk ranking approach
   iii) an identification of control measures with links to the safety management system described in the RSC
   iv) an assessment of individual risk and comparison with the individual risk targets
   v) a demonstration that collective risk has been reduced to a level that is as low as reasonably practicable including recognition of the potential for multiple fatality incidents.

A proposed methodology for an RSC risk assessment based on the use of the semi-quantitative risk ranking approach is detailed in Appendix B paragraphs 2.10 to 7.3.

d) Potential for fatalities – new type of operation, the level of risk assessment should be:

   i) a detailed hazard identification
   ii) a detailed quantified risk assessment using a semi-quantitative risk ranking approach, and a more detailed analysis methodology such as a fault and event tree analysis
   iii) an identification of control measures with links to the safety management system described in the RSC
   iv) an assessment of individual risk and comparison with the individual risk targets
   v) a demonstration that collective risk has been reduced to a level that is as low as reasonably practicable including recognition of the potential for multiple fatality incidents.

A proposed methodology for an RSC risk assessment based on the use of the semi-quantitative risk ranking approach is detailed in Appendix B. The background to the use of fault and event tree analysis is given in Appendix E.
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Identify requirement for RSC risk assessment

Undertake high level review of operations being subject to risk assessment

Is there potential for fatalities from the operation or maintenance of the system?

No

Yes

High level qualitative risk assessment
(Use methodology outlined in Appendix B paragraphs 2.3 to 2.9)

Is there a potential for fatalities identified during the high level assessment?

No

Yes

Quantitative risk assessment informed with information from the SRM
(Use methodology in Appendix A)

Similar to an existing operation & covered by the SRM?

Yes

Semi-quantitative risk ranking assessment
(Use methodology in Appendix B paragraphs 2.10 to 7.3 & Appendix D)

No

Similar to an existing operation but not covered by the SRM?

Yes

New type of operation not covered by the SRM

No

Initial semi-quantitative risk ranking assessment supported by fault tree and event tree analysis
(Use methodology in Appendix E)

Carry out risk assessment
Go to Figure B9.1

Figure B8.5: Process for selecting the most appropriate risk assessment methodology
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**B9 Key elements of the proposed RSC risk assessment methods**

**B9.1** The key elements of the risk assessment methods proposed in Appendices A and B are shown on the flowchart in Figure B9.1 and are summarised below:

**Involvement of staff**

**B9.2** There should be involvement of a full range of company staff with the competencies required to consider the whole operation in detail within the risk assessment process, particularly in relation to the hazardous event and precursor identification and ALARP assessment stages.

**Identification of hazardous events**

**B9.3** Identify all foreseeable hazardous events via a workshop, a review of records and from the Risk Profile Bulletin (RPB), where appropriate. Where workshops are used, a wide range of competencies from within the duty holder’s organisation should be drawn on.

Consideration should be given to identifying the most exposed groups which will be subject to the assessment of individual risk.

**Assessment of precursors (cause)**

**B9.4** For each hazardous event identify:

a) the precursors (cause) (consider all failure modes, human factors, local factors, etc)

b) the existing control measures preventing the precursor and who applies them

c) the frequency of the precursors and the resulting hazardous event (use actual data, SRM information or expert opinion).

**Consequences assessment**

**B9.5** For each hazardous event identify:

a) the most exposed group (railway employee, passenger, public)

b) the most likely outcome and its probability of occurrence (use actual data or expert opinion)

c) the realistic worst case outcome and its probability of occurrence (use actual data or expert opinion)

d) the control measures that effect the probability of the outcomes and the resulting accident consequences.

**Assess risk**

**B9.6** To risk assess:

a) For each hazardous event, using frequency from (c) above, and the probabilities and consequences from (d) above, calculate the collective risk. These can then be summed to give an overall risk estimate, or ranked if a semi-quantitative risk ranking scheme has been used.

b) For each exposed group:

i) if a numerical assessment has been done (Appendix A) add up the risk (with fatality outcomes only) from all applicable hazardous events and calculate the individual risk

ii) if a risk ranking assessment has been done, develop a clearly defined risk ranking matrix for each exposed group.
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iii) compare the individual risk against the individual risk criteria and identify any exposed groups in the intolerable region. (See table B12.3)

c) Do a sanity check on the results obtained – are they as you expected? Compare with the national results in the RPB, where appropriate.

d) Where the individual risk for an exposed group is found to be in the intolerable region, controls must be introduced to reduce risk to a tolerable level regardless of cost.

ALARP assessment

B9.7 To make an assessment of ALARP:

a) For each hazardous event:
   i) identify additional control measures which would reduce risk further
   ii) consider the cost associated with applying the additional control measures and the potential risk reduction (use expert judgement where no other data is available).

b) For each additional control measure identify:
   i) those that are not reasonably practicable (costs high and potential risk reduction low)
   ii) those that have marginal benefit and do a detailed cost benefit analysis, if appropriate
   iii) those that are reasonably practicable (costs comparable to or less than potential risk reduction).

c) Introduce new controls found to be reasonably practicable.

See Appendix F for more details on the use of good practice, expert judgement and cost benefit analysis when undertaking ALARP assessments.

Document the results of the risk assessment in the RSC

B9.8 The RSC should:

a) describe the risk assessment methodology
b) identify sources of information (including posts involved in any workshops) and any key assumptions
c) describe the results of the risk assessment for the most significant hazardous events (eg top 10) and identify where the arrangements for implementing the existing controls are in the RSC
d) consider the results of the individual risk estimates when compared to the individual risk criteria
e) summarise the results of the ALARP assessment
f) consider areas where there is a high level of uncertainty.
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Select methodology for risk assessment

Identify hazardous events
(a) events covered in SRM, where appropriate, and
(b) events relevant to operations not covered in SRM

Has correct risk assessment method been selected?

Review hazardous events and type of operation to identify the most exposed groups to be assessed for individual risk

Identify precursors (cause) for each hazardous event

Identify existing control measures for each precursor (cause)

Assess precursor (cause) and hazardous event frequencies

Brainstorm potential additional control measures for each precursor (cause)

Assess consequences for assessment of collective risk
- typical & realistic worst case outcomes

Assess consequences for assessment of individual risk for each exposed group
- typical & realistic worst case outcomes

Brainstorm potential additional control measures for each precursor (consequence) and consequence outcome

Assess risk
- collective & individual (each exposed group)

Carry out sanity check/sensitivity analysis

Do the results make sense?

Yes

No

Is individual risk for each exposed group tolerable?

Yes

No

Determine if the identified additional control measures are reasonably practicable

Is collective risk as low as reasonably practicable?

Yes

No

Review methodology, assumptions and input data

Identify additional control measures

Document results in RSC including commitment to implement the additional control measures identified

See Figure B8.5

Inform with information from Risk Profile Bulletin, previous RSC assessments & other relevant studies

Use actual data where possible

Inform with information from Risk Profile Bulletin, previous RSC assessments, actual data & other relevant studies

See Figure B9.1: Overall risk assessment methodology
B10 Risk assessment input data

B10.1 Data relating to the operation being analysed are a key input into the risk assessment process. In order to improve the accuracy of the risk assessment and to ensure local factors are accounted for, wherever possible data relating directly to the duty holder’s operation should be used. The primary source of data for the railway industry is the SMIS maintained on behalf of the railway industry by Railway Safety. It is recognised that it can be difficult to obtain data in a useable form from SMIS however every effort should be made by the duty holder to obtain data to support the risk assessment process. Railway Safety currently has advisors who can provide advice and support to assist in the report writing and data extraction process from SMIS – contact the Head of Risk Assessment at Railway Safety, see phone number in section A5.

B10.2 If there is only limited data available in SMIS (often the case for duty holders with small operations), consideration could be given to widening the data gathering to include other duty holder operations with similar rolling stock or system characteristics.

B10.3 Other potential sources of data include:

a) Duty holder maintenance depot equipment failure records.

b) Other locally held duty holder databases, if available.

c) Monthly SPAD reports issued by Railway Safety and HSE.

d) Quarterly and annual safety performance reports issued by Railway Safety.

e) Railway Safety special topic reports.

f) The Railway Safety RPB.

g) Her Majesty’s Railway Inspectorate (HMRI) annual reports.

h) Formal inquiry and investigation reports.

i) National incident logs.

j) Risk assessments undertaken in the development or application of Railway Group Standards.

B10.4 All data used should be referenced to their source, see section B11.

B11 Risk assessment records

B11.1 To enable a better understanding of the basis of the risk assessment and to make the assessment more meaningful, it is essential that all the assumptions made for the purposes of the risk assessment and the origin and derivation of the data behind each frequency and consequence estimate are justified and recorded within the risk assessment documentation. The records should refer to:

a) the sources of data used

b) any judgements made during workshop sessions. For cases where modified national data have been used an explanation of why it is believed the data is applicable should be given. Where possible, factors specific to the operation being considered which might increase or decrease the data with respect to the national average should be referred to, eg average passenger loadings, type of rolling stock and train speeds.
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c) any general assumptions made for the purposes of the risk assessment.

B11.2 This information would assist:

a) a reviewer to understand the background to the risk assessment
b) in demonstrating that the risk assessment is robust
c) anybody needing to change or update the risk assessment to understand where the assumptions, data and results have come from.

B12 Acceptance criteria

B12.1 Once a risk assessment has been completed, it is essential to determine the acceptability of the risk results. The two main requirements against which to judge the results of an RSC risk assessment are:

a) the criteria for individual risk, and
b) whether risk has been reduced to a level which is ALARP.

In assessing the results of a risk assessment, the influence of hazardous events with the potential to lead to multiple fatalities, referred to as ‘societal risk’ should be considered.

Individual risk criteria

B12.2 Individual risk relates to the probability of fatality per year that an individual is exposed from the duty holder’s operation. There is a need to identify all exposed groups relating to passengers, staff and members of the public. However it is likely to be impractical to undertake a quantitative assessment of individual risk for all the identified exposed groups. Examples of the minimum level of individual risk assessment expected within an RSC are:

a) For a train operating company - passengers and train drivers.
b) For an infrastructure controller - passengers, train drivers, trackside workers and members of the public using different types of level crossings.
c) For a station operator – platform staff.

In the examples given, the identified groups are likely to be the most exposed groups within the particular type of operation. If the individual risk for these groups can be shown to be at least in the tolerable region it is likely that the individual risk for all groups exposed to these duty holder’s operations will also be in the tolerable region.

B12.3 Having carried out a risk assessment it is necessary to understand what the results actually mean in the context of the criteria for bands of risk derived from HSE’s document Reducing Risks Protecting People [9] which includes guidance on risk tolerability. The criteria for individual passenger risk, individual employee risk (any group of staff) and individual public risk (railway ‘neighbour’) of fatality are as follows:
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<table>
<thead>
<tr>
<th>Group</th>
<th>Upper limit of tolerability*</th>
<th>Railway Group Safety Plan 2009 targets</th>
<th>Broadly acceptable*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual passenger risk (regular traveller, see definition in B12.9)</td>
<td>$1 \times 10^{-4}$ (1 in 10,000 per year)</td>
<td>$1 \times 10^{-6}$ (1 in 1,000,000 per year)</td>
<td>$1 \times 10^{-6}$ (1 in 1,000,000 per year)</td>
</tr>
<tr>
<td>Individual employee risk (any group of staff)</td>
<td>$1 \times 10^{-3}$ (1 in 1000 per year)</td>
<td>$5 \times 10^{-6}$ (1 in 20,000 per year)</td>
<td>$1 \times 10^{-6}$ (1 in 1,000,000 per year)</td>
</tr>
<tr>
<td>Individual member of the public risk (railway 'neighbour')</td>
<td>$1 \times 10^{-4}$ (1 in 10,000 per year)</td>
<td>$1 \times 10^{-6}$ (based on an average member of the UK population) (1 in 1,000,000 per year)</td>
<td>$1 \times 10^{-6}$ (1 in 1,000,000 per year)</td>
</tr>
</tbody>
</table>

* HSE Reducing Risks Protecting People [9]

**Table B12.3: Individual risk criteria**

**B12.4** The criteria for passengers and staff are shown diagrammatically in Figures B12.5a) and B12.5b) respectively.

**B12.5** To put these criteria into the context of the individuals using the railway today, consideration has been given to the number of regular travellers and train drivers on the system. If it is assumed that:

a) all passenger journeys on the national network (currently about 1000 million/year) are undertaken by regular travellers, at 500 journeys per regular traveller there would be about 2,000,000 regular travellers, and

b) there are approximately 15,000 train drivers.

The number of passenger and train driver fatalities equivalent to each individual risk criterion are shown on Figures B12.5a) and B12.5 b) respectively.
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**Figure B12.5a): Individual risk criteria for passengers**

- **Intolerable region**: 1 in 1,000,000 per year (200 fatalities per year)
- **Tolerable region**: 1 in 270,000 per year (RGSP 2009 target: 7 fatalities per year)
- **Broadly acceptable region**: 1 in 1,000,000 per year (2 fatalities per year)

What the criteria mean for passengers on the Railtrack network in terms of the average number of fatalities per year given ~ 2,000,000 regular travellers.

**Figure B12.5b): Individual risk criteria for staff**

- **Intolerable region**: 1 in 1,000,000 per year (15 fatalities per year)
- **Tolerable region**: 1 in 20,000 per year (RGSP 2009 target: 0.75 fatalities per year)
- **Broadly acceptable region**: 1 in 1,000,000 per year (0.015 fatalities per year)

What the criteria mean for train drivers on the Railtrack network in terms of the average number of fatalities per year given ~ 15,000 train drivers.
B12.6 For train operating companies and station operators it is not currently considered possible within an RSC to identify and estimate the individual risk for a specific group or groups of members of the public. However for an infrastructure controller RSC the most exposed member of the public group on the network is likely to be users of level crossings. An infrastructure controller RSC should therefore identify and estimate the individual risk for such groups of members of the public to enable comparison with the individual risk criteria for members of the public.

B12.7 It is important to note that when individual risk estimates are made for comparison with the criteria, the total risk to the individual is accounted for. For example, for a passenger the individual risk calculation should include the fatality risk associated with:

a) entering and moving through the station
b) boarding the train
c) the train journey
d) alighting from the train
e) moving through and leaving the station.

B12.8 In each case all the accident causes, both internal and external to the train, should be included even if the causes are not under the direct control of the duty holder eg track faults, signalling system faults and obstructions on the line.

B12.9 Having estimated the overall fatality risk to the most exposed groups, for example passengers and train drivers, their individual risk can be calculated as follows:

a) Individual passenger risk (probability of fatality per year) =

\[
\frac{\text{Passenger fatality risk (fatalities/year) from all hazardous events}}{\text{Total number of passenger journeys per year for the duty holder}} \times \frac{\text{Number of journeys per year for a typical passenger in the exposed group}}{\text{Number of journeys per year for the duty holder}}
\]

For a typical train operating company it is the regular travellers (commuters) who are normally considered to be the most exposed passenger group. It is assumed typically that a regular traveller on average makes 500 journeys/year (2 journeys/day, 5 days/week for 50 weeks/year). Other definitions can be used, eg 450 journeys/year taking account of typical annual leave, sickness, etc, providing a justification is given for the number used.

b) Individual driver risk (probability of fatality per year) =

\[
\frac{\text{Driver fatality risk (fatalities/year) from all hazardous events}}{\text{Number of full time equivalent drivers employed to operate the service}}
\]

B12.10 It should be noted that:

a) the individual risk criteria relate to the total individual risk (sum of the individual risk for all hazardous events) and not the individual risk estimated for each hazardous event. It is not therefore acceptable to compare the individual risk results for each hazardous event with the individual risk criteria.
b) there is a legal requirement to carry out an ALARP assessment for all hazardous events identified within the risk assessment regardless of the assessed individual risk, as defined in Section 12.11 to 12.21 below. However, the amount of effort that would need to be put into demonstrating ALARP given that the individual risk for each exposed group lies in the Broadly Acceptable region would be significantly less than if the individual risk lies in the Tolerable region.

**ALARP criteria**

B12.11 The requirement to undertake risk assessment derives from the Health and Safety at Work etc Act, 1974.

B12.12 The minimum content of an RSC is defined in the RSC Regulations 2000 and in particular, Schedule 1 of these regulations and its supporting guidance [10].

B12.13 Schedule 1(4) of the RSC Regulations 2000 requires particulars of risk assessments carried out by the duty holder in relation to railway operations undertaken by him including:

a) a statement of the assessment process undertaken, the methods of any calculation used and any assumptions made

b) a statement of the significant findings of the risk assessment including the measures in place and any further measures the duty holder intends to take to comply with the relevant statutory provisions, and

c) particulars of the arrangements the duty holder has made for the effective planning, organisation, control, monitoring and review of all measures identified in sub-paragraph (b) above.

B12.14 The supporting guidance to Schedule 1 of the RSC Regulations 2000 [10] states 'Risk assessment is essential in order to identify the measures which are necessary to meet health and safety obligations and to reduce risks to as low as reasonably practicable’ and ‘A risk assessment should identify the risk control measures already in place, assess their effectiveness, and evaluate the risk remaining. The process then involves considering what additional control measures are needed to reduce risks to a level that is as low as reasonably practicable’.

B12.15 From the relevant regulations and associated sources of guidance, it is clear that RSCs should contain sufficient information to demonstrate that risk is or will be managed to a level where either the individual risk to all exposed groups is broadly acceptable or, if individual risk is shown to be in the tolerable region, the collective risk is reduced to a level that is ALARP. For the majority of duty holder’s operations it is considered very unlikely that it will be possible to demonstrate that the individual risk to all exposed groups is broadly acceptable.

B12.16 It would be very difficult, if not impossible, for each duty holder to provide a comprehensive quantitative ALARP demonstration for all the hazardous events and precursors identified as being relevant to their operations. The essence of the application of the ALARP principle within the RSCs is not associated with providing a detailed quantitative ALARP demonstration but an ALARP demonstration that gives confidence that risk reduction is being considered and implemented by the duty holder in a comprehensive, structured and auditable way. Possible methods for consideration when undertaking ALARP assessments are described in Appendix F.

B12.17 To meet the above requirement in relation to demonstrating ALARP, and as described in Appendices A, B and F, the risk assessment supporting an RSC should include a demonstration that potential additional control measures have been considered in the context of reducing the collective risk associated with each precursor and hazardous event within the risk assessment. The rationale
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and strategy for dealing with the potential additional controls should also be stated ie:

a) Which additional controls are clearly reasonably practicable and will be implemented.

b) Where it is unclear whether the potential additional controls are reasonably practicable and cost benefit analysis required.

c) Where additional controls are clearly not considered reasonably practicable.

To ensure greatest efficiency in the assessment, the hazardous events with the highest collective risk contribution should be considered first, although ultimately all hazardous events should be considered.

B12.18 Only in the cases where there is considered the potential for a significant reduction of collective risk and there is uncertainty as to whether the proposal is reasonably practicable should detailed cost benefit analysis be considered (Appendix F).

B12.19 In such cases, it may not be essential to have completed all such analyses before submitting a safety case for review. However it will be necessary to include a commitment to undertake the analysis within the safety case development plan to a defined timescale. It is also possible that the issue is being considered at a national or zonal level and therefore not appropriate for the duty holder to pursue independently.

B12.20 The results of any such assessments should then be summarised in the RSC document.

B12.21 It should be noted that, in general, compliance with Railway Group Standards is not considered to be an acceptable ALARP demonstration in its own right. Compliance with Railway Group Standards can only be sufficient to demonstrate that risk is ALARP where all of the following apply:

a) the level of risk is completely controlled by the Railway Group Standard(s)

b) the Railway Group Standard(s) represent current good practice

c) any special issues have been considered, and

d) the duty holder has satisfied itself, using structured expert judgement, that no further reasonably practicable control measures can be applied to reduce collective risk further, taking due account of the conditions pertaining to their particular operation.

Societal risk

B12.22 As society in general has an aversion to single accidents that lead to catastrophic multiple fatality outcomes, it is important to consider the potential for such accidents within an RSC risk assessment. The frequency at which multiple fatality accidents occur is referred to as a ‘societal risk’.

B12.23 There are currently no specific railway related criteria for judging the acceptability of any societal risk results that may be estimated within an RSC risk assessment. However, an RSC should recognise the influence of such multi-fatality accidents by:

a) considering a higher level of value of preventing a fatality (VPF) when assessing additional reasonably practicable control measures in the ALARP demonstration, see Appendix F, and
b) providing a list of all the hazardous events that have the potential to lead to multiple fatalities ranked by their risk contribution. This should include a discussion of the issues relating to the highest risk contributors and the measures in place to control the risk should be included to provide confidence that such events have been recognised and the necessary controls are in place. Particular attention should be given to single failures that could lead directly to a catastrophic event.

B13 Sensitivity analysis

B13.1 In carrying out any risk assessment and subsequent ALARP assessment it is often necessary to make assumptions and, due to lack of data, use judgement when quantifying precursors frequencies and probabilities and hazardous event consequences. The results of the overall risk and ALARP assessment may therefore be very dependent on the way in which the assumptions and judgement are made and it is therefore necessary to be aware of the relative importance of these assumptions and judgements within the overall results. A guide to the influence of these assumptions and judgements can be made using sensitivity analysis.

B13.2 Having completed the risk assessment it cannot be assumed that the results are necessarily ‘correct’. It is therefore essential to review the results to make sure that they make sense, namely:

a) Do the results look believable in terms of overall collective risk, the hazardous events ranked by risk and the individual risk estimates?

b) Are they what you expected?

c) How do they compare with the national averages, etc?

d) Are the major risk contributors what you expected? If not, is there a rational explanation for the difference.

B13.3 Whether the results make sense or not it is important that the specific assumptions and judgements made and recorded within the risk assessment process (see section B11 above) are examined to determine if there are any for which there is a high level of uncertainty (for example a factor of 2 or greater). If there are, the sensitivity of the results to changes in the assumptions should be checked by asking the question, ‘if there were a factor of 2 to 5 difference (higher or lower) in the numbers affected by the assumption or judgement would it make a material difference to the conclusions of the risk and/or ALARP assessments?’ If it would make a material difference, consideration should be given to:

a) a more detailed examination of the assumptions and judgements to see if more accurate assessments can be made, and if this is not possible

b) confirm that the existing or potential additional control measures are sufficiently robust to cater for the potential level of uncertainty.

B14 Safety case document information and use of results

Details of the risk assessment

B14.1 Full details of the risk assessment including the methodology, assumptions, hazardous event assessment tables and individual risk calculations should be recorded in a separate risk assessment document, which will form a primary reference in the safety case itself. It is not necessary to include the complete risk assessment within the safety case document. However the safety case document should contain:
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a) An indication of the scale of the operation being considered in terms of, for example, the number of train miles, passenger journeys, average passenger loadings, route miles the services operate over and the number of staff employed in various roles. This information would assist a reader in being able to understand and judge the applicability of the frequency and risk estimates within the risk assessment.

b) For safety cases relating to operations other than passenger and freight train services, descriptions of the typical sequences of operation on or about the railway should be provided to enable the reader to understand the context of operations considered in the risk assessment.

c) Details of the risk assessment methodologies used.

d) A summary of the personnel involved in the hazard identification and safety review process together with details of their competence and experience to be able to input to the process.

e) The significant findings from the risk assessment (described in more detail below).

f) Description and discussion of the ALARP assessments (described in more detail below).

Significant findings - Overall risk profile

B14.2 The safety case document should provide a table listing all the hazardous events and their associated risk contributions ranked by risk contribution.

B14.3 For each of the hazardous events that provide a significant risk contribution, for example the top 10 hazardous events or all the hazardous events contributing more than 5% of the overall risk, there should be a discussion of:

a) the exposed groups

b) the event frequency

c) the event consequences

d) the existing control measures in place to control the frequency and consequences relating to the event

e) any potential additional control measures considered as a part of the risk assessment process and whether the acceptability of the RSC (in terms of reducing individual risk to a level which is in the tolerable region and reducing collective risk to a level that is ALARP) is dependent on these additional controls being implemented

f) any other issues considered relevant.

B14.4 The discussion should include references to any potentially high risk locations (e.g. tunnels, long bridges and below ground stations) on the routes used by the duty holder. These should have been identified as a part of the hazardous event identification process. Even if the risk at these locations is not quantified in detail within the risk assessment, the specific controls and interface procedures in place to minimise the risk should be described. This will help to demonstrate that:

a) the duty holder is aware of such locations

b) there are controls in place to minimise the occurrence of incidents and deal with incidents, and

c) the interfaces issues, e.g. with Railtrack and other train operating companies (TOCs), have been adequately addressed.
Significant findings - Catastrophic risk

B14.5 Particular consideration should be given to the infrequent catastrophic events with potentially high consequences. The document should provide a list of all the hazardous events that have the potential to lead to multiple fatalities ranked by their risk contribution. A discussion of the issues relating to the highest risk contributors and the measures in place to control the risk should be included to provide confidence that such events have been recognised and the necessary controls are in place. Particular attention should be given to single failures that could lead directly to a catastrophic event.

Significant findings - Precursor risk profile

B14.6 The document should provide a list of the precursors or groups of similar precursors with the highest risk contributions ranked by their risk contribution (perhaps the top 20). Discussion on the significance of the results should be included within the RSC.

Significant findings - Individual risk

B14.7 The RSC document should:

a) present results for each exposed group considered within the risk assessment

b) compare the results with the individual risk criteria

c) discuss the results in terms of the major contributors.

ALARP

B14.8 As noted in section B12.11 to B12.21 above Railway Safety is of the view that the essence of the application of the ALARP principle within the RSC is not associated with providing a detailed quantitative ALARP demonstration but an ALARP demonstration that gives confidence that risk reduction is being considered and implemented by the duty holder in a comprehensive, structured and auditable way.

B14.9 To show this, the RSC document should include a specific section relating to the application of the ALARP principle, in particular:

a) recognition of the need to apply the ALARP principle

b) a description of the ALARP assessment process used

c) a summary of findings in terms of any additional controls that will be or have been introduced or modified as a result of the risk assessment process

d) a description of the strategy in relation to cost benefit analysis that will be undertaken as a part of safety case development plan concerning the additional controls for which it is not clear whether they are reasonably practicable

e) in addition, the duty holder’s commitment to reducing risk could be reinforced by giving examples of:

i) risk reduction measures employed since the last safety case was accepted

ii) ongoing processes in place to review safety risk eg SPAD management

iii) safety data which indicate that initiatives are driving down the frequencies of incidents

iv) any initiatives (over and above the additional controls considered above) which are planned for consideration in the near future.

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On-going risk assessment process

B14.10 The RSC should include a description of the duty holder’s policy and process for systematically identifying and assessing risk on an on-going basis. This should include the application of risk assessment strategies and methodologies used for review and update of the RSC risk assessment as well as details on workplace risk assessments, task risk assessments, interface risk assessments and risk assessments for temporary activities or arrangements. The principles governing the determination of the type of methodology of risk assessment applied depending on the activity being considered and the degree of risk involved should be reflected within the RSC. The need for further guidance on the methods for other forms of risk assessment, such as workplace risk assessments, is being considered by Railway Safety.

B14.11 The RSC should include details of how the duty holder makes use of historical data, human factor considerations and assumptions made within risk assessments. The description provided should demonstrate how the duty holder uses the output of risk assessments to determine appropriate preventative and protective control measures and the incorporation of these measures into the SMS. Measuring the validity of output against benchmarks should also be recognised within the overall process. The use of risk assessment to inform management decision making within the company, particularly in relation to prioritising improvements, project design, business plans, formulating objectives and implementing control measures should be referenced. Principles governing the frequency of risk assessment reviews should be described as well as an explanation of how the overall approach to risk assessment is co-ordinated and integrated across all activities.

B14.12 The RSC should provide assurance about the competence of those involved in undertaking risk assessments at all levels within the organisation as well as describe how personnel are made aware of their responsibilities pertaining to risk assessment. Where expertise or resource is not available from within the duty holder’s organisation, the RSC should summarise the key components of the process for procuring technical expertise in risk assessment techniques.

B14.13 The RSC should additionally describe how the findings of risk assessments are communicated to all affected personnel as well as appropriate to other train and station operators, Railtrack, Railway Safety, contractors and suppliers. The involvement of these other interfacing organisations in the on going risk assessment process should also be recognised together with the input of local safety representatives and ground level personnel.

B15 Summary of the key factors relating to RSC risk assessments

B15.1 The following is a summary of the key factors relating to the RSC risk assessments:

a) Risk assessment is an important part of the overall safety case process.

b) While most risk assessments, particularly for hazardous events combining low frequency with potentially high consequences, require a level of risk quantification or risk ranking, it is the qualitative aspects of the risk assessment and the dissemination of this information throughout a company that provides significant potential benefits from the risk assessment process.

c) The risk assessment process, particularly the hazardous event and precursor identification and ALARP assessment stages should involve company staff with the range of competencies required to consider the whole operation in detail.

d) Where appropriate, use should be made of the results from the Railway Safety SRM to provide an input into the risk assessment process.
e) When using a semi-quantitative risk ranking approach to risk assessment, as defined in Appendix B, the frequency and consequence rankings should be added to give the risk ranking rather than the multiplication method used commonly within the industry at present.

f) Where possible, use should be made of duty holder specific data.

g) It is essential to keep records regarding the assumptions and data used within the risk assessment.

h) The risk assessment process should be applied in a way that ensures the results are meaningful in the context of the duty holder’s operations.

i) The ALARP and individual risk criteria should be addressed explicitly.

j) All risk assessments contain uncertainties in relation to the assumptions and judgements made within the assessment and therefore the results should be subject to some degree of sensitivity analysis and should only be used as a guide to the level of risk within the bounds of the uncertainty. The results of such assessments should therefore only be used as an input into decision making and should not be the sole basis for making a decision.

k) The development of risk assessments within RSCs and the railway industry generally is an important ongoing process. In carrying out a risk assessment for an RSC it is possible that a duty holder will:

   i) develop or refine the methodologies outlined in this guidance note

   ii) make improvements to the risk assessment templates, or

   iii) identify new hazardous events and/or precursors not considered within the current version of the SRM.

In such cases Railway Safety recognise that it would be beneficial for the changes to be considered for inclusion in future versions of the guidance note, risk assessment templates and SRM. Details of such enhancements and any other feedback on this guidance note or the SRM should be sent to Railway Safety at the address given in Section A6, marked for the attention of the Head of Risk Assessment.
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Appendix A

Safety case risk assessment method based on the use of the outputs from the SRM

1 Introduction

1.1 If the operations are similar to the type of operations considered within the SRM ie train operating companies (TOCs) operating passenger or freight trains on Railtrack controlled infrastructure or Railtrack as an infrastructure controller, the information from the SRM can be used as the initial basis for the RSC risk assessment, modified to take account of the specific factors applicable to the operation being considered. It is not acceptable to reproduce the information from the RPB within the safety case without the specific factors applicable to the operation being considered.

1.2 The RPB contains a detailed list of the hazardous events associated with train and station operations within the boundaries of Railtrack controlled infrastructure considered within the SRM. At present the SRM does not include on-train incidents or incidents occurring on station concourses that do not affect Railtrack controlled infrastructure or depots, yards and sidings.

1.3 The risk assessment method described in this appendix is a proposed method that, if followed correctly, would produce a risk assessment that is likely to be suitable and sufficient in the context of the assessment criteria given in the documents listed in section B4.3 in the main text. The proposed method is not mandatory. A duty holder can use other methods or adapt the proposed methods as required, providing the level of analysis and reporting provides a risk assessment of a suitable standard.

1.4 When undertaking a risk assessment within an RSC it is important that, in addition to the information contained within the SRM, use is made of any previous risk assessment studies that have been undertaken that can inform the process. Examples of such studies are:

a) Previous RSC risk assessment studies.

b) The East Coast Main Line HAZOP study [11].

c) Risk assessments carried out as in relation to the development or application of Railway Group Standards.

d) Hazard lists in the Yellow Book Issue 2 [12].

1.5 If a duty holder requires assistance in interpreting or applying the following risk assessment methodology please contact the Head of Risk Assessment at Railway Safety, 020 7904 7499.

2 Proposed method for risk assessment – hazardous event identification

2.1 A proposed method for risk assessment based on the use of the outputs from the SRM is shown diagrammatically in Figure 2.1 (Appendix A) and described in the sections below.
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**Stage 1: Hazardous event identification**  
App A 2.1 to 2.10

- Identify hazardous events  
  (a) events covered in SRM, and  
  (b) events relevant to operations not covered in SRM

**Stage 2: Precursor assessment**  
App A 3.1 to 3.8

- Has correct risk assessment method been selected?  
  No: Reconsider methodology to be used  
  Yes

- Review hazardous events and type of operation to identify the most exposed groups to be assessed for individual risk

- Identify precursors (cause) for each hazardous event

- Identify existing control measures for each precursor (cause)

- Assess precursor (cause) and hazardous event frequencies

- Brainstorm potential additional control measures for each precursor (cause)

- Assess consequences for assessment of collective risk  
  - typical & realistic worst case outcomes

- Assess consequences for assessment of individual risk for each exposed group  
  - typical & realistic worst case outcomes

- Brainstorm potential additional control measures for each precursor (cause) and consequence outcome

- Assess risk  
  - collective & individual (each exposed group)

- Carry out sanity check/sensitivity analysis

**Stage 3: Consequences**  
App A 4.1 to 4.7

- Review methodology, assumptions and input data

- Do the results make sense?  
  No

- Is individual risk for each exposed group tolerable?  
  Yes

- Determine if the identified additional control measures are reasonably practicable  
  No

- Is collective risk as low as reasonably practicable?  
  Yes

- Document results in RSC including commitment to implement the additional control measures identified

**Stage 4: Analysis of results**  
App A 5.1 to 5.5

- Inform with information from Risk Profile Bulletin, previous RSC assessments & other relevant studies

- Brainstorm potential additional control measures for each precursor (cause)

- Assess consequences for assessment of collective risk  
  - typical & realistic worst case outcomes

- Assess consequences for assessment of individual risk for each exposed group  
  - typical & realistic worst case outcomes

- Brainstorm potential additional control measures for each precursor (cause) and consequence outcome

- Assess risk  
  - collective & individual (each exposed group)

- Carry out sanity check/sensitivity analysis

- Review methodology, assumptions and input data

- Do the results make sense?  
  No

- Is individual risk for each exposed group tolerable?  
  Yes

- Determine if the identified additional control measures are reasonably practicable  
  No

- Is collective risk as low as reasonably practicable?  
  Yes

- Document results in RSC including commitment to implement the additional control measures identified

**Figure 2.1 (App A): Quantitative risk assessment methodology**
Guidance on the Preparation of Risk Assessments within Railway Safety Cases

Appendix A continued

Stage 1 – Hazardous event identification

2.2 The purpose of the hazardous event identification process is to establish a comprehensive list of the hazardous events taking full account of the factors specific to the duty holder’s operations.

2.3 As noted in section B7 of the main text, one of the main objectives of an RSC risk assessment is to help ensure that company managers and staff identify and understand all the foreseeable hazardous events, causes, control measures and consequences that can influence their operation. It is therefore recommended that the hazardous event identification process and data gathering is undertaken using a structured workshop approach involving a range of company staff.

2.4 The workshop should aim to involve individuals covering the broad range of skills and experience within the duty holder’s operation. For a TOC or an infrastructure controller this could include:

a) meeting chairman (preferably experienced in managing risk assessment workshops)
b) secretary (to record the details of the discussion)
c) safety manager
d) driver standards manager
e) driver
f) guard (if appropriate)
g) platform staff (if appropriate)
h) other train crew representative
i) representatives from other companies who interface with the duty holder, if appropriate eg train operations interface manager (Railtrack zone)
j) operations manager
k) depot staff eg a fitters representative who has direct experience of the types of failures occurring on the trains being considered
l) engineering manager.

The competency of the participants and the way the workshop is conducted are key to the success of the process. An incorrect or limited range of competencies or a poor workshop procedure could lead to an invalid process.

2.5 Twelve individuals is probably the maximum sensible attendance number within such a workshop.

2.6 The chairman should where possible be taken from within the company staff. The workshops could be facilitated by an external consultancy but the overall risk assessment should be owned, managed and understood by the duty holder.

2.7 The secretary’s role is critical in the workshop process to record the assumptions, rationale and justifications behind each decision and judgement made by the workshop members. It is essential to record this information to enable:

a) a reviewer to understand the background to the risk assessment
b) provide a demonstration that the risk assessment is robust
Appendix A continued

c) anybody needing to change or update the risk assessment in the future to understand the derivations of the assumptions, data and results.

2.8 The hazardous event identification process needs to consider all hazardous events relating to the duty holder operations including:

a) Railtrack controlled infrastructure related hazardous events covered in the RPB

b) on-train station platform and station concourse hazardous events which are not included in the RPB.

Stage 1 - Hazardous event identification - Preparation

2.9 The following steps are necessary to prepare for hazardous event identification:

a) Obtain the pre-prepared list of the Railtrack controlled infrastructure related hazardous events from the RPB (Table A1 on the Guidance Note CD available from Railway Safety).

b) Identify typical operations or journeys through the system which will be considered within the workshop eg:

   i) passenger arriving at station, moving through the station, boarding train, train journey, alighting the train and exiting the station

   ii) train driver (passenger or freight) boarding train, train journey, alighting from the train and other duties if appropriate

   iii) train crew (passenger or freight) – typical duties

   iv) platform staff – typical duties

   v) trackside worker

   vi) member of the public using a level crossing

   vii) member of the public living adjacent to the railway.

Stage 1 - Hazardous event identification - Workshop 1

2.10 The initial workshop would typically be a 1 to 2 day event for the purposes of introducing the participants to the risk assessment process and identification of the hazardous events that will form the core of the risk assessment. The workshop could include:

a) Introduction to the risk assessment and workshop processes.

b) Review the most exposed groups to be considered for the assessment of individual risk (see B12.2 in the main text) and confirm that the operations or journey stages identified in the preparation stage in 2.9 above are representative of the duty holder’s activities. Add or remove exposed groups and typical activities/journeys as appropriate.

c) For each operation or journey stage consideration of the hazardous events that have the potential to lead directly to death or injury to the exposed group. This should include:

   i) reference to the list of the Railtrack controlled infrastructure related hazardous events from the RPB (Table A1 on the Guidance Note CD available from Railway Safety)
Guidance on the Preparation of Risk Assessments within Railway Safety Cases

Appendix A continued

ii) identification of any additional Railtrack controlled infrastructure related hazardous events relevant to the duty holder but not identified in the RPB

iii) identification of any of the additional non-Railtrack controlled infrastructure hazardous events relevant to the duty holder operations relating to on-train incidents and station concourses

iv) reference to previous hazard identification studies and risk assessments, see section 1.4 above.

d) For each type of operation or journey the workshop team should be asked to consider if additional hazardous events could occur as a result of:

i) normal operations

ii) perturbed running eg train failure

iii) degraded or abnormal operations

iv) day or night

v) extreme weather

vi) disabled people or other vulnerable groups

vii) overcrowding on stations or in trains

viii) criminal activity

ix) other conditions specific to the duty holder’s operations.

e) As a part of the hazardous event identification process the routes that the duty holder’s trains operate over should be considered to determine if there are any potentially high risk locations (tunnels, long bridges, below ground stations, etc) for which additional controls may be required. Even if the risk at these locations is not quantified, the safety case risk assessment should demonstrate that the duty holder is aware of such locations, that there are controls in place to minimise the occurrence of incidents and deal with incidents, and that the interfaces issues, eg with Railtrack and other TOCs, have been adequately addressed.

f) Confirm that the most appropriate risk assessment methodology has been selected for the operations being considered, see B8.3 to B8.5 in the main text.

3 Proposed method of risk assessment – precursor assessment

Stage 2 – Precursor assessment

3.1 Having identified the hazardous events using the structured identification process above, it will be necessary to identify all the precursors that could individually, or in combination with other precursors, cause each hazardous event to occur. The information from the SRM contained within the RPB should assist in this process. Preparation of known information prior to the workshop will help speed up the precursor and hazardous event frequency assessment process.
Appendix A continued

Stage 2– Precursor assessment– Preparation

3.2 The following steps are necessary to prepare for precursor assessment:

a) From the output from Workshop 1, prepare a rationalised list of all hazardous events applicable to the duty holder’s operation.

b) Where possible cross-reference the identified hazardous events from the workshop to the prepared list of the Railtrack controlled infrastructure related hazardous events from the RPB (Table A1 on the Guidance Note CD available from Railway Safety).

c) Obtain the pre-prepared list of the cause precursors for each of the relevant Railtrack controlled infrastructure related hazardous events from the RPB (Table A2 on the Guidance Note CD available from Railway Safety) and on each hazardous event spreadsheet, enter the number of train miles, passenger journeys or track miles applicable to the duty holder in relevant cell on the spreadsheet. An example of a precursor assessment table for passenger train derailment (Table A2) is given in Appendix G.

d) Using recent safety performance data, SMIS or other sources of data (see section B8 in the main text) identify any duty holder or other available related data applicable to each cause precursor for each hazardous event. It should be noted that, if for example, the TOC data relating to axle failures leading to derailment shows 10 axle failures in 5 years but no derailments, this is still an indication of the scale of the failures and should be recorded in column (k) prior to the workshop.

e) Make up similar precursor assessment tables for any hazardous events not included in the RPB. Any known data relating to these hazardous events could also be recorded in column (k).

Stage 2– Precursor assessment– Workshop 2

3.3 This workshop is likely to take 2 days and should work systematically through each hazardous event to identify all the precursors, even if the precursors are not under the direct control of the duty holder. It should be noted that, when considering the individual risk to any exposed group it is the total risk exposure that should be considered for comparison with the individual risk criteria not just risk resulting from the hazardous event precursors controlled directly or indirectly by the duty holder.

3.4 Complete the pre-prepared precursor assessment table (Appendix G) for each hazardous event as follows:

a) For the hazardous events for which precursors are provided from the RPB, consider (i) whether the precursor is applicable to the duty holder operations and (ii) any additional precursors which are relevant to the duty holder operations.

For the hazardous events for which precursors are not provided in the RPB, consider and list the precursors relevant to the duty holder’s operation.

When considering the additional precursors associated with each hazardous event, the workshop participants should consider:

i) the type of traction and rolling stock being used

ii) the characteristics of the routes being used in terms of specific features, areas particularly prone to vandalism and other such issues
iii) any additional human factors issues relating to the duty holder’s operation.

Appendix A continued

3.5 List the identified precursors in column (c) under one of the predefined or new precursor category:

a) Identify in column (d) whether each cause precursor is under the direct control of the duty holder (D), is an interface issue (shared responsibility between the duty holder and another company) (I) or the duty holder has no control over the precursor (N). Where the precursor is an interface issue (I) or the duty holder has no control over the precursor (N) the company responsible for the precursor control measures should be identified in column (e).

b) For each precursor under the direct (D) or partial (I) control of the duty holder, consider in column (f) the existing control measures in place to control the frequency at which the precursor occurs. This should include a summary of the key control measures required by Railway Group Standards as well as any additional control measures applied by the duty holder. Information for this section can also be supplemented outside the workshop.

c) Identify in column (g) where each identified control measure is addressed within the RSC Safety Management System (this could be done outside the workshop).

d) Precursor frequency [column (h)] – number of events per train mile, per passenger journey or per track mile as applicable nationally (information included from RPB Appendix B as part of the pre-prepared lists on the Guidance Note CD). Where national data is not provided from the RPB, duty holder specific data or judgement from the workshop should be used in columns (k).

e) Precursor frequency [column (i)] - number of events/year for the duty holder based on national average data pro-rated for the duty holder operations calculated on spreadsheet.

f) Precursor frequency [column (j)] – number of years between events based on the national average data pro-rated for the duty holder operations calculated on spreadsheet. This information is designed to put each precursor into the context of the duty holder’s operation in terms of the national average data.

g) Precursor frequency [column (k)] - number of events in x years based on actual data from duty holder’s data sources. Origin of the data should be recorded in column (n). This is the preferred source of data if it is available.

h) Precursor frequency [column (l)] – number of events/year based on duty holders data sources.

i) Assessed precursor frequency [column (m)] – Based on the duty holder’s actual data, the normalised national data, any known duty holder specific factors and/or judgements, including the perceived effectiveness of the existing control measures, consider the number of events/year to be used as the basis for the risk assessment.

Where actual data is available for a particular precursor, care should be taken when interpreting the data. If there are 3 or more events recorded in column (k) for a precursor over the data period analysed, it can be considered that the actual data is representative of the duty holder’s operation and the actual data can be used.
Appendix A continued

However, if there are less than 3 recorded events for the precursor, we cannot have sufficient confidence that the data is representative of the duty holder’s operation. In such cases where sufficient actual data is not available (i.e., 0, 1 or 2 recorded occurrences of a precursor), consideration should be given to the duty holder specific factors that may make the failure frequency higher or lower than the national average. If national average data is not available the workshop participants should be asked to estimate the likely frequency in terms of for example 1 in 10 years, 1 in 25 years etc.

j) The sum of the individual frequencies in column (m) gives the overall hazardous event frequency for the duty holder.

k) Include in column (n) all references to supporting data, assumptions, judgements and justifications for the frequency estimate assigned in column (m).

ALARP assessment

3.6 Having identified the existing control measures and attempted to quantify the failure frequency for each precursor over which the duty holder has direct or indirect control, the next step is to consider whether all reasonably practical measures are being taken to control the failure frequency. This is a key step in providing a demonstration that the risk is ALARP:

a) ALARP assessment – All potential additional controls which could be employed to further reduce the rate at which each precursor under the direct control (D) or partial control (I) of the duty holder occurs should be identified using structured expert judgement and brainstorming, see section B12.11 to B12.21 in the main text and Appendix F. Record all identified additional controls in column (o). The practicability of each should be considered outside the workshop once the risk assessment for each hazardous event has been completed.

b) ALARP assessment – The proposed strategy for dealing with each potential additional control identified [this will need to be done outside the workshop once the risk assessment for each hazardous event has been completed and summarised in column (p)], see section B12.11 to B12.21 in the main text and Appendix F.

3.7 Following the completion of Workshop 2, the actual duty holder data relating to any additional precursors identified should be investigated, assessed against the judgements of failure frequency made in the workshop and modified as appropriate.

3.8 An example precursor assessment relating to HET-12 ‘Passenger train derailment’ is presented in Appendix G. The table shows a few example entries to give an idea of the type of information to be recorded.

4 Proposed method of risk assessment – consequences assessment

Stage 3 – Consequences assessment

4.1 Consequences assessments for the hazardous events within the SRM are assessed using event tree analysis. While the event trees are relatively simple for the movement and non-movement accidents, the event trees for some of the train accidents are very complicated with many possible outcomes resulting from the occurrence of each hazardous event.
Appendix A continued

This level of complexity is required to give an understanding of the risk profile and enable the influence of the potentially high consequence outcomes (catastrophic risk) to be considered. However to simplify this process while maintaining an understanding of the influence of high consequence outcomes, for the purposes of this safety case risk assessment methodology, the consequences analyses within the SRM have been simplified for each hazardous event into the consideration of:

a) the most likely outcome in terms of passenger, staff and members of public equivalent fatalities

b) where applicable, a realistic worst case outcome, in terms of single or multiple fatalities - passengers, staff and members of public equivalent fatalities

c) the fatality related consequences for the exposed groups which should be considered within the assessment of individual risk.

Stage 3 – Consequences assessment - Preparation

4.2 The following steps are necessary to prepare for consequence assessment:

a) Obtain the pre-prepared list of the consequences for each of the relevant Railtrack controlled infrastructure related hazardous events from the RPB (Table A3 on the Guidance Note CD available from Railway Safety) and enter the corresponding hazardous event frequency estimates from precursor assessment tables. An example of a consequences assessment table is given in Appendix H.

b) Prepare consequences assessment tables for any additional hazardous events identified in stages 1 and 2 above.

c) Confirm which exposed groups will be considered as a part of the assessment of individual risk (this could be done as the first part of Workshop 3).

d) Using recent safety performance data, SMIS or other sources of data (see section B8 in the main text) identify any duty holder or other available related data related consequences applicable to each hazardous events and record the information in column (i) prior to the workshop.

Stage 3 – Consequences assessment – Workshop 3

4.3 This workshop is likely to take 1 to 3 days and should work systematically through each hazardous event to identify the likely consequences resulting from the occurrence of each hazardous event.

4.4 Complete the pre-prepared consequences assessment tables (Appendix H) for each hazardous event as follows:

a) Overall risk:

   i) review the outcome definitions in column (c) for applicability to the duty holder’s operation. If the hazardous event is not addressed in the RPB define a typical outcome and a realistic worst case outcome (if applicable) for the hazardous event

   ii) review the probability of each outcome. If the hazardous event is not addressed in the RPB, estimate from duty holder specific data or judgement within the workshop the probability of each outcome occurring eg 1 in 2, 1 in 10, 1 in 100 etc, for each occurrence of the hazardous event. Record the rationale, data references etc in
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...column (k). Note the sum of the probabilities assigned to the two outcomes should always equal 1

Appendix A continued

iii) for each outcome, consider in column (g) the existing control measures in place to control or to mitigate the consequences from the hazardous event. This should include a summary of the key control measures required by Railway Group Standards as well as any additional control measures applied by the duty holder. Information for this section can also be supplemented outside the workshop.

iv) identify in column (h) where each identified control measure is addressed within the RSC SMS (this could be done outside the workshop).

v) consider the consequences in terms of equivalent fatalities applicable to each outcome in relation to the national average figure quoted from the RPB in column (e). The duty holder specific factors should be considered in the context of the consequences being higher or lower than the national average. Guidance on the key factors and other factors to be considered is given on the table for each hazardous event. If the hazardous event is not considered within the RPB, use duty holder specific data or judgement within the workshop to estimate the consequences in equivalent fatalities for each outcome.

vi) enter the consequences assumed for the duty holder’s operation in column (j) and recorded the rationale, data sources, assumptions and judgements in column (k).

vii) overall risk for the outcome is calculated by column (b) x column (d) x column (l) which can then be summed to give the overall risk for the hazardous event.

As described in section B12 in the main text, to determine whether individual risk is in the intolerable, tolerable or broadly acceptable region, a duty holder should consider the individual risk associated with the groups of individuals most exposed to the duty holder’s operation. As individual risk relates only to the probability of fatality per year, it is necessary to consider the fatality related consequences for each exposed group separately. To indicate the process the following examples consider the assessment of passenger and train driver individual risk.

b) Passenger individual risk:

i) consider the consequences in terms of passenger fatalities only applicable to each outcome in relation to the national average figure quoted from the RPB in column (m). The duty holder specific factors should be considered in the context of the consequences being higher or lower than the national average. Guidance on the key factors and other factors to be considered is given on the table for each hazardous event. If the hazardous event is not considered within the RPB, use duty holder specific data or judgement within the workshop to estimate the consequences in passenger fatalities for each outcome. If in such cases it is considered that a fatality will not always occur for the given outcome, the appropriate fraction of a fatality should be entered. For example, if it is considered that only 1 in every 10 occurrences of the outcome will result in a passenger fatality then 0.1 fatalities should be entered in column (m). See discussion of individual risk consequences in Appendix D. Record the rationale, data references etc in column (p)
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ii) enter the consequences assumed for the duty holder’s operation in column (o) and recorded the rationale, data sources, assumptions and judgements made in column (p)

Appendix A continued

iii) overall risk for the outcome is calculated by column (b) x column (d) x column (o). The results for each outcome can then be summed to give the overall passenger fatality risk for the hazardous event

iv) summate the passenger fatality risk for all the hazardous events and calculate the passenger individual risk as described in section B12.2 – B12.10 in the main text.

c) Driver individual risk:

i) consider the consequences in terms of driver fatalities only applicable to each outcome in relation to the national average figure quoted from the RPB in column (r). The duty holder specific factors should be considered in the context of the consequences being higher or lower than the national average. Guidance on the key factors and other factors to be considered is given on the table for each hazardous event. If the hazardous event is not considered within the RPB, use duty holder specific data or judgement within the workshop to estimate the consequences in driver fatalities for each outcome. If in such cases it is considered that a fatality will not always occur for the given outcome, the appropriate fraction of a fatality should be entered. For example, if it is considered that only 1 in every 10 occurrences of the outcome will result in a driver fatality then 0.1 fatalities should be entered in column (r). Record the rationale, data references etc in column (u)

ii) enter the consequences assumed for the duty holder’s operation in column (t) and recorded the rationale, data sources, assumptions and judgements made in column (u)

iii) overall risk for the outcome is calculated by column (b) x column (d) x column (t). The results for each outcome can then be summed to give the driver fatality risk for the hazardous event

iv) summate the driver fatality risk for all the hazardous events and calculate the individual risk as described in section B12.2 – B12.10 in the main text.

4.6 An example of a consequences assessment relating to HET-12 ‘Passenger train derailment’ is presented in Appendix H. The table shows example entries to give an idea of the type of information to be recorded.

ALARP assessment

4.7 Having identified the existing control measures and attempted to quantify the consequences for each outcome, the next step is to consider whether all reasonably practicable measures are being taken to control/mitigate the consequences resulting from each outcome. This is a key step in providing a demonstration that risk is ALARP:

a) ALARP assessment – All potential additional controls which could be employed to further minimise the consequences associated with each outcome should be identified using structured expert judgement and brainstorming, see section B12.11 to B12.21 in the main text and Appendix F. Record all identified additional controls in column (w) of Appendix H. The practicability of each should be considered outside the workshop once the risk assessment for each hazardous event has been completed.
Appendix A continued

b) ALARP assessment – The proposed strategy for dealing with each potential additional control identified (this will need to be done outside the workshop once the risk assessment for each hazardous event has been completed and summarised in column (x)), see section B12.11 to B12.21 in the main text and Appendix F.

5 Proposed method of risk assessment – analysis of results

Stage 4 - Analysis of results

5.1 Once the workshop and the risk estimates for each hazardous event have been completed it will be possible to:

a) rank each hazardous event by overall risk and identify the most significant risk contributors in relation to the duty holder’s operation

b) calculate the individual fatality risk for the passengers and drivers and compare the results with the individual risk criteria quoted in section B9 in the main text

c) assess which additional control measures are (a) considered to be reasonably practicable identified, (b) needed to be assessed using cost-benefit analysis and (c) are clearly not reasonably practicable

d) calculate the risk contribution from individual precursors or groups of specific precursor types (individual precursor frequency (events/year) x average consequences (eq fatalities) per event for the hazardous event.

5.2 Once the initial risk results have been obtained it is essential to do some sanity checks on the results to make sure that they make sense, namely:

a) Do the results look believable in terms of overall risk, the hazardous events ranked by risk and the individual risk estimates?

b) Are they what you expected?

c) How do they compare with the national averages in the RPB?

d) Are the major risk contributors what you expected? If not, is there a rational explanation for the difference.

e) Are there any specific assumptions made within the risk assessment process, for which there is a high level of uncertainty, which have a potentially significant affect on the overall risk, hazardous events risk or the individual risk estimates. Sensitivity analyses could be used to check the influence of specific assumptions or uncertainties on the overall results, see section B13 in the main text.

5.3 Following such reviews it may be necessary to re-visit parts of the risk assessment to re-assess and refine certain inputs to the process. Any re-visit and subsequent changes would need to be structured and appropriately recorded, in a similar way to the initial risk assessment.

5.4 It is also recommended that the once the risk and ALARP assessments have been completed that the workshop is re-convened to review and accept the results.
5.5 The level of discussion of the results within the safety case document is given in section B14 of the main text.
Appendix B

Safety case risk assessment method based on a risk ranking approach

1 Introduction

1.1 Risk ranking methods have been used widely within the railway and other industries particularly in cases where there is little data associated with an operation on which to base a more numerical risk assessment method. When well defined and used appropriately, a risk ranking methodology is a valid approach to risk assessment.

1.2 It is proposed that risk ranking methods could be used for risk assessments (a) where the nature of the operation is not covered in detail by the SRM, (b) general workplace/task based risk assessments or (c) other risk assessments, not required to be reported in the RSCs, but required under the management of Health and Safety at Work regulations eg train operations in yards, depots and sidings.

1.3 In reviewing the risk ranking methods being used currently within the industry, two areas of concern have been identified:

a) The practice of multiplying the frequency and consequence rankings, which has become common in the railway industry, produces inconsistencies and inaccuracies in the results of the risk assessment.

b) No attempt is generally made to determine what the risk ranking numbers actually mean in the context of the individual risk criteria given in the HSE’s guidance on risk tolerability and the Railway Group Safety Plan.

1.4 This appendix contains a description of the nature of the problems and proposes a methodology for using a risk ranking approach to risk assessment more effectively in RSCs.

1.5 The risk assessment method described in this appendix is a proposed method that, if followed correctly, is likely to produce a risk assessment that is suitable and sufficient in the context of the assessment criteria given in the documents listed in section B4.3 in the main text. The proposed method is not mandatory. A duty holder can use other methods or adapt the proposed methods as required, providing the level of analysis and reporting provides a risk assessment to an equivalent standard.

1.6 When undertaking a risk assessment within an RSC it is important that use is made of any previous risk assessment studies that have been undertaken that can inform the process. Examples of such studies are:

a) Previous RSC or Contractors Assurance Case risk assessment studies.

b) The East Coast Main Line HAZOP study [11].

c) Risk assessments carried out in relation to the development or application of Railway Group Standards.

d) Hazard lists in the Yellow Book Issue 2 [12].

1.7 If a duty holder requires assistance in interpreting or applying the following risk assessment methodology please contact the Head of Risk Assessment at Railway Safety, see phone number in section A5.
Appendix B continued

2 Background to risk ranking methods

2.1 There are two main approaches to risk assessment using risk ranking methods, namely qualitative and semi-quantitative. The required method should be selected carefully to provide the degree of risk assessment required for the operations being considered.

2.2 It should be noted that risk ranking methods only give approximate estimates of the level of risk. The results from such assessments should never be judged as absolute. If the risk ranking process identifies:

a) hazardous events which have a significant potential for an outcome which leads to multiple fatalities

b) that the individual risk to one or more groups may be in the intolerable region, or

c) hazardous events which have a significant collective risk contribution and there is a significant degree of uncertainty in relation to the frequency and consequences rankings applied.

It may, in such cases, be necessary to undertake more detailed analysis using techniques such as fault tree and event tree analysis as described in Appendix E.

Qualitative ranking

2.3 Qualitative ranking schemes for frequency and consequence may be appropriate as a first pass at assessing risk or in simple cases, such as for task risk assessment. Generally, a qualitative approach would not be adequate in a risk assessment to support an RSC.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Rare – eg 1 in 50 years</td>
<td>A Negligible – eg slight injury no absence from work</td>
</tr>
<tr>
<td>B Infrequent – eg 1 in 10 years</td>
<td>B Low – eg requiring first aid treatment</td>
</tr>
<tr>
<td>C Occasional – eg 1 year</td>
<td>C Moderate – eg injury leading to lost time accident</td>
</tr>
<tr>
<td>D Frequent – eg 1/month</td>
<td>D High – eg single fatality</td>
</tr>
<tr>
<td>E Regular – eg 1/day</td>
<td>E Severe – eg multiple fatalities</td>
</tr>
</tbody>
</table>

Table 2.3 (App B): Example qualitative ranking scheme
Appendix B continued

2.4 In a qualitative ranking scheme the magnitude of the ranking has no real meaning, it merely provides a label for the category. The gaps between rankings can vary significantly. To assess the results in risk terms, the rankings should be plotted directly onto a risk matrix as follows.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>XX</td>
</tr>
<tr>
<td>D</td>
<td>XX</td>
<td>X X</td>
<td>XX</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>XX</td>
<td>X X</td>
<td>XX</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>B</td>
<td>XX</td>
<td>X X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>XX</td>
<td>X X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.4 (App B): Qualitative risk matrix

2.5 In the matrix, the Xs plot the frequency and consequence of each hazardous event assessed. A predominance of Xs to the bottom left of the matrix means lower risk and to the top right means higher risk. Attempting to define a risk measure using the product of the frequency and consequence rankings is not meaningful because while, for example, it can be said that in AA is lower risk than a BB, the level of difference cannot be quantified.

2.6 This method therefore gives a feel of the relative levels of risk for each hazardous event considered.

2.7 It is not possible to draw any conclusions about the tolerability of the risk from such a qualitative approach (ie to determine whether individual risk of fatality meets the guidelines proposed by the HSE).

2.8 It is, however, possible to provide guidance on how to judge the results of such qualitative assessments by drawing boundaries on the risk ranking matrix, as shown in the table below, to classify the levels of risk as High (H), Medium (M) and Low (L). This may be an appropriate approach for some task based risk assessments. It would then be possible to define actions for each category of risk, eg high risk contributors should be addressed before the task is undertaken.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>D</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>C</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>B</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>A</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M</td>
</tr>
</tbody>
</table>

Table 2.8 (App B): Qualitative risk categories
Guidance on the Preparation of Risk Assessments within Railway Safety Cases

Appendix B continued

2.9 It should be noted that this approach does not encompass risk aversion to catastrophic, multiple fatality events. Such qualitative risk assessments would not be deemed to be suitable and sufficient for events which could lead to fatalities.

Semi-quantitative ranking approach

2.10 For the cases where data is available or a good degree of judgement can be applied to estimates of the frequency and consequences of each hazardous event, a greater level of accuracy and consistency in the risk estimates can be obtained by using a semi-quantitative risk ranking approach. It should be noted that while traditionally risk ranking methodologies have been based on a 5 x 5 matrix approach with the frequency and consequence rankings broadly separated by a factor of 10, this does not have to be the case. The size of the matrix and the factor difference in frequency and consequence rankings can be altered to give the best ranges to suit a particular duty holder’s operation. Consider the following example of frequency and consequence rankings.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Description</th>
<th>Frequency range</th>
<th>Mid-point estimated frequency</th>
<th>Approximate numerical value events/year</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote</td>
<td>&lt; 1 in 175 years</td>
<td>1 in 500 yrs</td>
<td>0.002</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Rare</td>
<td>1 in 35 years to 1 in 175 years</td>
<td>1 in 100 yrs</td>
<td>0.01</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Infrequent</td>
<td>1 in 7 years to 1 in 35 years</td>
<td>1 in 20 yrs</td>
<td>0.05</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Occasional</td>
<td>1 in 1 ¼ years to 1 in 7 years</td>
<td>1 in 4 yrs</td>
<td>0.25</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Frequent</td>
<td>1 in 3 months to 1 in 1 ¼ years</td>
<td>1 in 9 mths</td>
<td>1.25</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Regular</td>
<td>1 in 20 days to 1 in 3 months</td>
<td>1 in 2 mths</td>
<td>6.25</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Common</td>
<td>1 in 4 days to 1 in 20 days</td>
<td>1 in 12 days</td>
<td>31.25</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.10 a) (App B): Example frequency ranking scheme
Guidance on the Preparation of Risk Assessments within Railway Safety Cases

Appendix B continued

<table>
<thead>
<tr>
<th>Description</th>
<th>Approx. numerical value equivalent fatalities/event</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor injury</td>
<td>0.005</td>
<td>1</td>
</tr>
<tr>
<td>More serious injury/multiple minor injuries</td>
<td>0.025</td>
<td>2</td>
</tr>
<tr>
<td>Major injury</td>
<td>0.125</td>
<td>3</td>
</tr>
<tr>
<td>Multiple major/single fatality</td>
<td>0.625</td>
<td>4</td>
</tr>
<tr>
<td>Multiple fatalities (2 to 5 eq. fatalities)</td>
<td>3.125</td>
<td>5</td>
</tr>
<tr>
<td>Multiple fatalities (6 to 25 eq. fatalities)</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Multiple fatalities (&gt; 25 eq. fatalities)</td>
<td>75</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 2.10 b) (App B): Example of consequence ranking scheme

2.11 In this example each category is a factor of five different from its adjacent categories. The categories can be separated any factor e.g. a factor of two, five, ten or one hundred providing both the frequency and consequence estimates (as represented by the changes in their corresponding ranking numbers) are separated by the same factor.

2.12 To use the above frequency and consequence ranking scheme as a risk ranking matrix it has become common practice in the railway industry to represent the risk by multiplying the frequency and consequence ranking numbers to give an overall risk ranking. However, as demonstrated in Appendix C, the multiplication of the frequency and consequence rankings can lead to inaccuracies and inconsistencies within the final risk rankings, and it is therefore proposed that when using such risk ranking methods the frequency and consequence rankings are added not multiplied to give an overall risk ranking.

2.13 It is very important to note however, that adding the frequency and consequence rankings only works if the changes in both the frequency and consequence estimates (as represented by the changes in their corresponding ranking numbers) are separated by the same factor.

2.14 This solution works for any factor difference (two, five, ten, one hundred, etc) providing both the frequency and consequence ranking estimates are separated by the same factor.

2.15 The risk ranking matrix therefore becomes Table 2.15 (App B): Risk ranking matrix (below).
Appendix B continued

<table>
<thead>
<tr>
<th>Frequency</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 2.15 (App B): Risk ranking matrix

Events with the potential for significantly different outcomes

2.16 When assigning frequency and consequence rankings to hazardous events the rankings are based normally on the average frequency of occurrence and the average consequences for the event. For some hazardous events, however, different outcomes can lead to significantly different consequences. For example, a train derailment would typically only lead to minor injuries, due perhaps to passengers falling over inside the train, whereas in extreme cases, derailments can lead to multiple fatalities. It is recommended that in such cases, to get a better understanding of the risk profile, particularly in relation to potential multi-fatality outcomes, two separate rankings should be considered for the hazardous event as follows:

a) the first ranking should relate to the frequency and consequences of the typical (most frequent outcome), and

b) the second risk ranking should relate to the frequency and consequences of the realistic worst case outcome, if appropriate.

2.17 This is shown diagrammatically in Figure 2.18 (App B) below based on the example frequency and consequence ranking scheme from Tables B2.10a)-b).

2.18 It should be noted that the risk ranking in (b) above should relate to a realistic worst case outcome rather than necessarily the absolute worst case outcome.
## Appendix B continued

<table>
<thead>
<tr>
<th>Frequency of event</th>
<th>Actual Frequency</th>
<th>Consequences</th>
<th>Frequency Ranking</th>
<th>Consequence Ranking</th>
<th>Risk Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g. 5 events/year</td>
<td>4.95 events/year</td>
<td>Typical outcome e.g. minor injury</td>
<td>6 + 1 = 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g. 0.05 events/year</td>
<td>0.05 events/year</td>
<td>Realistic high consequence outcome e.g. multiple fatality (2 to 5 fatalities)</td>
<td>3 + 5 = 8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Figure 2.18 (App B): Risk ranking for events with the potential for significantly different outcomes

### 3 Risk assessment procedure – hazardous event identification

3.1 A proposed method for risk assessment based on the use of semi-quantitative risk ranking is shown diagrammatically in Figure 3.1 (Appendix B) and described in the sections below.
Guidance on the Preparation of Risk Assessments within Railway Safety Cases

Stage 1. Hazardous event identification

App B 3.2 to 3.10

Identify hazardous events - include all events relevant to operation

Has correct risk assessment method been selected?

No

Reconsider methodology to be used

Yes

Review hazardous events and type of operation to identify the most exposed groups to be assessed for individual risk

Identify precursors (cause) for each hazardous event

Identify existing control measures for each precursor (cause)

Assess hazardous event frequency rankings and precursor (cause) contributions

Brainstorm potential additional control measures for each precursor (cause)

Assess consequence rankings for assessment of collective risk - typical & realistic worst case outcomes

Assess consequences rankings for assessment of individual risk for each exposed group - typical & realistic worst case outcomes

Brainstorm potential additional control measures for each precursor (consequence) and consequence outcome

Derive risk rankings - collective & individual (each exposed group)

Carry out sanity check/sensitivity analysis

Do the results make sense?

No

Review methodology, assumptions and input data

Yes

Is individual risk for each exposed group tolerable?

Yes

Determine if the identified additional control measures are reasonably practicable

No

Is collective risk as low as reasonably practicable?

Yes

Document results in RSC including commitment to implement the additional control measures identified

No

Inform with information from Risk Profile Bulletin, previous RSC assessments & other relevant studies

See B12.1 to B12.10 & Appendix D

See B12.11 to B12.21 & Appendix F

Figure 3.1 (App B): Semi-quantitative risk ranking methodology

Stage 2. Precursor assessment

App A 4.1 to 4.4

Stage 3. Consequences assessment

App A 5.1 to 5.6

Stage 4. Analysis of results

App A 6.1 to 7.3

Inform with information from Risk Profile Bulletin, previous RSC assessments & other relevant studies

Use actual data where possible

Inform with information from Risk Profile Bulletin, previous RSC assessments, actual data & other relevant studies

Note: Separate individual risk matrices will be required for each exposed group, see Appendix D

See Appendix D for individual risk

See B12.2 to B12.10 & Appendix D

See B13.1 to B13.3 & Appendix D

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Appendix B continued

Stage 1 – Hazardous event identification

3.2 As with any risk assessment the first stage of the process is associated with the identification of the hazardous events applicable to the duty holder’s operation that form the basis of the risk assessment.

3.3 The purpose of the hazardous event identification process is to establish a comprehensive list of the hazardous events taking full account of the factors specific to the duty holder’s operations.

3.4 As noted in section B7 in the main text, one of the main objectives of an RSC risk assessment is to help ensure that company managers and staff identify and understand all the foreseeable hazardous events, causes, control measures and consequences that can influence their operation. It is therefore recommended that the hazardous event identification process and data gathering is undertaken using a structured workshop approach involving a range of company staff.

3.5 The workshop should therefore aim to involve individuals covering the broad range of skills and experience within the duty holder’s operation. This could include:

a) meeting chairman (preferably experienced in managing risk assessment workshops)
b) secretary (to record the details of the discussion)
c) safety manager
d) operations staff representatives
e) maintenance staff representatives
f) representatives from other companies who interface with the duty holder, if appropriate
g) operations manager
h) engineering manager.

The competency of the participants and the way the workshop is conducted are key to the success of the process. An incorrect or limited range of competencies or a poor workshop procedure could lead to an invalid process.

3.6 Twelve individuals is probably the maximum sensible attendance number within such a workshop.

3.7 The chairman should where possible be taken from within the company staff. However, the workshops could be facilitated by an external consultancy but the overall risk assessment should be owned, managed and understood by the duty holder.

3.8 The secretary’s role is critical in the workshop process to record the assumptions, rationale and justifications behind each decision and judgement made by the workshop members. It is essential to record this information to enable:

a) a reviewer to understand the background to the risk assessment
b) provide a demonstration that the risk assessment is robust
c) anybody needing to change or update the risk assessment in the future to understand where the assumptions, data and results have come from.
Appendix B continued

Stage 1 – Hazardous event identification – Preparation

3.9 The following steps are necessary to prepare for hazardous event identification:

a) Identify the group or groups or people who could be exposed to the duty holder’s operations and consider the most exposed group(s) to be assessed in relation to individual risk.

b) Identify typical activities or journeys through the system which are representative of the duty holder’s operations for consideration within the workshop eg:
   
i) travelling to and from a worksite
   
ii) setting up and leaving a worksite
   
iii) work activities within a worksite for different groups of workers and different types of work activities
   
iv) movements within a worksite.

Stage 1 – Hazardous event identification – Workshop 1

3.10 It is proposed that the initial workshop would, depending on the size of the operation being considered, be an initial 1 to 2 day workshop for the purposes of introducing the participants to the risk assessment process and identification of the hazardous events that will form the core of the risk assessment. The workshop could include:

a) Introduction to the risk assessment and workshop processes.

b) Review the most exposed groups to be considered for the assessment of individual risk (see B12.2 in the main text) and review the list typical activities/journeys developed in the preparation stage in 3.9 and confirm that the lists are complete. Add or remove exposed groups and typical activities/journeys as appropriate.

c) For each activity or journey stage, consideration should be given to the hazardous events that have the potential to lead directly to death or injury to the exposed group(s). The list of the Railtrack controlled infrastructure related hazardous events from the RPB [8] or previous safety case hazard identification studies (see paragraph 1.6 above) could, in some cases, provide an input into this process.

d) For each type of operation or journey the workshop team should be asked to consider if additional hazardous events could occur as a result of:
   
i) normal operations
   
ii) perturbed running
   
iii) degraded or abnormal operations
   
iv) day or night
   
v) extreme weather
   
vi) disabled people or other vulnerable groups
   
vii) overcrowding on stations or in trains
   
viii) criminal activity
Guidance on the Preparation of Risk Assessments within Railway Safety Cases

ix) other conditions specific to the duty holder’s operations.

Appendix B continued

e) As a part of the hazardous event identification process, consideration should be given to all the routes/locations used by the duty holder, to determine if there are any potentially high risk locations (e.g., tunnels, long bridges and below ground stations) for which additional controls are required. Even if the risk at these locations is not quantified, the safety case risk assessment should demonstrate that the duty holder is aware of such locations, that there are controls in place to minimise the occurrence of incidents and deal with incidents, and that the interface issues with other companies have been addressed adequately.

g) Confirm that the most appropriate risk assessment methodology has been selected for the operations being considered, see B8.3 to B8.5 in the main text.

4 Risk assessment procedure - precursor assessment

Stage 2 - Precursor assessment - Preparation

4.1 Having identified the hazardous events using the structured identification process above, it will be necessary to identify all the precursors that could singly, or in combination with other precursors, cause each hazardous event to occur. The information from the SRM contained within the RPB or previous studies may assist in this process for some of the hazardous events. Preparation of known information prior to the workshop will help speed up the precursor and hazardous event frequency assessment process:

a) From the output from Workshop 1, prepare a rationalised list of all hazardous events applicable to the duty holder’s operation and assign a hazardous event number. It is recommended that for clarity the hazardous events are grouped as train, movement and non-movement accidents.

b) Prepare a precursor assessment table (see format in Appendix I) for each hazardous event.

c) Using recent safety performance data, SMIS or other sources of data (see section B10 in the main text) identify any known duty holder or other available related data applicable to each hazardous event.

Stage 2 - Precursor assessment - Workshop 2

4.2 This workshop should work systematically through each hazardous event to identify all the precursors. It should be noted that, when considering the individual risk to any exposed group the total risk exposure due to the occurrence of all precursors should be considered for comparison with the individual risk criteria not just risk resulting from the precursors controlled directly or indirectly by the duty holder. The duration of the workshop will depend on the number of hazardous events identified in Stage 1.

4.3 Complete the pre-prepared precursor assessment tables (Appendix I) for each hazardous event as follows:

a) The workshop participants should be asked to consider the precursors or combinations of precursors that could cause each hazardous event to occur. This should include all the precursors not just those under the direct control of the duty holder. The lists of cause precursors in Appendix B of the RPB (see Table A2 on the Guidance Note CD available from Railway Safety) and any previous risk assessment studies may provide an input into this process for some of the hazardous events. Enter the cause precursor category eg
track, rolling stock, etc, a precursor code or number and a precursor description in columns (a), (b) and (c) respectively.
Appendix B continued

When considering the precursors associated with each hazardous event, the workshop participants should consider:

i) all foreseeable failure modes which could lead to the occurrence of the hazardous event

ii) any human factors issues relating to the operation

iii) local factors such as site specific features or areas particularly prone to vandalism, etc.

b) Identify in column (d) whether each cause precursor is under the direct control of the duty holder (D), is an interface issue (shared responsibility between the duty holder and another company) (I) or the duty holder has no control over the precursor (N). Where the precursor is an interface issue (I) or the duty holder has no control over the precursor (N) the other company or companies responsible for the precursor control measures should be identified in column (e).

c) For each precursor under the direct (D) or indirect (I) control of the duty holder, list in column (f) the existing control measures in place to control the frequency at which the precursor occurs. This should include a summary of the key control measures required by Railway Group Standards as well as any additional control measures applied by the duty holder.

d) Identify in column (g) where each identified control measure is addressed within the RSC SMS (this could be done outside the workshop).

e) Enter any information relating to duty holder’s actual data for each precursor or the hazardous event generally in column (h).

f) Hazardous event frequency – Based on the duty holder’s actual data, the national data (if available), any known duty holder specific factors and/or judgements, including the perceived effectiveness of the existing control measures, and with reference to the predefined frequency ranking table, consider the overall frequency ranking (estimated number of events/year) for the hazardous event. The overall frequency ranking should be entered at the bottom of column (i). All references to supporting data, assumptions, judgements and justifications for the frequency ranking selected should be recorded in column (j).

g) For the precursors which are under the direct (D) or indirect (I) control of the duty holder, the participants should then be asked to consider the percentage of the overall frequency that is likely to be applicable to each of the precursors. This assessment will give a measure of the overall frequency of each hazardous event that is under the direct or indirect control of the duty holder. Enter the agreed percentage in column (i).

h) Include in column (j) all references to supporting data, assumptions, judgements and justifications for the percentage of overall frequency estimated in column (i).

Stage 2 – Precursor assessment - ALARP assessment

4.4 Having identified the existing control measures and attempted to quantify the failure frequency for each precursor over which the duty holder has direct or indirect control, the next step is to consider whether all reasonably practical measures are being taken to control the failure frequency. This is a key step in providing a demonstration that risk is ALARP:
Appendix B continued

a) ALARP assessment – All potential additional controls which could be employed to further reduce the rate at which each precursor under the direct control (D) or partial control (I) of the duty holder occurs should be identified using structured expert judgement and brainstorming, see section B12.11 to B12.21 in the main text and Appendix F. Record all identified additional controls in column (k). The practicability of each should be considered outside the workshop once the risk assessment for each hazardous event has been completed.

b) ALARP assessment – Record proposed strategy for dealing with each potential additional control identified (this can be done outside the workshop and summarised in column (l)), see section B12.11 to B12.21 in the main text and Appendix F.

5 Risk assessment procedure – consequences assessment

Stage 3 – Consequences assessment.

5.1 When assigning consequence rankings to hazardous events the rankings are based normally on the average consequences for the event. For some hazardous events, however, different outcomes can lead to significantly different consequences. For example, a train derailment would typically only lead to minor injuries, due perhaps to passengers falling over inside the train, whereas in extreme cases, derailments can lead to multiple fatalities. It is recommended that in such cases, to get a better understanding of the risk profile, particularly in relation to potential multi-fatality outcomes, two separate rankings should be considered for the hazardous event as follows:

a) The most likely outcome – passengers, staff and members of public equivalent fatalities.

b) If applicable, a realistic worst case outcome, in terms of single or multiple fatalities - passengers, staff and members of public equivalent fatalities.

5.2 To recognise the fact that the individual risk criteria applies to specific exposed groups of individuals it is necessary to also consider the fatality related consequences for the exposed groups for both outcomes defined above.

Stage 3 – Consequences assessment – Preparation

5.3 The following steps are necessary to prepare for consequences assessment:

a) For each hazardous event, enter the hazardous event and the corresponding hazardous event frequency (mid-point frequency estimate for the assigned frequency ranking) from the precursor assessment tables (Appendix I) into columns (a) and (b) of the consequences assessment tables, using the format given in Appendix J.

b) Identify the most exposed group(s) to be considered as a part of the assessment of individual risk (this could be done as the first part of Workshop 3).

Stage 3 – Consequences assessment – Workshop 3

5.4 This workshop should work systematically through each hazardous event to identify the likely consequences resulting from the occurrence of each hazardous event. The duration of the workshop will depend on the number of hazardous events identified in Stage 1.
Appendix B continued

5.5 Complete the consequences assessment tables (Appendix J) for each hazardous event as follows:

a) Overall risk:

i) for each hazardous event consider the most likely outcome and a realistic worst case outcome (if applicable) for the hazardous event. The use of two different outcomes should only be considered where there is a clearly recognisable outcome that differs significantly in terms of the frequency and consequences when compared to the most likely outcome. Enter the definition of each outcome in column (c)

ii) estimate from duty holder specific data or judgement within the workshop the probability of each outcome occurring eg 1 in 2, 1 in 10, 1 in 100 etc, for each occurrence of the hazardous event and enter the assigned probability into column (d). Record the rationale, data references etc for the probability estimate in column (e). Note the sum of the probabilities assigned to the two outcomes should always equal 1

iii) using the overall hazardous event frequency in column (b), the outcome probabilities assigned in column (d) and the predefined frequency ranking table, assess the frequency ranking applicable to each outcome. Enter the frequency rankings in column (f)

iv) for each outcome, consider in column (g) the existing control measures in place to control or mitigate the consequences from the hazardous event. This should include a summary of the key control measures required by Railway Group Standards as well as any additional control measures applied by the duty holder. Information for this section can also be supplemented outside the workshop

v) identify in column (h) where each identified control measure is addressed within the RSC Safety Management System (this could be done outside the workshop)

vi) use duty holder specific data or judgement within the workshop to estimate and record the consequences ranking for each outcome in column (i). Record the rationale, data references etc in column (j)

vii) Overall risk ranking for the outcome (column (k)) is calculated by adding the frequency ranking in column (f) and the consequence ranking in column (i).

b) Individual risk for exposed groups:

As described in sections B12.2 to B12.10 in the main text and Appendix D, to determine whether individual risk is in the intolerable, tolerable or broadly acceptable region, a duty holder should consider the individual risk associated with the groups of individuals most exposed to the duty holder’s operation. As individual risk relates only to the probability of fatality per year, it is necessary to consider the fatality related consequences for each exposed group separately. To indicate the process the following example considers the assessment of individual risk for an exposed group:

i) use duty holder specific data or judgement within the workshop to estimate the consequences in terms of the exposed group only for each outcome. If in such cases it is considered that a fatality will not always occur for the given outcome, the appropriate fraction of a fatality should be considered for the consequence ranking, see Appendix D. The consequence ranking should be entered in column (l). Record the rationale, data references etc in column (m)
Appendix B continued

ii) overall risk ranking for the outcome (column (n)) is calculated by adding the frequency ranking in column (f) and the consequence ranking in column (l)

iii) complete the process for other identified exposed groups where necessary.

Stage 3 – Consequences assessment - ALARP assessment

5.6 Having identified the existing control measures and attempted to quantify the consequences for each outcome, the next step is to consider whether all reasonably practical measures are being taken to control/mitigate the consequences resulting from each outcome. This is a key step in providing a demonstration that the risk is ALARP:

a) ALARP assessment – All potential additional controls which could be employed to further minimise the consequences associated with each outcome should be identified using structured expert judgement and brainstorming, see section B12.11 to B12.21 in the main text and Appendix F. Record all identified additional controls in column (r). The practicability of each should be considered outside the workshop once the risk assessment for each hazardous event has been completed.

b) ALARP assessment – The proposed strategy for dealing with each potential additional control identified in column (L) (this will need to be done outside the workshop once the risk assessment for each hazardous event has been completed and summarised in column (s)), see section B12.11 to B12.21 in the main text and Appendix F.

6 Risk assessment procedure – analysis of results

Stage 4 - Analysis of results

6.1 Once the workshop and the risk estimates for each hazardous event have been completed it will be possible to:

a) Rank each hazardous event by overall risk and identify the most significant risk contributors in relation to the duty holder’s operation.

b) Assess what the risk ranking results actually mean for the exposed group(s) in the context of the individual risk criteria for intolerable, tolerable and broadly acceptable regions of risk derived from HSE’s guidance on risk tolerability, see Appendix D.

c) Assess which additional control measures are (a) considered to be reasonably practicable identified, (b) needed to be assessed using cost-benefit analysis and (c) are clearly not reasonably practicable.

d) Assess which individual precursors or groups of specific precursor are likely to provide the highest risk contribution for the duty holder’s operation.

6.2 Once the initial risk results have been obtained it is essential to do some sanity checks on the results to make sure that they make sense, namely:

a) Do the results look believable in terms of overall risk, the hazardous events ranked by risk and the individual risk rankings?

b) Are the results what you expected?

c) How do they compare with the national averages in the RPB?
Appendix B continued

d) Are the major risk contributors what you expected? If not, is there a rational explanation for the difference.

e) Are there any specific assumptions made within the risk assessment process, for which there is a high level of uncertainty, and which have a potentially significant affect on the overall risk, hazardous events risk or the individual risk estimates.

6.3 Following such reviews it may be necessary to re-visit parts of the risk assessment to re-assess and refine certain inputs to the process. Any re-visit and subsequent changes would need to be structured and appropriately recorded, in a similar way to the initial risk assessment.

If the risk ranking process identifies:

a) hazardous events which have a significant potential for an outcome which leads to multiple fatalities

b) that the individual risk to one or more groups may be in the intolerable region, or

c) hazardous events which have a significant collective risk contribution and there is a significant degree of uncertainty in relation to the frequency and consequences rankings applied.

It may, in such cases, be necessary to undertake more detailed analysis using techniques such as fault tree and event tree analysis as described in Appendix E.

6.4 It is also recommended that the once the risk and ALARP assessments have been completed that the workshop is re-convened to review and accept the results.

6.5 The level of discussion of the results within the safety case document is given in section B14 of the main text.

7 Risk assessment procedure – conclusions based on risk ranking

Drawing conclusions from risk assessments based on risk ranking

7.1 As the use of a risk ranking method is not a detailed quantified risk assessment methodology, potential inaccuracies will always exist. However, the use of the risk ranking and assessment methodologies proposed above, will enable the results of the risk assessment to be produced in a consistent way which can be put into context. If the results of the risk assessment indicate that a number of individual hazardous events are above the broadly acceptable or intolerable limits, the risk assessment can then be examined in more detail to see if the findings are reasonable. If they are, further controls will be needed for those events that fall into the intolerable region and are likely to be needed for those events that fall into the tolerable region.

7.2 It should be emphasised that the individual risk criteria relate to the total individual risk (the sum of the individual risk for all hazardous events) and not the individual risk estimated for each separate hazardous event. The risk ranking process only considers the risk associated with each separate hazardous event and therefore, to give confidence that the overall risk is ALARP, there is a requirement to carry out an ALARP assessment for all hazardous events identified within the risk assessment regardless of the assessed risk ranking. However, the amount of effort that would need to be put into demonstrating ALARP for the hazardous events with low risk contributions would be less than for hazardous events with the more significant risk contributions.
7.3 It should be noted that for a risk assessment to be successful based on a risk ranking approach:

a) The frequency and severity rankings should be defined carefully.

b) The frequency and severity rankings should be added and not multiplied as has become common practice within the railway industry. For this method to be accurate the changes in both the frequency and severity estimates (as represented by the changes in their corresponding ranking numbers) should be separated by the same factor eg a factor of two, five, ten or one hundred.

c) A matrix does not have to be a 5 x 5 matrix. Providing the same factor difference is maintained between the rankings, a matrix can be expanded or reduced as necessary to encompass the range of event frequencies and consequences experienced by the operation being assessed.

d) To judge the tolerability of the results of the risk ranking process, the risk ranking numbers should be aligned with the defined individual risk criteria.

e) The rationale behind each frequency and consequence ranking used in the risk assessment should be recorded within the risk assessment documentation.

f) An ALARP assessment should be carried out for all hazards identified within the risk assessment regardless of the assessed risk ranking.

g) If the risk ranking process identifies:

i) hazardous events which have a significant potential for an outcome which leads to multiple fatalities

ii) that the individual risk to one or more groups may be in the intolerable region, or

iii) hazardous events which have a significant collective risk contribution and there is a significant degree of uncertainty in relation to the frequency and consequences rankings applied.

It may, in such cases, be necessary to undertake more detailed analysis using techniques such as fault tree and event tree analysis as described in Appendix E.
Appendix C

Rationale behind the addition of frequency and consequence rankings to give a risk ranking

1. Frequency and consequence rankings

1.1 When using risk ranking methodologies for risk assessments it has become common within the railway industry for the frequency and consequence rankings to be multiplied together to give a risk ranking. However, it is considered that the multiplication of the rankings produces inconsistencies and inaccuracies in the results of the risk assessment.

1.2 The level of inconsistency and inaccuracies can be demonstrated by considering the following 5 x 5 risk ranking scheme.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Description</th>
<th>Frequency range</th>
<th>Mid-point estimated frequency</th>
<th>Approx. numerical value events/year</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rare</td>
<td>1 in 7 years to 1 in 35 years</td>
<td>1 in 20 yrs</td>
<td>0.05</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Infrequent</td>
<td>1 in 1 ¼ years to 1 in 7 years</td>
<td>1 in 4 yrs</td>
<td>0.25</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Occasional</td>
<td>1 in 3 months to 1 in 1 ¼ years</td>
<td>1 in 9 mths</td>
<td>1.25</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Frequent</td>
<td>1 in 20 days to 1 in 3 months</td>
<td>1 in 2 mths</td>
<td>6.25</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Regular</td>
<td>1 in 4 days to 1 in 20 days</td>
<td>1 in 12 days</td>
<td>31.25</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Table 1.2a) (App C)

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Description</th>
<th>Approx. numerical value equivalent fatalities/event</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor injury</td>
<td>0.005</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>More serious injury/multiple minor injuries</td>
<td>0.025</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Major injury</td>
<td>0.125</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Multiple major/single fatality</td>
<td>0.625</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Multiple fatalities (2 to 5 eq fatalities)</td>
<td>3.125</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Table 1.2b) (App C)
Appendix C continued

1.3 Plotting the frequency and consequence estimates onto a 5 x 5 matrix and calculating the risk (frequency x consequence) in equivalent fatalities/year for each point on the matrix gives the following quantified matrix, eg the risk associated with an event with a frequency of 1.25 events/year and a consequence of 0.125 eq fats/events gives a risk estimate of $1.25 \times 0.125 = 0.16$ (1.6E-01) eq fats/year.

<table>
<thead>
<tr>
<th>Consequence Equivalent fatalities/event</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Once in No./year</td>
<td>0.005</td>
<td>0.025</td>
<td>0.125</td>
<td>0.625</td>
<td>3.125</td>
</tr>
<tr>
<td>5 12 days</td>
<td>31.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 2 months</td>
<td>6.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 9 months</td>
<td>1.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 4 years</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 20 years</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.3 (App C): Quantified 5 x 5 matrix

1.4 Because each frequency and consequence ranking is separated by a consistent factor (in this case five) it can be seen that lines of constant risk (top left to bottom right) are present in the matrix.

1.5 Now consider the effect of multiplying the above frequency and consequence rankings to form the overall risk ranking matrix in Table 1.5 (App C).

<table>
<thead>
<tr>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>5 5 10 15 20 25</td>
</tr>
<tr>
<td>4 4 8 12 16 20</td>
</tr>
<tr>
<td>3 3 6 9 12 15</td>
</tr>
<tr>
<td>2 2 4 6 8 10</td>
</tr>
<tr>
<td>1 1 2 3 4 5</td>
</tr>
</tbody>
</table>

Table 1.5 (App C): Frequency and consequence rankings multiplied
Appendix C continued

1.6 Comparison of the risk rankings in Table 1.5 (App C) with quantified risk estimates in Table 1.3 (App C) shows clearly the inaccuracies associated with multiplying the frequency and consequence rankings. For a line of constant risk of 1.6E-01 equivalent fatalities/year in Table 1.3 (App C), the corresponding risk ranking in Table 1.5 (App C) ranges from 5 to 9 for the same risk. One would logically expect a risk ranking of 9 to be worse than a risk ranking of 5 such that priority would be given to addressing the higher risk ranking. This would be wrong because they actually represent the same level of risk.

Proposed solution

1.7 A way of resolving this inaccuracy is to add the frequency and consequence rankings as follows:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 1.7 (App C): Frequency and consequence rankings added

1.8 Comparison of Table 1.7 (App C) with Table 1.3 (App C) shows that lines of equal risk ranking are now associated with lines of constant risk, with the frequency and consequence ranking separated by the same factor.

1.9 This can be shown to be mathematically correct as follows:

Given that each ranking is separated by a factor of 5, the approximate value of each frequency and consequence ranking = 5^R x C

Where R = the ranking and C = a constant
Appendix C continued

1.10 The frequency and consequence ranking scheme above, can therefore be represented as follows:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Approx. Value no./year</th>
<th>( 5^x \times C )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>12 days</td>
<td>31.25</td>
</tr>
<tr>
<td>4</td>
<td>2 months</td>
<td>6.25</td>
</tr>
<tr>
<td>3</td>
<td>9 months</td>
<td>1.25</td>
</tr>
<tr>
<td>2</td>
<td>4 years</td>
<td>0.25</td>
</tr>
<tr>
<td>1</td>
<td>20 years</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 1.10 a) (App C)

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Approx. Value Eq. fats/event</th>
<th>( 5^x \times C )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3.125</td>
<td>( 5^5 \times 0.001 )</td>
</tr>
<tr>
<td>4</td>
<td>0.625</td>
<td>( 5^4 \times 0.001 )</td>
</tr>
<tr>
<td>3</td>
<td>0.125</td>
<td>( 5^3 \times 0.001 )</td>
</tr>
<tr>
<td>2</td>
<td>0.025</td>
<td>( 5^2 \times 0.001 )</td>
</tr>
<tr>
<td>1</td>
<td>0.005</td>
<td>( 5^1 \times 0.001 )</td>
</tr>
</tbody>
</table>

Table 1.10 b) (App C)

As numerically \( \text{Risk} = \text{Frequency} \times \text{Consequence} \), a risk of 0.16 eq. fats/yr on the matrix in Table 1.3 (App C) = \( (5^4 \times 0.01) \times (5^2 \times 0.001) \), and

\[
given\ y^x \times y^z = y^{x+z}
\]

a risk of \( 0.16 = 5^{(4+2)} \times 0.00001 = 5^6 \times 0.00001 \)
Appendix C continued

1.11 This risk matrix in Table 1.3 (App C) then becomes:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Once in</td>
<td>0.005</td>
<td>0.025</td>
<td>0.125</td>
<td>0.625</td>
<td>3.125</td>
</tr>
<tr>
<td>5 x C</td>
<td>5^1 x 0.001</td>
<td>5^2 x 0.001</td>
<td>5^3 x 0.001</td>
<td>5^4 x 0.001</td>
<td>5^5 x 0.001</td>
</tr>
</tbody>
</table>

| 5 | 12 days | 31.25 | 5^1 x 0.01 | 5^2 x 0.00001 | 5^3 x 0.000001 | 5^4 x 0.00000001 | 5^5 x 0.0000000001 |
| 4 | 2 months | 6.25  | 5^1 x 0.01  | 5^2 x 0.00001  | 5^3 x 0.000001  | 5^4 x 0.00000001  | 5^5 x 0.0000000001  |
| 3 | 9 months | 1.25  | 5^1 x 0.01  | 5^2 x 0.00001  | 5^3 x 0.000001  | 5^4 x 0.00000001  | 5^5 x 0.0000000001  |
| 2 | 4 years  | 0.25  | 5^1 x 0.01  | 5^2 x 0.00001  | 5^3 x 0.000001  | 5^4 x 0.00000001  | 5^5 x 0.0000000001  |
| 1 | 20 years | 0.05  | 5^1 x 0.01  | 5^2 x 0.00001  | 5^3 x 0.000001  | 5^4 x 0.00000001  | 5^5 x 0.0000000001  |

Table 1.11 (App C)

1.12 Each risk ranking can therefore be seen to be directly proportional to the frequency ranking + the consequence ranking.

1.13 It is very important to note however, that adding the frequency and consequence rankings only works if the changes in both the frequency and consequence estimates (as represented by the changes in their corresponding ranking numbers) are separated by the same factor.

1.14 This solution works for any factor difference (two, five, ten, one hundred, etc) providing both the frequency and consequence ranking estimates are separated by the same factor.
Appendix D

Methodology for assessing the results from a risk ranking matrix in relation to individual risk

1 Individual risk for passengers

1.1 Having carried out a risk assessment based on a matrix approach it is necessary to understand what the risk ranking results actually mean in the context of the criteria for intolerable, tolerable and broadly acceptable regions of risk derived from HSE’s guidance on risk tolerability. The criteria for individual passenger risk in terms of the probability of fatality per year are as stated in Table B12.3 in the main text as follows:

a) Is intolerable if the probability of fatality per year exceeds $1 \times 10^{-4}$ (1 in 10,000) per year.

b) Is tolerable if the probability of fatality per year lies in the region $1 \times 10^{-4}$ to $1 \times 10^{-6}$ (1 in 10,000 to 1 in 1,000,000) per year.

c) Is broadly acceptable if the probability of fatality per year is less than $1 \times 10^{-6}$ (1 in 1,000,000) per year.

1.2 As individual risk is defined only in terms of fatalities, it is necessary to establish a separate consequence ranking and risk matrix for each exposed group to be considered. The hazardous event frequency rankings will remain the same as for the collective risk assessment considered for example in Appendix B.

1.3 If we consider the example of a train operating company who has 10,000,000 passenger journeys per year, the frequency and consequence rankings for passenger individual fatality risk could be as shown in Tables 1.3a) (AppD) and 1.3b) (AppD) below, where the consequence rankings are based only on passenger fatalities. It should be noted that the frequency rankings will be the same as the rankings used in the collective risk assessment in Appendix B. The resultant risk ranking is therefore the addition of the original frequency and the specific fatality risk rankings applicable to each individual risk assessment.

<table>
<thead>
<tr>
<th>Frequency of hazardous event</th>
<th>Description</th>
<th>Frequency range</th>
<th>Mid-point estimated frequency</th>
<th>Approx. numerical value events/ year</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rare</td>
<td>1 in 7 years to 1 in 35 years</td>
<td>1 in 20 yrs</td>
<td>0.05</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Infrequent</td>
<td>1 in 1 ¼ years to 1 in 7 years</td>
<td>1 in 4 yrs</td>
<td>0.25</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Occasional</td>
<td>1 in 3 months to 1 in 1 ¼ years</td>
<td>1 in 9 mths</td>
<td>1.25</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Frequent</td>
<td>1 in 20 days to 1 in 3 months</td>
<td>1 in 2 mths</td>
<td>6.25</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Regular</td>
<td>1 in 4 days to 1 in 20 days</td>
<td>1 in 12 days</td>
<td>31.25</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Table 1.3a) (App D)
Appendix D continued

<p>| Consequence (in terms of probability of passenger fatality) |</p>
<table>
<thead>
<tr>
<th>Description</th>
<th>Approx. numerical value fatalities/event</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 fatality every 125 events</td>
<td>0.008</td>
<td>1</td>
</tr>
<tr>
<td>1 fatality every 25 events</td>
<td>0.04</td>
<td>2</td>
</tr>
<tr>
<td>1 fatality every 5 events</td>
<td>0.2</td>
<td>3</td>
</tr>
<tr>
<td>1 fatality every event</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>5 fatalities every event</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 1.3b) (App D)

1.4 These frequency and consequence rankings give rise to the following risk matrix:

<table>
<thead>
<tr>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Fatalities/event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 fatality in every 125 events</td>
<td>0.008</td>
</tr>
<tr>
<td>1 fatality in every 25 events</td>
<td>0.125</td>
</tr>
<tr>
<td>1 fatality in every 5 events</td>
<td>0.25</td>
</tr>
<tr>
<td>1 fatality in every event</td>
<td>1</td>
</tr>
<tr>
<td>5 fatalities in every event</td>
<td>5</td>
</tr>
</tbody>
</table>

(Units are fatalities per year)

Table 1.4 (App D)

Assuming that on average a commuter using the service travels 500 journeys per year, it is possible to convert the risk matrix in Table 1.4 (App D) to a measure of individual passenger risk by dividing each risk point by the number of passenger journeys per year and multiplying by the average number of journeys a commuter makes per year. For example, risk ranking 6 is calculated as follows:

\[(0.25 / 10,000,000) \times 500 = 1.25E-05 \text{ fatalities/passenger/year} \]
1.5 The matrix therefore becomes:

<table>
<thead>
<tr>
<th>Consequences</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 fatality in every 125 events</td>
<td>0.008</td>
<td>0.04</td>
<td>0.2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>1 fatality in every 25 events</td>
<td>1.25E-06</td>
<td>6.25E-05</td>
<td>3.13E-04</td>
<td>1.56E-03</td>
<td>7.81E-03</td>
</tr>
<tr>
<td>1 fatality in every 5 events</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>1 fatality in every event</td>
<td>2.50E-05</td>
<td>6.25E-05</td>
<td>3.13E-04</td>
<td>1.56E-03</td>
<td></td>
</tr>
<tr>
<td>5 fatalities in every event</td>
<td>3.13E-04</td>
<td>3.13E-04</td>
<td>3.13E-04</td>
<td>3.13E-04</td>
<td></td>
</tr>
</tbody>
</table>

(Units are individual risk in probability of fatality per year)

Table 1.5 (App D): Risk matrix in terms of individual passenger risk

1.6 The individual risk criteria can then be plotted onto the risk ranking matrix as represented by the heavy black lines and the following shading:

<table>
<thead>
<tr>
<th>Intolerable</th>
<th>Tolerable</th>
<th>Broadly Acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Considering single and multiple hazardous events

1.7 In any semi-quantitative risk ranking assessment it is likely that there will be a large number of hazardous events each making their own contribution to individual risk such that the total individual risk attributable to all the hazardous events could exceed the limit of tolerability.

1.8 In order to give confidence that the overall individual risk is not exceeding the limit, an estimate should be made of the overall individual risk and the tolerability region on the risk matrix adjusted accordingly. This is best demonstrated via an example. Consider the following results from a risk assessment involving 42 hazardous events based on the risk rankings in Table 1.5 (App D) derived from the frequency and consequence rankings in Tables 1.3a) (App D) and 1.3b) (App D) respectively.

<table>
<thead>
<tr>
<th>Risk ranking</th>
<th>No. of hazardous events with risk ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
Appendix D continued

1.9 By considering the approximate value of risk associated with each risk ranking from Table 1.5 (App D) and the number of hazardous events associated with each risk ranking, the overall individual risk from the risk assessment can be estimated as follows:

<table>
<thead>
<tr>
<th>Risk ranking</th>
<th>Approximate value of risk for each risk ranking from Table 1.5 (App D) (Probability of fatality per year)</th>
<th>No. of hazardous events with risk ranking</th>
<th>Overall individual risk (Probability of fatality per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) (b) (c) (d) = (b) x (c)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6.25E-05</td>
<td>2</td>
<td>1.25E-04</td>
</tr>
<tr>
<td>6</td>
<td>1.25E-05</td>
<td>3</td>
<td>3.75E-05</td>
</tr>
<tr>
<td>5</td>
<td>2.50E-06</td>
<td>20</td>
<td>5.00E-05</td>
</tr>
<tr>
<td>4</td>
<td>5.00E-07</td>
<td>10</td>
<td>5.00E-06</td>
</tr>
<tr>
<td>3</td>
<td>1.00E-07</td>
<td>5</td>
<td>5.00E-07</td>
</tr>
<tr>
<td>2</td>
<td>2.00E-08</td>
<td>2</td>
<td>4.00E-08</td>
</tr>
<tr>
<td>Total individual risk =</td>
<td>2.18E-04</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.9 (App D)

1.10 The overall individual risk is therefore estimated to be above the limit of tolerability for passengers of 1.0E-04 per year. To ensure that the limit of tolerability is not exceeded in this example, the limit of tolerability would have to lie between a risk ranking of 5 and 6 ie if the hazardous events with a risk ranking of 7 and 6 were reduced to a risk ranking of 5 via the introduction of new control measures we could be confident that the overall risk would be in the tolerable region, as follows.

<table>
<thead>
<tr>
<th>Risk ranking</th>
<th>Approximate value of risk for each risk ranking from Table 1.5 (App D) (Probability of fatality per year)</th>
<th>No. of hazardous events with risk ranking</th>
<th>Overall individual risk (Probability of fatality per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) (b) (c) (d) = (b) x (c)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6.25E-05</td>
<td>0</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>6</td>
<td>1.25E-05</td>
<td>0</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>5</td>
<td>2.50E-06</td>
<td>25</td>
<td>6.25E-05</td>
</tr>
<tr>
<td>4</td>
<td>5.00E-07</td>
<td>10</td>
<td>5.00E-06</td>
</tr>
<tr>
<td>3</td>
<td>1.00E-07</td>
<td>5</td>
<td>5.00E-07</td>
</tr>
<tr>
<td>2</td>
<td>2.00E-08</td>
<td>2</td>
<td>4.00E-08</td>
</tr>
<tr>
<td>Total individual risk =</td>
<td>6.80E-05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.10 (App D)
Appendix D continued

1.11 For the overall individual risk to be broadly acceptable, new control measures would have to be introduced such that the risk ranking for all 42 hazardous events was reduced to a level of no greater than 2, as follows.

<table>
<thead>
<tr>
<th>Risk ranking</th>
<th>Approximate value of risk for each risk ranking from Table 1.5 (App D) (Probability of fatality per year)</th>
<th>No. of hazardous events with risk ranking</th>
<th>Overall individual risk (Probability of fatality per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
<td>(d) = (b) x (c)</td>
</tr>
<tr>
<td>7</td>
<td>6.25E-05</td>
<td>0</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>6</td>
<td>1.25E-05</td>
<td>0</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>5</td>
<td>2.50E-06</td>
<td>0</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>4</td>
<td>5.00E-07</td>
<td>0</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>3</td>
<td>1.00E-07</td>
<td>0</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>2</td>
<td>2.00E-08</td>
<td>42</td>
<td>8.40E-07</td>
</tr>
</tbody>
</table>

Total individual risk = 8.40E-07

Table 1.11 (App D)

1.12 The limit for broadly acceptable (1.0E-06 per year) would therefore lie between a risk ranking of 2 and 3 and the risk matrix becomes:

<table>
<thead>
<tr>
<th>Consequences</th>
<th>1 fatality in every 125 events</th>
<th>1 fatality in every 25 events</th>
<th>1 fatality in every 5 events</th>
<th>1 fatality in every event</th>
<th>5 fatalities in every event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1 fatality in every 125 events</td>
<td>1 fatality in every 25 events</td>
<td>1 fatality in every 5 events</td>
<td>1 fatality in every event</td>
<td>5 fatalities in every event</td>
</tr>
<tr>
<td>No/year</td>
<td>1 fatality in every 125 events</td>
<td>1 fatality in every 25 events</td>
<td>1 fatality in every 5 events</td>
<td>1 fatality in every event</td>
<td>5 fatalities in every event</td>
</tr>
<tr>
<td>5</td>
<td>31.25</td>
<td>1.25E-05</td>
<td>6</td>
<td>1.25E-05</td>
<td>7.81E-03</td>
</tr>
<tr>
<td>4</td>
<td>6.25</td>
<td>2.50E-06</td>
<td>5</td>
<td>2.50E-06</td>
<td>1.56E-03</td>
</tr>
<tr>
<td>3</td>
<td>1.25</td>
<td>5.00E-07</td>
<td>4</td>
<td>5.00E-07</td>
<td>3.13E-04</td>
</tr>
<tr>
<td>2</td>
<td>0.25</td>
<td>1.00E-07</td>
<td>3</td>
<td>1.00E-07</td>
<td>1.56E-03</td>
</tr>
<tr>
<td>1</td>
<td>0.05</td>
<td>2.00E-08</td>
<td>2</td>
<td>2.00E-08</td>
<td>7.81E-03</td>
</tr>
</tbody>
</table>

(Units are individual risk in probability of fatality per year)

Table 1.12 (App D): Risk matrix for individual hazardous events
Appendix D continued

Deriving tolerability rules for ranked estimates of risk

1.13 Having carried out the above exercise, it is possible to define risk classifications against which the risk ranking results for each hazardous event for a particular risk assessment can be compared, e.g., for the risk assessment example above this would be:

<table>
<thead>
<tr>
<th>Risk Rating</th>
<th>Risk Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Broadly acceptable</td>
</tr>
<tr>
<td>3 to 5</td>
<td>Tolerable</td>
</tr>
<tr>
<td>6 to 10</td>
<td>Intolerable</td>
</tr>
</tbody>
</table>

Table 1.14 (App D): Risk classification for passengers

1.15 This approach does not encompass risk aversion to single incidents that lead to catastrophic multiple fatality outcomes. This 'societal risk' should be addressed explicitly in the discussion of results as defined in sections B12.22, B12.23 and B14.5 in the main text.
2 Individual risk for other exposed groups

2.1 In addition to individual passenger risk, the above methodology can be applied to estimates of individual staff risk eg drivers and track workers. A separate risk classification should be developed for each exposed group considered within the matrix.

2.2 The criteria for individual worker risk of fatality are as stated in section B12.2 to B12.10 in the main text as follows:

a) Is intolerable if the probability of fatality per year exceeds 1E-03 (1 in 1000) per year.

b) Is in the tolerable if the probability of fatality lies in the region 1E-03 (1 in 1000) to 1E-06 (1 in 1,000,000) per year.

c) Is broadly acceptable if the probability of fatality is less than 1E-06 (1 in 1,000,000) per year.

2.3 If we consider the example of a company that operate RRV on Railtrack controlled infrastructure, the risk assessment will have considered the risk to drivers relating to the typical number of vehicle operations per year. It is possible in such companies that many different drivers are hired in to operate the vehicles suggesting that the risk is divided among a large number of drivers. However to get a true picture of the individual risk it is suggested that the number of drivers is assessed as the number of full time equivalent drivers that would be required for the typical number of vehicle operations per year.

2.4 Assuming that on average it would require 20 full time equivalent drivers to operate the vehicles, it is possible to convert an example 7 x 4 risk matrix to a measure of individual driver risk by dividing each risk point by the number of full time equivalent drivers per year. For example, risk ranking 6 is calculated as follows:

\[
(1.25 \times 0.008) / 20 = 5.0E-04 \text{ fatalities/driver/year}
\]

It should be noted that for RRV driver individual risk, there is no real possibility of a hazardous event leading to as many as 5 RRV driver fatalities and therefore the number of consequence rankings has been limited to 4, with the highest consequence ranking relating to a single fatality occurring on every occasion.
Appendix D continued

2.5 The matrix therefore becomes:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 fatality in every 125 events</td>
</tr>
<tr>
<td>No/year</td>
<td>0.008</td>
</tr>
<tr>
<td>7 31.25</td>
<td>1.25E-02</td>
</tr>
<tr>
<td>6 6.25</td>
<td>2.50E-03</td>
</tr>
<tr>
<td>5 1.25</td>
<td>5.00E-04</td>
</tr>
<tr>
<td>4 0.25</td>
<td>1.00E-04</td>
</tr>
<tr>
<td>3 0.05</td>
<td>2.00E-05</td>
</tr>
<tr>
<td>2 0.01</td>
<td>4.00E-06</td>
</tr>
<tr>
<td>1 0.002</td>
<td>8.00E-07</td>
</tr>
</tbody>
</table>

(Units are individual risk in probability of fatality per driver/year)

Table 2.5 (App D): Risk matrix in terms of individual RRV driver risk

2.6 The individual risk criteria can then be plotted onto the risk ranking matrix, as represented by the heavy black lines and the following shading:

<table>
<thead>
<tr>
<th></th>
<th>Intolerable</th>
<th>Tolerable</th>
<th>Broadly Acceptable</th>
</tr>
</thead>
</table>

Considering single and multiple hazards

2.7 In any semi-quantitative risk ranking assessment it is likely that there will be a large number of hazardous events each making their own contribution to individual risk such that the total individual risk attributable to all the hazardous events could exceed the limit of tolerability.

2.8 In order to give confidence that the overall individual risk does not exceed the limit of tolerability, an estimate should be made of the overall individual risk and the tolerability region on the risk matrix adjusted accordingly. The methodology to do this and a worked example are described in paragraphs 1.7 to 1.14 (App D) above, except that the reference risk matrix is Table 2.5 (App D).

2.9 Having accounted for the overall individual risk from all the hazardous events the resulting individual risk matrix could be as follows.
Consequences

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.008</td>
<td>0.04</td>
<td>0.2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1.25E-02</td>
<td>6.25E-02</td>
<td>3.13E-01</td>
<td>1.56E+00</td>
</tr>
<tr>
<td>3</td>
<td>2.50E-03</td>
<td>1.25E-02</td>
<td>6.25E-02</td>
<td>3.13E-01</td>
</tr>
<tr>
<td>4</td>
<td>5.00E-04</td>
<td>2.50E-03</td>
<td>1.25E-02</td>
<td>6.25E-02</td>
</tr>
<tr>
<td>5</td>
<td>1.00E-04</td>
<td>5.00E-04</td>
<td>2.50E-03</td>
<td>1.25E-02</td>
</tr>
<tr>
<td>6</td>
<td>0.25</td>
<td>1.00E-04</td>
<td>5.00E-04</td>
<td>2.50E-03</td>
</tr>
<tr>
<td>7</td>
<td>0.05</td>
<td>2.00E-05</td>
<td>1.00E-04</td>
<td>5.00E-04</td>
</tr>
<tr>
<td>8</td>
<td>4.00E-06</td>
<td>2.00E-05</td>
<td>1.00E-04</td>
<td>5.00E-04</td>
</tr>
<tr>
<td>9</td>
<td>8.00E-07</td>
<td>4.00E-06</td>
<td>2.00E-05</td>
<td>1.00E-04</td>
</tr>
</tbody>
</table>

(Units are individual risk in probability of driver fatality per year)

Table 2.9 (App D): Risk matrix for individual hazardous events

Deriving tolerability rules for ranked estimates of risk

2.10 It is then possible to define risk classifications against which the risk ranking results for each hazardous event can be compared, for example:

<table>
<thead>
<tr>
<th>Risk Rating</th>
<th>Risk Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Broadly acceptable</td>
</tr>
<tr>
<td>2 to 5</td>
<td>Tolerable</td>
</tr>
<tr>
<td>6 to 12</td>
<td>Intolerable</td>
</tr>
</tbody>
</table>

Table 2.10 (App D): Example Risk classification for drivers

2.11 This approach does not encompass risk aversion to single incidents that lead to catastrophic multiple fatality outcomes. This ‘societal risk’ should be addressed explicitly in the discussion of results as defined in sections B12.22, B12.23 and B14.5 in the main text.
Appendix E

Safety case risk assessment for new operation with little or no experience to use

1 Introduction

1.1 There may be cases where an RSC risk assessment has to be produced for a completely new type of operation for which there is little or no experience to use as input into the risk assessment.

1.2 In such cases it is recommended that initially a structured semi-quantitative risk ranking methodology as described in Appendix B is used to establish a basic understanding of the hazardous events, precursors and risk profile. In such cases the selection of frequency and consequence rankings would be based almost entirely on judgement.

1.3 If as a result of this process one or more accident sequences are identified for which there is considerable uncertainty about the failure frequency relating to systems or sub-systems, or the types of outcomes that could occur particularly relating to fatalities, it is recommended that more detailed fault tree and event tree analysis techniques are used to examine the risk issues and quantification in more detail. The outputs from such assessment can be used in a manner similar to that described in Appendix A.

1.4 The text below gives a broad overview of the fault tree and event tree analysis techniques. It is not however the intention of this guidance note to give a detailed guidance on how to undertake fault and event tree analyses. There are many commercially available courses that could be used to obtain a working knowledge of the techniques. Alternatively, external consultants with specific expertise in risk assessment could be used.

1.5 Specific advice on the use of fault tree and event tree analysis techniques can be obtained from the Head of Risk Assessment at Railway Safety, see Phone number is section A5.

2 Fault and event tree analysis

Fault tree analysis

2.1 Fault tree analysis (FTA) is a technique which analyses the possible causes of a specified undesirable end or 'Top' event. Logic symbols, known as 'gates', are used to work back systematically to the originating failure or basic events. This technique is particularly useful for systems having substantial redundancy, since the combination of failures which will lead to the top event can be determined and quantified.

2.2 The most commonly used gates in fault tree analysis are 'AND' and 'OR' gates. An 'AND' gate is used when all inputs should fail for the output to occur. For an 'OR' gate any failure will cause the output failure.

2.3 By assigning a probability (or frequency) to each basic event and using the mathematical rules of Boolean algebra the basic event probabilities can be combined at each gate to give the top event probability or in the case of this study the top (initiating) event frequency.
Appendix E continued

Event tree analysis

2.4 In the context of a risk analysis the event tree analysis technique can be used to identify and, if necessary, quantify (in terms of the frequency of occurrence) all the possible outcomes which could result from a particular initiating event. This includes the consideration of the success and failure of the components, systems and operator actions which are intended to prevent the initiating event developing into undesirable consequences. In addition, the influence of physical effects or other factors which could affect the outcome of the initiating event can be considered.

2.5 An event tree takes the form of a diagrammatic representation of the events which could occur following an initiating event. An event tree expands out as an increasing number of physical effects, components, systems or operator actions are considered.

2.6 Once an event tree is fully expanded, the consequences of each possible outcome can be assessed. Probabilities can then be assigned to each branch of the tree and combined with the frequency of the initiating event to give the overall frequency of occurrence and the risk for each possible outcome.
Appendix F

Methods for demonstrating risk is as low as reasonably practicable (ALARP)

1 Introduction

Once the risk has been assessed, the next step in the risk management process is the identification and implementation of controls to reduce the risk to a level that is ALARP. In order to demonstrate ALARP it is necessary to identify, assess and implement all reasonably practicable controls.

The purpose of this appendix is to give guidance on how the reasonable practicability of a proposed control or controls can be determined. Where a number of controls are proposed, they should be assessed in combinations rather than individually in order to determine the lowest residual risk that can be achieved within the bounds of reasonable practicability.

2 Reasonable practicability

2.1 There are three main methods for assessing reasonable practicability:

a) comparison with good practice

b) expert judgement, and

c) through cost benefit analysis.

These are described in more detail below.

Comparison with good practice

2.2 Where the proposed control represents current, relevant, established good practice, this should be considered as sufficient evidence to conclude that it is reasonably practicable.

The following should be considered as examples of good practice:

a) The practice is established in more than one other national railway, which is similar in scale and operation to the British system.

b) The practice is established and widely implemented in another industrial sector.

c) The practice is enforced by legislation in more than one other country.

d) The practice is already established elsewhere on the UK railway.

2.3 If all of the following also apply:

a) It has demonstrably improved safety in its current application.

b) It can be implemented without significant modification or difference in cost.

c) It is relevant to the circumstances, for example similar operating conditions.

Good practice is generally most relevant to new builds and upgrades rather than existing operations.
Appendix F continued

Expert judgement

2.4 A proposed control should be considered reasonably practicable where it can be established by an appropriate group of experts that it has clear safety benefits, and the costs associated with its introduction are relatively small. Judgements of this type should also be made where the costs of carrying out further analysis would contribute a material proportion to the costs of the control. The process of ALARP assessment proposed in Appendices A and B is based largely on expert judgement.

Cost benefit analysis

2.5 Where it is not clear via expert judgement that a specific control or group of controls are reasonably practicable it may be necessary to undertake a quantitative cost benefit analysis (CBA).

CBA is a methodology for comparing the benefits achieved by a control or combination of controls with the costs of implementation. The level of detail can vary significantly depending on the complexity of the issue, the scale of costs involved and the level of uncertainty in the analysis.

It is recommended that the advice of a professional experienced in quantitative cost benefit analysis (in-house or external) is sought before undertaking detailed quantitative CBAs.

The elements of a CBA are summarised as follows:

- **Proposed control measure**
- Quantify the safety benefits in terms of equivalent fatalities, and subtract any safety disbenefits
- Quantify the whole life costs, and subtract avoided costs of accidents
- Translate safety benefit into equivalent financial value using appropriate Vpf
- Discount net costs over measure lifetime
- Discount net safety benefits over lifetime of measure
- Compare
- Decision

**Figure 2.5 (App F)**

Each item (a) to (f) is described in turn below.

a) Quantification of costs:

The cost side of the analysis needs to include all costs that are necessary and sufficient to the introduction of the control, less any direct cost savings. They should be evaluated in real terms for the years in which they are to be incurred. The outcome of this stage of the CBA is a cost profile of the control over its full lifetime.

Costs and/or cost savings should include:

i) capital investment

ii) installation and commissioning
Appendix F continued

iii) training

iv) management and administration

v) operation and maintenance

vi) decommissioning

vii) avoided costs of accidents (excluding any effects of insurance).

Costs and cost savings should not include those which are speculative, for example:

i) improved reputation and the response of the market to the new control and its safety or commercial effects

ii) reduced insurance premiums.

The costs identified above are described in more detail in section 3 below.

b) Evaluation of safety benefits:

The benefit side of the analysis includes all safety benefits arising directly from the implementation of the control, less any safety risk imported by its implementation. Imported safety risks typically include those imposed on the workforce during installation.

The safety benefit, in equivalent fatalities should be calculated according to the equivalent fatality ratio published in the Railway Group Safety Plan. At the time of publication, the equivalent fatality ratio is:

\[1 \text{ equivalent fatality} = 1 \text{ fatality} = 10 \text{ major injuries} = 200 \text{ minor injuries}\]

Given that the current risk has already been assessed, an estimate of the risk remaining after the implementation of the control(s) enables the safety benefit to be calculated as the difference between the two. The evaluation should generate a profile of safety benefits over the whole life of the control, taking into account any initial period in which the benefit may be lower.

c) Translation of safety benefit into financial terms:

The safety benefits in equivalent fatalities should be multiplied by the appropriate VPF to obtain a financial value for the benefits. Two values of VPF are published annually in the Railway Group Safety Plan, the basic value for evaluating controls for single fatality type events, and a higher value for evaluating controls for events with the potential to cause multiple fatalities, or where the level of individual risk is close to the intolerable region. At the time of publication, the values are £1.24 Million and £3.46 Million respectively.

d) Discounting of costs and benefits:

The costs should be discounted at a rate equating to the organisation's cost of capital. In many cases the costs will be primarily capital outlay so discounting will have little effect. The result is the present value of the costs.
Appendix F continued

The safety benefits should be discounted to reflect the preference for safety benefits now over those in the future. A net rate of about 2% as applied by the HSE is recommended. The result is the present value of the safety benefits.

e) Comparison of costs and benefits:

Once the costs and safety benefits are in comparable present value units, a simple comparison can be carried out, either as a ratio of benefits to costs, or as benefits minus costs.

Both the costs and the benefits will be subject to uncertainties, and even in fully quantitative analyses there will typically be a number of subjective judgments. The nature and scale of both uncertainties and assumptions should be recorded. A sensitivity analysis to test the robustness of the CBA conclusion should be carried out. This may vary from a simple estimate to a complex evaluation, and professional advice should be sought where necessary.

Where, making suitable allowances for the uncertainties and assumptions, the safety benefits exceed the costs, the control is considered reasonably practicable. Where the uncertainties are large, this should be made clear to the decision makers, who should bias their decision towards concluding that the control is reasonably practicable.

f) Decision on whether to implement controls:

Numerical cost-benefit analysis cannot always capture all relevant factors. The actual decision has to be taken by the responsible management, taking into account any issues that were not quantified. The analysis should always be seen as an aid to the decision, not the decision itself.

3 Quantification of costs

Details of each of the types of cost outlined in section 2.5(a) that should be considered within a CBA are as follows. It should be noted that these descriptions are not exhaustive, nor should it be assumed that all these costs are relevant to all analyses.

Capital investment

3.1 This is the total cost to the company of procuring the proposed control, including as appropriate design and development costs, and purchase costs where a tangible item is required.

Installation and commissioning, including out of service costs

3.2 This is the total cost of implementing the control into the railway system. It will include material costs, labour costs, certification costs, and costs of taking equipment, infrastructure or people out of normal service.

In all cases where out of service costs will be incurred, account should be taken of opportunities to include the installation in existing maintenance windows, or undertake the work alongside other improvements to minimise the costs. Equally account should be taken of the potential opportunity to undertake other work during an out of service period, and costs reduced appropriately. This is in accordance with recommendations in Reducing Risks, Protecting People [9].

Where there is the option to implement the control retrospectively, or apply it only to new builds, two separate cost estimates should be made.
Appendix F continued

Training
3.3 All training costs associated with the new measure, both initially and on an ongoing basis should be included. Where training will be incorporated in existing programmes, only the incremental cost of adding a new element to it should be counted. Consideration should be given to the training of all those affected, including installers, maintainers, operators and managers.

If a measure reduces overall training costs, this difference should be added to the cost savings and offset against expenditure.

Management and administration
3.4 All additional management and administrative costs associated with the procurement, implementation and operation of the new control should be included. This includes project management of the initial implementation. Whilst this will in many cases be difficult to quantify, estimates should be made.

If a control reduces management or administration costs, for example by simplifying a procedure, then the difference should be added to the cost savings and offset against expenditure.

Operation and maintenance
3.5 If the control changes maintenance methods or schedules, or makes any change to operations, then the incremental costs or savings compared to existing practice should be included.

A loss of utility is also considered a cost, for example if the passenger capacity would be reduced below that currently utilised, then there would be a guaranteed loss that should be included. However if spare capacity is lost, or it is anticipated that the measure may deter passengers then any financial losses are speculative so are excluded.

The cost of additional delays should be accounted for where these are certain to follow implementation of the measure.

Offset against these costs should be any cost savings, or commercial benefits where these are guaranteed to follow the implementation of the measure and can be quantified. Any speculative savings or commercial benefits, for example gaining new passengers should not be included.

Decommissioning
3.6 This includes any costs relating to the removal and disposal of the equipment or infrastructure required by the measure at the end of its life. Care must be taken not to double count, as the costs of removal may also be included with the costs of installing new equipment in its place.

If there is any residual value which can be reclaimed through resale or recycling, this should be deducted from the costs.

Avoided costs of accidents
3.7 There are three components of the costs arising from an accident:

a) Material damage includes all costs of repair and replacement to property damaged in the accident.

b) Business Interruption includes temporary loss of revenue or profit, or increased costs of working due to the disruption of the accident, including expenses such as British Transport Police activity.

c) Third party liability includes claims against the company for injury or property damage arising in the accident.
Appendix F continued

Where the losses would be insured, the avoided costs should be taken as the total costs of accidents avoided, not just the excess as payable by the company.

The costs included should only be those directly incurred by such accidents, costs incurred to implement inquiry recommendations or to make other consequential equipment or operational changes should be excluded.

**Improved reputation and response of the market to the new measure and its safety or commercial effects**

3.8 It might be anticipated that the installation of a significant new safety measure would attract more passengers, or make them prepared to pay higher fares. However, these consequences are not certain so cannot be included within the cost assessment.

**Reduced insurance premiums**

3.9 The link between insurance premiums and improvements in the safety measures on the system is considered tenuous, therefore there is no certain cost saving which can be included in the assessment.
## Appendix G

### Hazardous event precursor assessment table – SRM based risk assessment

Draft for information only  
(the numbers quoted are examples and should not be used)

(Example of Table A2 on the Guidance Note CD available from Railway Safety)

<table>
<thead>
<tr>
<th>Precursor category</th>
<th>SRM Precursor code</th>
<th>Cause Precursor Description</th>
<th>Existing Control measures</th>
<th>Cross reference to SMS in RSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROLLING STOCK</td>
<td></td>
<td></td>
<td>Direct control (D), Interface issue (I) or No control (N)</td>
<td>If (I) or (N) Define other company responsible</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1 ROLLING STOCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 PAXL----PF</td>
<td></td>
<td>Axle failure leading to PT derailment – D</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>3 PBRG----PF</td>
<td></td>
<td>Seized axle box bearing leading to PT derailment - D</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>4 PBUP----PF</td>
<td></td>
<td>Buffer locking leading to PT derailment - D</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>5 PCUP----PF</td>
<td></td>
<td>Coupling failure leading to PT derailment - E</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>6 PSNT----PF</td>
<td></td>
<td>Severe braking/snatch leading to PT derailment - E</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>7 PSUS----PF</td>
<td></td>
<td>Suspension system/brake failures leading to PT derailment - D</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>8 PTRE----PF</td>
<td></td>
<td>Running into objects fallen from trains leading to PT derailment - D</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>9 PWHF----PF</td>
<td></td>
<td>Wheel flats or wheel/sleeve wear beyond limits leading to PT derailment - E</td>
<td>N</td>
<td>Railtrack</td>
</tr>
<tr>
<td>10 PWHL----PF</td>
<td></td>
<td>Wheel failure leading to PT Derailment - D</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>11 TRACK</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>12 RDRN----UF</td>
<td></td>
<td>Drainage culvert/pipework collapse leading to train derailment - E</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>13 RSLP----PF</td>
<td></td>
<td>Subsidence/ landslip under track leading to PT derailment - E</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>14 TBCK----PF</td>
<td></td>
<td>Buckled rail leading to PT derailment - E</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>15 TBKX----PF</td>
<td></td>
<td>Broken rail leading to PT derailment – D</td>
<td>N</td>
<td>Railtrack</td>
</tr>
<tr>
<td>16 TFSH----PF</td>
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<td>Broken fishplate leading to PT derailment - E</td>
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<tr>
<td>17 TSPQ----PF</td>
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<td>Gauge spread leading to PT derailment - D</td>
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<tr>
<td>18 TKTD----UE</td>
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<td>Track damage from other undetected derailment leading to train derailment - E</td>
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</tr>
<tr>
<td>19 TTUNBKR-PF</td>
<td></td>
<td>Broken rail in tunnel leading to PT derailment - D</td>
<td>N</td>
<td>Railtrack</td>
</tr>
<tr>
<td>20 TTWS----PF</td>
<td></td>
<td>Track twist leading to PT derailment - D</td>
<td>D</td>
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</tr>
<tr>
<td>21 KSOC----PF</td>
<td></td>
<td>Defective S&amp;C leading to PT derailment - D</td>
<td>D</td>
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</tr>
<tr>
<td>22 XPDI----PF</td>
<td></td>
<td>Points in the wrong position and not detected leading to PT derailment - D</td>
<td>D</td>
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<tr>
<td>23 XPRD----PH</td>
<td></td>
<td>Track maintenance staff errors leading to PT derailment - D</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>24 KSBO----PH</td>
<td></td>
<td>Incorrect scotch and clip of points leading to PT derailment - D</td>
<td>D</td>
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</tr>
<tr>
<td>25 SIGNALLING/SIGNALMAN</td>
<td></td>
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<tr>
<td>26 SWRG----PF</td>
<td></td>
<td>Wrongside signal failure at S&amp;C leading to PT derailment - D</td>
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<tr>
<td>27 KSICM----PF</td>
<td></td>
<td>Movement of points under train (equipment faults) leading to PT derailment - E</td>
<td>E</td>
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<tr>
<td>28 KSISM----PF</td>
<td></td>
<td>Signalman/crossing keeper error leading to PT derailment - D</td>
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</table>

(Table continues across to next page)
### ALARP ASSESSMENT

<table>
<thead>
<tr>
<th>National average Frequency events/train mile</th>
<th>Duty holder frequency - based on national average data</th>
<th>Duty holder number of actual events recorded over x years in data sample period</th>
<th>Duty holder frequency based on actual data for the duty holder or similar operation events/year</th>
<th>Assessed duty holder frequency used as the basis of the RSC events/year</th>
<th>References to supporting data, assumptions, judgements and justifications for the data used</th>
<th>Potential additional control measures to reduce risk</th>
<th>Proposed strategy for each additional control measure</th>
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</thead>
<tbody>
<tr>
<td>Events/year</td>
<td>Years between events</td>
<td>Duty holder train miles</td>
<td>Enter length of data sample period in years</td>
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<tr>
<td>(h)</td>
<td>(i)</td>
<td>(j)</td>
<td>(k)</td>
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<td>(m)</td>
<td>(n)</td>
<td>(o)</td>
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<tr>
<td>1.00E+07</td>
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<td>1.10E-09</td>
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<td>No recorded derailments or axle failures</td>
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<td>Data from SMIS Jan 1997 to July 2001. Comprehensive control measures in place to inspect and monitor axle condition. No evidence to indicate frequency above or below average+N31</td>
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<tr>
<td>1.60E-09</td>
<td>0.016</td>
<td>63</td>
<td>No recorded derailments, but above average frequency of broken rails</td>
<td>0.032</td>
<td>Railtrack broken rail data 2000/2001 indicates above average frequency of broken rails for lines used. Frequency doubled to reflect above average frequency of broken rails</td>
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<td>625</td>
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<td>625</td>
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(Table continued across from previous page)
## Appendix G continued

<table>
<thead>
<tr>
<th>Precursor category</th>
<th>SRM Precursor code</th>
<th>Cause Precursor Description</th>
<th>Existing Control measures</th>
<th>Cross reference to SMS in RSC</th>
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<tbody>
<tr>
<td>Direct control (D), Interface issue (I) or No control (N)</td>
<td>If (I) or (N) Definition other company responsible</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>30 RUNNING INTO OBSTRUCTIONS</strong></td>
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<tr>
<td>31 ANAM—UE</td>
<td>Running into large animals leading to train derailment</td>
<td>D</td>
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<tr>
<td>32 BBLD—UE</td>
<td>Running into objects from building site leading to train derailment</td>
<td>E</td>
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<tr>
<td>33 BLBN—UE</td>
<td>Running into items blown onto the line leading to train derailment</td>
<td>E</td>
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<tr>
<td>34 BTRE—UE</td>
<td>Running into trees leading to train derailment</td>
<td>D</td>
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<tr>
<td>35 BVAN—UE</td>
<td>Running into items placed on the track by vandals leading to train derailment</td>
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<tr>
<td>36 WMAT—UE</td>
<td>Running into Engineers materials left foul leading to train derailment</td>
<td>D</td>
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<tr>
<td>37 DEGO—UE</td>
<td>Running into derailed OTM or Engineers train leading to train derailment</td>
<td>E</td>
<td></td>
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</tr>
<tr>
<td>38 RBGD—UF</td>
<td>Running into to debris from overbridges leading to train derailment</td>
<td>E</td>
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<tr>
<td>39 RBLD—UF</td>
<td>Running into debris from lineside structures/buildings leading to train derailment</td>
<td>D</td>
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<tr>
<td>40 RLNS—UF</td>
<td>Running into landslide leading to train derailment</td>
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<tr>
<td>41 RORL—UF</td>
<td>Running into debris from CHUE structures leading to train derailment</td>
<td>E</td>
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<tr>
<td>42 RSIO—UF</td>
<td>Running into debris from signalling gantries leading to train derailment</td>
<td>E</td>
<td></td>
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</tr>
<tr>
<td>43 RTUNWALLUF</td>
<td>Running into debris in the tunnel leading to train derailment</td>
<td>E</td>
<td>N</td>
<td>Railtrack</td>
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<tr>
<td>44 RUXL—UF</td>
<td>Running into debris from retaining walls leading to train derailment</td>
<td>E</td>
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<tr>
<td>45 RUTRN—UE</td>
<td>Running into train derailed while in deposits/sidings leading to train derailment</td>
<td>E</td>
<td></td>
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</tr>
<tr>
<td>46 VBGV—UE</td>
<td>Running into vehicles fallen from overbridge leading to train derailment</td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47 VBNR—UE</td>
<td>Running into vehicles through boundary fence leading to train derailment</td>
<td>D</td>
<td></td>
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<tr>
<td>48 VMVE—UE</td>
<td>Running into maintenance vehicles leading to train derailment</td>
<td>E</td>
<td></td>
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<tr>
<td>49 VSIO—UE</td>
<td>Running into snow/ice leading to train derailment</td>
<td>D</td>
<td></td>
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<tr>
<td>50 MISC.</td>
<td></td>
<td></td>
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<tr>
<td>51 YMSC—PE</td>
<td>Miscellaneous/unknown causes on plain line leading to PT derailment</td>
<td>D</td>
<td></td>
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</tr>
<tr>
<td>52 ENVIRONMENTAL</td>
<td></td>
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<tr>
<td>53 RQAK—UE</td>
<td>Structural damage due to earthquake leading to train derailment</td>
<td>E</td>
<td></td>
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</tr>
<tr>
<td>54 WFLD—UE</td>
<td>Running into flooding leading to train derailment</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 WWIN—UE</td>
<td>High winds leading to train derailment</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>56 DRIVER/ TRAIN CREW</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>57 PCHR—PH</td>
<td>Other driver/train crew error at S&amp;C leading to PT derailment</td>
<td>D</td>
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<tr>
<td>58 POSL—PH</td>
<td>Overspeeding on leading to PT derailment</td>
<td>D</td>
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<tr>
<td>59 PSHN—PH</td>
<td>Shunter errors leading to PT derailment</td>
<td>D</td>
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<tr>
<td>60 PSFO—PH</td>
<td>Signal passed at danger at S&amp;C leading to PT derailment</td>
<td>D</td>
<td>I</td>
<td>Railtrack</td>
</tr>
<tr>
<td><strong>61 BRIDGES</strong></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>62 RBOG—UF</td>
<td>Rail bridge structural failure leading to train derailment</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>63 RBSHCOL—UE</td>
<td>Rail bridge collapse - bridge bashing leading to train derailment</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>64 RBSH—UE</td>
<td>Bridge bashing leading to bridge displacement (not collapse) and train derailment</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65 RSRC—UE</td>
<td>Rail bridge collapse - scour leading to train derailment</td>
<td>D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Table continues across to next page)
### Appendix G continued

<table>
<thead>
<tr>
<th>Events/year</th>
<th>Years between events</th>
<th>Duty holder train miles</th>
<th>Enter length of data sample period in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>(h)</td>
<td>(i)</td>
<td>(j)</td>
<td>(k)</td>
</tr>
<tr>
<td>1.00E+07</td>
<td></td>
<td></td>
<td>(l)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(m)</th>
<th>(n)</th>
<th>(o)</th>
<th>(p)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Duty holder frequency - based on national average data</th>
<th>Duty holder number of actual events recorded over x years in data sample period</th>
<th>Assessing duty holder frequency used as the basis of the RSC events/year</th>
<th>References to supporting data, assumptions, judgements and justifications for the data used</th>
<th>Potential additional control measures to reduce risk</th>
<th>Proposed strategy for each additional control measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>National average Frequency events/train mile</td>
<td>Duty holder frequency - based on national average data</td>
<td>Duty holder number of actual events recorded over x years in data sample period</td>
<td>Assessing duty holder frequency used as the basis of the RSC events/year</td>
<td>References to supporting data, assumptions, judgements and justifications for the data used</td>
<td>Potential additional control measures to reduce risk</td>
</tr>
<tr>
<td>30</td>
<td>0.014</td>
<td>71</td>
<td>1.9</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>31</td>
<td>1.40E-09</td>
<td>0.014</td>
<td>71</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>32</td>
<td>7.50E-12</td>
<td>0.000</td>
<td>13333</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>33</td>
<td>7.50E-12</td>
<td>0.000</td>
<td>13333</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>34</td>
<td>1.40E-09</td>
<td>0.014</td>
<td>71</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
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<td>35</td>
<td>3.60E-09</td>
<td>0.036</td>
<td>28</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>36</td>
<td>4.50E-10</td>
<td>0.005</td>
<td>222</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>37</td>
<td>4.50E-11</td>
<td>0.000</td>
<td>2222</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>38</td>
<td>4.50E-10</td>
<td>0.005</td>
<td>222</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>39</td>
<td>4.50E-10</td>
<td>0.005</td>
<td>222</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>40</td>
<td>4.10E-09</td>
<td>0.041</td>
<td>24</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>41</td>
<td>1.90E-12</td>
<td>0.000</td>
<td>52632</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>42</td>
<td>1.90E-13</td>
<td>0.000</td>
<td>526318</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
<tr>
<td>43</td>
<td>1.90E-10</td>
<td>0.002</td>
<td>538</td>
<td>No tunnels on routes used</td>
<td>0.046 Data from SPAD report 2000/2001. Derailment rate reduced to reflect lower SPAD rate</td>
</tr>
</tbody>
</table>

Overall frequency for hazardous event (events/year) (HE12-freq) = 0.514

(Table continued across from previous page)
### Appendix H

**Hazardous event consequences assessment table – SRM based risk assessment**

Draft for information only
(the numbers quoted are examples and should not be used)

(Example of Table A3 on the Guidance Note CD available from Railway Safety)

<table>
<thead>
<tr>
<th>Hazardous event</th>
<th>Hazardous event frequency /year</th>
<th>Outcomes</th>
<th>Probability of outcome</th>
<th>Average eq. Fats/ event (national)</th>
<th>Major Factors affecting estimate</th>
<th>Existing control measures which control or mitigate the consequences</th>
<th>Cross reference to SMS in RSC</th>
<th>Consequences of such events from recorded data</th>
<th>Consequences assumed for the duty holder operation</th>
<th>References to supporting data, assumptions, judgements and justifications for the consequences used</th>
<th>Risk eq. fats/ year</th>
<th>Passenger fats/ event (national)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 HET-12</td>
<td>0.015</td>
<td>Typical - train remains upright, no significant chance of fatality</td>
<td>0.96</td>
<td>0.05</td>
<td>Key factors: Train speed and average passenger loading</td>
<td>0.1</td>
<td>Consequences doubled because trains operate normally at speeds above 100 mph. All other factors considered to be average (see note 1 below)</td>
<td>0.0483</td>
<td>0.008</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Fatality/ multi-fatality - train falls on side, obstructs adjacent line, secondary collision, strikes adjacent structure</td>
<td>0.04</td>
<td>6.5</td>
<td>Key factors: Train speed, average passenger loading, type of rolling stock, density of trains on adjacent lines which could be involved in a secondary collision, presence of diesel trains leading to possibility of fire Other factors: presence of significant lineside structures, carriages falling on their side</td>
<td>13</td>
<td>Consequences doubled because trains operate normally at speeds above 100 mph. All other factors considered to be average (see note 1 below)</td>
<td>0.267</td>
<td>4.7</td>
<td></td>
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<tr>
<td>Total Risk =</td>
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<td></td>
<td>0.316</td>
</tr>
</tbody>
</table>

(Table continues across to next page)
### Appendix H continued

#### Estimates for the passenger individual risk (fatalities only)

<table>
<thead>
<tr>
<th>Major Factors affecting estimate</th>
<th>Passenger consequences assumed for the duty holder operation</th>
<th>References to supporting data, assumptions, judgements and justifications for the consequences used</th>
<th>Passenger fatality risk (fatalities only)</th>
<th>Driver fatality risk (fatalities only)</th>
<th>ALARP assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td>(n) (o) (p) (q) (r)</td>
<td>(b)(d)(x)(o)</td>
<td></td>
<td>(f) (g) (h) (i) (j)</td>
<td>(v) (w) (x) (y) (z)</td>
<td></td>
</tr>
<tr>
<td>1 As for (f)</td>
<td>0.016</td>
<td>Consequences doubled because trains operate normally at speeds above 100 mph. All other factors considered to be average (see note 1 below)</td>
<td>0.00790</td>
<td>0.015</td>
<td>0.0148</td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>2 As for (f)</td>
<td>9.4</td>
<td>Consequences doubled because trains operate normally at speeds above 100 mph. All other factors considered to be average (see note 1 below)</td>
<td>0.193</td>
<td>0.4</td>
<td>0.0164</td>
</tr>
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</tr>
</tbody>
</table>

#### Estimates for the driver individual risk (fatalities only)

<table>
<thead>
<tr>
<th>Major Factors affecting estimate</th>
<th>Driver consequences assumed for the duty holder operation</th>
<th>References to supporting data, assumptions, judgements and justifications for the consequences used</th>
<th>Driver fatality risk (fatalities only)</th>
<th>Potential additional control/mitigating measures to reduce risk</th>
<th>Proposed strategy for each additional control measure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

#### Potential additional control/mitigating measures to reduce risk

- Document Withdrawn as of December 2008
- Uncontrolled When Printed
Guidance on the Preparation of Risk Assessments within Railway Safety Cases

Appendix H continued

For explanatory notes see overleaf

(Table continued across from previous page)

Note 1: Average loading about 30%
All post mark 1 rolling stock
Normal mix of electric and diesel stock
No significant lineside features on the routes used

GUIDANCE ON RELATING CONSEQUENCES TO SPECIFIC TRAIN OPERATIONS

<table>
<thead>
<tr>
<th>Key factors guide</th>
<th>Train speed</th>
<th>Consequences doubled for trains normally operating at speeds above 100 mph consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Consequences halved for trains normally operating at speeds below 40 mph consequences</td>
<td></td>
</tr>
<tr>
<td>Passenger loading</td>
<td>Average loading = 25%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consequences doubled for trains operating with average loadings of 50%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consequences halved for trains operating with average loadings of 12.5%</td>
<td></td>
</tr>
<tr>
<td>Rolling stock type</td>
<td>Consequences doubled if majority of rolling stock is Mark 1 type</td>
<td></td>
</tr>
<tr>
<td>Density of trains</td>
<td>Average approximately 7 trains/hour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50% increase in consequences for high density lines, average number of trains/hour &gt; 13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50% decrease in consequences for low density lines, average number of trains/hour &lt; 4</td>
<td></td>
</tr>
<tr>
<td>Presence of diesel trains</td>
<td>15% increase for all diesel trains</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5% decrease for all electric trains</td>
<td></td>
</tr>
<tr>
<td>Other factors</td>
<td>The workshop must consider other factors which may be above or below average and determine if any further allowances should be made</td>
<td></td>
</tr>
</tbody>
</table>

(The numbers and ranges quoted are examples and should not be used)
Guidance on the Preparation of Risk Assessments within Railway Safety Cases

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Appendix I

Hazardous event precursor assessment table – risk ranking based risk assessment

Draft for information only
(the numbers quoted are examples and should not be used)

(Example of Table B2 on the Guidance Note CD available from Railway Safety)

<table>
<thead>
<tr>
<th>Precursor category</th>
<th>SRM Precursor code/No.</th>
<th>Cause Precursor Description</th>
<th>Direct control (D), Interface issue (I) or No control (N)</th>
<th>If (I) or (N) Define other company responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
<td>(d)</td>
<td>(e)</td>
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<td>25</td>
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</tr>
</tbody>
</table>

(Table continues across to next page)
## Guidance on the Preparation of Risk Assessments within Railway Safety Cases

### Appendix I continued

<table>
<thead>
<tr>
<th>Cross reference to SMS in RSC</th>
<th>Duty holder frequency based on actual data for the duty holder or similar operation events/year</th>
<th>% of overall hazardous event frequency attributed to precursor</th>
<th>References to supporting data, assumptions, judgements and justifications for the data used</th>
<th>Potential additional control measures to reduce risk</th>
<th>Proposed strategy for each additional control measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>(g)</td>
<td>(h)</td>
<td>(i)</td>
<td>(j)</td>
<td>(k)</td>
<td>(l)</td>
</tr>
</tbody>
</table>
| (Table continued across from previous page)
## Appendix J

**Hazardous event consequences assessment table – risk ranking based risk assessment**

Draft for information only
(the numbers quoted are examples and should not be used)

*(Example of Table B3 on the Guidance Note CD available from Railway Safety)*

<table>
<thead>
<tr>
<th>1.</th>
<th>Hazardous event</th>
<th>Hazardous event frequency</th>
<th>Outcome</th>
<th>Probability of outcome</th>
<th>References to supporting data, assumptions and justifications for the probabilities used</th>
<th>Outcome frequency ranking</th>
<th>Existing control measures which control or mitigate the consequence(s)</th>
<th>Cross reference to SMS in RSC</th>
<th>Consequence ranking assumed for the duty holder operation</th>
<th>References to supporting data, assumptions and justifications for the consequence ranking used</th>
<th>Risk ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>(a)</td>
<td>(b) (HE-freq from Table A2)</td>
<td>(c)</td>
<td>(d)</td>
<td>(e)</td>
<td>(f)</td>
<td>(g)</td>
<td>(h)</td>
<td>(i)</td>
<td>(j)</td>
<td>(k)</td>
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<td>3.</td>
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<td>4.</td>
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<td></td>
</tr>
</tbody>
</table>

(Table continues across to next page)
## Appendix J continued

<table>
<thead>
<tr>
<th></th>
<th>Estimates for exposed group 1 individual risk (fatalities only)</th>
<th>Estimates for exposed group 2 individual risk (fatalities only)</th>
<th>ALARP assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Exposed group 1 consequence ranking</td>
<td>References to supporting data, assumptions, judgements and justifications for the consequences ranking used</td>
<td>Exposed group 1 consequence ranking</td>
<td>References to supporting data, assumptions, judgements and justifications for the consequences ranking used</td>
</tr>
<tr>
<td>2. (l)</td>
<td>(m)</td>
<td>(n) (f) + (l)</td>
<td>(o)</td>
</tr>
<tr>
<td>3.</td>
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<tr>
<td>4.</td>
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</tr>
</tbody>
</table>

(Table continued across from previous page)
Guidance on the Preparation of Risk Assessments within Railway Safety Cases

References

Railway Group Standards and other Railway Group Documents

GA/RT6001 Railway Group Standards Change Procedures
GA/RT6509 Guidance on Assessment by Railway Safety of Train and Station Operators’ Railway Safety Cases

The Catalogue of Railway Group Standards and the Railway Group Standards CD-ROM give the current issue number and status of documents published by Railway Safety

Other References

1 Safety Case Assessment Criteria published on the HSE web site www.hse.gov.uk/railway/criteria .
5 Railtrack Engineering Safety Management Issue 3 (Yellow Book 3).
9 Reducing Risks Protecting People (R2P2) HSE’s decision-making process. HSE 2001.
11 Railtrack HAZOP studies for the East Coast Main Line. EWI-2997.05 Revision 1. 04 August 1995.