Best practice international solutions for mitigating human factor causes of signal passed at danger

August 2016

A Moors, Interfleet Technology Ltd, Derby, UK

New Zealand Transport Agency research report 595
Contracted research organisation – Interfleet Technology New Zealand Ltd

ISBN 978-0-478-44569-5 (electronic)
ISSN 1173-3764 (electronic)

NZ Transport Agency
Private Bag 6995, Wellington 6141, New Zealand
Telephone 64 4 894 5400; facsimile 64 4 894 6100
research@nzta.govt.nz
www.nzta.govt.nz

Moors, A (2016) Best practice international solutions for mitigating human factor causes of signal passed at danger. *NZ Transport Agency research report 595*. 109pp.

Interfleet Technology New Zealand Ltd[1] was contracted by the NZ Transport Agency in 2014 to carry out this research.

This publication is copyright © NZ Transport Agency 2016. Material in it may be reproduced for personal or in-house use without formal permission or charge, provided suitable acknowledgement is made to this publication and the NZ Transport Agency as the source. Requests and enquiries about the reproduction of material in this publication for any other purpose should be made to the Manager National Programmes, Investment Team, NZ Transport Agency, at research@nzta.govt.nz.

Keywords: change management, driver error, human error, human factors, resilience, risk reduction, signal passed at danger (SPAD), SPAD intervention, systems approach

---

[1] On 5 January 2016, Interfleet Technology New Zealand Ltd became SNC-Lavalin Rail & Transit NZ Ltd.

An important note for the reader

The NZ Transport Agency is a Crown entity established under the Land Transport Management Act 2003. The objective of the Agency is to undertake its functions in a way that contributes to an efficient, effective and safe land transport system in the public interest. Each year, the NZ Transport Agency funds innovative and relevant research that contributes to this objective.

The views expressed in research reports are the outcomes of the independent research, and should not be regarded as being the opinion or responsibility of the NZ Transport Agency. The material contained in the reports should not be construed in any way as policy adopted by the NZ Transport Agency or indeed any agency of the NZ Government. The reports may, however, be used by NZ Government agencies as a reference in the development of policy.

While research reports are believed to be correct at the time of their preparation, the NZ Transport Agency and agents involved in their preparation and publication do not accept any liability for use of the research. People using the research, whether directly or indirectly, should apply and rely on their own skill and judgement. They should not rely on the contents of the research reports in isolation from other sources of advice and information. If necessary, they should seek appropriate legal or other expert advice.

Acknowledgements

A full list of references is provided within the report; however, we would like to acknowledge the contribution from the following sources:

- the 'Swiss Cheese Model' of accident causation developed by James Reason (UK) as a basis for understanding the human and organisational contribution to risk
- the Rail Management Maturity Model (RM^3)
- Manchester Patient Safety Framework (MaPSaF)

The research described in this report is largely based on contributions.

Thanks also to:

- the Steering Group: Chris Ballantyne (Chair), Principal Advisor, NZ Transport Agency; Jane Goulding, Team Leader Research, NZ Transport Agency; Michael Wilkinson (part), Senior Advisor, Ministry of Transport; Andrea Mackie (part), Senior Advisor, Ministry of Transport; Liam Sands, HSE Improvement & Innovation Analyst, KiwiRail; Phillip O'Connell Manager Zero Harm Systems, KiwiRail; Huw Bridges, General Manager – Safety & Compliance, Transdev; Grant Craig, President, Federation of Rail Organisations of New Zealand
- the external peer reviewer of the final report: Jessica Paton (Queensland Rail, Australia)
- the external peer reviewer for the literature review and final report: Ann Mills (Rail Safety and Standards Board, UK)
- Interfleet reviewers of the SPAD strategy evaluation tool: Bev Norris, Andrew Small, Thea Tester (Interfleet Technology, UK)
- external reviewers of the SPAD strategy evaluation tool: Chris Ballantyne (NZ Transport Agency), Phil O'Connell (KiwiRail), Grant Craig (FRONZ), Huw Bridges (Transdev).

Contents

Executive summary

Interfleet Technology[2] was commissioned to carry out a project on behalf of the New Zealand Transport Agency to identify best practice international solutions for mitigating human factor causes of 'signal passed at danger' (SPAD). SPADs are considered by the rail industry as a major safety issue as they carry the potential for high consequence accidents which generate significant reputational risk to the industry. The recorded number of SPAD has risen in recent years and this study was commissioned to identify:

- the human factor causes of SPAD that are most applicable in a New Zealand context
- best practice and relevant international solutions to address the human factors involved in a SPAD
- strategies for intervention to mitigate the risk of, and reduce the incidence of, SPADs in a New Zealand context
- barriers and risks to implementing identified solutions in New Zealand.

The first stage of the project comprised a literature review (see appendix B) of the full known range of possible human factors that can lead to a SPAD, the range of SPAD options already being utilised in rail operations and existing barriers and risks to the application of SPAD mitigations.

During the second and final part of the project, the focus of the scope of work changed in response to the Steering Group's input during the project. This led to the development and application of a SPAD strategy evaluation tool which aimed to:

- provide clear descriptions of excellence and describe a mature SPAD risk-reduction programme
- establish a common framework for use both by the regulator and duty holders
- allow the three rail organisations participating in the trial of the tool to identify their current strengths and weaknesses against each of the tool's dimensions
- allow the rail participants to make comparisons across different areas of their organisation in approach to SPAD risk reduction
- help drive continuous improvement
- support shared best practice.

The tool was applied in a self-assessment process by all participants.

The tool enabled consideration of various SPAD reduction strategy actions and identified the areas where these were likely to deliver positive benefit, placing the emphasis on a range of contributory causes and mitigation strategies and avoiding focusing on 'single' events. Both Participant 1 and Participant 2 found the tool and the process useful and are using the outputs to guide their future SPAD risk-reduction strategy.

Participant 3 found it more difficult to apply the tool and generally thought it less relevant to their organisation which is much less complex than those of Participants 1 and 2. The tool would benefit from minor modifications to remove less relevant points for small operators to improve applicability. One of the advantages of the tool is that it provides a dashboard of leading indicators. This is especially important for

---

[2] On 5 January 2016, Interfleet Technology New Zealand Ltd adopted the name of its parent group and became SNC-Lavalin Rail & Transit NZ Ltd.

those organisations, such as small heritage operators, that may not have comparable opportunities to learn from near misses in the way that larger operators do.

Abstract

This report describes the development and application of a tool to establish a framework for rail participants to explore their current strengths and weaknesses for SPAD risk reduction and to provide the New Zealand Transport Agency with an overview of the rail industry as a whole. The project was commissioned by the New Zealand Transport Agency and undertaken in November 2014 to August 2015 by Interfleet, with input from rail organisations and network access providers, identified as Participant 1, Participant 2 and Participant 3.

The tool is based on concepts derived from the 'Swiss cheese model' of accident causation. It comprises:

- a user guide which provides advice on the self-assessment process
- a Microsoft Excel spreadsheet which provides a tool with 16 dimensions of factors that impact on SPAD risk covering organisational factors, work processes and practices, work environment and workplace and individual factors.

The tool demonstrated that significant value can be gained by shifting organisational and regulatory focus from simple lag indicator assessment to clearly identifiable improvement opportunities as an indicator of safety system capability and reliability.

1 Introduction

1.1 Background

Interfleet carried out a research project on behalf of the New Zealand Transport Agency (hereafter referred to as 'the Transport Agency') relating to the human factors (HF) underlying 'signal passed at danger' (SPAD) events. The research project took place from December 2014 to August 2015. It was managed by Interfleet Technology New Zealand Ltd with HF expertise supplied by Interfleet Technology Ltd (UK).

SPADs are considered by the rail industry as a major safety issue as they carry the potential for high consequence accidents which generate significant reputational risk to the industry. The recorded number of SPADs in New Zealand has risen in recent years and this study was commissioned to identify:

- which human factor causes of a SPAD are most applicable in a New Zealand context
- best-practice and relevant international solutions to address the HF involved in a SPAD
- strategies for intervention to mitigate the risk of and reduce the incidence of SPADs in a New Zealand context
- barriers and risks to implementing identified solutions in New Zealand.

There were two distinct phases to the research:

1 The first part of the project was completed in January 2015 and constituted a literature review to re-examine the scientific theory underpinning the HF approaches to SPAD mitigation (see appendix B). It focused on using knowledge of human behaviour (the train driver and other railway staff) to understand the causation of SPAD and how this is influenced by the wider railway system. The review identified a range of SPAD mitigations that have been developed from this theory, thereby providing provenance and a theoretical basis to current international SPAD interventions.

   The specific objectives for the literature review were to:

   a document the full known range of possible HF that can lead to SPAD

   b understand the range of SPAD options already being utilised in rail operations

   c document the existing barriers and risks to application of SPAD mitigations into operations elsewhere.

   The findings from the literature review were used to inform the second part of the project.

2 The scope and objectives of the research are set out in the following sections. This report has been subject to peer review in order to ensure that the methodology used, and the findings and conclusions of the report are suitable and robust.

   An earlier draft of this report was read and considered by a project Steering Group representing the Transport Agency and different stakeholders within the New Zealand rail industry in order to agree on the content for the final report.

1.2 Scope

The original methodology proposed to undertake workshops with New Zealand rail organisations to analyse options for proposed mitigations for use in the New Zealand context and to recommend mitigations for best success on the New Zealand railway network, taking into consideration the context of application. However, the scope of this part of the work was altered in view of findings from the initial stage of work. The literature review clearly showed that SPAD risk mitigations should be multi-factorial to address the different causes of SPAD events and it was agreed following the Steering Group meeting it would be of more benefit to the Transport Agency and the industry to focus on better understanding the layers of protection currently in place. As such, this research report concentrates on delivering this goal, producing outputs that are useful to both the Transport Agency and other project stakeholders and promoting good engagement with industry.

In line with the Steering Group's desire to better understand how the current SPAD strategies fit within a 'Swiss cheese' model of layers of protection, Interfleet developed and applied a SPAD strategy evaluation tool to assess the layers of protection currently in place for rail operators in New Zealand.

1.3 Objectives

The Transport Agency's overall objective for the research was to 'develop a better understanding of how the current SPAD strategies fit within a "Swiss cheese" model of layers of protection'.

Interfleet's specific objective for this final stage of work was to develop and apply a tool that helps rail organisations and network access providers to:

- understand the levels of protection that are important to reducing SPAD risk
- evaluate the effectiveness of their organisation's levels of protection
- develop an implementation plan for improving SPAD risk reduction.

While the SPAD strategy evaluation tool is designed to be used by an individual organisation, the outputs from each organisation can be used to give an overall view of the way the New Zealand rail industry as a whole manages SPAD risk reduction. The SPAD strategy evaluation tool was developed to achieve the following aims:

- Provide clear descriptions of excellence and describe a mature SPAD risk reduction programme.
- Establish a common framework between the regulator and duty holders, facilitating communication and clarity, and strengthening relationships between the rail regulatory body and industry stakeholders.
- Allow rail organisations to identify current strengths and weaknesses against each of the SPAD dimensions in the tool.
- Allow rail organisations to make comparisons across different areas of the organisation in their approach to SPAD risk reduction.
- Help drive continuous improvement.
- Support shared best practice.

1.4 Structure of this report

- Chapter 2 describes the method used to develop the SPAD strategy evaluation tool, to implement it and interpret the results.
- Chapter 3 describes the SPAD strategy evaluation tool itself, including the user guide and the Excel spreadsheet.
- Chapter 4 provides a summary of the findings for the organisations that undertook a self-assessment process using the tool.
- Chapter 5 reflects on the usability and efficacy of the tool in achieving the stated aims.
- Chapter 6 summarises conclusions from the whole research project.
- Appendix A, part 1 contains the user guide for the SPAD evaluation tool. The Excel spreadsheet is published separately as appendix A, part 2 at www.nzta.govt.nz/resources/research/reports/595/.
- Appendix B contains the literature review and appendix C is the glossary.

2 Method

2.1 Best practice review

This section outlines key points from the best practice literature review and how they were used as a basis for developing the SPAD strategy evaluation tool. The full findings from the literature review are reported in appendix B.

2.1.1 Range of contributory factors and interventions

The literature review sets out a range of human and system influences that contribute to the risk of SPAD and is based on the systems approach and the Swiss cheese model (Reason 1990) of safety which is widely accepted within rail and other high hazard industries. The systems approach enables SPAD to be assessed from many different angles, from the level of the individual (driver, signaller), the workplace and the organisation. The Swiss cheese model provides a means to define the layers of protection that are important to managing and controlling risk of SPAD. The conclusion from the literature review is that there is a wide range of factors contributing to driver error and risk of SPAD and consequently there is the need for a broad spectrum of SPAD reduction strategies to provide and maintain layers of protection. Understanding the full range of these factors is essential to defining a strategic approach to SPAD reduction rather than focusing on driver actions or tackling SPAD risk reduction in a piecemeal fashion. Historically, SPAD management has tended to focus on engineering interventions. However, in general, these do not fully address all the contributory causes of SPAD and can create new error modes in the system.

The literature review contains a comprehensive description of the SPAD tools and strategies used within the UK and internationally, and highlights some of the problems that have been encountered with implementation. Interventions include:

- SPAD investigation, data collection and analysis to provide a basis to prioritise interventions
- tools to aid signal sighting and route design
- strategies to manage personnel with safety-critical responsibilities
- workplace and equipment controls
- driver risk reduction strategies.

2.1.2 Effectiveness of change programmes

The literature review revealed a general lack of published research relating to barriers encountered during implementation programmes of specific interventions. However, the review drew on a large body of knowledge to provide useful lessons on barriers to change in the context of rail and how to manage change in order to ensure the SPAD risk reduction interventions are embedded within organisations in a successful and sustainable way.

2.1.3 Leading indicators

The review uses the recent concept of ‘resilience engineering’ (Hollnagel et al (2006) to suggest meaningful ways of measuring the effectiveness of proposed interventions and monitoring the health of the organisational system. It also advocates using leading indicators. Leading indicators are proactive, forward-looking measures that can identify performance degradation or deterioration of the system prior to an incident. This contrasts with 'lagging indicators' – measures such as accident statistics which measure incidents after they occur. The emphasis is to refocus safety management from 'avoiding things going wrong' to 'ensuring that everything goes right', fostering a proactive approach that sustains everyday acceptable performance, rather than one that prevents hazards from being realised.

The review describes how the oil and gas industry has tried to take this concept on board by developing 'leading indicators' to monitor the effectiveness of control systems and give advance warning of any developing weaknesses before problems appear. This is the approach that has been taken in developing the SPAD strategy evaluation tool as it attempts to check the organisational defences in place that impact on SPAD risk.

It is not intended as a replacement for more traditional 'lagging' indicators such as SPAD frequency, rather as a complementary approach. It will also benefit organisations that do not have measurable data of lagging indicators.

2.2 SPAD strategy evaluation tool

2.2.1 Basis for the tool

The tool was developed using the international best practice literature review, the Swiss cheese model (Reason 1990), the Railway Management Maturity Model (RM^3) (ORR 2011) and the Manchester Patient Safety Framework (MaPSaF) (University of Manchester 2006). Additional input came from rail experts within Interfleet and from the Transport Agency and New Zealand rail operators. The underlying concepts of the Swiss cheese model, RM^3 and MaPSaF as applied to the tool are described here.

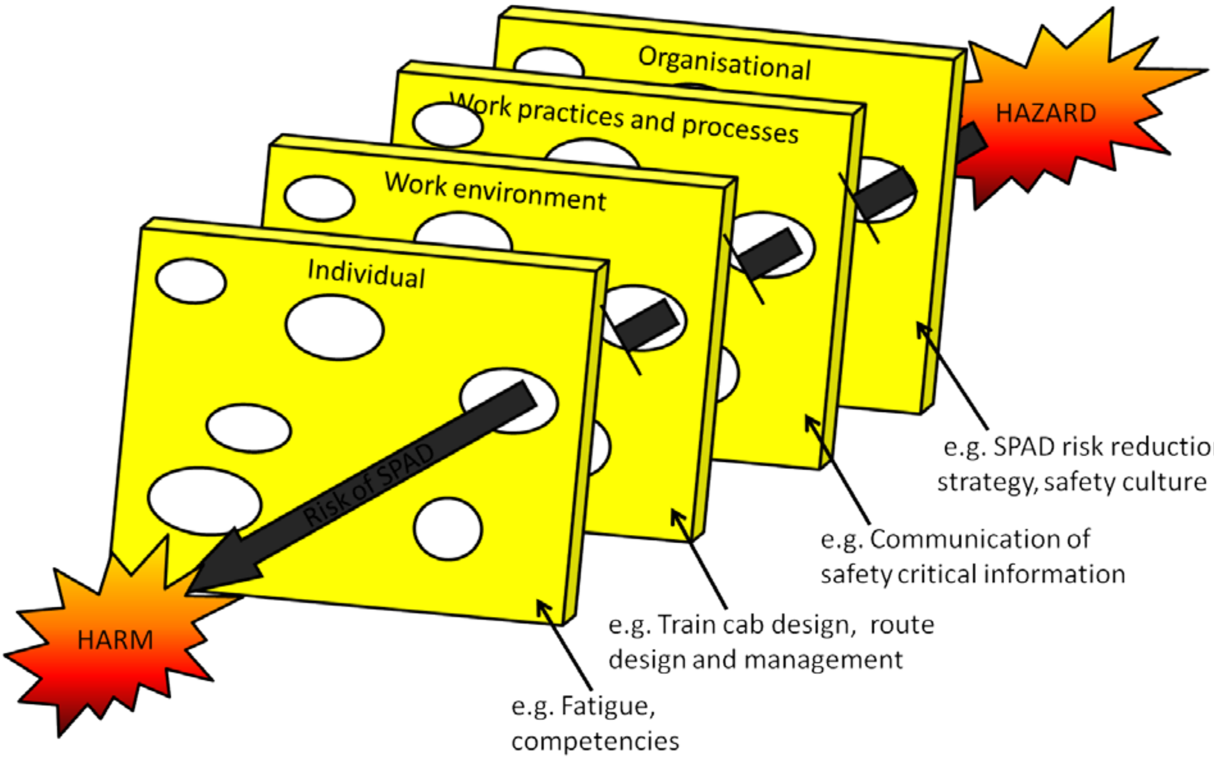
2.2.1.1 Swiss Cheese and systems approach

The international best practice literature review identified the importance of a multi-factorial model of SPAD causation and SPAD risk reduction. In particular, the Swiss cheese model is a commonly used model of accident causation which is discussed in the international best practice literature review and is widely known within rail and other high hazard industries. It describes layers of protection within the organisation used to control risk. The layers of protection are likened to 'slices of cheese'. For example fatigue management – through good practice in rostering, monitoring and managing working hours and shift work –provides a layer of protection against the effects of fatigue. The principle of the model is that at any one time there will be weaknesses and inadequacies in these layers of protection. These are likened to the 'holes' in the Swiss cheese. Incidents occur when these holes align – usually in unique ways and often coinciding with an 'active' failure in some way by front line staff, for example inattention or distraction (see figure 2.1).

A systems approach, in the context of HF assessment, is predicated on the principle that humans (or train drivers) cannot be expected to perform 100% error free and that human error can, to some extent, be predicted. This approach has been taken by the UK rail industry which has resulted in a framework of SPAD risk reduction strategies that tackle underlying causes of SPAD at the level of the individual, the workplace and the organisational processes. The SPAD strategy evaluation tool described in this report is based on this model. The tool identifies layers of protection in the form of dimensions that fall within four categories:

- organisational factors
- work practices and processes
- work environment
- individual factors.

Figure 2.1 Simplified Swiss cheese model



2.2.1.2 Railway management maturity model (RM³)

RM³ was published as a tool for UK inspectors assessing duty holders' safety management systems against the requirements for the Railways and other Guided System Regulations 2006. It provides a measure of management capability by means of a five-point maturity scale for key elements of an organisation's safety management system (SMS), and it provides a useful tool for setting the standard for SMS and measuring continuous improvement towards excellence. It is used within the UK railway industry and is increasingly influencing activity in Europe through its adoption by the European Railway Agency.

The SPAD strategy evaluation tool was developed with consideration to the RM³ framework. To this end, key aspects for adapting the RM³ framework were:

- dimensions such as organisational culture were adapted to better fit the context of SPAD risk reduction
- many RM³ dimensions were excluded on the basis of not being relevant to SPAD risk reduction
- additional dimensions specific to SPAD risk reduction were developed, eg train management systems and timetabling.

The full set of dimensions included in the SPAD strategy evaluation tool is provided in table 2.1.

Table 2.1 Dimensions in the SPAD strategy evaluation tool

Organisational	**Work practices and processes**
Planning and implementing SPAD risk reduction strategy Organisational culture Incident response and investigation Managing change Leadership	Communication of safety critical information Timetabling Operational procedures Driver strategies
Work environment	**Individual**
Design and management of route and infrastructure Train management systems Train cab design	Competencies Teamwork Fatigue management Workload

2.2.1.3 Manchester patient safety framework

The Manchester patient safety framework (MaPSaF) is a tool that has been used in the UK National Health Service to help healthcare organisations and teams assess their progress in developing a safety culture.

MaPSaF proposes 10 dimensions of patient safety and, for each of these, describes five levels of increasingly mature organisational safety culture. The 10 dimensions were developed from a variety of sources such as literature review about patient safety in primary care and the National Health Service (NHS) in general, feedback from opinion leaders and interviewees and focus group discussions with senior managers and clinical specialists. The 10 dimensions all relate to aspects of safety culture and so have parallels with the dimensions in the RM[3]:

1 Commitment to overall continuous improvement

2 Priority given to safety

3 System errors and individual responsibility

4 Recording incidents and best practice

5 Evaluating incidents and best practice

6 Learning and effecting change

7 Communication about safety issues

8 Personnel management and safety issues

9 Staff education and training

10 Team working.

A key aspect of MaPSaF is that it comprises a self-assessment process that brings together different perspectives. It is carried out in interactive workshops led by a facilitator and is intended to generate collaborative relationships and insightful discussion. The collaborative feature of MaPSaF was seen as a desirable element to retain within the SPAD strategic evaluation tool. Like the MaPSaF framework, it is envisaged that the SPAD strategic evaluation tool can be used in different ways, for example:

- to facilitate reflection on the maturity of different aspects of the organisation that impact on SPAD risk

- to stimulate discussion about the strengths and weaknesses of the organisational processes and potentially to reveal differences in perception between staff groups
- to help understand the principle features of a mature SPAD risk reduction strategy
- to help evaluate any specific intervention needed to improve the SPAD risk reduction strategy.

The findings from the self-assessment process can be used by organisations as inputs to further workshops to develop sustainable solutions.

2.2.2 Iterative development

Interfleet developed a set of four categories of dimensions that impact on SPAD risk, based on the Swiss Cheese/systems approach to accident causation. These were then subdivided into 16 critical dimensions as shown in figure 3.1. For each critical dimension, descriptive text relating specifically to SPAD risk reduction was developed to describe a continuum towards excellence.

2.2.2.1 Internal review

The first draft was reviewed and amended iteratively using specialist expertise from the domains of HF, rail safety management and assurance, and New Zealand rolling stock engineering.

2.2.2.2 Review of Participant 1's and Participant 2's SPAD risk reduction strategies

The existing SPAD risk reduction strategies employed by Participant 1 and Participant 2 were reviewed to ensure the tool was cognisant of, but not limited to the programmes currently being undertaken.

2.2.2.3 External review

After internal checking and review, the tool was reviewed by project stakeholders. This identified missing layers of protection, added context and clarified terminology.

2.2.2.4 Following first application

The tool incorporated minor amendments following its first application with Participant 1.

2.2.3 Review of SPAD risk reduction strategies

As part of the development of the tool, the SPAD risk reduction strategies currently employed by Participant 1 and Participant 2 were reviewed to ensure the tool was comprehensive and to gain an initial understanding of the likely outcomes of the evaluation.

2.2.4 Structured assessment

As the application was only to three organisations, no attempt was made to complete a quantitative analysis of the efficacy of the tool. However, structured feedback was sought during the application of the tool using the statements in table 2.2 against a 'Likert scale' of 1 to 5. The results are provided in chapter 5 of this report.

Table 2.2 Questions for structured feedback on the tool

Content	Interface
The content is relevant to this organisation and SPAD risk reduction. The user guide is easy to understand. The tool is easy to understand. The content of the tool is comprehensive. The level of knowledge required before using the tool is prohibitive to its use. I find the output of the tool useful. I find the process of using the tool helpful. The tool is too resource intensive.	The interface is simple to use. The interface is error tolerant. The tool is easy to learn. The tool is intuitive to use. The tool is cumbersome to use.

2.2.5 Application methodology

There were three applications of the tool, one each with Participant 1, Participant 2 and Participant 3. Table 2.3 records the roles of the participants present. The mix of expertise in the first workshop worked particularly well, as it enabled both an understanding of the organisational systems and, through individual experience and participation in driver subject matter expert workshops, a good perspective on frontline operational aspects.

Table 2.3 Roles of New Zealand rail organisation participants

Participant 1	Participant 2	Participant 3
National Manager Health Safety and Environment, Improvements and Innovation Professional Head Signals and Telecommunication Senior Rail Accident Investigator (also has current train driving licence so brings driving operational knowledge to the process)	General Manager, Safety & Assurance Operations Standards Manager	Operations Manager

The tool is designed to encompass a self-assessment process that engages frontline staff and line managers in addition to higher-level management. However, the desired level of integration was not achieved within this project.

3 The SPAD strategy evaluation tool

The aim of the SPAD strategy evaluation tool is to help infrastructure managers and railway operators evaluate the way their organisation addresses SPAD risk.

The tool can be used to understand the different organisational practices and processes that provide resilience against SPAD risk. It should be used to promote discussion about the initiatives that work well within an organisation, what can be improved, the benefits from improvements and any barriers or limitations.

It provides a consistent means of evaluating resilience of the organisation at different levels – namely organisational factors, working practices and processes, work environment and workplace, and individual factors.

The tool consists of a user guide and a Microsoft Excel spreadsheet. The user guide is attached as appendix A, part 1 and the spreadsheet (appendix A, part 2) is located at www.nzta.govt.nz/resources/research/reports/595/.

This chapter provides an overview of the tool.

3.1 User guide

As the tool is designed as a self-assessment tool, rather than an external audit tool, the user guide contains information regarding the process by which the tool should be applied to generate the greatest benefits in terms of:

- helping users to understand there is no 'one fix' to SPAD risk and that all parts of the organisation need to be considered.
- promoting discussion from different perspectives within the organisation about what works well, what can be improved, the benefits from improvements and any barriers or limitations.
- sharing ownership of problems and solutions.

The user guide provides a background to the tool, its aims and objectives and gives detailed guidance on how to use the tool as a self-assessment process to inform the SPAD risk reduction programme. The self-assessment process comprises five steps as follows:

Step 1: Assign roles and responsibilities; define the remit, appoint a champion, get the right people together.

Step 2: Work through the matrix.

Step 3: Develop a plan; interpret of the results.

Step 4: Present and disseminate.

Step 5: Monitor and review.

The user guide recommends a workshop setting with multiple people, as this enables experience and perspectives to be shared and contributes to the development of a learning culture within the organisation.

3.2 SPAD strategy evaluation spreadsheet

The Excel spreadsheet has three worksheets:

1. Front sheet. This records details pertinent to the assessment such as date, participants, version control and scope of the assessment.
2. Evaluation matrix. This worksheet outlines the categories and dimensions against which organisations assess their levels of performance in terms of SPAD risk reduction, recording the evidence and identifying potential improvement opportunities.
3. Organisational profile. This worksheet provides a graphical profile of the scores against each dimension.

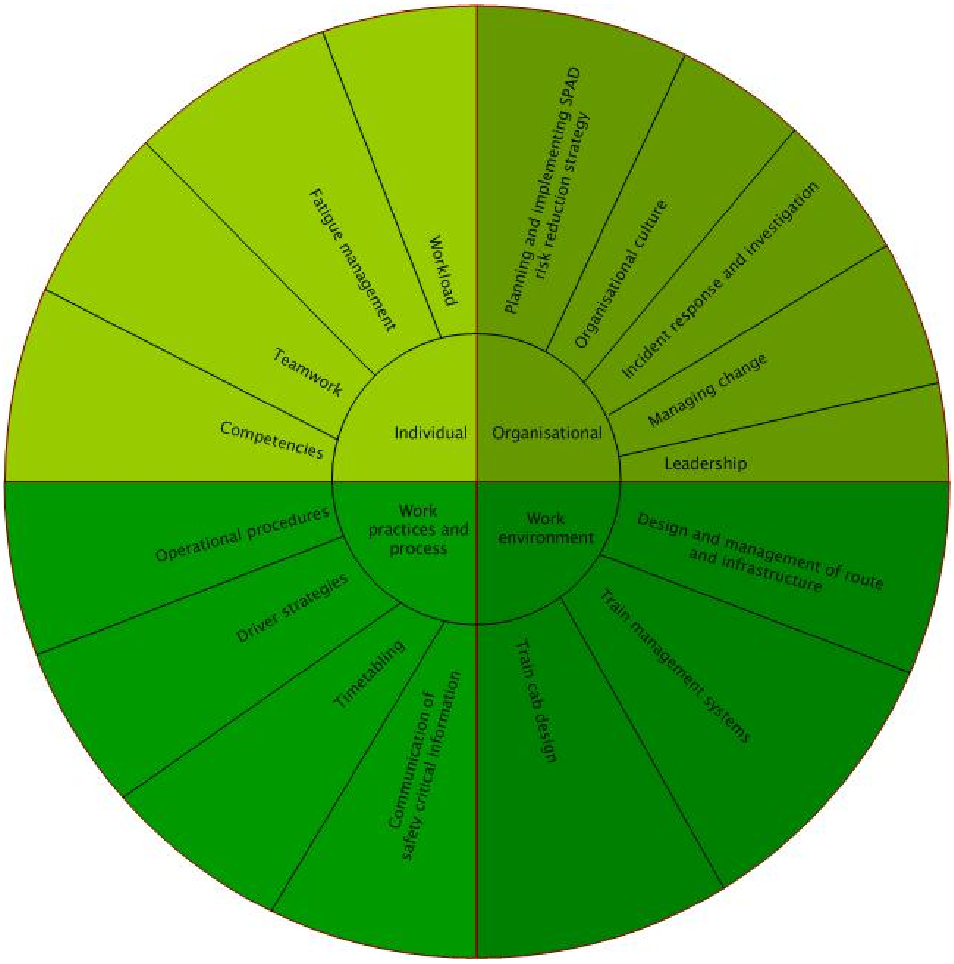
The evaluation matrix and organisational profile are described below in more detail.

3.2.1 The evaluation matrix

3.2.1.1 Categories and critical dimensions

The evaluation matrix presents the four categories (inner circle) and 16 critical dimensions (the layers of protection, outer circle) as illustrated in figure 3.1.

Figure 3.1 Four categories and their critical dimensions



For each dimension, there is a description of how effective or 'mature' that dimension is, on a scale of 1 to 5. They correspond with those used in the RM[3] and are similar to those used in other high hazard industries to assess the maturity of safety culture within an organisation. Each level has examples of SPAD management activities or approaches to help the participants match their organisation to a level. Participants read and discuss which description best fits their organisation. An example for one of the dimensions is provided in table 3.1.

Table 3.1 Example of a dimension with five levels of excellence from the SPAD strategic evaluation tool

Level	Planning and implementing SPAD risk reduction strategy
Level 1	There is no SPAD risk reduction strategy or it exists but is out of date or has not been effectively communicated within the organisation. There is no evidence of employees being consulted.
Level 2	The SPAD risk reduction strategy is up to date and is communicated within the organisation, but local managers and supervisors have inconsistent approaches or interpretations. This results in the strategy being applied in different ways across the organisation. The strategy is not seen as vital to maintaining railway safety.
Level 3	The SPAD strategy encompasses accident investigation and analysis, route and signal design and management (infrastructure managers only), train systems and crew management (train operating companies only). The SPAD risk reduction strategy is used as a focus for managers, which results in them being interpreted in the same way by all staff. Employees are actively involved in reviewing and revising the SPAD risk reduction strategy and how it is applied.
Level 4	The SPAD strategy encompasses accident investigation and analysis, route and signal design and management (infrastructure managers only), train systems and crew management (train operating companies only). The SPAD risk reduction strategy is consistent with the actions of everyone acting in the management chain. There is evidence of extensive collaboration throughout the management chain. The SPAD risk reduction strategy includes a realised commitment to continually improving the efficiency and effectiveness of risk controls. There is measurement of the efficacy of SPAD interventions. The SPAD strategy has a risk-based approach.
Level 5	The SPAD strategy encompasses accident investigation and analysis, route and signal design and management (infrastructure managers only), train systems and crew management (train operating companies only). The SPAD risk reduction strategy is used to challenge the organisation to achieve business performance that is in line with the best-performing organisations. There is proactive monitoring and measurement of the SPAD risk reduction programmes, the results of which are used to effect continual improvement of the strategy. The SPAD strategy has a risk-based approach. There is a consistent method for risk ranking SPAD, interventions that target high-risk SPAD are prioritised.

3.2.1.2 Improvement opportunities

It is possible there will be different opinions within any individual group and that no one box provides an entirely suitable fit. In such cases, the level that is closest to the organisation should be chosen and the evidence for this recorded along with the improvement opportunities.

The level chosen is recorded on the spreadsheet, along with evidence for the choice and identification of opportunities to improve towards best practice. The user guide suggests it is useful to provide notes on and evidence of:

- existing measures in place
- whether/how effectiveness is monitored
- weaknesses
- assumptions/judgements used to assign criteria.

It is considered that the most important parts of the discussion to capture are the improvement opportunities, as these may be used to develop implementation plans for SPAD risk reduction and to steer future SPAD risk reduction strategies.

3.2.2 Organisational profile

The scores that are identified during the session are recorded on the evaluation matrix and these are transferred automatically to a third worksheet which illustrates them as a graphical profile or snapshot of the organisation.

It should be noted that the descriptions of each dimension are qualitative so, although the overview gives a snapshot view, values are not necessarily equivalent across dimensions. For example, a '2' score for workload is not equal to a '2' for fatigue management in any quantitative way. The purpose of the snapshot is to highlight areas of weakness and excellence and to prompt discussions around potential risk reduction strategies.

Figure 3.2 Summary profile for Participant 1

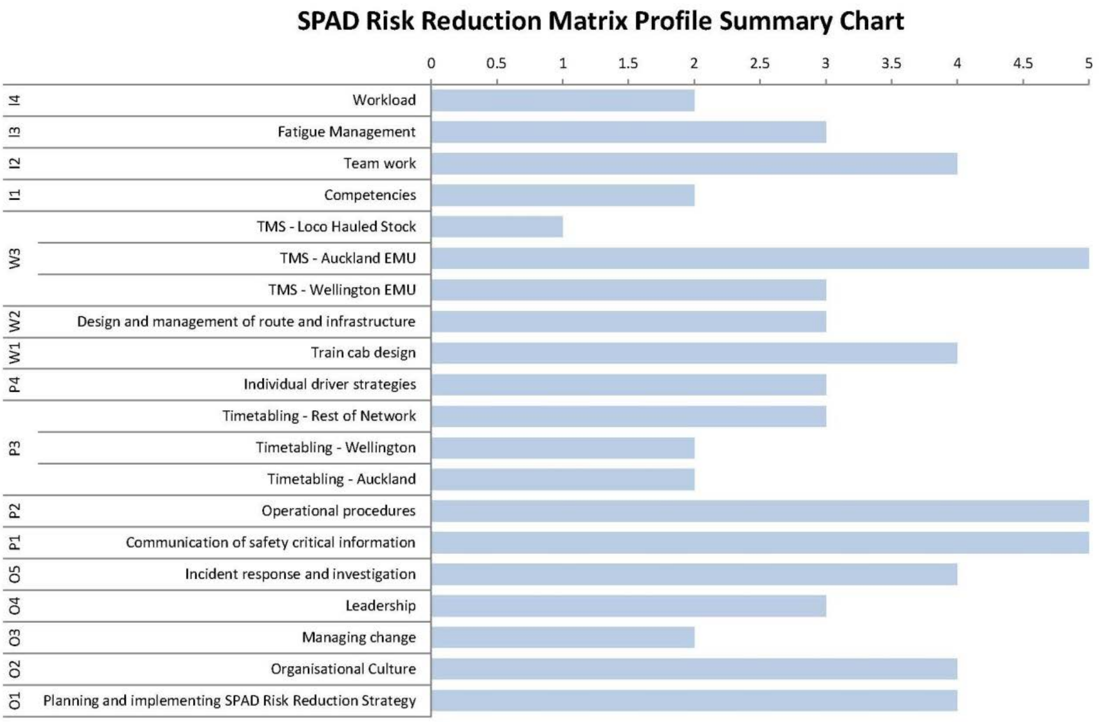
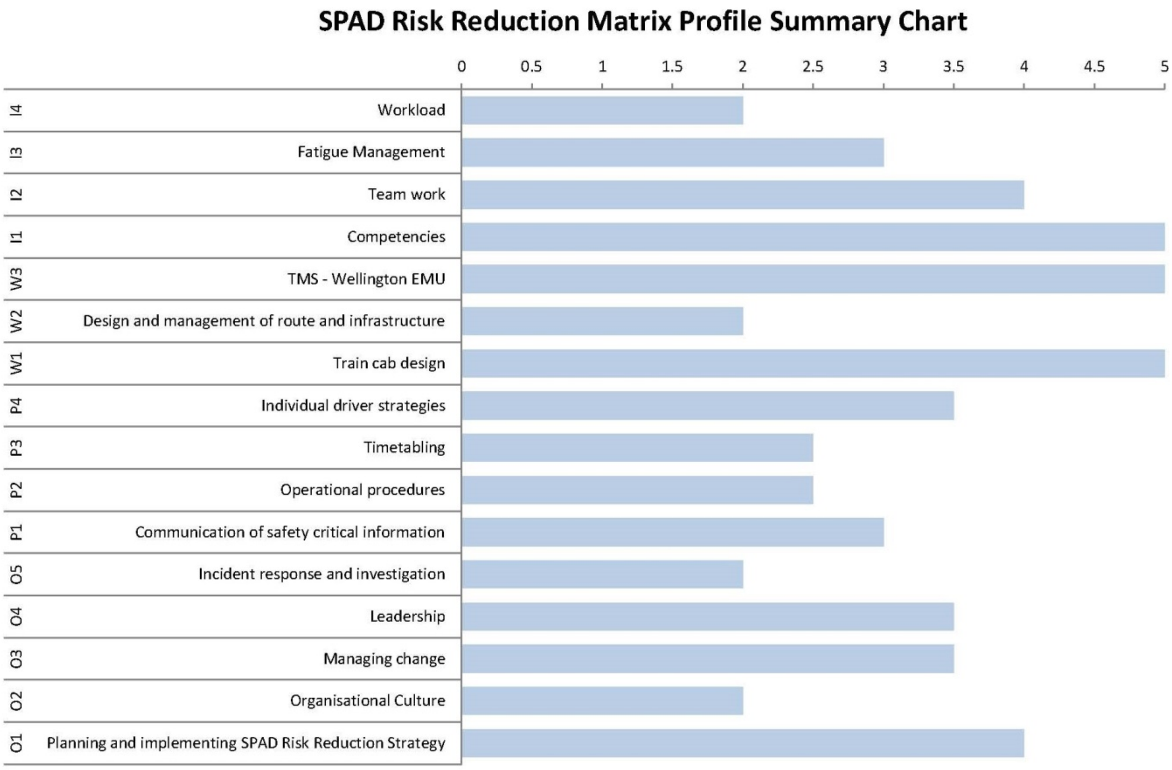


Figure 3.3 Summary profile for Participant 2



4 Self- assessment findings

The subsections below provide:

- an overview of the context of New Zealand rail operations relevant to SPAD risk
- a summary of findings for Participant 1 and Participant 2 for each category of dimensions – namely organisational factors, work processes and practices, workplace and work environment, and individual factors
- a summary of findings from Participant 3 – note these have been separated out as no score was obtained during application of the tool, and the nature and context of operations of the organisation are very different from those of Participants 1 and 2.

4.1 The context of New Zealand rail operations

4.1.1 The New Zealand national rail system

Key features of the New Zealand national rail system (NRS) are summarised below:

- The Wellington and Auckland suburban areas accommodate comparatively high density metropolitan passenger operations.
- Locomotive-hauled services operate across the entire NRS.
- Participant 3 services operate on both the NRS and a private branch line that only has signals at the point of connection to the NRS.
- On the NRS, locomotive-hauled passenger and freight trains share the network with metro services operating in the Wellington and Auckland suburban areas. This mix of traffic results in heavy freight trains operating amongst more agile multiple unit and carriage stock with very different braking capabilities.
- Train separation on the NRS is managed with colour light signalling, track warrant control and a paper-based limit of authority system.
- Operational procedures and traditional railway engineering controls such as signal overlaps, catch points, mechanical train stops and track circuit interrupters have been deployed to mitigate against SPAD risk.
- On most of the NRS, trains operate by driver-only operation without any form of automatic train protection (ATP).
- The European train control system (ETCS) has been deployed across the Auckland suburban rail network.

4.2 Summary of findings for Participants 1 and 2

This section provides a summary of the findings for Participants 1 and 2. As they were successful in using the tool to provide a numerical rating, charts are provided giving a visual representation of their self-assessment of the effectiveness of the dimensions.

4.2.1 Organisational factors

Figure 4.1 shows the scores for Participants 1 and 2 for organisational factors that contribute to SPAD risk reduction. Both Participants 1 and 2 scored highly for the implementation of their respective SPAD risk reduction strategies. Both have strategies that follow a multimodal approach.

Participant 1's strategy encompasses improved incident investigation and analysis, driver management, signalling systems and technological solutions. Participant 1 considers that its strategy has a high degree of commitment from senior management. However, Participant 1 acknowledges room for improvement as they perceive there to be less commitment to the strategy by middle management – particularly from personnel that have less experience in rail operations.

Participant 2 has delivered a SPAD risk reduction strategy for 2013 and, at the time of writing this report, Participant 2 is having the 2015 SPAD risk reduction strategy reviewed at board level. The strategy encompasses the following elements:

- enabling and leadership
- recruitment and selection
- education and training of staff with safety critical responsibilities
- competence management
- engineering (trains and systems/infrastructure)
- information and data management.

Figure 4.1 Organisational factors for Participants 1 and 2

Note that the relative size of the circles is a reflection of the number of critical dimensions to which the score applies.

Although Participants 1 and 2 have similar scores for their SPAD risk reduction strategies and leadership, Participant 1 presented a significantly better assessment of their organisational culture and of their incident reporting and investigation. Participant 2 is aware of legacy issues with integrating Participant 1 staff into its workforce and has undergone changes to its senior management team which should improve the development of good communications within Participant 2 and promote a just and fair culture going forward. In particular, Participant 2 has plans to co-locate line managers with train crews to improve team working and communications.

4.2.2 Work practices and processes

Figure 4.2 Work practices and processes for Participants 1 and 2

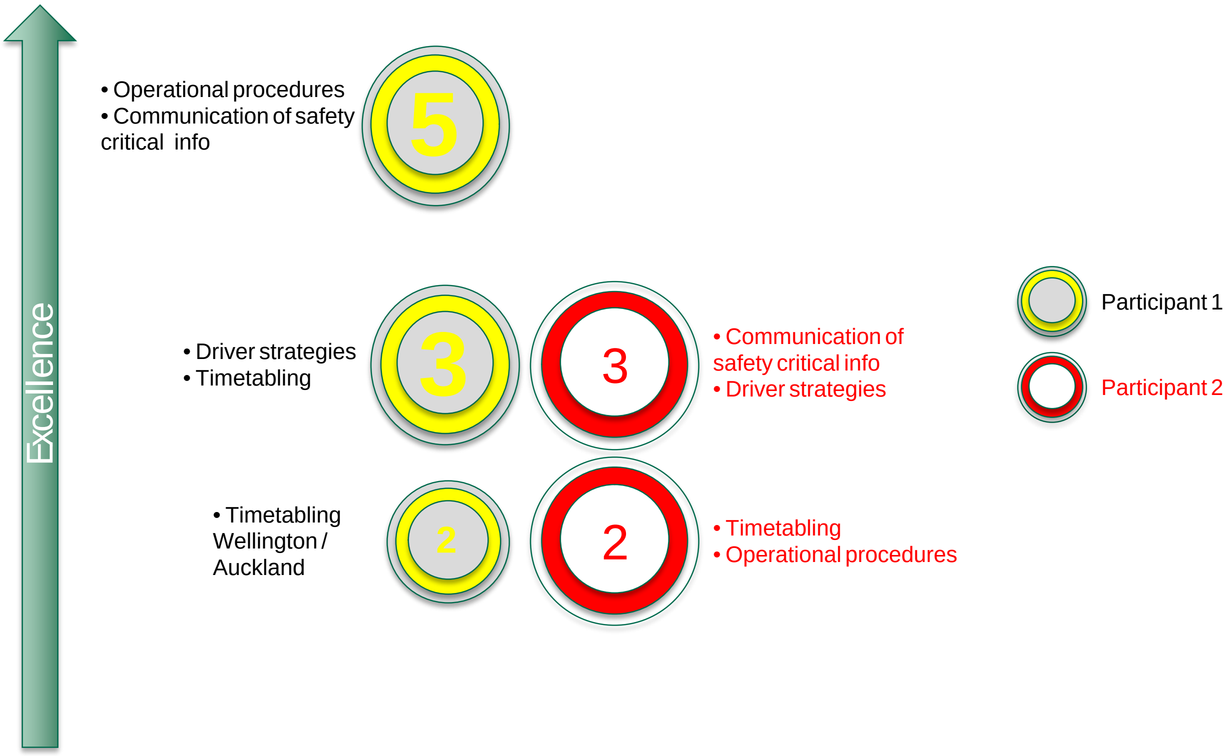


Figure 4.2 compares the self-assessment findings identified by Participants 1 and 2 for their work practices and processes.

Participant 1 scored highly for operational procedures as it was felt that good engagement exists with frontline staff in the development of procedures and the driver subject matter expert group is influential. Participant 1 would be open to a shared forum with a similar group from Participant 2 to share knowledge, problems and solutions. The findings indicated Participant 2 had a mixed record for considering SPAD risk within the development of operational procedures.

Overall, it was noticeable that timetabling is an area that would benefit from improvement. Introduction of the new electrical multiple units (EMUs) in Auckland has evidently not provided the anticipated benefit to journey times – possible reasons for this include increased dwell times and driver inexperience with train characteristics during the transition phase. There was a general perception that the Auckland and Wellington timetables would benefit from increased resilience to perturbations such as rostering failure and train failure. Poor timetabling can lead to time pressures and route conflicts which can increase stress on the driver, leading to increased SPAD risk

Participants 2 and 1 felt they achieved level '3' for driver strategies, both having work underway to understand and improve driver techniques:

- Participant 2 is presently reviewing driver strategies for passing signals at caution
- Participant 1 is reviewing 'risk-triggered commentary driving' and strategies to reduce 'start against red' SPAD.

Participant 1's assessment of how safety critical information is communicated within the organisation was very positive, whereas Participant 2's was more moderate. However, Participant 2 does have face-to-face communications for driver 'booking on' and good quality poster information on SPAD.

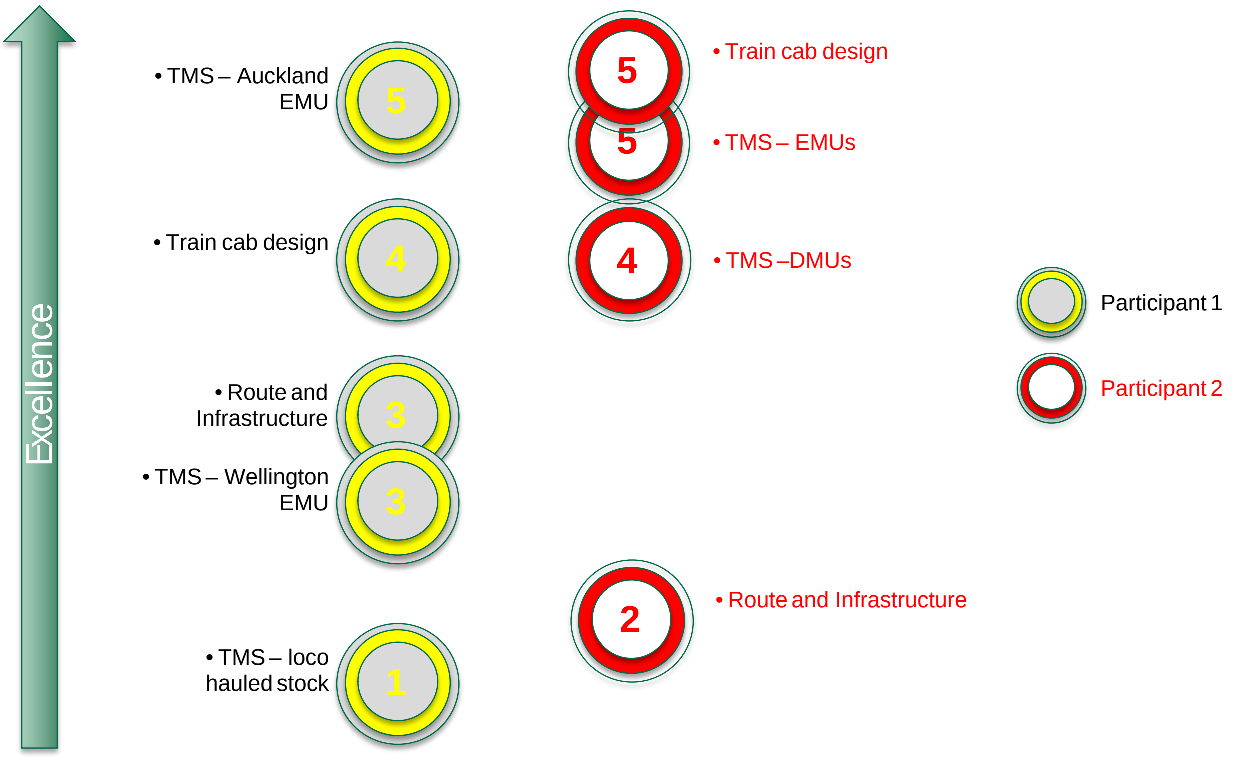
Participant 2 identified the following areas for improvement:

- reduce paperwork for driver 'booking on'
- provide more formalised briefings
- consider different ways of communicating the same message, eg using the TV screen to show interesting SPAD information.

4.2.3 Work environment and workplace

Figure 4.3 shows the summary of scores for work environment and workplace.

Figure 4.3 Work environment and workplace for Participants 1 and 2



The diesel multiple unit and locomotive-hauled rolling stock is thought to be less well designed than the newer EMU rolling stock built using European standards that integrate HF into the design process. Participant 1 rated this process less highly than Participant 2, as the latter perceived the input of drivers to the process as being somewhat unstructured and unsystematic.

Train management systems that demonstrate higher levels of automatic protection such as ETCS scored more favourably. The results for train management systems reflect the variation in rolling stock in use on the network.

There has been a significant amount of change to the network infrastructure in the Auckland suburban area in recent years, including commissioning of electrification, additional tracks, signalling and signalling systems. Design and management of the route and infrastructure shows clear room for improvement due to a present lack of signal standards and variability in signal sighting committees in particular (remit, roles efficacy). A clear plan for improving the remit, scope, objectives and process for the signal sighting committees should be included within future SPAD strategies. It was felt that this area should be explored in more detail, as time did not allow for sufficient clarity to be gained in regard to specific failings of the sighting committees and objectives for improvement.

4.2.4 Individual factors

Figure 4.4 Individual factors for Participants 1 and 2

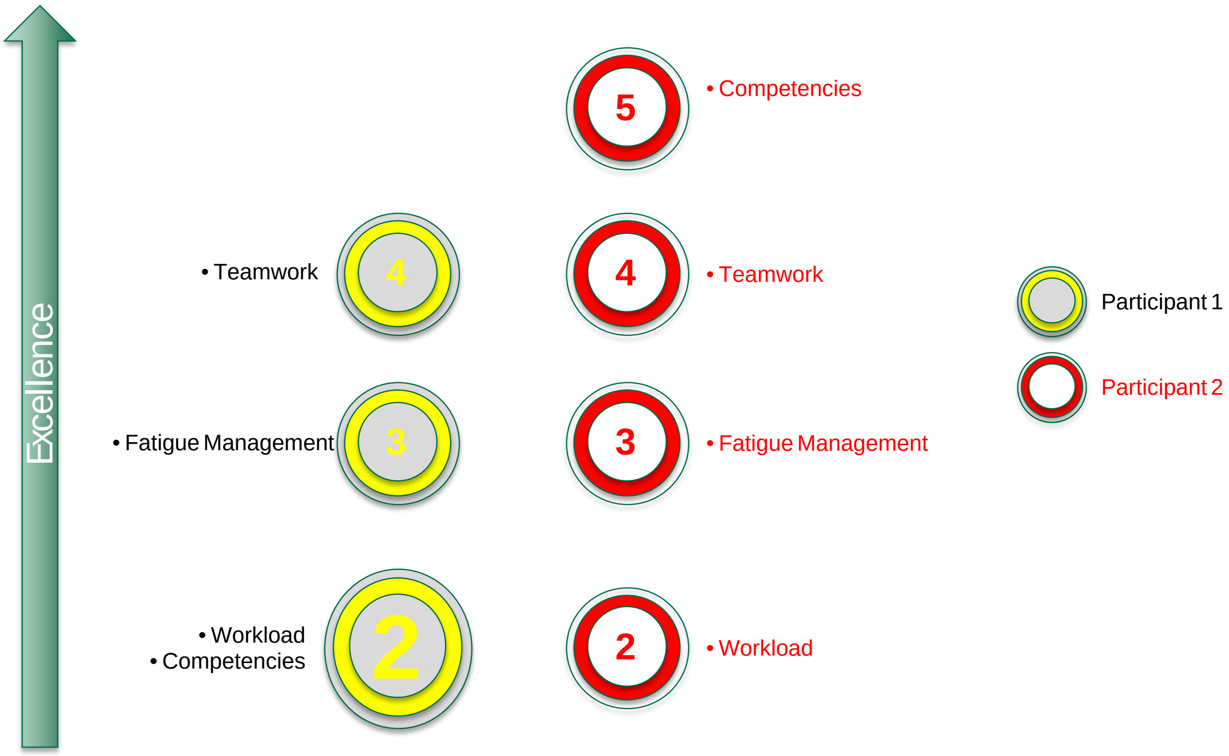


Figure 4.4 compares the self-assessment findings identified by Participants 1 and 2 for individual factors.

Both organisations scored themselves relatively highly for teamwork. Participant 2 has delivered non-technical skills training to staff and Participant 1 is also hoping to implement this type of training. Participant 2 is relocating some staff to encourage better teamwork, for example, train crew managers are being relocated into the same office as driver managers. Participant 2 foresees that this will bring improvements in the near future as driver managers will be doing less driving and more mentoring and coaching (driver managers are currently backfilling to allow driver EMU conversion training).

Participants 1 and 2 had similar scores for fatigue management, both having elements of a fatigue management system, but acknowledging room for improvement. Fatigue is monitored and rosters are assessed for fatigue in keeping with good practice as measured by a fatigue monitoring tool (FAID).

There is a comparatively wide discrepancy in terms of Participant 1 and 2's self-assessment of competency management. Participant 2 has worked hard to improve both the selection and recruitment process and the competency management system, and is looking to have its competence management tool recognised by the New Zealand Quality Authority. Participant 1, however, is cognisant of weaknesses both in their recruitment process and in their competency management system. Participant 1 perceives that these weaknesses currently lead to elevated rates of attrition during training and an over-representation of drivers with less than two years' experience in SPAD incident data.

4.3 SPAD risk reduction at Participant 3

Participant 3 is the operator of a railway line and tourist trains. Train operations are seasonal, peaking in the tourist season and limited to daytime running. Cabs are double-manned by a locomotive engineer and a second man. The trains run on single track with open section working. In the context of SPAD, this means that:

- trains are not signalled – they have written instructions which can only be changed by the operations manager (drivers receives written instructions when they sign on)
- trains do not leave the station until the train in front has arrived.

Unlike Participants 1 and 2, Participant 3 does not have a written SPAD risk reduction strategy. This is because Participant 3 considers that SPAD risk is very low, and that attention to other risk areas should take priority, eg tunnels. In attempting to apply the tool, it was found that the descriptions of critical dimensions were not readily applicable to an organisation of such small size. The principles behind each dimension were discussed and considered in the context of Participant 3's operations. This led to some insights and recognition of potential improvement opportunities.

The session was carried with only one representative from Participant 3, namely the operations manager. Although he was able to give insightful and detailed responses, it would have been beneficial to have had other perspectives from within the organisation to validate the evidence. For example, it would have been useful to have had confirmation from frontline staff regarding the approachability of management by frontline staff, and their perspective on the effectiveness of how change is managed, communications, etc.

The fact that Participant 3 found the tool too complicated and not relevant for small scale operators meant that the conversation was less productive than for the larger operators considered. There was a general feeling that SPAD risk is low. On the whole, Interfleet felt there was a perception of SPAD risk being very low, with little evidence of a healthy attitude of 'chronic unease' (Reason 1990). Chronic unease is a healthy scepticism about what you see and do; not just assuming that because systems are in place everything will be fine.

4.3.1 Findings for Participant 3

The participant in the self-assessment session found it very difficult to attribute a score, as they found some of the text not relevant to their organisation. Because of this, the critical dimensions were not given a numerical value, only a qualitative assessment was recorded. Table 4.1 provides a summary of the sessions with additional comments from the facilitator.

Table 4.1 Participant 3 discussion points

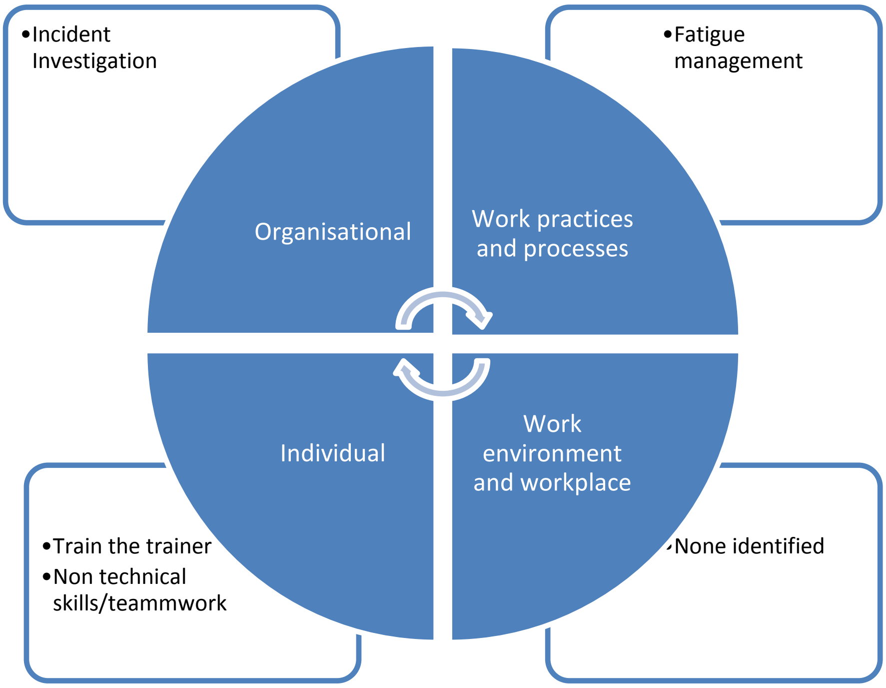
Critical dimension	Discussion points from the session	Comments from the researcher
Organisational factors		
Planning and implementing SPAD Risk Reduction Strategy	Participant 3 does not have a written SPAD risk reduction strategy; they feel there are higher areas of operational safety risks within their organisation.	The evidence for good management of SPAD risk could be presented formally as part of the safety case to provide assurance to the board/trustees.
Organisational culture	The organisation is comparatively small, which makes for easy communications. Management staff are approachable when it comes to safety issues.	This should be validated by conversations with different people in the organisation.
Managing change	Changes are not formally reviewed for SPAD risk, but this is something that the operations manager considers informally on a case-by-case basis.	A 'lessons learnt' review on the effectiveness of ongoing signalling changes could usefully determine how good Participant 3 is at managing change, and whether there are any opportunities for improvement.
Leadership	Senior locomotive engineers are long time railway employees who have not really been trained to train other drivers. Participant 3 has no formal qualification for trainers to be able to pass on knowledge.	Could benefit from leadership/ communications training.
Incident response and investigation	There is a formal reporting process. Participant 3 does have an investigation tool which aims to get at the underlying causes of the accident, but no training to supplement this.	Tools are often ineffective at getting to the root cause if the investigator does not have a good understanding of a systems approach. This can lead to action plans centring on the individual to 'be retrained or be more careful'.
Working practices and processes		
Communication of safety critical information	Safety briefings are run on an 'ad hoc' basis with driver face-to-face. As the depot is small, communication is generally effective and drivers always volunteer suggestions for improvements.	If email is relied on, safety critical communications can be missed, especially if the number of emails increases. Alternative means should be used for safety critical communications, or checks made to ensure that emails have both been read and understood.
Operational procedures	Drivers are very proactive in wanting to know about changes. Any changes to the procedures are required to be agreed in consultation with the Transport Agency.	Again, Participant 3 could possibly benefit from a 'lessons learnt' review on the effectiveness of operational changes due to the ongoing signalling changes.
Timetabling	Timetable is very simple and not considered to be an issue.	No comment.
Individual driver strategies	There are no individual driver strategies other than defensive driving as trained by Participant 1. Participant 3 drivers undergo the same training as drivers in Participant 1 and so understand the impact of driving approaches, etc.	Participant 3 may be interested in the 'risk-triggered commentary' driving technique and other driving strategies under consideration by Participant 1 as new signalling is introduced on shared infrastructure or as part of NTS training.

Critical dimension	Discussion points from the session	Comments from the researcher
Work environment and workplace		
Train cab design	Participant 3's locomotives were built in 1968 (although they do have modern communications systems), so there is little scope for influence on train cab design.	No comment.
Design and management of route and infrastructure	The signalling system is very simple and there is good consultation with Participant 1 on where to place the signals.	Again, Participant 3 could possibly benefit from a 'lessons learnt' review on the effectiveness of operational changes due to the ongoing signalling changes.
Train management systems	There are no train protection systems.	No comment.
Individual factors		
Competencies	Driver training is concentrated on technical skills – trained by Participant 1 with a 2 year review of the rules and regulations and an 8 monthly (observational assessment) check	The 'second man' is a critical safety feature, acting as the error recovery mechanism should the loco engineer forget, misinterpret, or be distracted from the written instruction. The error recovery relies on the ability of the second man to retain situational awareness and alert the locomotive engineer to any potential errors. This is similar to the situation in aviation whereby the pilot relies on his co-pilot. Lessons have been learnt in aviation that this does not always happen naturally – it requires good teamwork, good communication skills and a very flat 'hierarchy gradient'. It is suggested that Participant 3 takes proactive steps to ensure good communications and teamwork within the cab, eg through NTS training.
Team work	The operations manager feels that train crews consistently work well together as a team and this is due to good training.	As for competencies
Fatigue management	Fatigue is not thought to be an issue as workload is not high, rest time is considered when putting together the roster and good practice taken into account when rostering (eg no backwards rotations).	May be opportunities to ensure that drivers are aware of effect of fatigue and proactively assure that it does not impact performance.
Workload	Workload is not high due to the simple service run on this railway.	No comment.

4.3.1.1 Participant 3 improvement plan

Figure 4.5 shows the areas that have been identified as potential areas for improvement. These are discussed in more detail below.

Figure 4.5 Participant 3 – areas for improvement



4.3.1.2 Training needs

1 Train the trainer

It was identified that senior locomotive engineers/anyone who trains others would be likely to benefit from a 'train the trainer' course including:

- communications skills
- training material to standardise the message to ensure that key points are passed on along with the rationale 'what we do' and 'why we do it' that reinforces the safety message.

2 Identifying systems causes to incidents

In addition, Participant 3 could consider a HF course for those who investigate incidents. Although there is a tool available that provides some guidance on identifying underlying causes of incidents, it is Interfleet's experience that, without training, the human is often seen as the underlying cause and systems causes are not adequately understood or identified, hence opportunities for systems improvements are lost.

3 Teamwork between the senior locomotive engineer and the 'second man'

It has been highlighted that there are no engineering controls to prevent SPAD and that the second man is a critical safety feature, acting as the error recovery mechanism should the locomotive engineer forget, misinterpret or be distracted from the written instruction. It is therefore recommended that proactive steps are taken to ensure a flat 'hierarchy gradient' between the driver and the second man, eg via non-technical skills training to promote an understanding of how/why mistakes are made, promoting an open culture, good communications.

4.3.1.3 Operational procedures/communications

Although no improvement points were made during the session, as email is used to notify staff of changes, Interfleet would suggest that the effectiveness of the email system is monitored to ensure messages are read and understood, especially if message volumes increase.

4.3.1.4 Fatigue management

Although there were no improvement opportunities discussed during the session and it is noted the second man provides a redundancy mechanism for errors that may occur due to driver fatigue, it is suggested drivers are briefed:

- to be aware that tiredness is a safety issue
- regarding how tiredness impacts performance at work
- to report fatigue if personal circumstances mean that they are tired at work and feel unsafe.

This is considered important, as there are other factors outside the control of the organisation that can influence fatigue, such as personal circumstances (eg crying baby, stress of divorce, long commute times) that might not be picked up, and if the driver tries to 'push through' this could lead to driver error.

5 Efficacy of the SPAD strategy evaluation tool

5.1 Usability of the tool

The feedback on usability is provided in table 5.1 below and presents a very mixed picture with Participants 1 and 2 finding the tool very user friendly in contrast to Participant 3 who found the tool difficult to use. The negative assessment by Participant 3 relates principally to the amount of information within the spreadsheet that they thought was irrelevant to their organisation making it difficult to read and to print out.

Table 5.1 Structured feedback on the tool – usability

Please tick as appropriate	Strongly disagree 1	Disagree 2	Don't know 3	Agree 4	Strongly agree 5
The user guide is easy to understand		Participant 3		Participant 2	Participant 1
The tool is easy to understand		Participant 3			Participant 1, Participant 2
The level of knowledge required before using the tool is prohibitive to its use	Participant 1	Participant 2		Participant 3	
The interface is simple to use		Participant 3, Participant 2			Participant 1
The interface is error tolerant		Participant 2	Participant 3		Participant 1
The tool is easy to learn		Participant 3, Participant 2			Participant 1
The tool is intuitive to use				Participant 3, Participant 2	Participant 1
The tool is cumbersome to use	Participant 1	Participant 2		Participant 3	

5.2 Content and application of the tool

5.2.1 Relevance

The feedback on content of the tool is provided in table 5.2 and again provides a mixed picture with Participants 1 and 2 finding the content very relevant to their organisation while Participant 3 reported that the detail within the tool was not relevant to the profile of their organisation (heritage, small scale with principally track instructions rather than signalled).

Table 5.2 Structured feedback on the tool – usability

Please tick as appropriate	Strongly disagree 1	Disagree 2	Don't know 3	Agree 4	Strongly agree 5
The content is relevant to this organisation and SPAD risk reduction		Participant 3			Participant 1, Participant 2
The content of the tool is comprehensive				Participant 3, Participant 2	Participant 1
I find the output of the tool useful		Participant 3		Participant 2	Participant 1
I find the process of using the tool helpful		Participant 3		Participant 2	Participant 1
The tool is too resource intensive	Participant 1	Participant 2			

5.2.2 Applicability to large and small

Participant 3 struggled to use the rating scale. The tool requires some amendments in order to make it more relevant and applicable to smaller operators. While aimed at New Zealand railway operators, the concepts and critical dimensions should be relevant for application in other countries, although some alignment of wording with specific signalling systems and technology may be necessary. It would therefore be beneficial to the rail industry to make the tool and user guide available for wider use internationally.

5.2.3 Guiding strategy

Participants 1 and 2 found the tool and the process useful and are using the outputs to guide their future SPAD risk reduction strategies, giving confidence that appropriate change initiatives are either underway, or are being considered for future deployment. It gives confidence that the strategies under development span the four different areas of organisational factors, work practices and processes, workplace and work environment and individual factors. For example, Participant 1 is considering:

- Organisation interventions:
  - ‘just and fair’ culture programme
- Technical interventions:
  - ETCS for the Wellington metro network
  - how ETCS or another ATP solution might be applied to the remainder of the NRS
  - GPS-derived monitoring and intervention of train speed on approach to worksites, GPS-position monitoring and in-cab limit of authority approach warning and automatic braking when a paper-based limit of authority is overrun
- Procedural strategies:
  - risk-triggered commentary driving
  - development of stabilised approach procedures (by train class)
- Training initiatives:
  - non-technical skills training.

Participant 3 found the tool less relevant to their organisation which is comparatively much less complex, having just four locomotive engineers, a simple timetable and single track operations with predominantly track instructions rather than signalling. That said, the discussions did leave them with some insights and some improvement points which they were willing to pursue. For example, the discussions highlighted the importance of the second man in the cab, and the reliance on teamwork to recover from error by the locomotive engineer. This led to a discussion on how Participant 3 could ensure good in-cab communications and flatten any ‘hierarchy gradient’ between the locomotive engineer and second man. Non-technical skills training should be integrated within the broader competency management system.

5.3 Some lessons learnt

5.3.1 Delivering success

Key elements of the workshop sessions that delivered success are:

- participants were open to approach the sessions as a learning opportunity, and they were unflinchingly honest
- all contributed
- enough time was allowed for the discussion sessions – typically three hours per session
- participants provided a variety of experience, driver representation, safety knowledge, operational knowledge; there was representation from management at a level senior enough to ensure actions would be followed up
- involving different people allowed responsibility for, and ownership of, the problems and solutions to be openly and equally shared
- the sessions benefited from good note-takers to capture key discussion points without interrupting the flow of discussion.

5.3.2 Barriers to success

5.3.2.1 Video/teleconferencing

Some difficulties encountered with the sessions were that videoconferencing rather than face-to-face workshops limited the scope to a straightforward application of the tool and prevented more interactive exploration of improvement plans. However, the conversations were generally frank and open and did not require special facilitation, although the lack of an on-site facilitator prevented more in-depth probing regarding the evidence/rationale presented by participants. The session with Participant 3 was limited to a teleconference with just one representative from the organisation. This did not give the opportunity to get different perspectives and confirmed that the tool is best applied in a workshop setting with a several participants. The tool supports the consideration of all the causal and contributing factors of a SPAD occurring, eg between driver performance, company support to drivers and the wider design choices for the technology and equipment.

Due to the researcher being in the UK and the participants being in New Zealand (with a 13-hour time difference), the tool was applied via video conferencing facilities with Participant 1 and via telephone conference for Participants 2 and 3.

It is critical that the tool is used with front line staff as they may well have a different perspective to managers. Given some of the high ratings, these should be checked with front-line staff to validate management perceptions of how well existing mitigations are working on the ground. There should be careful consideration of who should attend and how the session is facilitated to ensure open feedback.

5.3.2.2 Focus on the spreadsheet

It was noticeable that the focus of the sessions was on the content of the spreadsheet. This ignored some of the guidance within the guidance notes which present the spreadsheet as part of a wider process. Some of the key elements for implementing sustainable solutions may be missed if too much focus is placed on the spreadsheet alone, for example:

- defining the remit
- appointing a champion
- getting the right people together
- understanding the wider benefits and potential barriers
- deciding what to do with the outputs – dissemination of what and to whom.

A further session would be required to explore the improvement plans in terms of processes, staff and organisational factors for sustainability, eg:

- Which points have greatest potential for risk reduction, and what are the key benefits?
- Are there internal pressures within the organisation that may resist the change?
- Does the change rely heavily on an individual, technology or finance? Will these be available and maintained over time?
- What will need to be put in place to monitor whether the change is effective or indicate that there are problems?
- How can staff be involved in developing the change?
- How will staff be encouraged to implement and sustain the change?
- Will team leaders and senior managers be involved in the development of change and will they promote it?
- Does the change fit with the organisation's strategic aims?
- Does the change fit with the organisation's culture?
- Are there enough competent staff to implement/sustain the change?

5.4 Opportunities for improvement to the tool

1. A small improvement opportunity was identified by the Transport Agency within the incident investigation section (O5) – addition of a statement regarding conflicts of interest – eg ensuring the lead investigator has sufficient independence to ensure there are no potential conflicts of interest, for example to roster drivers back on duty quickly or where a systemic cause may be found.
2. Modify the tool content to make it applicable and relevant to small operators. It is recommended that there is a scope that puts application of the tool within the context of its use to identify potential barriers for small-scale operators, for example, recognition by participants that there is an inherent SPAD risk to be managed.

3 The tool could be made more specific to solutions or assessment tools that the Transport Agency wishes to promote use of within the rail industry.

4 Change programmes often experience problems with sustainability. The tool should emphasise that engagement of stakeholders within the organisation to identify weaknesses and strengths will improve sustainability of SPAD risk reduction interventions. The tool should be presented in its entirety (user guide plus spreadsheet), rather than focusing on the spreadsheet only.

5 It may be helpful to provide additional support to rail organisations on how to act on the information they gather from the tool, for example by promoting use of the taking safe decisions approach. This aligns with the ethos and methodology of the tool and is understood to be well received and used in the GB railway system and may be appropriate in the New Zealand context (see RSSB 2014).

6 Provide supplementary information on using the tool as a leading indicator dashboard. Leading indicators are proactive and forward-looking measures that can identify performance degradation or deterioration of the system prior to an incident. This contrasts with ‘lagging indicators’, such as accident statistics which measure incidents after they occur.

7 The tool is a starting point for interventions; it provides a measure that can be monitored on a yearly or biannual basis. It could also benefit from guidance for participants to consider how they will measure the impact of proposed interventions.

8 Provide supplementary information to explain how the tool can be used alongside SPAD data to provide weight to decisions regarding improvement plans.

6 Discussion and conclusions

This chapter provides a general discussion and a tabular summary assessment of whether the tool achieved its stated objectives.

6.1 Multi-modal approach

This approach successfully takes the focus away from 'single' events and considers a range of contributory causes and mitigation strategies. There is a danger that SPAD investigations emphasise single events leading to action plans put in place for the driver involved, while the company misses the opportunity to look for common patterns across events and the more systemic issues that the tool considers. Matching the tool outputs with detailed data of causal and contributory factors of incidents would allow a very strong triangulation of 'real' data and staff perceptions of key causes. This would provide weight to decisions for SPAD mitigation solutions, which can be both costly and resource intensive.

Companies and regulators need to be actively examining systems and output performance to identify common patterns across events and the more systemic issues. The tool enables this to occur and can be further enhanced by matching the tool outputs with detailed causal and contributory factors, as described in the paragraph above.

Another successful feature of the tool is the provision of a framework that promotes assessment in terms of leading indicators. Traditional SPAD lag indictor measurement only provides a raw assessment of safety performance and can be misleading, for example comparing high density metro operations with long-haul freight assumes consistent signal exposure rates and system performance. The tool provides alternative measures that enable consideration of organisational commitment, infrastructure controls, activities, contributing factors and SPAD risk management plans. This went well beyond traditional lag indictor reporting and introduced a robust framework that provided confirmatory evidence to support improvement strategies.

6.2 Achievement of objectives

Table 6.1 takes the stated objectives and the potential benefits of the tool and summarises whether these have been achieved and, if not, how they may be.

Table 6.1 Achievement of objectives

Objectives and potential benefits	Was this achieved?
Understand the levels of protection that are important for reducing SPAD risk.	This was achieved for the larger scale operators, focusing their attention on the wide range of contributory factors and on different organisational systems that impact on SPAD risk.
Evaluate the effectiveness of the organisations' levels of protection.	The tool was effective in generating good discussion within the larger scale organisations; identifying organisational strengths and weaknesses. Although some improvement opportunities were identified by Participant 3, this was more limited.
Develop an implementation plan for improving SPAD risk reduction	Improvement objectives were identified for all three participants that spanned different categories. Some sessions did not follow some of the guidance within the user guide and focused on the spreadsheet, rather than the spreadsheet as part of a wider process, thereby missing some of the key elements for implementing sustainable solutions.
Provide clear descriptions of excellence and describe a mature SPAD risk reduction programme	The spreadsheet provides clear descriptions of different levels of maturity over 16 dimensions that are relevant to SPAD risk.
Establish a common framework between the regulator and duty holders, facilitating communication and clarity, and strengthening relationships between the rail regulatory body and industry stakeholders.	The self-assessment process provides outputs that can be shared with the regulator and allows comparisons to be made.
Allow rail organisations to identify current strengths and weaknesses against each of the SPAD dimensions in the tool.	This was achieved in each of the sessions.
Allow rail organisations to make comparisons across different areas of the organisation in approach to SPAD risk reduction.	The tool enables this within complex organisational structures by targeting key areas of risk/opportunity.
Help drive continuous improvement.	Application of the tool is a starting point for improvement.
Support shared best practice.	The participants have allowed the results to be shared with the regulator.

7 Recommendations

- Collaborate with small scale operators to trial the SPAD tool described in appendix A. If appropriate, simplify the tool to:
  - include only dimensions that are relevant
  - reword relevant dimensions to be more appropriate.

  Undertaking this as an interactive session with different operators present could provide an excellent learning opportunity for the operators.

  To validate the results we recommend the findings are checked for sense by front-line staff as they may well have a different perspective from managers.
- Explore ways to focus attention on the process rather than just the spreadsheet element of the tool.
- Although the dimensions themselves are generic enough to be relevant to any rail organisation, consider making some improvements to tailor these to small-scale operators.
- Explore ways in which the rail regulatory body can support improvement plans and share good practice.
- For ongoing improvement, consider providing:
  - supplementary information on using the tool as a leading indicator dashboard to be monitored as part of long-term measurement
  - guidance on developing measurements of the impact of proposed interventions
  - supplementary information to explain how the tool can be used alongside SPAD data to provide weight to decisions regarding improvement plans
  - guidance on risk-based approach to prioritising actions, for example using the *Taking safe decisions* approach as promoted by the RSSB (2014).
- An alternative approach to applying the tool could be one of a facilitated self-assessment session with an element of peer-to-peer assessment, for example inviting members from Participant 2 to a Participant 1 session. This could foster better understanding of problems and solutions as an industry.

8 References

Hollnagel, E, D Woods and N Leveson (2006) *Resilience engineering: concepts and precepts*. Aldershot, UK: Ashgate Press.

Office of Rail Regulation (ORR) (2011) *Railway management maturity model RM³*, v1.02. Accessed 25 April 2016. http://orr.gov.uk/__data/assets/pdf_file/0013/2623/management-maturity-model.pdf

Rail Safety and Standards Board (RSSB) (2014) *Taking safe decisions*. Accessed 25 April 2016. www.rssb.co.uk/risk-analysis-and-safety-reporting/risk-analysis/taking-safe-decisions

Reason, J, (1990) *Human error*. Cambridge University Press.

University of Manchester (2006) *Manchester patient safety framework* (MaPSaF). Accessed 21 July 2015. www.nrls.npsa.nhs.uk/resources/?entryid45=59796.

Appendix A: Part 1: The SPAD tool – how to evaluate your organisation's ability to monitor and manage SPAD

A1 Introduction

A1.1 About the tool

This guidance has been produced to help infrastructure managers and railway operators evaluate the way their organisation addresses SPAD risk. It is based on research on the Railway Management Maturity Model (RM^3) (ORR 2011) and the Manchester Patient Safety Framework (MaPSaF) (University of Manchester 2006) (see the literature review in appendix B). It provides an approach to:

- understanding the levels of protection that are important to reducing SPAD risk
- evaluating the effectiveness of your organisation's levels of protection
- developing an implementation plan for improving SPAD risk reduction.

Although the tool enables a baseline measure, it is best used as a team-based reflection and educational exercise which enables critical reflection on your organisation's layers of protection, rather than to generate numbers in a benchmarking exercise.

A1.2 Who should use it

Managers, team leaders and directors -

Section A2 provides an overview and background to SPAD risk. Anyone involved in managing teams and/or operations can learn more about their role in SPAD risk reduction.

Those leading SPAD risk reduction programmes -

Section A3 presents the principles behind the tool and the user guide to the tool.

A1.3 Understanding SPAD risk factors

There are many factors that can influence SPAD risk, and the tool organises these into four groups. The four groups are in increasing proximity to the driver and the cab:

- Organisational factors
- Working practices and processes
- Work environment and workplace
- Individual factors (eg driver, signaller)

The tool describes each group of influencing factors and the sub-categories within each group that can contribute to SPAD risk. The tool gives examples of the activities and interventions that organisations may undertake in each category, and presents them in a 5-point scale of increasing effectiveness or 'maturity'. Organisations can rate their SPAD activities against the descriptors on the 5 point scale. An example under the 'Organisational' group of factors is shown in table A.1.

Table A.1 Example from the tool

Group	Subcategory	How does this affect SPAD risk?	Level 1 (ad hoc)	Level 2 (managed)	Level 3 (standardised)	Level 4 (predictable)	Level 5 Goal (excellence)
Organisational	Train management systems	The presence of a train protection or warning system can reduce SPAD risk by varying degrees by alerting the driver to signal aspects, bringing the train to a standstill before or within the overlap or by preventing the train from passing a signal at danger.	There are no on board train devices to alert the driver to signal aspect or device is out of order/non-functioning.	Selected signals or trains, which are deemed to be high risk are fitted with train protection or warning systems which will warn the driver of upcoming signal aspects and apply the brakes should the train pass the signal at danger. There is no guarantee that the train will be brought to a stop safely.	Selected signals or trains, which are deemed to be high risk are fitted with train protection or warning systems which will warn the driver of upcoming signal aspects and/or apply the brakes should the train pass the signal at danger, eg Tripcock system.	All signals or trains are fitted with train protection or warning systems which will warn the driver of upcoming signal aspects and apply the brakes should the train pass the signal at danger. Interventions occur only at signal locations. The system monitors the speed of the train and there is a greater degree of certainty that the train will be brought to a stop safely.	The network is fitted with a full ATP system which continually monitors the speed and distance to the next signal at danger, calculating the required stopping distance automatically and intervening if necessary to bring the train back to operation within safe limits. All speed limits are automatically enforced. The system takes account of braking performance and there is an extremely high degree of certainty that the train will be brought to a stop before the signal at danger, eg European Train Control System.

A1.4 The aims of the tool

The tool helps explain the wide range of factors that provide resilience against SPAD risk. It will help identify the factors that are being addressed well, and those that are not. Most importantly, it can be used to promote discussion about what works well within your organisation, what can be improved, the benefits from improvements and any barriers or limitations. This helps everyone understand that there is no 'one fix' to SPAD risk and that all parts of the organisation need to be considered.

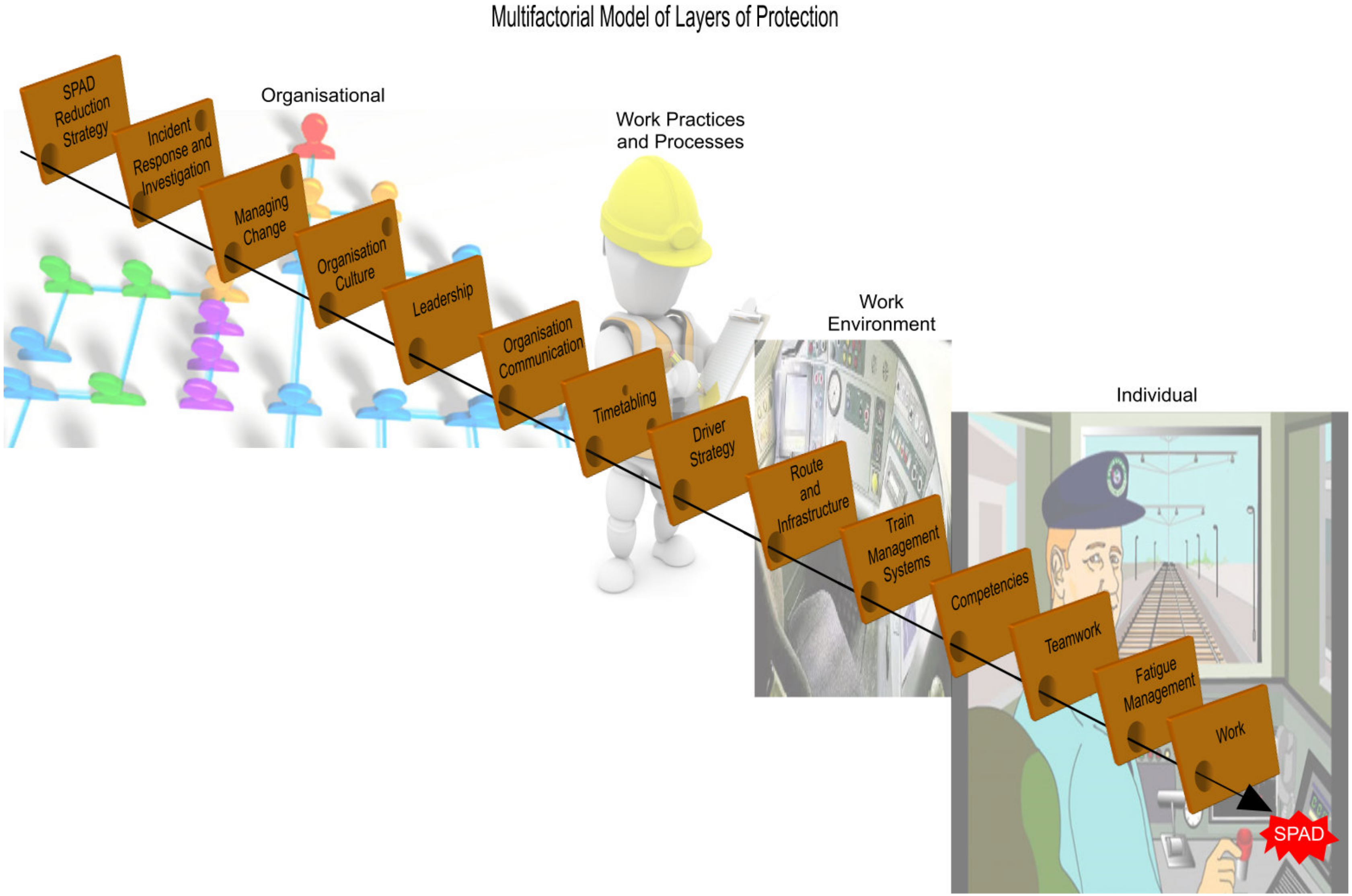
Using the SPAD tool will:

- ✓ **Promote a learning culture within your organisation**: help staff understand that SPAD events are complex and multi-factorial and stimulate discussions about strengths and weaknesses of the existing SPAD risk reduction measures
- ✓ **Provide a snapshot of the layers of protection that mitigate SPAD risk**
- ✓ **Help plan and prioritise future SPAD risk reduction interventions:** examples of a mature approach to SPAD risk reduction are included
- ✓ **Encourage monitoring and review** of the effectiveness of SPAD risk reduction interventions.

A1.5 SPAD risk factors

The tool is underpinned by a SPAD model that demonstrates the multiple layers of causation and protection, based on the Swiss cheese model (Reason 1990). Each layer of protection is a feature of an organisation that is resilient to SPAD risk, and are classified in the same 'levels' as shown in section 3.1. It shows that within each level there are sub-categories such as fatigue management, competencies and team work at the level of the individual. Each layer will change over time and will depend on the maturity of the organisation's management systems. The tool builds on this model by explaining how each of these layers can be made more resilient.

Figure A.1 Multifactorial model of layers of protection; organisational, work practices, work environment and individual



A2 User guide: How to use the tool

Please note that the evaluation tool is an Excel spreadsheet which is available for download. Please refer to appendix A: part 2 for details.

There are five steps to using the tool to evaluating your organisation's SPAD risk reduction strategy:

Step 1: Assign roles and responsibilities

Step 2: Work through the matrix

Step 3: Develop a plan

Step 4: Present and disseminate

Step 5: Monitor and review

These are described in more detail in the following sections A2.1 to 0.

A2.1 Step 1: Assign roles and responsibilities

Define your remit	**Define what you want to achieve by using this approach and the scope of work to be undertaken.**
Appoint a champion	For the tool to be effective, the process of applying it and managing the outputs should be led by someone within the organisation with influence who is able to foster stakeholder engagement. The process will need appropriate resources, for example to arrange the venue, attendees, gathering evidence and disseminate findings.
Get the right people together	The tool evaluates factors at many levels within the organisation and it is important to have as many different perspectives on the effectiveness of the layers of protection. For example a senior manager's view of the efficacy of safety communications briefs may be very different from the views of the people who receive them. Decide who is likely to be involved in implementing any changes and get them involved at an early stage to ensure buy-in at all levels: Include front-line staff to get a perspective of day-to-day operational aspects. Include senior management in setting the scope and objectives. The tool is best used as a team-based reflection and educational exercise so it is important to get different perspectives.

A2.2 Step 2: Work through the matrix

The process used to work through the tool may be tailored to suit the size of your organisation. You may want to organise several relevant people within one meeting or organise several meetings with individuals. A workshop setting with multiple people has the advantage of being able to share experience and perspectives to achieve a better shared understanding, and contributes to the development of a learning culture within the organisation. Evidence to support the assessment can come from a mixture of techniques including interviews, observations and document review.

The tool provides a consistent way of evaluating management systems and factors that impact on SPAD risk. It helps your organisation understand the level of excellence that is currently being achieved in your operation and identifies areas in which improvements can be made. The criteria should be used as a framework; as you know your organisation better than anyone it is for you to decide on which level best describes your organisation and provide rationale or evidence for the results achieved. If there are mixed levels of achievement use the criteria to formulate improvement plans.

The Excel spreadsheet has three worksheets:

1 Front sheet

To record details pertinent to the assessment for future record. It is important that you are clear about and record the boundaries of the assessment, whether this is for the whole organisation or a part of it.

2 The risk assessment matrix

The matrix presents the layers of protection shown in earlier in the SPAD model together with the sub-categories in each layer. There are five progressive levels of SPAD management for each sub-category, against which you can review your organisation. Each level has examples of SPAD management activities or approaches to help you match your own practices. For example, for fatigue management there may be no monitoring or management (level 1) or employees and employers may be encouraged to actively manage fatigue issues and the process is regularly reviewed (level 5). By discussing the examples in the matrix your team can not only identify where your organisation sits on the five levels but more importantly you can discuss how to improve this.

It is likely there will be different opinions within the group and that no box entirely fits. In this case choose the one you agree is closest to your organisation. An independent facilitator can keep the tone of these discussions objective. It is useful to have a copy of the business goals and objectives in order to steer the conversation towards aligning strategies with them.

You can record your choice in the column provided on the spreadsheet and provide a commentary in the 'Evidence' column. We suggest it would be useful to provide notes on and evidence of:

- existing measures in place
- whether/how you monitor the effectiveness
- weaknesses
- assumptions/judgements used to assign criteria.

Table A.2 Format of worksheet 2

Category	Layer of protection	Level 1 Ad hoc	Level 2 Managed	Level 3 Standardised	Level 4 Proactive	Level 5 Best practice
Organisational	Planning and implementing SPAD risk reduction strategy					
	Organisational culture					
	Incident response and investigation					
	Managing change					
	Leadership					

Category	Layer of protection	Level 1 Ad hoc	Level 2 Managed	Level 3 Standardised	Level 4 Proactive	Level 5 Best practice
Work environment	Design and management of route and infrastructure					
	Train management systems					
	Train cab design					
Work practices and processes	Communication of safety critical information					
	Timetabling					
	Operational procedures					
	Driver strategies					
Individual	Competencies					
	Teamwork					
	Fatigue management					
	Workload					

3 Your organisation's profile

The levels identified in the matrix (1: ad hoc, 2: standardised, 3: managed etc) can be regarded as representing the maturity of the management systems. They correspond with those used in the Railway Management Maturity Model (RM3) (ORR 2011) and are similar to those used in other safety critical industries to assess the maturity of safety culture within an organisation (Hollnagel et al 2006). The scores identified during your evaluation are recorded on matrix and these are transferred automatically to the third worksheet which illustrates them as a graphical profile or snapshot of the organisation.

This can be used to provide an overview when presenting results to senior management. The weaknesses identified during the discussions should be logged as improvement points.

A2.3 Step 3: Develop a plan

Interpret the results

- The purpose of the tool is to promote discussion and proactively seek out ways that the organisation may become more resilient to SPAD risk. The results should be viewed both qualitatively and quantitatively.
- The profile gives an illustrative snapshot view of the layers of protection. This is to enable you to give an overview to senior management and will highlight any areas that are much lower in score.
- The detail within the different levels should be used to identify weaknesses that could be addressed to take your organisation to the next level.
- Your organisation should agree on a prioritisation plan in order to target potential improvement; for example it may be better to achieve level 3 in all areas rather than moving from level 4 to 5 in some. It would also be beneficial to consider at this early stage the sustainability and effectiveness of different options for change.
- Develop some ideas regarding what types of improvements may be

	made in order to move your organisation upwards in the scales of 1 to 5. • Identify those factors you feel have greatest potential for improvement and discuss the following issues.
Process	• For sustainability, attendees should be encouraged to identify key benefits from introducing a robust process for change and who would benefit? • Are there internal pressures within the organisation that may resist the change? • Does the change rely heavily on an individual, technology or finance? Will these be available and maintained over time? • What will need to be put in place to monitor whether the change is effective or indicate that there are problems?
Staff	• How can staff be involved in developing the change? • How will staff be encouraged to implement and sustain the change? Will they think that the change brings about better working practices? • Will team leaders and senior management be involved in the development of change and will they promote it?
Organisation	• Does the change fit with your organisations strategic aims? • Does the change fit with your organisation's culture? • Are there enough competent staff to implement/sustain the change? • What other resources will be needed? Do you have them? • What communications will be put in place to effect the change?

A2.4 Step 4: Present and disseminate

The results of the evaluation and the improvement plan should be clearly presented so the rationale for decisions is understood.

The tool includes a graphical profile as an output. This should be accompanied by the main findings such as:

- strengths
- weaknesses and potential for improvement
- what will be needed from the organisation and staff to implement change sustainably
- benefits.

When compiling messages it is important to consider the audience and tailor the message and the way it is delivered accordingly.

A2.5 Step 5: Monitor and review

It is essential that any programme of change builds in an element of measurement in order to understand the impact of change. In the tool there is reference to 'pro-active monitoring of implemented changes to ensure they are effective or to take further action if full efficacy is not verified'. It is recommended that you consider indicators that give insights into how risk is controlled *before* the outcome is realised. These are sometimes referred to as leading indicators. The RSSB (2014) provides guidance on leading and lagging indicators (these are also known as activity and outcome measures and generally are thought of as being on a continuum). An example is shown in table A.3.

For your change programme ask:

- What does success look like?
- Which elements are critical to the success of the risk reduction intervention?
- How can they be measured?

Table A.3 Leading and lagging indicators

Leading/lagging		Risk control	Potential measure
Activity (leading)		Driver training	Effectiveness of training
Outcome	Results (leading)	Better driving styles	Occurrences of over-speeding
	Precursors (leading/lagging)	SPADs	Occurrences of SPAD
	Accidents (lagging)	Collision	Occurrences of collisions

The review process should establish:

- the effectiveness of the intervention
- whether introducing the intervention has caused any unwanted side effects or behaviours
- whether indicators are a good measure of risk reduction.

A3 Using the tool for a monitoring national SPAD risk reduction

The results of the tool can be used at an organisational level to review and develop SPAD risk reduction measures within individual operating companies and network managers. The results of the tool can also be aggregated at a national level to review and monitor national interventions and strategies. This is important in order to identify gaps in the levels of protection within the national network and to inform national SPAD strategies. The tool can also be updated over time with international best practice in order to monitor and develop national strategies as solutions develop.

A4 References

Office of Rail Regulation (ORR) (2011) Railway management maturity model RM^3, v1.02. Accessed 25 April 2016. http://orr.gov.uk/__data/assets/pdf_file/0013/2623/management-maturity-model.pdf

Parker, D and P Hudson (2001) *Understanding your culture*. Shell International Exploration and Production.

Rail Safety and Standards Board (RSSB) (2014) *Measuring safety performance. How to develop and manage safety performance indicators for Britain's railways*. Accessed 25 April 2016. www.rssb.co.uk/risk-analysis-and-safety-reporting/safety-intelligence/measuring-safety-performance

Reason, J (1990) Human error. Cambridge University Press.

University of Manchester (2006) Manchester patient safety framework (MaPSaF). Accessed 21 July 2015. www.nrls.npsa.nhs.uk/resources/?entryid45=59796.

Appendix A: Part 2: SPAD tool evaluation matrix

This is located at www.nzta.govt.nz/resources/research/reports/595/.

Appendix B: Literature review

B1 Introduction

Interfleet Technology Ltd. (Interfleet) carried out a literature review on behalf of the New Zealand Transport Agency ('the Transport Agency') relating to the human factors (HF) underlying signals passed at danger (SPADs). SPADs are considered by the rail industry as a major safety issue as they carry the potential for high consequence accidents which generate significant reputational risk to the industry. The recorded number of SPADs has risen in recent years and this study was commissioned to identify:

- which human factor causes of SPADS are most applicable in a New Zealand context
- best-practice and relevant international solutions to address the HF involved in SPADS
- strategies for intervention to mitigate the risk of and reduce the incidence of SPADs in a New Zealand context
- barriers and risks to implementing identified solutions in New Zealand.

The aim of the literature review was to review the scientific theory underpinning the HF approaches to SPAD mitigation. This focused on using knowledge on human behaviour (the train driver and other railway staff) to understand the causation of SPADs, and how this is influenced by the wider railway system. The review identified a range of SPAD mitigations that had been developed from this theory, thereby providing provenance and a theoretical basis to current international SPAD interventions.

There were a number of specific objectives for the literature review:

1. Document the full known range of possible HF that can lead to SPADs.
2. Understand the range of SPAD options already being utilised in rail operations.
3. Document the existing barriers and risks to application of SPAD mitigations into operations elsewhere.

International academic literature, standards, industry guidance and best practice related to the HF basis of SPAD mitigation were identified and reviewed. This literature review was used to inform the rest of study.

B1.1 What is a SPAD?

SPADs are a major railway risk. The failure of a train to stop at a red signal has the potential for catastrophic collision or derailment. SPADs are usually classified in terms of severity; however, classifications vary between networks and a substantial amount of work has been done in terms of the classification of SPADs to enable monitoring of the causation and trends in SPADs (Naweed and Rainbird 2014). In New Zealand, KiwiRail defines a SPAD as:

> *any signal, which has been passed without the correct authority or where the safe-working authority has been exceeded*

and a category A SPAD as:

> *where a stop signal indication (and any associated preceding cautionary indications) was displayed correctly, in sufficient time for the train to be stopped safety at the signal (includes points indicators, notice boards requiring a train to stop, and Track Warrant limit over-runs).*

Factors that affect SPAD performance and risk are varied and multi-factored. They have been and continue to be the subject of considerable analysis and review (RSSB 2014).

B1.2 Literature review method

There is a wide body of documentation on SPADs, encompassing a range of research methods and interventions. The following resources were used:

- SPARK – UK database of research managed by the Rail Safety and Standards Board (RSSB) which includes the HF library
- OPSWEB – on-line resource centre designed for the rail industry to access and share information and resources on operational safety
- website for the Australian Independent Transport Safety Regulator, www.transportregulator.nsw.gov.au/
- the proceedings from the series of International Rail Human Factors Conferences (2005, 2007, 2012 and 2013)
- Google search
- Health and Safety Executive (UK) website, www.hse.gov.uk/
- Resilience Engineering Association website for the 2013 Resilience Engineering International Symposia Proceedings, www.resilience-engineering-association.org/

An Excel spreadsheet was developed listing all publications with an indication of the content of the publication and relevance to the project. Key points of the relevant publications were summarised for inclusion in this review. It became apparent during the search that the UK has the largest body of evidence and has been actively researching the HF influences on SPAD for at least 10 years. This means the UK has the longest international experience of a practical, HF-based approach to reducing the risks of SPADs (ITSR 2008) and that many international approaches, including recent strategies in New South Wales (ISTR 2011) stem from this body of research and application. Therefore the RSSB research and resources have formed the basis of this report, using additional international examples where they add to the knowledge base.

The Transport Agency research programme was also reviewed to gain an understanding of the level of research, past, present and future relevant to this project. This was carried out online by reviewing:

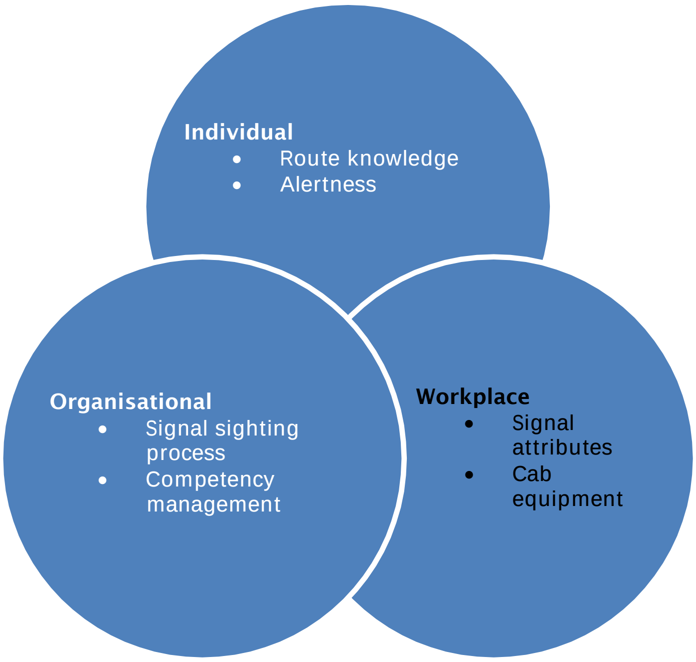
- The Transport Agency's spreadsheet of research programme reports, available at www.nzta.govt.nz/planning/programming/research.html from 1997 to 2014 using the following key words: SPAD, risk, human error, driver, signal.
- The latest copy of the newsletter *NZTA research*, Issue 26 December 2014.
- The online Transport Agency Research Programme active research projects available at www.nzta.govt.nz/resources/research/index.html#safety.

B2 Human and system influences on SPADs

Work by the British psychologist James Reason on human error and system safety has been widely influential in informing safety management across many industries. Reason's work focuses on humans within complex systems, and how human behaviour and technical components can work together to increase and control risk (Reason 1990). This is known as a systems approach, and a simple model is presented in figure B.1.

Reason's work is relevant for all socio-technical systems and particularly for understanding the system and human influences on the risk of SPADs. The principles behind Reason's work, and those which underpin modern HF thinking, have therefore been included here to help set the scene for the review of HF-based SPAD mitigations. As these are widely documented and in common use this report does not explore them in great detail.

Figure B.1 Systems approach



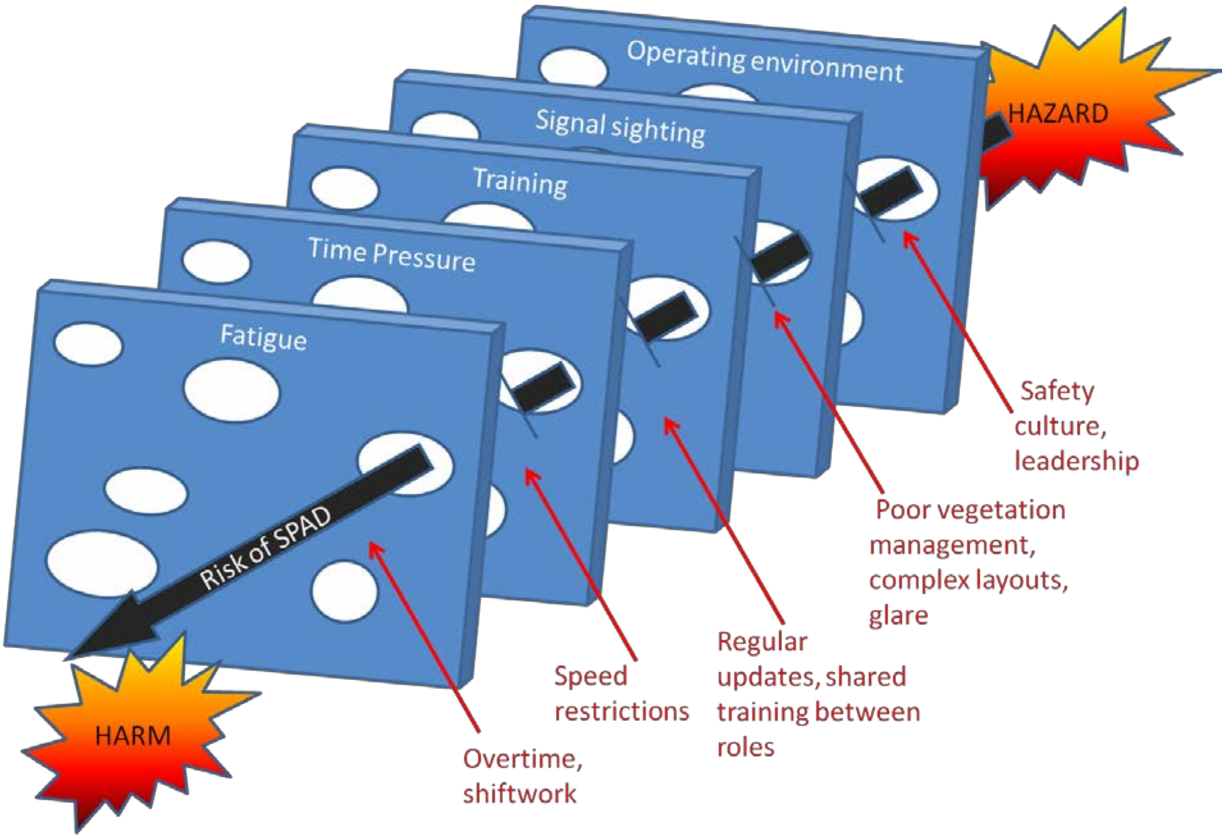
This section of the report describes the Swiss cheese model as it is important to understand how SPAD interventions fit into the overall safety management system to reduce risk. It also gives a brief description of models of human error as it is important to understand that error is influenced by many and varied contributory causes. Other high-hazard industries take the view that, although the safety management system should strive to improve organisational systems that influence contributory causes, human performance will never be 100% error free.

The section then describes driver behaviour and system influences on the risk of SPADs. This is collated in a large database of information described in section B2.6.1, which underpins the way risk is defined, data collected and analysed, and interventions prioritised in the UK. The section ends with a short description of 'resilience' a concept that has recently emerged and has some useful ways of thinking about rail safety and for developing ways to measure and monitor the health of organisations.

B2.1 The Swiss cheese model

The Swiss cheese model, as it has come to be known, was developed in the early 1990s. An example of this as applied in rail is provided in figure B.2. It describes layers of protection within the organisation used to control risk. The layers of protection are the 'slices of cheese'. For example fatigue management, through good practice in rostering, monitoring and managing working hours and shiftwork. The principle of the model is that at any one time there will be weaknesses and inadequacies in these layers of protection. These are the 'holes' on the Swiss cheese. Incidents occur when these holes align – usually in unique ways and coincide with an active failure in some way by front line staff, for example inattention or distraction.

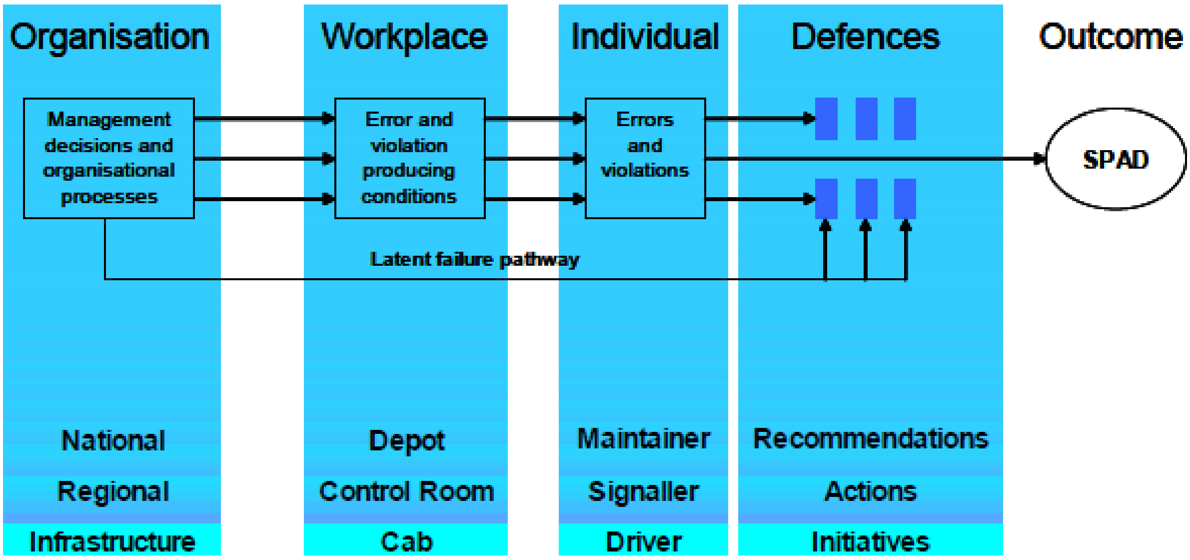
Figure B.2 An example of the Swiss cheese model as applied in rail



B2.2 The Swiss cheese model applied to SPADs

A study by the RSSB (2004a) looking at the factors contributing to SPADs adapted Reason's (1990) Swiss cheese model to show there are system-wide influencers on SPAD risk, and not just the individual train driver (figure B.3).

Figure B.3 System wide influences on risk and the defences available



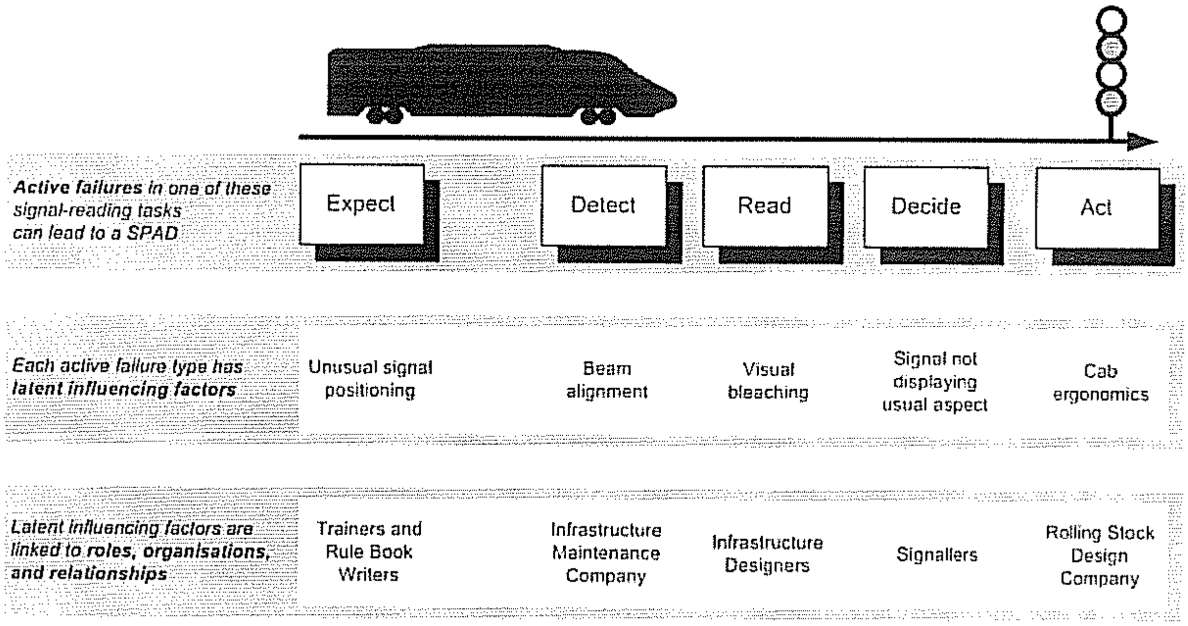
Source: RSSB (2004)

Figure B.3 shows that management decisions at all levels (national, regional and infrastructure) combine with factors in the workplace (driver cab, signal control centre, infrastructure) to produce the potential for driver error. These are referred to as 'error producing conditions'; the set of circumstances, scenarios and conditions that make an error (or rule violation) more or less likely.

This approach looks beyond the immediate work environment and incident precipitation and at what may have influenced behaviour. This recognises that incidents are multi-causational and there will be latent, error-producing conditions, often remote from the incident. These latent conditions are due in part to the fact that humans design, manufacture, operate and manage these systems and therefore introduce human error at all stages of the system. These latent conditions, such as safety culture, leadership, operational pressures, may remain hidden in systems for months or years before they combine with local conditions and active failures (such as lapse in driver attention) to produce an incident. The ways in which systems factors can influence behaviour are discussed further in section B2.5.

The systems approach contrasts with a behavioural approach which focuses on the individual act that leads to a failure (known as the 'active failure'). The example shown in figure B.4 gives an example of the train driver's failure to expect, detect, comprehend or follow the information provided to slow or stop the train. Behavioural approaches would consider issues around why the driver may fail, such as fatigue, distraction, attention or interpretation of rules. This driver-centric approach, however, can fail to recognise that a driver is compelled by the wider system, which is why the systems approach is more appropriate to the management of SPAD risk.

Figure B.4 A driver's active failures and the latent influencing factors contributing to a SPAD



Source: RSSB (2004)

A systems approach, which underpins HF thinking, is predicated on the principle that humans (or train drivers) cannot be expected to perform 100% error free and that human error can, to some extent, be predicted. This approach has been taken by the UK rail industry which has resulted in a framework of SPAD risk reduction strategies that tackle underlying causes of SPADs at the level of the individual, the workplace and the organisational processes.

B2.3 Models of human error

It is important to understand human error as different types of error need different types of error reduction/prevention strategy. Models of human error (Reason 1990) help us to understand types of human errors (such as memory failures or failure to respond in time) and crucially that training or experience does not guarantee error-free performance. High hazard industries such as process control and aviation have drawn upon theories of human error developed by Rasmussen (1982) and error categorisation schemes such as the systematic human error reduction and prediction approach (Embrey 1986) to:

- enable error to be quantified
- enable meaningful data collection
- understand the underlying causes of error
- develop effective error reduction strategies.

Detailed discussion of these is outside the scope of this report. The interested reader is directed to the references for more detail of these techniques and also to the RSSB website at www.sparkrail.org/Lists/Records_StaffMembers/DispForm.aspx?ID=103 for an example of Railway Action Reliability Assessment as a human error analysis technique adapted to be more specific to the train driving task.

Examples are given in section B3.3.3 of tools that have been developed using this academic research.

A UK study (RSSB 2007a) looked at a multi-SPAD station departure signal that had been passed at danger four times in 17 years. They found three potential error mechanisms leading to a start on yellow SPAD:

- Failure to check signal at departing station (unlikely as drivers highly motivated to read signal).
- Memory failure - driver correctly reads caution signal at departing station but forgets requirement to stop or misses braking point, due to distraction or mixed messages.
- Expectation bias - driver reads signal correctly but incorrectly expects next signal to clear before arrival, due to prior experience or wrong cues.

In fact, some errors become more likely the more experienced we are in a job (which leads to operation on 'automatic pilot' as a task has become familiar and is not fully attended). By understanding error in this way, safety management will be based on the acceptance of human behaviour and fallibility, the anticipation and prediction of error and recognition of the system's latent, error-precipitating factors in order to build appropriate defences.

The relevance of this is that, as with other high-hazard industries there should be an acceptance that humans, because of the cognitive mechanisms that make us skilled at some tasks, predispose us to error. Some safety regulators, eg the UK Health and Safety Executive, place the burden on organisations to expect and plan for humans to err and to demonstrate within their safety case that they have planned for this (HM Government 1999: the enforcing regulations within the UK applicable to any establishment storing or otherwise handling large quantities of industrial chemicals of a hazardous nature) by using a hierarchy of risk control which emphasises removal of the hazard and engineering controls before reliance on training and procedures.

B2.4 Driver behaviour and risk of SPAD

This section outlines some driver behaviours that are associated with risk of SPADs.

B2.4.1 Route knowledge

Naweed and Rainbird (2014) focus on driver route knowledge and note that extensive training is needed for drivers to understand the braking performance of different trains, plus knowledge of gradients, adhesion levels and how this relates to signal spacing and sighting. Misjudgement or misunderstanding of this can lead to drivers braking too late and overshooting stop signals.

The findings of a large UK study (RSSB 2004b) stressed that drivers should realise that perfect route knowledge is not enough for safe train operation; it is one component necessary for situational awareness. The RSSB is about to undertake another significant piece of work on behalf of the industry in this area with the ultimate aim of developing a route risk assessment tool/framework that will help underpin how best to train drivers in route knowledge and to understand the impact of automation such as ETCS on driver route knowledge.

B2.4.2 Drivers' use of protective devices

Traditionally signalling systems in the UK and worldwide have relied on drivers responding to signals. Failure to respond to commands from signal aspects has led to a number of accidents, some fatal. To reduce risk of failure to respond, various forms of warning devices and signal command enforcement systems have been developed.

RSSB (2005) looked at drivers' use of protective devices and their effect on performance. This was a broad ranging study involving 650 driver questionnaires, 70 video observations, a predictive error analysis, a hierarchical task analysis, confidential incident reports, focus groups and interviews. They found the following issues associated with each device in use in the UK:

1 Driver safety device and vigilance system

Many drivers found the frequent alarms distracting from their other driving tasks. Importantly, there is the opportunity for confusion as there is an inconsistent method of foot pedal operation, pedal design varies from train to train and 50% of drivers have to switch between trains on a daily basis with and without a vigilance system. It is therefore important for effectiveness that some level of consistency is achieved as rolling stock is developed and introduced.

2 Automatic warning system (AWS)

The AWS is a long-established system which provides the driver with a sound indication and a visual reminder (sunflower) of the next signal that will be encountered. As long as the alert is acknowledged (if required, typically in the case of a non-green aspect) the driver may continue to drive the train at any speed. It is therefore only useful as a reminder rather than as a hardwired engineering control.

This study found that the unconscious cancelling of AWS warnings through driver's anticipation is commonplace. Also, drivers sometimes forget the signal aspect following acknowledgement of AWS and there is confusion by the lack of discrimination of the AWS black/yellow indicator. There are sometimes contradictions between AWS warnings and observed signal aspects as a result of proximity of temporary speed restrictions and signals. There are trust issues and it is often not clear why a brake application has occurred. Also the ergonomics of the layout of the AWS indicator and control could be improved.

Note that other countries use vigilance type systems that are versions of AWS, for example, Crocodile (France).

3 Train protection and warning system (TPWS)

TPWS was implemented in the UK as an interim SPAD control in 2003 pending full protection systems (eg the European rail traffic management system (ERTMS)) that continually monitor driver performance. The SPAD risk has reduced by 90% since its introduction, although this has of course been working alongside other interventions. It will remain the primary protection system in the UK until ETCS is fitted. It has been installed on 13,000 junctions, protecting signals, buffer stops and speed reductions. There is a 0.005% technical error rate (where TPWS fails to operate) but TPWS does still rely on human behaviour, and human error is not eliminated. There is a 2% human error rate known as 'reset and continue' – where the driver resets the system in error and continues journey, following a Category A SPAD. On introduction of the TPWS the 2004 RSSB study found there were trust issues as the TPWS interface did not always make it clear to the driver why a brake application had been made. It was reported that drivers tended to spend more time thinking about speeds than signals and therefore belief of the speed setting on TPWS can undermine compliance with the system. This was an unforeseen error at the time of installation but is now proactively managed through standards change and education.

TPWS is also limited in its effectiveness where train speeds are high, braking force is less than 12g or if rail adhesion is low.

The UK RSSB currently has a TPWS Strategy Group looking at system reliability.

4 Automatic train protection (ATP)

This system uses a target speed indication and audible warnings to warn the driver if they are likely to exceed a speed profile. The system will apply the brakes if the driver does not respond to these warnings. The system takes into account the position and speed of the train relative to the end of its 'Movement Authority'. ATP is fitted to six classes of vehicle in the UK.

Drivers report that there is too much visual information to cope with and mistakes in data input appear quite high. Most drivers have to switch between ATP/non ATP operation and again there is a lack of trust of ATP due to the contradiction between lineside and ATP visual information (50% drivers reported problems).

5 Driver reminder appliance (DRA)

The DRA was introduced in the UK in 1998 to assist with the prevention of SPADs. It is a pushbutton or twist control that the driver operates when the train is stopped at a red aspect. It prevents the driver from starting against a red signal until the device is reset.

Violations of DRA procedures were reported by drivers to be widespread, and this was confirmed in the study in which drivers failed to set the DRA even though they were being filmed.

The study found that the system of protective devices as a whole in use in the UK at the time did result in some driver confusion between the different systems, and there was some conflict/masking of alarms. External noise and noise from the traction itself is also an issue in masking alarms. The confusion over what has caused a brake application (the common result of all protective devices) can engender a feeling of lack of control for the driver as the systems operations are not transparent, and this can contribute to the risk of procedural violations. Driver education, rationalisation of systems and ensuring congruity between the operation of the systems and alarms is therefore paramount. It is important to think of the system as a whole rather than overlaying one system on top of another, for example fitting ETCS to a cab that has other protection systems such as DRA.

RSSB (2005) found that current driver vigilance devices ensure the driver is not asleep but they do not ensure the driver is fully alert and vigilant. It highlighted the difficulty in maintaining a high level of driver vigilance through a shift – particularly in conditions of low workload. There is work underway (currently unpublished) at the RSSB to investigate the effects of cognitive underload on train driver performance and potential ways to mitigate declining performance. The output of this research could be useful for the context of New Zealand railways which, the researchers assume will have areas with long stretches of track of low cognitive demand.

B2.4.3 Rest days and fatigue

Fatigue can be defined as a loss of alertness which eventually ends in sleep. Fatigue can take the form of either physical fatigue, or mental fatigue, or the combination of both. There are various causes for fatigue, for example, duration of work, work under stress or time pressure, type of jobs/tasks, workplace layout, experience, environmental conditions, and individual's abilities and physical conditions. Fatigue in the workplace has various negative consequences as it leads to reduced performance which can result in errors and accidents. In fact, all cognitive and sustained attention tasks are affected by fatigue, and evidence suggests this performance decrement is not due to occasional lapses in attention, but an overall drop in capability. The influence of fatigue on human performance includes increased reaction time and recall time, decreased vigilance, and perceptual and cognitive distortions. These can lead to errors and other industries have recognised the importance of managing fatigue. We discuss here the aviation industry as a good parallel example.

Human fatigue is a well-known cause or contributing factor for aviation accidents (NTSB 1997; Gander et al 1998; Graeber et al 1990). Fatigue has been suggested to reduce situational awareness (NTSB 1997) and the flight crew's alertness and ability to make decisions during periods of multiple sources of information. In response to this, several aviation and transport bodies have attempted to develop counter measures for operational use:

- 'Guidelines for situation awareness training' (NTSB 1997, p113), which provides training tips to assist pilots recognise indications of loss of situation awareness not only to themselves but also to other crew members. It also provides countermeasures to restore awareness.
- An update to the guidelines ('Crew resource management training', NTSB 1997, p113) gives guidance for identifying fatigue among the flight crew and taking action.

Also, the issue of fatigue due to shift work in aviation has been investigated since the 1980s. The NASA – Ames Research Centre Fatigue Countermeasures Program was initiated to investigate the role of fatigue in flight operations and translate research findings into operational measures. Key deliverables from this program are:

- 40-minute planned in-flight rest period can significantly improve performance and physiological alertness in long haul flight operations (Graeber et al 1990; Rosekind et al 1994).
- An electronic sleep/wake diary organiser. It is programmed with an extensive number of sleep/wake and duty questions which can be downloaded on a computer for subsequent analysis (Rosekind et al 1996).
- Training module providing information on the physiological mechanisms underlying fatigue, some misconceptions and fatigue countermeasures (Rosekind et al 1994).
- Development of an operational document *Principles and guidelines for duty and rest scheduling in commercial aviation* (Dinges et al 1996).

The International Air Transport Association (IATA), the International Civil Aviation Organisation (ICAO), and the International Federation of Airline Pilots' Associations (IFALPA) developed the Fatigue Risk Management System[3], which aims to provide air operators with guiding information to implement a fatigue management policy (IATA et al 2011). Among other things, the document aims to control pilots' commuting practices to work, monitor pilots' resting time before flight and enhance stronger company attitude towards safety.

The UK RSSB (2005) study looked at the effect of returning from rest days on SPAD risk, which has been raised many times. At the time of the study there was no clear evidence of this effect, although it was thought there was a possible risk if returning from one day's rest only.

A further UK RSSB (2004c) study looking at mixed freight and passenger traffic found that freight train drivers' work patterns result in higher SPAD rates. This suggests that fatigue, shift working and maintaining vigilance are significant factors.

Policies and standards that require good practice for managing rail fatigue are now available in different countries, for example Sydney Trains' Fatigue Risk Management Policy and RSSB (2012) *Managing fatigue – a good practice guide*. The referenced good practice guide provides good background information on the causes and risks associated with fatigue as well as guidance on achieving the steps necessary to comply with UK legislation:

- identifying safety critical workers
- setting standards and designing work patterns
- limiting exceedances

[3] www.iata.org/publications/Documents/FRMS%20Implementation%20Guide%20for%20Operators%201st%20Edition-%20English.pdf

- consulting with safety critical workers
- recording working arrangements
- providing information to safety critical workers
- monitoring
- taking action when critical workers are fatigued.

B2.4.4 The effect of experience

Another survey (RSSB 2004b) of nearly 650 drivers gathered drivers' ratings of 48 hazards associated with signal reading. This information was used to assess route driveability. The study looked at the effect of experience on perception of hazard severity. While drivers tended to rate most hazards less severely as they become more experienced, some hazards showed a different effect. Inconsistent signalling, signal design, layout and approach controlled signals were considered more severe by moderately experienced drivers than new drivers. This may be a facet of drivers only becoming aware of these hazards as they get more experience. The most experienced drivers considered perceptual problems such as distance to the signal, sunlight and brightness of signal more severe than any other drivers. The study suggested that this might be a facet of ageing, such as driver eyesight.

The Co-operative Research Centre (CRC) report (Naweed and Rainbird 2014) found that experienced drivers are more likely to be able to prioritise safety when responding to conflicting task demands, ie not be influenced by time pressure.

B2.4.5 Driver distraction and inattention

The body of work in the UK has recently been added to by a large research programme carried out by the CRC for Rail Innovation in Australia (Naweed and Rainbird 2014). This study found four common themes emerged as risk factors that lead to train driver distraction and inattention:

- sighting restrictions
- time pressure
- station dwells
- controller interactions (communications).

The model draws attention to the increased risk when these factors converge and finds that some are naturally paired; sighting restrictions plus time pressure are likely to occur together on a daily basis as are station dwells plus controller interactions. Our research explored overt (endorsed by organisation) and covert (personal and informal) behavioural strategies that could address these four themes.

B2.4.6 Devaluing the meaning of signals

Another key theme to emerge from the CRC Research (Naweed and Rainbird 2014) was the high prevalence of caution aspects on the network and the conflicting pressure to keep time to the timetable. This was reported to lead drivers to treat caution signals as a clear signal and continue to drive at line speed with the expectation that they would not encounter a signal at danger. This finding was common across the study participants who included both Australian and New Zealand drivers. Although this can be viewed from the perspective of the individual driver if using a behavioural approach, the subsequent future inquiry workshops held as part of the CRC study usefully identified systems interventions as the route to SPAD risk reduction:

- better signal sighting distance
- processes to identify signals that are ineffective

- end users to be part of the signal sighting process.

A remaining challenge for the UK rail industry is to improve railway operational performance, thereby reducing the number of caution and danger signals encountered (Reason 2008). Currently, the number of red signals encountered is not fully understood. This data would be useful for normalising SPAD data for a good appreciation of the frequency of driver error in relation to the frequency of encountering red signals.

B2.5 System influences on risk of SPADs

In order to better understand the latent influences on SPAD risk, a subsequent RSSB study attempted to structure and quantify system factors (RSSB 2006).

The study used a mixed research approach including: literature review, brainstorming and risk ranking workshops, review of five years of Category SPAD A error categories and 1:1 interviews with 41 railway staff from 16 organisations (ranging from operations directors to frontline staff). It produced a framework of these influences, which helps demonstrate how factors far removed from the driver in the cab affect the risk of a SPAD (table B.1).

The final output was reviewed by an industry forum to assess which factors were already ‘in hand’ in the wider industry. This can therefore be taken to be based on frontline experience and industry knowledge as well as academic literature and SPAD causation data. The study also identified the industry roles other than the driver that have an influence on SPAD risk (from signal manager to human resources managers) and the organisations involved (ranging from government to train operators).

Table B.1 System influences on SPAD risk, based on UK RSSB research (2006)

System level influence	Roles	Influencing factor	How does this influence SPADs?
Organisational leadership	Executive management RSSB	Safety and commercial demands	Perceived tension between commercial and safety demands by staff
	Network rail unions (Her Majesty’s Rail Inspectorate) Signal Sighting Committee	Staff cohesion	Poor communication leads to a lack of awareness about key safety issues and procedures
		Communications with industry	Lack of understanding of each other’s roles
Day to day management	Roster clerks Driver standards managers Platform staff Signal managers	Holiday, overtime: Staff take either a long period of leave or work for long periods without rest	Long leave periods: influences staff’s ability to be up-to-speed with the job Long working periods lead to fatigue
Recruitment policy	Government ORR Executive directors Human resource managers	Experience amongst frontline staff	Reduced number of experienced candidates to promote for line managers Extra training costs for new staff and shortage of trainers Fewer staff to learn ‘on the job’
		Middle management roles	Shortage of middle managers leads to being overworked and not having enough time to manage each member of staff
		The general management training scheme	Lack of understanding of the broad issues regarding rail safety by future executive leading to poor management
		Workload of frontline	Overworked managers have less time to

System level influence	Roles	Influencing factor	How does this influence SPADs?
		staff managers	spend with each staff member and safety briefings leading to a communication break down
Training and competence	Signallers Network Rail Driver manager technical Director driver trainer RSSB ORR/Her Majesty's Rail Inspectorate Maintenance organisation's HR manager	Route familiarity	Drivers may be more likely to make signal sighting errors on unfamiliar/unexpected routes
		Unnecessary danger aspects	Drivers may struggle to stop at some signals or their expectations may decrease the likelihood of spotting a signal showing a danger aspect if it is usually clear.
		Regulation of track workers	Lack of awareness of good practice and rules may lead to errors and violations.
Cab and signalling design	Cab designer procurement Driver representative fitter HF analyst roster clerk HRM/occupational psychologist	Improvements to the design process	Poor design may cause: distractions at critical times – cognitive overload Interfaces that are not user friendly. Task to conflict with other tasks the operator must complete Accessibility issues
		Job design	Monotony can potentially lead to poor performance on a signal detection task

B2.6 Contribution of risk factors to likelihood of SPADs

In 2004, the RSSB commissioned a piece of work in the UK to look at the possible level of contribution of risk factors to SPAD probability (RSSB 2004d). The work used two indicators; a) the common factors in SPADs and a SPAD risk analysis category. These are described below. The variety and number of factors and different ways in which they influence risk of SPADs demonstrates the need for a system-wide approach to SPAD management and that mitigation strategies focusing on the driver's behaviour alone will not be effective. These are described here as, although they may no longer be widely used, they provide a comprehensive database from which UK and international frameworks for collecting and analysing SPAD data have evolved.

B2.6.1 Common factors in SPADs category

This was developed based on a 1,000 article database of literature relating to the underlying causal factors and methods of mitigating SPADs. The influencing factors that emerged from the literature were categorised and linked to available evidence. The categories formed the 'Common factors in SPADs' which follow a systems approach framework of individual, workplace and organisational factors.

The Australian Rail Safety Regulators has also used a systems approach to the categorisation of factors that contribute to SPAD risk and has published a contributing factors framework. As it is based on the UK model and to keep a degree of consistency and avoid repetition it is not presented here, but can be downloaded from www.transport regulator.nsw.gov.au.

Table B.2 Common factors in SPADS

Individual factors	Workplace factors	Organisational factors
Vigilance and attention	Signal/sign attributes	Safety management issues
Experience and route knowledge	Signal location	Ongoing competence assurance
Fatigue and alertness	Equipment interface	Use of rules, procedures and standards
Perception	Workplace layout	Design process
Task workload	Track layout	Workforce organisation
Shift patterns	Infrastructure features	Communication/dissemination
Individual differences	Ambient environment	Safety culture
Risk-taking behaviour	Time of day/month	Training and selection
Experience and habituation	Weather condition	Commercial
Situation awareness		Maintenance
Decision making/strategy		
Manual control		
Work history		
Person-person communication		
Stress		

B2.6.2 SPAD risk analysis category

This is based on work to calculate the relative importance of different types of risk factor based on the statistical significance of risk factors taken from the UK Network Rail SPADMIS database (1990–1997).

Influencing factors were grouped as those relating to the individual (driver), operational and environmental factors (see table B.3 for definition). The outcome of this work was to identify that individual factors such as experience and returning from leave have the greater influence (35.2%) and environmental factors the least (4.1%). It should be noted that this does not reflect cause, but this is a reflection of the relative strength with which these factors predict the variation in SPADs over time.

While it is of value to know that driver factors are closely related to SPADs, it must still be borne in mind that not all individual factors are within driver control, and they are in turn influenced by the wider system as discussed above. Therefore wakefulness/alertness for instance is not within an individual's control but will be influenced by shift patterns, rostering, route profiles, overtime and so on.

Table B.3 SPAD risk analysis category

Grouping	Mean predictive power	SPAD risk analysis category	Common factors in SPADS category
Individual factors	35.2%	Previous SPAD records	Work history
		Experience	Experience and route knowledge, expectancy and habituation
		Wakefulness/alertness	Fatigue and alertness
		Return from leave	Shift patterns
		Visual accommodation	Perception, signal location, signal attributes

Grouping	Mean predictive power	SPAD risk analysis category	Common factors in SPADS category
Operational factors	25.7%	Service level	Commercial
		Time of day	Time of day, month, year
		Public performance measures	Commercial
		Cab environment	Workplace layout
Environmental factors	4.1%	Cab temperature	Ambient environment
		Rail adhesion	Infrastructure features
		Foliage	Infrastructure features
		Sunshine	Weather

B2.7 Additional factors – non-technical skills

In response to numerous aviation incidents in the 1970s the international aviation community introduced a series of cockpit resource management programmes. Over time in the aviation industry these have collectively developed as crew resource management (CRM) and it is not mandatory training for flight crew. They cover a number of 'non-technical skills' such as:

- situation awareness
- decision making
- communication
- teamwork
- leadership
- managing stress
- coping with fatigue.

Other high-risk industries such as process industry, healthcare (particularly in anaesthesia and the operating room environment), military and emergency services have also recognised that these factors have been implicated in high-profile accidents and are important aspects for safe and efficient performance. When relating these to the theory of accident causation presented by Reason in section B2.2, non-technical skills are an important last line of protection in the system's defences. They are responsible both for active failures that can contribute to incidents, but also and importantly they regularly catch and correct their own and others errors, so improving the resilience of the system.

It has been suggested, following the wide implantation of CRM within the aviation industry and more recent adoption for some healthcare settings that CRM may have some benefit for improving performance and reducing SPAD risk.

The Federal Railroad Administration (FRA) Office of Research and Development funded research to assess CRM at the North American Class I railroad. The research was conducted by the Texas Transportation Institute between the years 2001 and 2003 (Morgan et al 2003). Data was collected through site visits across five different railroad types: eastern Class I railroad, a western Class I railroad, a shortline railroad, an urban commuter railroad and an inter-city passenger railroad. The study found that 'none of the US Class I railroads currently have a comprehensive formal CRM training or awareness program that covers all employee crafts' (p72).

Furthermore, it was identified that where an active CRM training exists, it is restricted to train and engine service employees. According to the authors, CRM training needs to be extended to other craft areas such as dispatchers, engineering and mechanical crews to reduce HF-related events (Roop et al 2007). International and Australian accident investigation and research (McInerney 2005) supports the view that this could also be beneficial to the rail industry and a national project to develop generic CRM training for the Australian rail industry is underway under the name of rail resource management (RRM), which draws on experience from other industries and adapts it to the Australian rail environment (Klampfer et al 2012).

Non-technical skills (NTS) have seen recent focus within the UK rail industry and the RSSB provide information on the NTS required in the train driver role, a NTS train the trainer course, a forum for NTS trainers, mini conferences and company briefings. NTS is believed to be a cornerstone of mitigating the driver errors that stem from slips and lapse type errors, which are known from incident analysis to be a major contributor to SPADs. Research has shown that drivers that have 'lesser' events are more likely to have a SPAD (RSSB 2010a); drivers with two or more station stopping incidents during their career were statistically more likely to have had a SPAD. Therefore competence management and NTS training that improves performances in these 'precursor' areas may also reduce risk of SPADs.

Driver selection processes in the UK have also been updated to include psychometric tests that evaluate key NTS (RSSB 2013)

B2.8 International best practice

The Independent Transport Safety Regulator (ITSR) in New South Wales has adopted a systems approach in the way it manages SPADs (ITSR 2011). ITSR recognises that SPADs are a result of 'trigger' events influenced by a broad range of factors relating to the individual, the workplace/operations and the organisation. It presents two complementary and equally important approaches – data collection and analysis. As this is acknowledged to be built on the UK RSSB approach we present the latter in section B7 with reference to the ITSR where relevant.

From the review of past, present and future research projects carried out on behalf of the Transport Agency, no past projects were identified that could be considered relevant to this project. Two active research projects were identified that may be relevant if they relate to rail in terms of providing baseline measures and indicators of success for SPAD risk reduction strategies. These are:

- demonstrating the benefit of network operation activities (Traffic Design Group Ltd)
- assessing new approaches to estimate the economic impact of transport interventions (MWH New Zealand Ltd).

B2.9 Resilient organisations

In recent years, high-hazard industries such as process control, aviation and healthcare have started to discuss safety in terms of 'resilience'. Safety has both a negative and a positive face and it is usually the former that receives attention. Negative aspects are the reactive outcome measures, such as measurement of incidents, collisions, near hits and SPADs. Positive outcomes have been described as 'dynamic non-event' (Weick 1991) and they relate to the organisation's intrinsic resistance to its operational hazards.

Whereas conventional risk management approaches are based on hindsight, resilience engineering presents an approach that looks for ways to:

- enhance the ability at all levels of organisations to create processes that are robust yet flexible
- monitor and revise risk models

- use resources proactively in the face of disruptions or ongoing production and economic pressures.

With this in mind, Hollnagel et al (2006) recommend changing the definition of safety management from ‘avoiding things going wrong’ to ‘ensuring that everything goes right’ in an attempt to foster a proactive approach that sustains everyday acceptable performance, rather than one that prevents hazards from being realised.

The oil and gas industry have tried to take this concept on board by developing ‘leading indicators’. Leading indicators can be used to monitor the effectiveness of control systems and give advance warning of any developing weaknesses before problems appear. For example, by measuring the degree to which best practices are being followed, leading performance indicators can complement the use of lagging indicators such as accident data. They provide a complementary method of measuring the ‘health’ or resilience of an organisation. Using leading indicators means making regular checks on the organisational defences (the slices of cheese in the Swiss cheese model). Reason (2008) provides a useful table, adapted below in table B.4 which summarises the benefits of the two complementary sides to using lagging and leading indicators.

Table B.4 Leading and lagging indicators as safety measures

	Reactive measure (lagging indicator)	**Proactive measure (leading indicator)**
Local and organisational conditions	Large amounts of data reveals trends and underlying causes	Identifies conditions most needing correction – steady gains in organisational ‘health’
Defences, barriers and safeguards	Each event shows ‘holes’ in organisational defences	Regular checks show where holes are now.

Note: Adapted from Reason (2008)

The relevance of this development in other industries to SPADs is to prompt discussion on several fronts:

- SPAD interventions are many and varied; there should continue to be a focus on interventions that improve the robustness of different layers of protection
- How will SPAD interventions be measured to determine the effectiveness of the intervention – will it be measured in terms of lagging or leading indicators?
- How will this fit within a long term and holistic organisation ‘fitness’ programme?

Reason (2008) advocates that, rather than struggling to reduce an already low level of adverse events, such as is the case for SPADs in the UK, organisations (in this case UK train operating companies and infrastructure managers) should regularly assess and improve the basic processes. This could for example take the form of improving operational performance (to reduce number of red aspects encountered), signal sighting, cab environment, fatigue management etc. that are known to influence SPADs. A Precursor Indicator Model has been developed within the UK rail industry to model train accident risk[4] and following research into leading and lagging indicators (RSSB 2011), the RSSB (2015) also provides a good practice document and supporting materials to measure safety performance.

[4] www.rssb.co.uk/risk-analysis-and-safety-reporting/safety-intelligence/precursor- indicator-model

B3 SPAD interventions

B3.1 Introduction

The HF/systems approach that has underpinned the research and development of tools to reduce SPADs in the UK has led to a holistic framework that addresses SPAD risk through a suite of tools. This section of the review aims to give a comprehensive list of those SPAD tools and interventions.

It is based on the systems approach adopted by the RSSB and the ITSR and emphasises the importance of integrating SPAD risk reduction methods within an overall framework to improve the 'health' of the organisations in order to reduce the size of the holes in different layers of the Swiss Cheese.

The largest international body of research on the HF issues associated with SPADs has been conducted in the UK over the last 10–15 years by the UK RSSB (as evidenced from this review and acknowledged in ITSR 2011). There has been a wide ranging and emerging research programme exploring the HF theory associated with SPADs and building on this to develop tools and mitigation strategies which have now been in place in the UK for a number of years. The research has included large scale studies, reviewing thousands of SPAD data, consultation with hundreds of railway staff including drivers and cross-industry peer review.

The outcome of this research has been the development of a range of SPAD reduction and mitigation measures, many based on an understanding of the human and system influences on SPAD risk.

SPAD risk rate in the UK has been reduced by 90% in the last 13 years (RSSB 2014b).

It is the view of RSSB that this has been achieved through 'sustained practical application of control measures'.

Because many of the measures have run in parallel, it would be difficult to allocate reduction in risk to a single measure or intervention and there is a general absence of data, both in the UK and internationally that relates to the measured effectiveness of SPAD interventions. The provenance of the measures, however, can be identified and for many of the UK HF tools have been based on large-scale, peer-reviewed studies subject to industry consultation and have been in use for a number of years. Together, these tools allow the full range of system and individual influences on SPADs to be identified and managed.

A good example of this is the recent work carried out by the ITSR which published an information paper on SPAD management in 2009 and has since developed several tools that together provide a similar framework to that developed by the UK RSSB. It comprises:

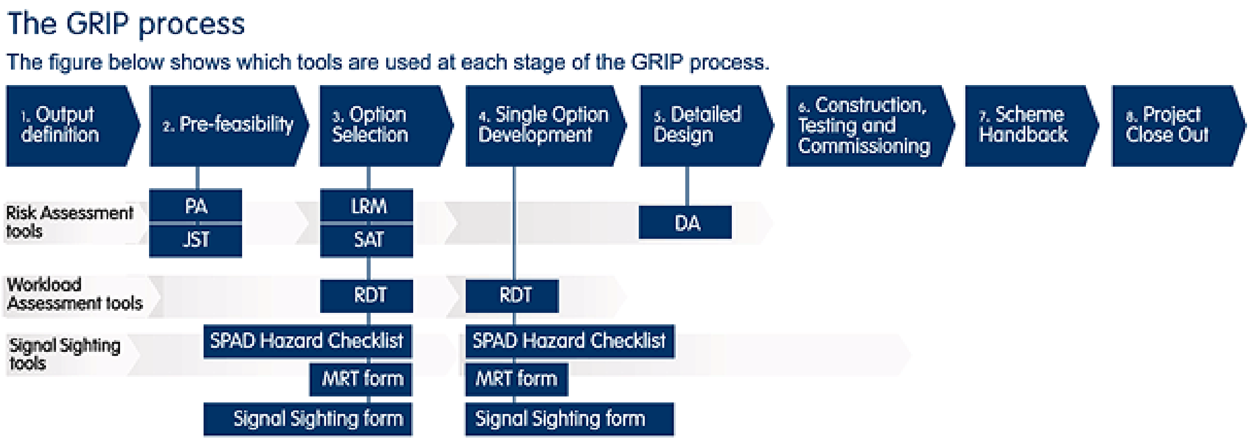
- Tool A: Data collection tool for rail infrastructure managers
- Tool B: SPAD data collection tool for rolling stock operators and mitigation measures for rolling stock operators
- Tool C: SPAD data collection tool and mitigation measures for rail infrastructure managers.

The aim of the following sections is to provide a broad overview of the many and varied SPAD risk reduction techniques.

B3.2 The UK framework

The UK has a project management process that manages and controls all projects that enhance or renew the UK national rail network – the Network Rail Guide to Railway Investment Projects process. The tools developed by the industry for SPAD risk assessment tools are integrated within the project management process as illustrated in figure B.5.

Figure B.5 The GRIP process



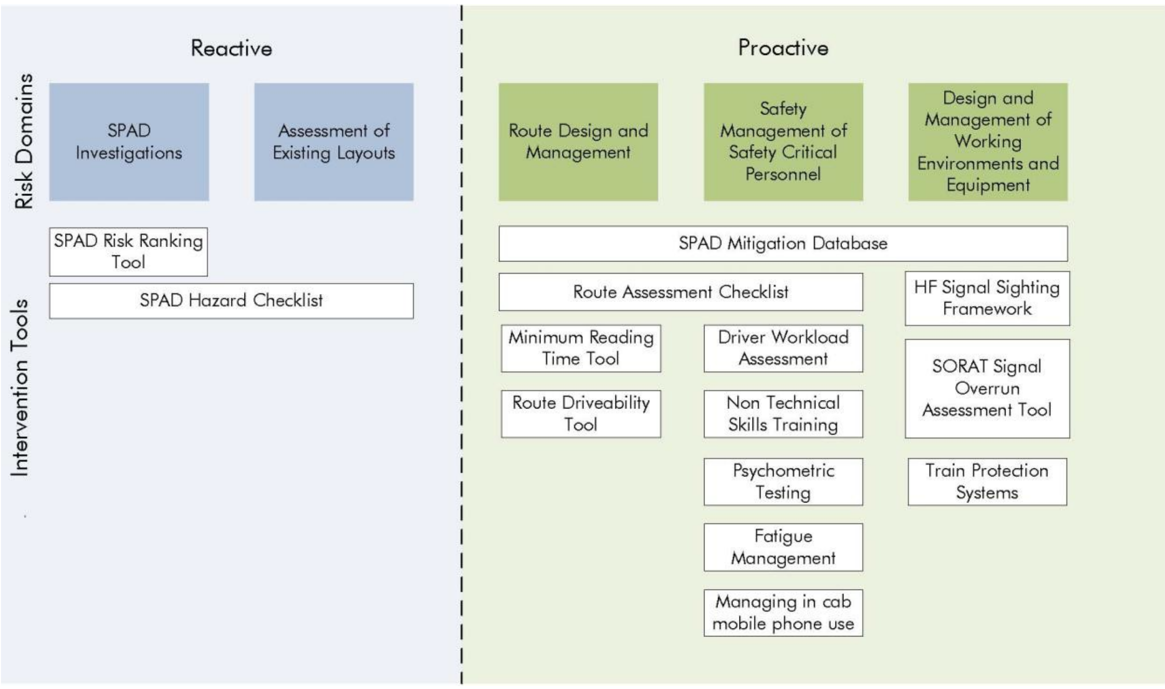
Note: PA = preliminary assessment; JST = junction screening tool; SAT = standard assessment tool; LRM = layout risk method; DA = detailed assessment, MRT = minimum reading time, RDT = route driveability tool

This overall risk management process would need to be adapted for New Zealand's network but the principle of an overarching strategy with associated tools based on HF principles would appear to be of value. It should be noted that some of these tools may be used more than others. The SPAD hazard checklist and mitigations database described in sections B3.3.2 and B3.3.3 are thought to be no longer widely used within the UK, possibly due to the familiarity with SPAD causes and mitigations by investigators. They are included here for thoroughness and section B3.3.4 is included to describe what is used in practice.

B3.2.1 Overview of the UK SPAD risk management and reduction tools

Figure B.6 provides an overview of the five risk domains identified in the UK framework and maps current SPAD intervention tools onto these domains. The following sections of this report describe the UK SPAD tools, parallel tools being developed by the ITSR and other risk reduction strategies that have been implemented internationally.

Figure B.6 UK SPAD risk management framework of risk domains and tools



B3.2.2 SPAD risk management support tool

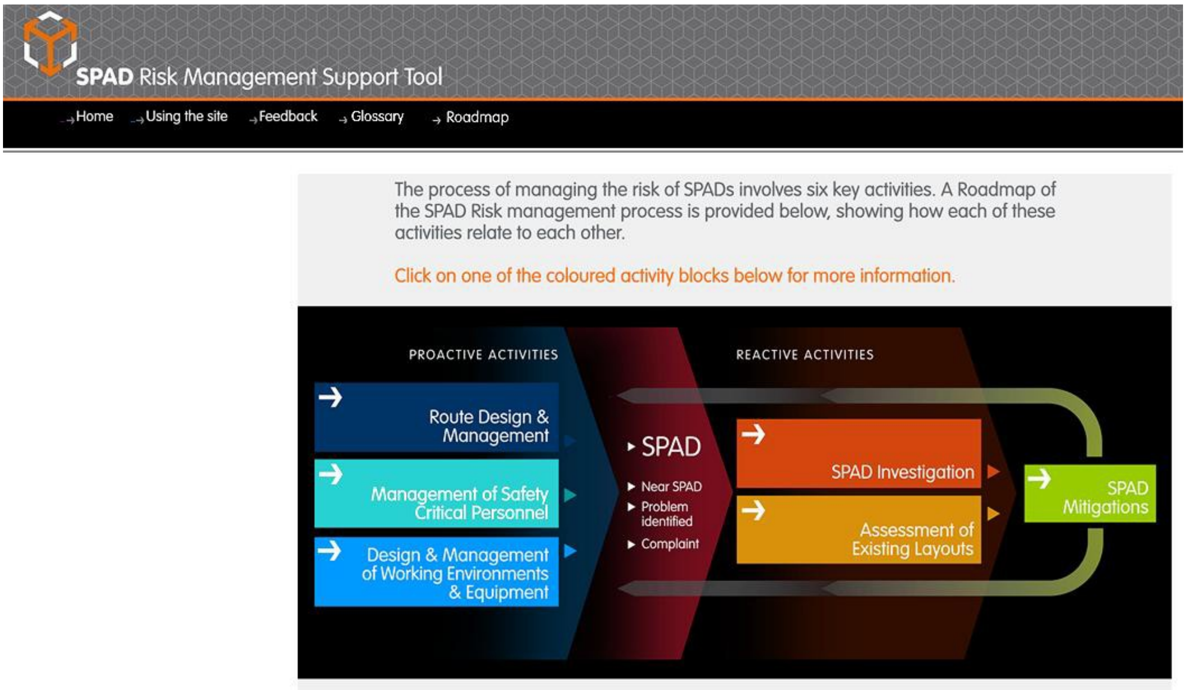
Available online[5], this is a comprehensive approach to managing SPAD risk, used on the UK rail network. It provides links to the mandated activities, including national standards required to proactively and reactively manage SPAD risk, using formal risk assessment methods to consider the five main domains related to SPAD risk:

Table B.5 Domains related to SPAD risk

Route design and management Safety management of safety critical personnel Design and management of working environments and equipment	Proactive tools
SPAD investigations Assessment of existing layouts	Reactive tools

The basis of the UK approach is developed using a resource called the common factors in SPADs' database. As this is an underlying body of research it is described in section B3.2.3

Figure B.7 SPAD risk management support tool



Within each of these stages are specific risk assessment tools and processes that fulfil the need to evaluate each of the influencing system factors that can increase risk. For instance, signal sighting tools, driver workload assessments and so on. These form the UK rail group standards, for instance, GI/RT7006 Prevention & Mitigation of Overruns – Risk Assessment.

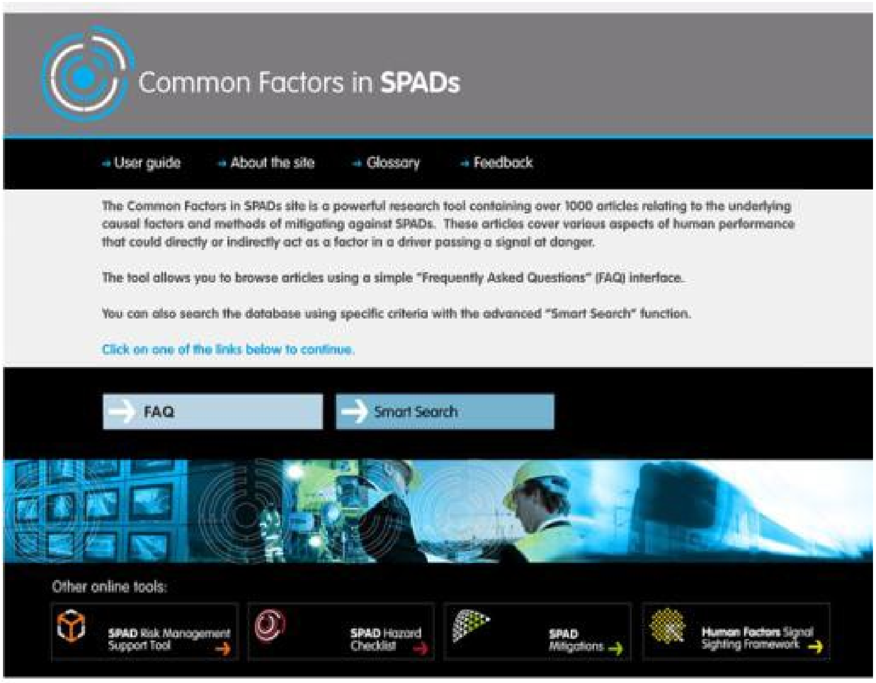
Specific tools/approaches of interest are discussed in more detail in the following sections.

[5] www.opsweb.co.uk/TOOLS/risktool-site/index.html

B3.2.3 The common factors in SPADs' database

Also available online[6] is a powerful tool containing over 1,000 articles relating to the underlying causal factors and methods of mitigating SPADs. The site allows access to literature on a range of topics and has a detailed search function. There are also 'topic' statements, for instance relating to the effect of the environment, which explain the links between influencing factors. The full list of factors is provided in annex BA, table BA.1.

Figure B.8 Common factors in SPAD tool



Development of the database also included developing the concept of 'common factors statements', which is a list of summary statement alongside the evidence on which it based (from the literature).

While this is not a mitigation tool, the classification of influencing factors, the explanatory text and the links could be a useful source of information for developing an organisational understanding of the HF issues underlying SPADs.

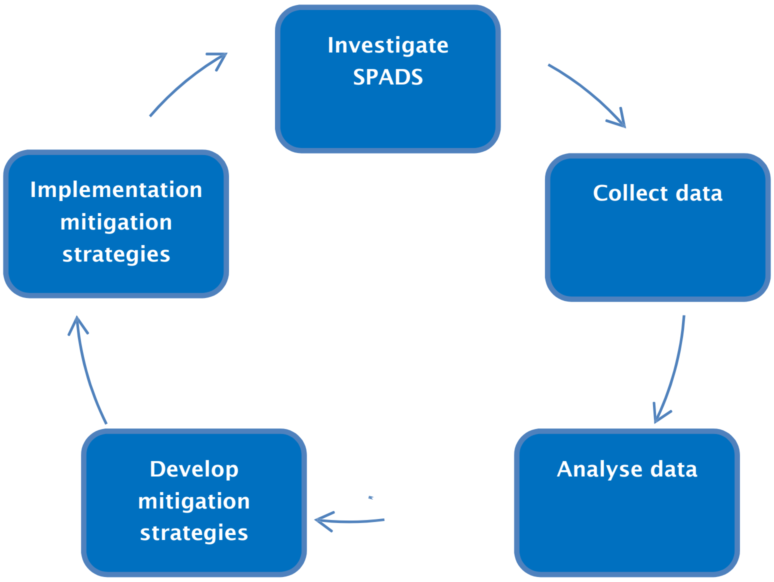
B3.3 Data collection and analysis

Effective SPAD risk reduction can only take place if the causes of SPADs are understood. Regulators of different countries collect incident data with the intention of identifying trends and advising industry on effective mitigation measures, SPADs are often considered to be precursors or antecedents which, although they may be low frequency, have the potential for high consequence events and are therefore important to understand.

The Australian ITSR is taking a continuous improvement cycle approach to the management of SPADs, following a philosophy of 'measure in order to manage' as shown in figure B.9.

[6] www.opsweb.co.uk/TOOLS/common-factors/index.html

Figure B.9 SPAD management continuous improvement cycle



Shorrock and Kirwan (2002) assert that classification of errors in a meaningful way is imperative for recording data which is to be used for detecting trends in incident occurrence. Wright (2002) provides a useful set of criteria against which any prospective taxonomy can be assessed:

- is based on suitable underlying theory of human behaviour
- includes technical, behavioural, organisational and management factors
- is reliable such that independent analysts arrive at the same conclusions
- is comprehensive
- is quantitative
- suggests methods of improving and recovery based on identified root causes
- can differentiate between direct causes and root causes.

The data collection and analysis processes used in the UK are standardised and based on the SPAD research. They are described in sections B3.3.1 and B3.3.2 as examples of recognised good practice. The ITSR has also developed data collection tools for SPAD incidents.

The Dutch use a 'bow tie' model and have recently expended considerable effort in collecting and analysing SPAD data in response to an upward trend in SPAD occurrence. They have recently investigated moving from the bow tie method to a more detailed technique used in some other industries such as healthcare (prevention and recovery information system for monitoring and analysis (Dabekaussen et al 2007) and based on the Reason model of accident causation.

The UK rail industry has long recognised the importance of identifying the root causes based on a HF approach. Therefore their system for SPAD data collection is based on a framework of individual, organisational and workplace factors. Other countries (eg Australia) have adopted an approach based on the UK experience.

This is useful in determining whether the existing taxonomies used, for example, by the RSSB and ITSR are suitable for use by the Transport Agency and to ensure that if elements are 'cherry picked' that the aim is to continue to satisfy these criteria.

It is also critical that SPAD risk mitigations strategies can be properly linked to the underlying and contributory causes. This focus, along with targeted programmes to train investigators in a consistent root cause analysis approach has enabled the UK industry to successfully move away from 'retrain the driver in the rules'.

Sections B3.3.1 and B3.3.2 describes the SPAD risk ranking tool and hazard checklist that have been developed to provide a standard data collection and analysis tools and section B3.3.3 describes the database of mitigations that is used to address the identified issues. These have evolved into a simpler classification system which is described in section B3.3.4.

B3.3.1 SPAD risk ranking tool

This tool gives a measure of the level of risk from each SPAD, enabling the industry's total risk to be monitored. It is used both to track performance and to inform incident investigations. The score ranges from 0 (no risk) to 28 (very high risk) and is based on the potential for the SPAD to lead to an accident and the potential consequences of an accident that did occur. SPADS with risk rankings between 16 and 19 are classed as potentially significant and those above 20 are classed as potentially severe.

B3.3.2 SPAD hazard checklist

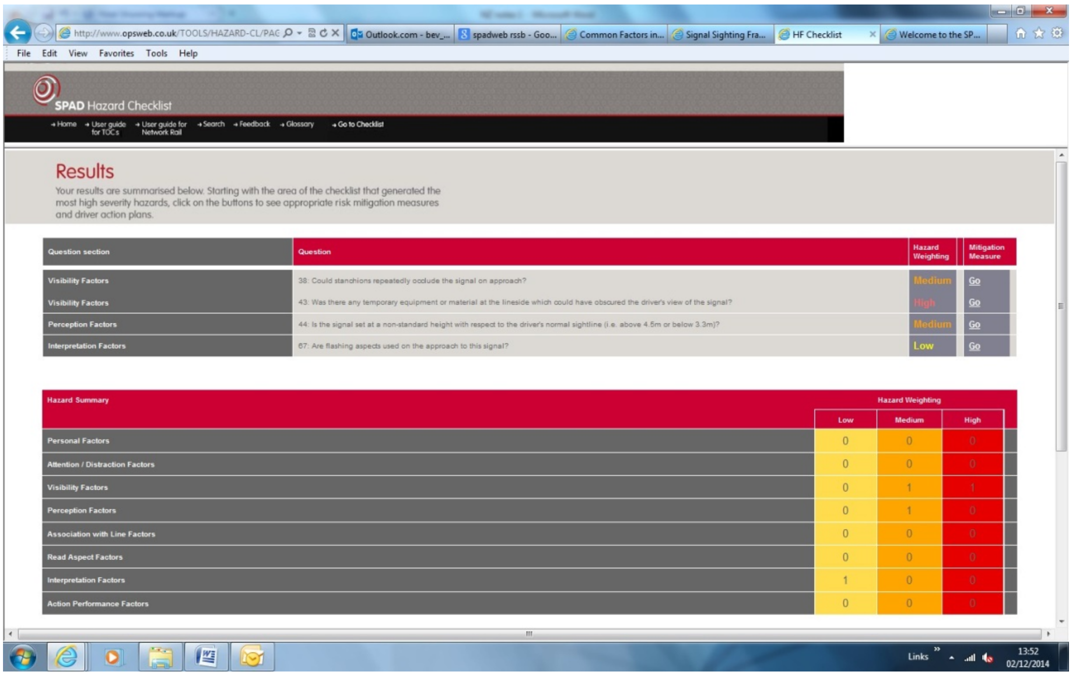
The HF SPAD hazard checklist can be found online[7] and was developed for Network Rail and the RSSB. It is for use in investigations and by train and freight operating companies to produce driver action plans as part of the formal investigation process. This is a questionnaire that steps through three key areas to identify the contribution of individual versus system factors:

- individual (personal, attention/distraction)
- signal sighting (visibility, perception, line association, read aspect, interpretation)
- cab equipment factors

It provides a useful approach to investigation and outcome planning. The output of the HF hazard checklist is shown in figure B.10. The Australian ITSR approach is based on the UK SPAD hazard checklist although they have separate tools for the rolling stock operator and the infrastructure manager.

[7] www.opsweb.co.uk/TOOLS/HAZARD-CL/INDEX.html

Figure B.10 Example of SPAD hazard checklist output



B3.3.3 SPAD mitigations database

This is a database of mitigations for SPADs[8], organised along the same classification structure as the risk management support tool and addressing mitigations for the first three domains (route design and management; safety management of safety critical personnel; design and management of working environments and equipment – see section B3.2.1). It replaced the anti-SPAD toolkit and is intended for use by the UK infrastructure manager (Network Rail) to manage SPAD risk factors, in combination with national standards and procedures. This is an extensive database of mitigations which includes procedural advice onto how to assess and implement the mitigations and also the HF derivation of the cause and solution. The classification of mitigation categories is shown in figure B.11. This is an extensive resource which provides an extensive overview of the potential issues and mitigations available and should be valuable tool for any rail system considering how to comprehensively manage SPAD risk. For this reason the complete list of hazards is presented in annex BA. Mitigation strategies are many and varied, to give a flavour of the range if mitigation strategies table B.6 takes one type of issue 'Distraction on approach to signals' and presents the hazards and mitigation from the database.

The RSSB database has provided the basis for the ITSR data collection and mitigation measure tools for rolling stock operators and infrastructure managers.

It is important to remember that this collection of strategies is contained within an overall framework and vision for the railway.

[8] www.opsweb.co.uk/tools/SPAD_MITIGATION/index.html

Figure B.11 Areas for risk mitigation strategies in the SPAD mitigation database

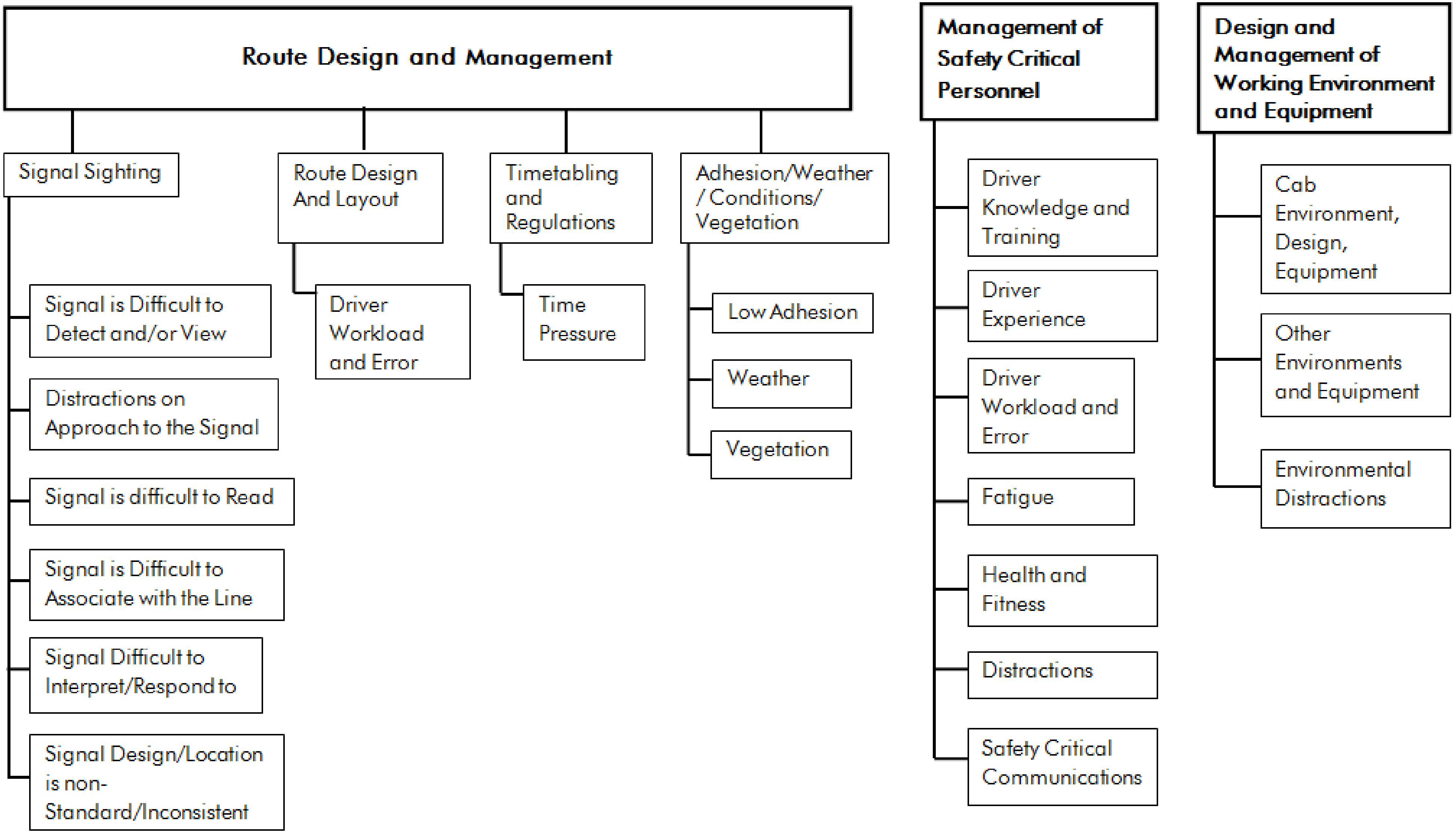


Table B.6 Hazards and mitigation strategies associated with 'Distraction on approach to signals'

Hazard	Suggested mitigation
Signal multiple reminder aids	Reducing the number of signs on approach to multi-SPAD signals
	Removal of signal awareness aids between AWS magnet and associated signal
	Do not over-use reminded aids – consider driver opinion
Temporary materials/equipment	Contractors/maintenance workers acknowledge drivers and move into a position of safety
	Screening off major works from drivers' view to reduce distraction
	Brief drivers about major trackside work
	Take drivers on a ride to observe the building work from trackside
	Inform drivers how building work can be a distraction and what countermeasures to take to refocus
Lineside information hard to see	Lineside information kept clean
	All signal ID plates in good condition, correctly identified, not duplicated and readable
	Encourage drivers to report any sighting difficulties / use video technique to convey the extent of the problem
	Review maintenance arrangements and driver reporting procedures
Signal after traction gap	Train operating companies to ensure drivers are trained to re-focus on their primary responsibility (eg rheostatic braking)
	Ensure adequate route knowledge so that drivers are alert and expect the signal
	Route knowledge training and assessment covers how gaps can be an issue at a signal
Complex track layout	Remove excess lineside information to simplify drivers' task
	Ensure adequate driver route knowledge through a high quality training and competency assessment
Non-operational lineside distraction	Make drivers aware that they can get distracted and inform on the types of distractions
	Introduce re-focusing techniques and commentary driving in driver training
Driver preoccupied with controlling speed	Maximise viewing time by providing banner repeaters or countdown markers for signals. Exercise this with caution not to overdo and create additional distraction
	Route knowledge training and effective training on various gradient profiles
Driver distracted by driver only operation (DOO)	Locate DOO in position so that proper sighting of the signal is available
	Provide mini banner repeater adjacent to DOO CCTV equipment

Hazard	Suggested mitigation
	Route knowledge training so that drivers are aware of DOO locations and how the potential for distraction
Incorrect signal aspect	Determine whether approach control is still needed and justified at a signal
	If sighting is good and risk of speeding through switches and crossovers is low, consider earlier release of the signal from red
	Other junction controls (eg flashing aspects) may give better warning of routing
	Consider speeding through a junction to avoid unnecessary speed reductions imposed by signalling
	Make drivers aware of the nature of attention and the type of errors they can make so that they are better prepared to manage it
	Additional route knowledge
Limited sighting	On high speed lines, signal conspicuity is crucial
	When possible, sighting distances should be longer than the existing recommended standard

B3.3.4 Incident factor classification system

While the SPAD hazard checklist is still relevant and it is understood that use is still encouraged, there is a move in the UK tend to encourage investigators to identify human error in incidents using the '10 incident factors'.

These factors along with established classifications of human error types are being identified from the incident reports and entered into the incident factor classification system (IFCS); part of the industry safety management system (SMIS). Currently this is being completed for a sample of significant events by RSSB HF specialists and it is hoped that eventually industry will itself enter this detailed data along with other details of events. This approach to data collection and analysis has enabled trends to be determined on the influence of human performance and organisational systems to the cause of incidents, and is being used to develop the industry SPAD risk reduction strategy.

The 10 factors considered in the database are:

- communications
- equipment
- information
- knowledge, skills, expertise
- personal
- practices and processes
- management and supervision
- teamwork
- work environment
- workload

B3.4 Proactive tools

B3.4.1 Human factors signal sighting framework

This is a tool[9] that provides support to signal sighting committees on HF issues associated with SPADs. It is based on a set of performance shaping factors that influence signal vigilance, detection, recognition, interpretation and action, based on an extensive review of the literature. This has resulted in a prioritised list of 35 HF principles (HFP) for signal sighting, such as (the full list is shown in annex BA):

> *1 Speed signs and their associated AWS magnets should be placed 275 metres before a platform starter or a stop signal. Source of Distraction*
>
> *2 Avoid positioning stop signals immediately beyond a converging or crossover junction on multiple parallel lines*
>
> *3 Any signal-like lights that may be confused with the signal in the driver's field of vision on approach to the signal should be shielded from view, eg from a nearby facility with strong lighting, streetlights, station lighting, etc. Special attention should be paid to this distraction at night, or in dark conditions*

[9] www.opsweb.co.uk/TOOLS/HFSSF-SITE/index.html

> *4 Position the signal where the driver is unlikely to be distracted by other duties, eg setting up train radio, arming ATP, operating TASS* [tilt authorisation/speed supervision] *visual indicator, responding to lineside signs.*

Other countries, such as Australia have comprehensive processes for signal sighting including a signal sighting committees, signal sighting working group and guidelines for positioning of new and altered signals (Australian Rail Track Corporation Ltd 2010). The UK signal sighting framework is cited here as an example of best practice which has integrated HF good practice within the tools and process and is embedded within the legislative framework as there are UK standards such as *Signal positioning and visibility GE/RT 8037* (RSSB 2003a) which require the process to be undertaken. UK signalling standards and guidance *GK/RT 0045* (RSSB 2010b) are currently being re-drafted and restructured into a suite of new standards, to provide advice on factors that influence visibility, readability and driveability. This includes revisiting the signal sighting elements and the factors that influence minimum read time.

Banner repeater signals

In addition to the good practice for signal sighting contained in the tool an additional intervention used in Australia is the use of banner repeater signals. These are additional signals that act as repeaters of approaching signals which may be obscured to provide advanced warning of signal aspect and consequently increase the decision making time available to the driver.

B3.4.2 Signal overrun assessment tool

The signal overrun assessment tool was implemented by Network Rail in 2011 for use in re- signalling projects and signals are assessed on a five-year cycle. It is an update of the VariSPAD probability model, and assesses signals for the combination of characteristics that make the signal vulnerable to a high consequence SPAD, eg infrastructure failures or maintenance activity, and has been extended to include underlying checklist prompt questions to make it more comprehensive. It is based on analysis of SPAD incident data including a national profile of scenarios, a comprehensive SPAD dataset, SPAD probability weighting factors or comparative likelihood factors for the likelihood modifying factors in each SPAD scenario. It has also helped the development of the Accident Consequence Model and has fed into RSSB Safety Risk Model and SPAD Risk Ranking Methodology.

The UK standard on overrun risk evaluation and assessment was issued on 6th December 2014 and sets out the UK industry's approach to the management of signal overrun risk.[10] A range of formal tools for overrunning assessment include preliminary assessment (PA); junction screening tool; standard assessment tool; layout risk method and detailed assessment.

B3.4.3 Route driveability tool

The route drivability technique[11] (RDT) is a computer-based tool that allows an early assessment of route drivability to support the design of new and revised infrastructure on the railway network. The basic RDT procedure involves:

- entering infrastructure features along a journey, based on a signalling scheme diagram or other source of information
- running the model to calculate the speed profile and driver workload rating
- interpreting the workload ratings/speed profile

[10] www.opsweb.co.uk/TOOLS/HFSSF-SITE/index.html

[11] http://rdt.ergotools.co.uk/Default.aspx

- discussing and iterating the journey, incorporating HF advice to optimise the driver's workload.

It is currently under further development to consider its use by non-HF specialists and to integrate into other SPAD mitigation processes and such is not available for use outside of Network Rail. It is, however, an example of how HF issues such as driver workload can be integrated into SPAD mitigation measures.

B3.4.4 Route assessment checklist

The route assessment checklist assesses existing routes for driver cognitive loading and therefore attention limitations and the likelihood of distraction. It is also used for driver training.

The tool includes a HF technique called cognitive task analysis, which breaks down the driver's job and considers this in terms of human capabilities and limitations. It asks questions about the number and type of hazards found on a route, route features and their density. It adds sensitivity to other risk assessment measures by considering the cognitive aspects of residual risk (those SPAD risks that cannot be removed through design and in areas of high workload). It can also be used in driver training for residual SPAD risk and difficult routes.

B3.4.5 Minimum reading time tool

Used by signal sighting committees to determine the minimum reading time required to for the signal reading task, in turn determining appropriate signal locations for new signalling scheme designs. Potential hazards at a signal are presented in order to estimate additional reading time. It can be used in investigations to assess sufficiency of reading time. Note that this tool may be subject to revision in the near future as a result of current work being undertaken to revise signal sighting standards.

B3.4.6 Driver mental workload tools

There is a range of tools available to help judge mental workload, and some of these have been adapted for the railway. The assessments are based on the principle that both a high and low workload will contribute to SPAD risk through multiple tasks, distraction, memory failure and failure to attend to signals. There is an online tool for railway signallers[12] and work was carried out to develop these tools for train drivers[13], although an online version is not available. Assessing workload will help to identify routes with workload issues, and also the effect of infrastructure and equipment changes on workload, and the resultant risk of SPADs.

B3.5 Managing safety: critical personnel

B3.5.1 SPAD briefing measures

A study by RSSB (2003b) made recommendations to the National SPAD Focus Group regarding methods of delivering SPAD safety messages, as follows:

- SPAD reduction methods must be supported by senior management within each rail organisation.
- Messages need to be customised for each audience and the current stage of SPAD reduction.
- Communications policies need to be monitored and assessed and messages need to be developed over time.
- Marginal groups such as maintenance, on-train and station staff need to be included.

---

[12] www.ergotools.co.uk/swt/default.aspx

[13] www.rssb.co.uk/research-development-and-innovation/research-and- development/research-reports-catalogue/pb009400

- Briefings need to use real life testimony and contributions from front line staff and include discussions to allow staff to feel engaged.

B3.5.2 Train driver selection

In 2004 the RSSB commissioned a report to deliver a strategic overview of the use and benefit of psychometric testing within the train driver selection process. It investigated where and how psychometric testing is currently applied in the industry and reviewed the effectiveness of the current regime in selecting the best applicants to the role. Comparisons were made with experience in other industries in Great Britain and rail industries in Europe. It was found that the British rail industry uses a recruitment process for train drivers, which is recognisably similar to those used for train driver recruitment in other countries and in other industry sectors. Key findings were that:

- The selection criteria should be updated to give better coverage of the abilities recognised to underpin good performance in modern train driving.
- Selection criteria which address safety and train handling performance should form the core of driver selection and be assessed by all companies in the same way either by the assessment centres or by qualified individuals in companies.
- Companies should have flexibility in the way they assess criteria relating to personal effectiveness.
- New tests should be identified or developed to assess the new or extended selection criteria that have been identified.
- Companies need to give greater thought to the use of psychometric tests for post-incident investigation. A process is outlined for how tests can be better integrated into the investigation process.

An industry steering group was set up and in 2013 a new psychometric assessment process and driver selection and recruitment process was introduced in the UK. The work updated selection criteria for train drivers, to reflect the demands of modern train driving and to align more closely with European standards for traffic operation and management[14]. It also identified a new suite of assessment methods which assessed all of the new selection criteria and addressed weaknesses in the previous assessment method. These changes were integrated into UK Rail Industry voluntary standards (RSSB 2013a).

The CRC report (Naweed and Rainbird 2014) also identified that recruitment was a challenge within the Australian rail industry and with drivers being recruited by mining companies there may be both a loss of experience and a lowering of standards in the recruitment drive.

B3.5.3 Fatigue management and shiftwork

In the USA, Congress has mandated fatigue risk management in the rail industry (Gertler and Raslear 2009) and the NTSB has developed a methodology for investigating fatigue in transportation accidents.

In the UK, RSSB (2012) promotes a holistic fatigue risk management system, noting the need for adaption to organisational needs as there is no generic, 'one-size-fits-all' system. Guidance in the UK also covers managing road driving/travel to and from work (RSSB 2013b). There are also fatigue risk modelling tools (eg such as the HSE's Fatigue and Risk Index (FRI) in the UK) that can be used to review work practices before and after implementing change.

The National Transport Commission (NTC) in Australia implemented legislation to manage fatigue risk (NTC 2012). A recent accident investigation by the Australian Transportation Safety Board (ATSB 2013) in

[14] Technical Specification for Interoperability, TSI 2006/920/EC

which a freight train passed two signals at danger, found fatigue to be a significant contributory factor to the incident and in addition to recommendations relating to improving fatigue management it concludes that 'rail operators should ensure that fatigue management systems incorporate integrated and multi-layered risk control mechanisms and that SPAD strategies devised by rail operators should have regard to broad systemic issues rather than focus simply on individual train crew actions'. What this means is that, while methods that control fatigue for the individual should be implemented, other controls, such as engineering controls (eg vigilance devices) designed to mitigate the consequences of fatigue should also be part of the broad spectrum of risk control. The ITSR has developed a model of fatigue to help accident investigators understand the organisational factors that contribute to fatigue (ITSR 2011, appendix B). This model identifies factors that:

- optimise sleep
- optimise alertness
- manage errors.

B3.5.4 Crew resource management training

Section B2.7 introduced the concept of CRM and non-technical skills training for drivers. We therefore present some of the recent findings relating to CRM implementation in railroad industry.

North America

The FRA Office of Safety sponsored the development and implementation of a pilot programme of rail-based CRM training (Morgan et al 2003). This work was undertaken with the assistance of the Burlington Northern Santa Fe and Kansas City Southern Railways in 2004 and 2005. This work resulted in the development of separate CRM training materials for the various crafts in the railroad industry, such as: transportation, engineering and mechanical crews (Roop et al 2007). The programme is a one-day long, scenario-based training that introduces employees to the principles of CRM and how it can be applied in their relevant operating environment. It has been suggested that the CRM training developed by Texas Transportation Institute, could be utilised as a starting point to create rail-specific CRM programmes (Roop et al 2007). Also, each rail operator could tailor the training programme to meet their needs.

China/Hong Kong

More recently, an attempt was made to introduce and evaluate CRM in Hong King in the West Rail division of the Kowloon-Canton Railway Corporation (Tsang and Hoermann 2009). One hundred and twenty crewmembers took part in this study such as drivers, station and traffic controllers. The recruited individuals took part in a three-day CRM training programme which included lectures; video aided training and integrated training facilities. Various data was collected such as: evaluation of change in safety attitude (pre- and post- CRM training), performance observations from emergency drills (CRM-trained and non-CRM trained crews), post-training feedback and workplace performance between 2005 and 2006. Findings indicated that CRM-trained crews developed higher levels of synergy and effectiveness, while the quality of radio communications increased when compared with non-CRM trained members.

Australia

In Australia, a RRM project was conducted which developed a national programme for RRM training for rail safety workers[15]. The project was piloted on a major Victorian rail operator (V/Line) aiming to implement best practice version of RRM. The implementation of RRM has resulted in improved human performance

[15] www.transportsafety.vic.gov.au/rail-safety/safety-improvement/rail-resource- management-training

while reducing human error[16]. There is also a best practice toolkit for implementing RRM training for the Australian rail industry has been developed in 2007 (Lowe et al 2007).

UK

In the UK, based on research and development by the RSSB, training in non-technical skills is being rolled out with support available for train operators on how to implement this in their companies[17]. The skills taught cover the areas in table B.7. The roll out of NTS in the UK aims to move competence management from being perceived as solely the responsibility of the company and something done **to** the driver to be one of continual professional development that the driver shares responsibility for.

Table B.7 RSSB non- technical skills programme

Category	Skill
1 Situational awareness	Attention to detail; overall awareness; maintain concentration; retain information (during shift); anticipation of risk
2 Conscientiousness	Systematic and thorough approach; checking; positive attitude towards rules and procedures
3 Communication	Listening (people not stimuli); clarity; assertiveness; sharing information
4 Decision making and action	Effective decisions; timely decisions; diagnosing and solving problems
5 Cooperation and working with others	Considering others' needs; supporting others; treating others with respect; dealing with conflict/aggressive behaviour
6 Workload management	Multi-tasking and selective; attention; prioritising; calm under pressure
7 Self-management	Motivation; confidence and initiative; maintain and develop skills and knowledge; prepared and organised

Critical to the roll out of any of the interventions/approaches relating to driver behaviour and competency is the development of a culture where front line staff are able to freely discuss issues with their managers. In industries and organisations that have a 'blame culture' it will be difficult to implement them effectively as, if a member of staff highlights issues such as being tired they may be labelled a trouble maker or trying to swing the lead.

In summary, the initiatives presented above suggest that CRM training programmes can be beneficial for the rail industry as a vehicle for reducing HF-related events and improving operational safety.

B3.5.5 Managing in- cab mobile phone use

The use of mobile phones in train driving cabs can be beneficial for some operational communication, but clearly present a risk in terms of driver distraction. A study in the UK found that of nearly 400 drivers, 4% admitted to using a mobile phone while driving and California banned mobile phone use for railway workers following the 2008 Chatsworth metro crash. The UK has a voluntary standard to try to standardise company policy towards mobile phone use (RSSB 2010) and an education campaign for drivers has been instigated.

[16] www.onrsr.com.au/safety-improvement/rail-resource-management

[17] www.rssb.co.uk/Library/improving-industry-performance/2012-leaflet-non-technical- skills.pdf

B3.6 Driver strategies

This section describes some strategies employed by drivers to improve/maintain human performance. The non-technical skills training described previously in section B3.5.4 can be a vehicle for transferring driver strategies to both experienced and new drivers.

B3.6.1 Point and call technique

Other techniques used within the rail industry are not non-technical skills as such, but aim to improve driver response to signals. In Japan rail workers carry out 'point and call' checks; train operators check a railway signal while pointing at it and calling out the aspect, station staff similarly confirm platform safety and maintenance workers inspect their maintenance work on completion. Although not validated, the research suggests that this may help to:

- accelerate and maintain duration of eye gaze
- strengthen the memory of the action
- make the person more aware of human error
- enhance arousal level through muscular activity
- suppress automatic habitual responses.

The research carried out by the Japanese Railway Transport RI notes that although point and call checks are used to prevent human error, since it is thought that these errors are extremely rare in practice, that it is difficult to grasp whether it is effective. The Japanese instil knowledge of the effectiveness as part of driver training using experiential software. As such it is a procedure that may be difficult to implement in an existing culture and may be difficult to maintain in practice if the frontline operators cannot see benefits from the technique.

B3.6.2 Multi- occupancy cabs and cross calling signals

Some countries use multi-occupancy cabs as a measure to mitigate the risk of driver error. Independent checks are used in other industries to provide a degree of redundancy. Some industries, eg pharmaceuticals have fallen foul of the assumption that a check by a second person provides adequate redundancy and that risk is reduced to an acceptable level. Over time independent checks often become less independent and are of course also subject to the fallibility of the person carrying out the check.

The efficacy of this measure is not assured as demonstrated in the incident described in section B3.5.3 (ATSB 2013) which had two drivers in the cab.

B3.6.3 Individual driver strategies

The CRC research (Naweed and Rainbird 2014) identified driver strategies that may be useful in addressing SPAD risk related to situations involving risk factors of controller interactions and time pressure. These are:

Driver engagement:

Some drivers report carrying out mental preparation exercises before driving to be in the correct state of mind. This type of activity is evidence of a good safety culture and alertness to the risks of driving.

Decision making:

Drivers evaluate their mental health and alertness and take a 'sickie' if they feel driving would be compromised by personal issues or fatigue. Experienced drivers are better at decision making to prioritise tasks to ensure safe driving when presented with conflicting demands, for example due to time pressure or controller interactions.

Internal dialogue:

Some drivers report using internal dialogue as a way of helping concentration, particularly when distracted. The internal dialogue is used to evaluate and dismiss the distraction, for example a passenger disturbance.

While these strategies are presented in the CRC research as potentially useful ways of mitigating SPAD risk, unless they are made part of the system or culture they will be of variable effectiveness. It would be useful to better understand their efficacy and integrate them within the training programme – they would fit well with elements of the non-technical skills type training described in section B3.5.4.

Proprioceptive strategies: a cognitive process based on instinct and awareness. As this is described as being aligned with subconscious processes, route knowledge and accumulated experienced, it is not unlikely to be of value as a mitigation strategy that can be implemented.

Task focusing; drivers describe the ability to concentrate on signals and ignore distracting information.

Multisensory techniques; similar to the point and call technique mentioned in B3.6.1, some drivers use physical movement, verbal and auditory cues and even physical objects as memory aids, particularly during station dwells. Techniques include:

- calling the signal out load three times
- pointing down for a caution aspect, pointing up for a green aspect
- standing up when leaving a station on a caution aspect
- holding a pen/bottle when going past a caution signal
- pulling down the cab blinds while waiting in the station.

The CRC report makes the important point that these reports of driver strategies indicate the driver-signal dynamic is a very important one and drivers would benefit from the being at the forefront of consultation processes with regard to signal and track reviews. The reader is directed to annex BB, which collates HF principles for signal sighting as used within the UK by signal sighting committees.

B3.7 Engineering controls

B3.7.1 Train protection systems previously described

A number of train protection systems and their drawbacks have been described in section B2.4.2:

- driver reminder appliance (DRA)
- driver safety device and vigilance system
- automatic warning systems (AWS)
- automatic train protection (ATP)
- train protection and warning system.

B3.7.2 Continuous automatic warning system

In Ireland some sections of track have coded track circuits that provide in-cab indications which repeat lineside signals and generate an audible alert when a restrictive aspect on the signal. The driver is required to acknowledge the alert within eight seconds or there is an emergency brake application.

B3.7.3 European rail traffic management system

ERTMS is the European implementation of ATP. It is an initiative backed by the European Union, which not only seeks to decrease the occurrence of SPADs, but seeks to enhance cross-border interoperability and the procurement of signalling equipment by creating a single Europe-wide standard for train control and command systems. The two main components of ERTMS are the ETCS, a standard for in-cab train control, and the GSM mobile communications standard for railway operations.

B3.7.4 Train stops

London Underground uses mechanical train stops combined with fixed blocks and individually calculated train overlaps to provide train protection. A SPAD triggers the emergency brake, and the train is brought to rest as the full braking distance beyond every stop has been calculated so that the train will come to a standstill before infringing a restricted block. In addition to this trains are restricted to 10 miles per hour speed for three minutes after a trip to enforce driving on sight. The system can be reset and the train can proceed after a two-minute delay.

B3.7.5 Conclusions to be drawn from engineering controls

While the UK uses DRA, TPWS and ERTMS as engineering controls, other international systems are variations on similar themes of ATP, such as Automatische Trein Beinvloeding (Netherlands), Ebicab (Sweden), KVB (France), TBL 2 (Belgium). Full descriptions are outside the scope of this report. In terms of risk control it is in keeping with the ethos of assuming that the driver will inevitably fail to detect, interpret and respond to a caution or stop signal at some point and that ultimately an engineering control will be more effective than ‘soft’ interventions that rely on the driver. However, given the problems with adding one technology on top of another that have been encountered (for example AWS plus DRA and TPWS in the UK) an integrated approach is to be favoured that considers the driver as part of the system and that wraps up all these interventions into one holistic protection system.

B3.8 New technology

B3.8.1 Light emitting diodes

The advent of new technology has enabled signals to take advantage of LED lighting which increases readability.

B3.8.2 Signal sighting and infrastructure design

Optimal placing of signals for driver readability is fundamental to reducing SPAD risk. Three-dimensional modelling, high definition video and other photogrammetry tools are available to assist in the design of new signalling and infrastructure layout. These tools can also be used to model signal layout for driver training/simulation.

B3.9 Interventions that have not been implemented

This section presents risk reduction strategies that have been suggested, but have not been implemented.

B3.9.1 Check AWS signs

A train operator in the UK (Arriva Trains Wales) introduced ‘Check AWS’ signs at stations with a high rate of start on yellow SPADs (RSSB 2007b). Eye tracking research indicated that drivers did check the boards and interviews with drivers suggested they were a positive addition. The report concluded that while the boards were useful, their effectiveness would obviously be negated with extensive use across the network (reducing the novelty and therefore drivers’ attention to them) and so a strategy for placement would be needed. The effectiveness of the use of the boards in the UK is not known.

B3.9.2 Extended AWS

RSSB (2004e) looked into the implications of extending AWS in the UK to include forewarning drivers of approaching signals with a history of multiple SPADs. This was not taken forward due to concern over the effectiveness of the existing system and alarm saturation due to too frequent warning sounds, leading to drivers becoming habituated to the warning.

B3.10 Summary

SPAD interventions are many and varied. It is useful to see the framework that has evolved over time in the UK as this is based on a database that has thousands of research papers that contribute to the body of knowledge regarding causes of SPAD risk. The risk domains considered are:

- SPAD investigations
- assessment of existing layout
- route design and management
- management of safety critical personnel
- design and management of working environment and equipment

It should be noted that, in addition to the resources available in the form of tools, industry working groups both at operational and senior management levels also contribute to awareness of SPAD risk and help to share understanding of causes and how implementation of interventions can be carried out effectively.

The Australian approach has built on the UK framework and also emphasises the importance of continuous improvement; using SPAD investigations to understand underlying causes and contributory factors, collect and analyse data to develop and implement mitigation strategies. It is important to stress the importance of collecting and analysing data to understand the underlying and contributory causes that are prevalent in the context of New Zealand railway operations.

Unfortunately there is little evidence within the literature of measures of success for individual SPAD risk reduction interventions or of the barriers to implementation of individual strategies; this is discussed further in section B4.

B4 What does success look like?

The previous sections describe a multitude of contributory causes to SPADs and wide ranging SPAD reduction tools and strategies. It is clear that piecemeal or ad hoc implementation of tools and strategies will have variable success. It is therefore important to develop a strategy built on the systems approach to human error and safety and to ensure SPAD reduction tools and strategies address different layers of protection in order to manage SPAD-related risk.

Given that there is little documented evidence of barriers to the implementation of SPAD reduction interventions, this section presents a guide to key factors for managing change. This comes both from hands-on experience as HF consultants involved in developing and implementing change in different industries and from quality improvement initiatives identified in the literature.

This section looks at the importance of managing change and at barriers to success in a rail context, and presents a model of factors necessary for the successful implementation of SPAD risk reduction strategies. The rail industry will need to learn lessons from other industries regarding the importance of setting a vision, having good leadership and engagement and communication with staff at all levels of the organisations in order to implement successful programmes for risk reduction. It also highlights the importance of measuring change and reminds the reader of the model of leading and lagging indicators presented in section B2.9.

B4.1 UK SPAD risk reduction

A number of major Western European railways have suffered serious SPAD caused train accidents: Belgium and the Netherlands in 2010, Germany in 2011, Netherlands, Germany and Switzerland in 2012.

The UK use a safety risk model[18] that provides the total safety risk associated within a railway operation expressed in terms of fatalities and weighted injuries (FWI). The risk is composed of hazardous events and their precursors and the tool which measures risk shows the risk contribution from each hazardous event and precursor. The UK has driven down SPAD rates to a level of underlying SPAD risk from 8.2FWI/year in 2001 to 0.82 FWI/year. This represents a 90% reduction in risk (RSSB 2014b).

Although there are some year-on-year variations, it is thought to be the sustained practical application of control measures that has improved UK industry performance and reduced the underlying SPAD risk.

When considering the high mileage and volume of signals passed on the network and given that the last layer of protection is controlled by the driver it has been suggested that the limits of human performance are being approached. Despite this, additional strategies to improve the resilience of the system are being considered and implemented, such as non-technical skill training. It does mean that to drive SPAD rates lower engineering controls may be necessary.

The current position in the UK suggests that SPADs account for a relatively low level of long-term residual system safety risk. As they still carry the potential for a high consequence accident it is recognised that a future strategy needs to be developed to manage SPADs going forward for the next 10 years to build on the success to date (RSSB 2014b). Section B5 outlines some of the components of this strategy.

B4.2 Managing change

B4.2.1 Importance of managing change

Organisational change often involves new technological initiatives and new ways of working. This can lead to feelings of uncertainty among employees (Terry and Jimmieson (2003), which has been linked with various negative consequences such as the following as well as the problem of encountering resistance to the change:

- higher stress levels (Schneider and DeNisi 1991)
- increased turnover of staff
- reduction in job satisfaction (Johnson et al 1996).

Two key strategies for alleviating uncertainty and reducing resistance during a period of change have been taken from manufacturing industries and used within rail: a) communication of the change and b) employee participation in the change.

Communication of the change

Effective communication can serve as a vehicle to provide employees with a degree of information as to why, how and when changes will take place (Wanberg and Banas 2000). The purpose of communication is twofold: a) to inform its employees regarding their tasks, the policy and other issues of the organisation

[18] www.safetyriskmodel.co.uk

and b) create community within the organisation (De Ridder 2003). Empirical research from the manufacturing industry has revealed that the existence of a formal communication avenue in organisations when introducing a change initiative can reduce uncertainty and enhance employee acceptance (Charalambous et al 2013). In terms of promoting successful SPAD risk reduction interventions it is useful to note that it has been found to promote change supportive behaviour among the workforce (Jimmieson et al 2008).

Employee participation in implementation

Employee participation in the implementation of change is the process by which decisions are being shared between superiors and sub-ordinates (Sagie et al 1995; Zanoni and Janssens 2007) and empirical research supports that front line employees need to be involved. Employee participation in implementation and decision making has been found to enable supportive behaviour from employees (Jimmieson and White (2011) Through participation employees take a sense of ownership and control regarding the upcoming change which in turn increases their readiness. There is a large body of research from Lean Manufacturing to support this.

B4.3 Barriers to success

It is the nature of HF consultancy to be involved in helping organisations understand human-related sources of risk and developing plans to manage risk. Our team have had collective experience of:

- seeing the failed projects that have been imposed by management
- developing interventions that have the support of frontline staff, but fail due to lack of resources, commitment or movement of key personnel within the organisation.

Within the literature there is evidence of high failure rates of change initiatives (70%, Daft and Noe 2001) Healthcare has seen numerous interventions over the past 25 years in response to a growing awareness of medical error as the source of preventable deaths. These have had variable success rates and even successful interventions that have dramatically improved patient safety (Pronovost 2008) have failed when transferred to a different hospital. It is clear in other settings that what works in one setting may not work in other. This may be due to local differences in organisational systems, local operating procedures or the culture or differences. A recent paper at the 2012 Rail HF Conference asked 'Why are Dutch cargo trains 2.6 times more often involved in SPADs compared to passenger trains?' (Weide et al (2012). The differences thought to contribute were:

- less predictable timetabling
- freight encounters more (unplanned) red signals
- a higher demand on driver route knowledge
- freight train braking characteristics.

Local context and differences between and even *within* organisations need to be considered both in terms of prioritising the right intervention and as part of the change management process.

Table B.8 provides examples of barriers to change that should be considered when deciding what and how SPAD risk reduction measures are implemented within the New Zealand operational context.

Table B.8 Barriers to change

Organisational systems	People
Change makes job more difficult, longer, tedious or unpleasant, eg too many audible alarms in the cab.	Frontline staff not involved in developing the change, for example the equipment interface not user friendly or in a poor location in the cab.
The change suits one part of the organisation but not others or is not transferrable to different organisation, eg what is suitable for freight may not be suitable for passenger rolling stock.	Benefits of the change are not recognised by key stakeholders (frontline staff, middle management and senior management), eg staff thinking that new incident reporting scheme will be used against them rather than to understand underlying causes.
There is no system in place to identify evidence of effectiveness of the change.	Staff do not have the necessary levels of knowledge and experience to implement and sustain the change, for example how to communicate safety briefings.
There is no system in place to communicate evidence of effectiveness of the change.	Staff not trained in how to carry out the change or in how to sustain the change to working practices.
There is no system in place to act on evidence of problems or issues arising during the implementation process.	Frontline staff feel disempowered by the changes.
There is not the infrastructure within the organisation to support the change, eg staffing levels, equipment.	Frontline staff do not believe the changes will be sustained, eg will not receive required resources.
The aims of the change are not clearly communicated/ understood.	Management does not take responsibility to sustain the changes, eg does not give time to support, communicate.
The changes/outcomes do not align with the organisation's strategic aims.	
Change/the outcomes are not perceived as important within the organisation.	
The outcomes do not align with the culture of the organisation.	

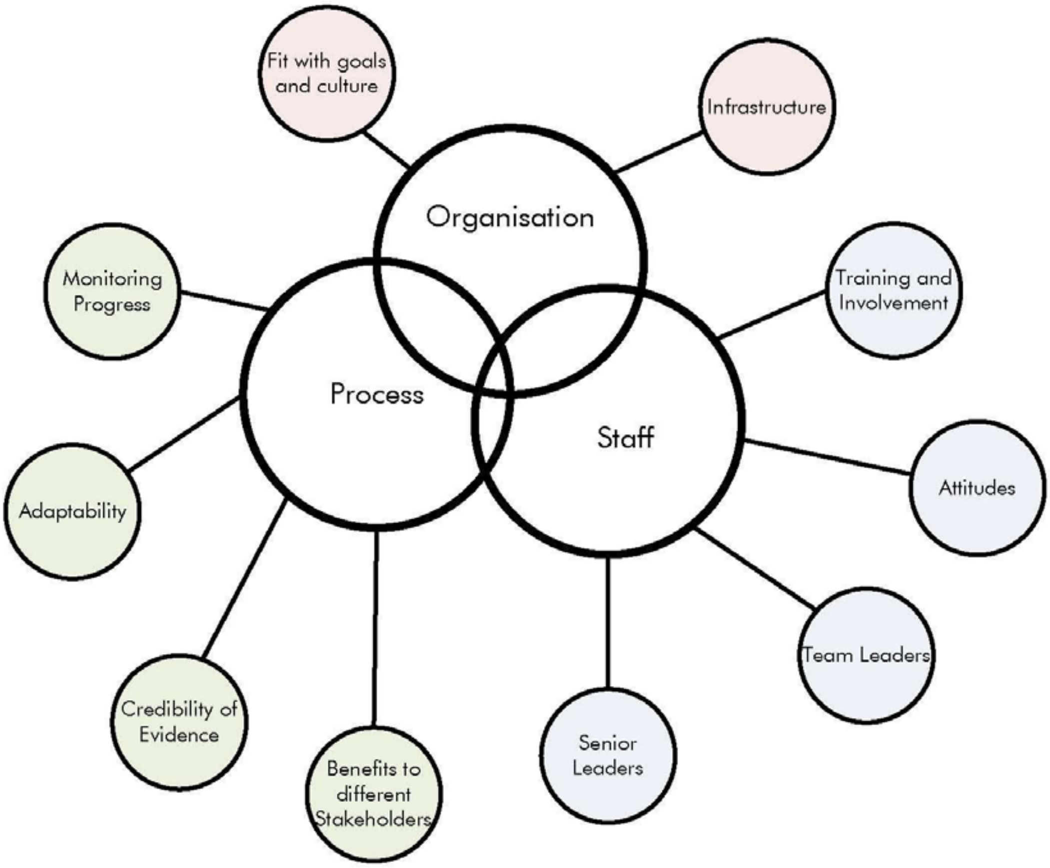
B4.4 Models for successful implementation of change

It is important therefore, when considering any intervention, whether it has been tried and accepted or proved as efficacious elsewhere, to build sustainability into the change management programme at the outset. The aim of any intervention will be to change something, albeit a piece of hardware, a process or behaviour. Sustainability is about making the new way of working or the improved outcome the norm.

This section therefore draws on experience from consultancy both within the rail industry and other high hazard industries and from change management programmes, particularly healthcare, to identify some key drivers for successful implementation of interventions.

Using a sociotechnical systems approach the UK NHS has developed a sustainability model with three core areas; process, staff and organisation. It is a useful model that has lessons for change management within the rail industry and is outlined below. An adapted model is illustrated in figure B.12. A model along these lines is useful for the Transport Agency in determining the barriers to and enablers for success when considering potential SPAD reduction interventions.

Figure B.12 NHS sustainability model (adapted)



B4.5 Safety culture

One of the aspects not quite captured by the NHS model is the culture of the organisation (Reason 1998). There is no widely accepted definition of safety culture, but it is a concept that has been much discussed in the risk and safety forums of high-hazard industries. Essential components are:

- shared values (what is important) and beliefs (the way things work round here)
- the organisational processes
- behavioural norms (the way we do things here).

There are tools available to measure the safety culture of an organisation; however, that is the easy part – changing it is a more difficult task. Reason (1998) puts it well: ‘Safety cultures evolve gradually in response to local conditions, past events, the character of the leadership and the mood of the workforce’.

As an example of sustained effort to improve safety culture, Eurocontrol was awarded the 2014 Institute of Ergonomics and Human Factors President’s Award for their Eurocontrol Safety Culture Programme. This is a pan-European initiative that has been instrumental in improving the safety of air traffic management in more than a dozen member states. The collaborative nature of air traffic management and the complexity of the systems, procedures and data mean that every part of the organisation is related in some way to delivering safety. Eurocontrol started the work on understanding, measuring and enhancing safety culture in air traffic management in 2004.

The programme involved application of a structured method to:

- understand underlying themes
- help organisations to develop self-help improvement plans.

The method was developed in partnership with Aberdeen University and underwent rigorous statistical testing to ensure it was a valid and reliable tool. Eurocontrol provide a check and balance on the interpretation of the data to ensure that the survey remains an independent assessment of the culture. The programme is reported to have had a positive and sustained impact upon the daily service provided to hundreds of millions of flying passengers within European airspace.

B4.6 Measuring change

It was noted during the literature review that there was little evidence of measurement of the impact of change for individual SPAD risk reduction strategies other than reduction in the overall SPAD rates. The implications of this are that:

- the effectiveness of the intervention is not known
- there may be complacency that the risk is managed when it is not
- the benefits are not perceived by stakeholders and the change is not supported or sustained
- issues and problems are not identified and desired outcomes are not achieved
- resources are wasted on ineffective intervention
- a safety culture has been said to rely on staff continuing to be cognisant of the hazards in their everyday working life. This can be difficult in industries with low accident rates, or in the case of the railway industry few collisions and derailments. Safety was discussed in section B2.9 in the context of 'resilient organisations as a 'dynamic non-event'. In the absence of non-events it is therefore proposed that the organisation should gather other kinds of data; that relate to the 'health' of the organisation.

If the concept of resilient organisations is taken up then safety should be thought of, and measured in terms of the 'health' of the organisation rather than focusing entirely on negative outcomes. A Swedish study (Lindvall et al (2011) used the concept of resilience to proactively anticipate impact before making an organisational change that concerned dispatching trains across a national border where two different languages are used. Before the organisational change, train dispatching was handled by a local train traffic controller with knowledge of both languages. After reorganisation, train dispatching was planned to be handled by a remote train traffic controller without knowledge of the language spoken by the train traffic controller across the border. A solution with an interpreter as a middle hand between train traffic controllers was planned to handle the new situation. The impact of the change was measured in terms of the ability of the organisation to learn, respond, monitor and anticipate.

The process industry has been trying to implement leading indicators as a tool for measuring safety and has come up with interesting measures that they feel may demonstrate 'organisational health such as senior leadership time in the field, performance of independent protection layers, alarm management, reporting of near miss incidents, safety culture' (CCPS 2011).

Measuring and monitoring the effectiveness of SPAD risk reduction strategies should therefore be considered by rolling stock operators and infrastructure managers at an early stage. The following aspects should be considered:

- What is the impact of change? This may be improved communication, driver alertness, better signal sighting etc. It provides a proactive measure in addition to traditional reactive measures such as number of SPADs.
- How can it be measured? This may include qualitative and subjective measures as well as quantitative measures.
- What is the baseline? Can we benchmark against others?
- How/what will be monitored? This will ensure that any 'holes' in the Swiss cheese that develop over time are identified and addressed.
- If the intervention is effective, how will this layer of protection be monitored proactively?

The concept of resilience and measuring the integrity of layers of defence could be a useful method for SPAD risk reduction strategies to be measured and monitored.

B5 Future strategies for SPADs

This review sets out a huge range of tools and potential SPAD mitigation techniques. A challenge for any rail industry is to identify the current level of SPAD risk and understand which interventions are likely to be effective. The following sections identify how SPAD risk is being taken forward in Australia as this may have similarities to the New Zealand context and in the UK as an example of a context that has already implemented many interventions and still sees challenges ahead. Conclusions are then drawn for New Zealand future strategy.

B5.1 Future strategy in Australia

The CRC report (Naweed and Rainbird 2014) highlighted the following areas as those that would benefit from interventions to reduce SPAD risk:

- recruitment
- signals and signal systems
- training
- data collection
- collaboration between Australia and New Zealand towards common operating procedures, reporting and standards
- collaboration to work towards SPAD reduction
- SPAD investigation processes
- improved (realistic) timetabling.

B5.2 Future strategy in the UK

Drawing on the RSSB experience of sustaining low SPAD rates it is useful to identify some areas that, after the sustained programme of SPAD interventions, still present a challenge to the rail industry:

- Operational performance. Reducing the number of caution and red aspects that drivers are faced with both reduces exposure rates (and therefore probability) and reduces potential for driver error. However, there is currently no standard method for measuring driver exposure to red signals so no reliable measure of how many caution or red aspects are presented to the driver. Improved operational performance could perhaps take the form of:
  - improved reliability of the timetable
  - high reliability traffic management and train protection systems
  - improved traffic management through better understanding by signallers of the implications of how they manage traffic and the potential SPAD traps.
- Existing engineering controls such as TPWS that have driven down SPAD rates have recognised limitations.
- Freight services (UK and Europe) have disproportionately higher number of SPAD incidents compared with passenger services. It is also reported that light locos and empty coaching stock have higher incidence of SPADs. The underlying causes of freight SPAD risk may be different from that of passenger trains and consequently the way in which interventions are implemented and managed may need to be different. Dutch research (Weide et al 2012) suggests operational differences that impact on SPADs, although ongoing work (RSSB 2015 unpublished) suggests that the top five causes are similar for freight and passenger services.
- There is ongoing work in the UK to improve vegetation management to provide a clear and unobstructed view of signals and reduce the occurrence of low adhesion when braking.
- In order to manage SPADs effectively there needs to be joined up thinking between the safety management systems (SMS) of the rolling stock operator and the infrastructure manager. The risk control measures identified within the SMS of both organisations need to be applied consistently and effectively.
- As there are existing signal sighting and route design that cannot be changed, there is a continued need to manage risk at high-risk areas such as know multi-SPAD signals.

B5.3 Future strategy for New Zealand

In order to ensure any strategy is appropriate to the context of New Zealand operations it will be essential to have a thorough and accurate knowledge of the trends in causes of SPADs within New Zealand. As mentioned, these may be different for passenger/freight or for urban/rural. This will require a data collection and analysis process based on known existing SPAD risk factors and used consistently by competent accident investigators.

We suggest this would be a good basis from which to look at the existing layers of protection and SPAD risk reduction interventions that exist within New Zealand railways.

Our research identified two recent Transport Agency research projects that may be relevant to this project if they relate to rail operations in terms of providing baseline measures and indicators of success for SPAD risk reduction strategies. These are:

- RR594 ‘Demonstrating the benefit of network operation activities’
- RR586 ‘Assessing new approaches to estimate the economic impact of transport interventions’ (MWH New Zealand Ltd).

It is recommended these projects are considered to identify any useful crossover.

B6 Conclusions

The objectives of this literature review were to:

1. Document the full known range of possible HF that can lead to SPADs
2. Understand the range of SPAD options already being utilised in rail operations
3. Document the existing barriers and risks to application of SPAD mitigations into operations elsewhere.

B6.1 Document the full known range of possible human factors

The report reviewed a large body of literature, finding many relevant references to SPAD reduction. The most relevant were summarised and have been included within this report. The UK was used as a basis for the report as their body of work is based on HF research and a systems approach to reduce human error which is an approach taken in other high-hazard industries. This approach has also been adopted by the Australian ITSR. Additional relevant documentation exists which was not reviewed due to project timescale limitations.

B6.2 Understand the range of SPAD options already being utilised

The report documents a wide range of SPAD reduction strategies covering:

- standardised SPAD investigation, data collection and analysis based on the wide range of individual, workplace and organisational contributors to SPAD risk
- tools to aid signal sighting and route design
- strategies to manage safety critical personnel, including communications, train driver selection, fatigue, CRM and managing in-cab mobile phone use
- workplace and equipment controls, including reminder devices and train protection devices
- driver strategies for reducing SPAD risk associated with controller interactions and time pressure and with the driver-signal dynamic.

It is tempting to cherry pick interventions that seem to be quick wins or applicable to the context. However, these should be based on a strategy that identifies the layers of protection the interventions aim to provide as part of the whole safety management system.

As the context of New Zealand operations had not been defined within the project at the time of compiling the review, it does not cover the relevance of the described SPAD risk reduction strategies to the New Zealand operational context. It does identify drawbacks or issues with interventions where they are described in the literature, but there were few examples of these (see section 6.3).

The UK is presented as an example of success as, over a period of 13 years and through application of a wide range of interventions they have reduced underlying SPAD risk by 90% (RSSB 2014). Drawbacks in the UK programme are discussed, for example the use of engineering controls to reduce SPAD risk in itself generates new error mechanisms. A robust strategy must consider a systems approach, which considers the part that both engineering controls and HF play to reduce the incidence of SPADs on the network in question.

The literature review only revealed one specific example of case studies/incident investigation reports to be used during stakeholder workshops (ATSB 2013). Further examples will be developed during the next phase of work.

B6.3 Document the existing barriers and risks to application of SPAD mitigations

There was little evidence found of the effectiveness of individual SPAD risk reduction strategies. The review therefore concentrated on applying knowledge of barriers to change to the rail setting and providing good practice for the implementation of quality improvements and risk reduction programmes from the other industries such as lean management, aviation and healthcare.

Examples of barriers to success include issues with the organisational systems and processes, people and culture. The review puts forward a model for successful implementation of change which identifies key factors for success. It also highlights the importance of establishing a baseline and measuring success both in terms of reduced SPAD rates and other, more proactive measures, for example quality of investigation and implementation of effective recommendations. It draws on the model of safety from resilience engineering to suggest that, in addition to measuring the success of individual interventions measures of the 'health' of the organisation, the robustness of the layers of protection would be a useful and complementary approach to the traditional safety measures of negative outcomes.

The Australian regulator has recognised the importance of adopting a continuous improvement approach and is using a systems approach to identify a variety of approaches to address the contributory causes to SPAD risk which cover many of the risk domains set out in this review. Although the UK is presented as an example of successful SPAD risk reduction the review also documents the future strategy for the UK as it is recognised that, even though the industry may be approaching the limits of human performance there are still areas which can be addressed to improve the resilience of the organisation. This includes better traffic management to reduce the number of caution and red aspects encountered, implementation of ERTMS, implementation of non-technical skills training and improved vegetation management. The Australian regulator also notes the disproportionately high number of SPADs involving some areas of service such as freight, light locos and empty coaching stock as an area for future improvement.

B7 Recommendations

The planned next stage of the project should use the following framework to achieve its objectives:

- Understand the current layers of safety protection within the current New Zealand operational networks. Compare this to the best practice frameworks to determine what options should be considered by the project.
- Formulate a framework to ensure that the mitigations are part of a suitable systems approach. This may require consultation with other ongoing research streams.
- Use workshops and focus groups to:
  - identify which HF causes are perceived to exist within the New Zealand operational context. This could include new/unique factors to the New Zealand context
  - confirm the described HF mitigations within the New Zealand operational context, and document their perceived success/failure. Work with stakeholders to analyse options for relevant mitigations.
- Analyse the fit of proposed mitigations to the New Zealand operational context and derivation of recommendations to take forward for further consideration.
- Develop a key findings document detailing the strategy, proposed mitigations and reasoning why they are considered best for success within the New Zealand context.

- The key findings document may make recommendations for strategic organisational change/structure which will enable the mitigations to take place within a suitable organisational environment. The findings are likely to include recommendations to measure the health of the ongoing SPAD mitigations and also pro-actively monitor its weaknesses (leading indicators). It will identify quick wins and longer term strategies and also give an indication of priority based on perceived effectiveness.

In addition to the planned work and as a result of this body of work and the peer review comments we also recommend:

- identifying whether there is available New Zealand data to provide guidance on the trends of SPAD causes that are specific to New Zealand railway operations
- holding meetings with the relevant parties to establish the outcomes of ongoing (unpublished) relevant research and identify opportunities to cross-fertilise research findings
- exploring the effects of cognitive underload on train driver performance and potential ways to mitigate declining performance due to underload. This would be useful to the project as we predict this is a factor relevant to New Zealand operations
- comparing the efficacy of risk triggered commentary driving in comparison to point and call. This could be useful in determining the priority of these techniques in relation to other driver strategies or other types of intervention in the next phase of work.
- reading ‘Incident factor classification system review of SPAD incidents’ (unpublished report RSSB 2015)
  - a small amount of additional work is carried out to identify case studies for use in the workshops as these have not been identified during the review.

B8 References

Australian Rail Track Corporation Ltd (2010) Signal sighting and position. *ESC-04-01*.

Australian Transport Safety Bureau (ATSB) (2013) Multiple SPAD by freight train 9837. *ATSB Transport Safety report RO-2013-003*.

Charalambous, G, S Fletcher and W Philip (2013) Human-automation collaboration in manufacturing: identifying key implementation factors. In *The Proceedings of the 11th International Conference on Manufacturing Research* (ICMR).

Center for Chemical Process Safety (CCPS) (2011) *Leading and lagging metrics: You don’t improve what you don’t measure.* Accessed 16 June 2016. www.aiche.org/ccps/resources/overview/process-safety-metrics/recommended-process-safety-metrics

Dabekaussen, M, TW van der Schaaf and L Wright (2007). Improving incident analysis in the Dutch railway sector. *Safety Science Monitor,* no.2, article 2.

Daft, RL and R Noe (2001) *Organizational behaviour.* Chicago: Dryden Press.

De Ridder, J (2003) Organisational communication and supportive employees. *Journal of Human Resource Management 13*, no.4: 20–30.

Dinges, DF, RC Graeber, MR Rosekind, A Samel and HM Wemann (1996) Principles and guidelines for duty and rest scheduling in commercial aviation. *NASA technical memorandum #110404*. Moffett Field, CA: NASA Ames Research Center.

Embrey, DE (1986) SHERPA: A systematic human error reduction and prediction approach. *Paper presented at the International Meeting on Advances in Nuclear Power Systems*, Knoxville, Tennessee.

Gander, P, K Gregory, D Miller, R Graeber, L Connell and M Rosekind (1998) Flight crew fatigue V: long-haul air transport operations. *Aviation, Space, and Environmental Medicine 69*, no.9, section II, supplement): B37–B48.

Gertler, JB and TG Raslear (2009) The fatigue status of the US railroad industry: a preliminary analysis. *International Conference on Fatigue Management in Transportation Operations.*

Graeber, RC, MR Rosekind, LJ Connell and DF Dinges (1990) Cockpit napping. *ICAO Journal*

HM Government (1999) *Control of Major Accident Hazards Regulations 1999*. Accessed 25 May 2016. www.legislation.gov.uk/uksi/1999/743/contents/made

Hollnagel, E, D Woods and N Levesen (2006) *Resilience engineering: concepts and precepts*. Ashgate.

Independent Transport Safety Regulator (ITSR) (2008) *International review of railway safety practices.*

Independent Transport Safety Regulator (ITSR) (2011) *Managing signals passed at danger.*

International Air Transport Association (IATA), International Civil Aviation Organisation (ICAO) and International Federation of Airline Pilots' Associations (IFALPA) (2011) Fatigue risk management systems: implementation guide for operators.

Jimmieson, NL, M Peach and KM White (2008) Utilising the theory of planned behavior to inform change management: an investigation of employee intentions to support organisational change. *The Journal of Applied Behavioral Science 44*, no.2: 237–262.

Jimmieson, NL and KM White (2011) Predicting employee intentions to support organisational change: an examination of identification processes during a re-brand. British Journal of Social Psychology 50: 331–341.

Johnson, JR, MJ Bernhagen, V Miller and M Allen (1996) The role of communication in managing reductions in work force. *Journal of Applied Communication Research 24*: 139–164.

Klampfer, B, E Grey, A Lowe, B Hayward and K Branford (2012) Reaping the benefits – how railways can build on the lessons learned from the crew resource management. In *Rail human factors around the world: impacts on and of people for successful rail operations*. JR Wilson, A Mills, T Clarke, J Rajan and N Dadashi (2012). CRC Press.

Lindvall, J, L Kecklund and M Arvidsson (2011) Measuring and visualizing resilience: a railway example. Pp 331–336 in *Human factors in organizational design and management – XI Nordic Ergonomics Society Annual Conference*.

Lowe, AR, BJ Hayward and AL Dalton (2007) *Guidelines for rail resource management*. Queensland: Rail Safety Regulators Panel.

McInerney, PA (2005) *Special commission of inquiry into the Waterfall rail accident*. Final report, vol. 1 and vol 2. Sydney: NSW Government.

Morgan, CA, LE Olson, TB Kyte and SS Roop (2003) Railroad crew resource management (CRM): Survey of teams in the railroad operating environment and identification of available CRM training methods. College Station, TX: *Technical report DFTR-091-00030/474450/00001.* Texas Transportation Institute.

National Transport Commission (NTC) (2012) *Rail safety national law: fatigue risk management – hours of work and rest.* Australia: NTC.

National Transportation Safety Board (NTSB) (1997) *Controlled flight into terrain: Korean Air Flight 801*. Washington DC: NTSB.

Naweed, A and S Rainbird (2014) Managing and mitigating SPAD risk in rail operations. CRC for Rail Innovation.

Pronovost, P (2008) Translating evidence into practice: a model for large scale knowledge translation. *British Medical Journal 337.*

Rail Safety and Standards Board (RSSB) (2003a) Signal positioning and visibility. Issue 1. *GE/RT 8037*.

Rail Safety and Standards Board (RSSB) (2003b) Evaluating the effectiveness of SPAD briefing methods. *RSSB T204*.

Rail Safety and Standards Board (RSSB) (2004a) Common factors in SPADs*. RSSB T070.*

Rail Safety and Standards Board (RSSB) (2004b) Analysis of driver survey material about signal sighting. *RSSB T313*.

Rail Safety and Standards Board (RSSB) (2004c) Mixed passenger and freight operations. *RSSB T108.*

Rail Safety and Standards Board (RSSB) (2004d) Analysis of the 'May peak' in SPAD data: human factors support to SPAD management in the southern and Scotland zones – summary report. *RSSB T255.*

Rail Safety and Standards Board (RSSB) (2004e) Driver reliability with extended AWS. *RSSB T021*.

Rail Safety and Standards Board (RSSB) (2005) Human factors associated with driver error and violations. *RSSB T148*.

Rail Safety and Standards Board (RSSB) (2006) Who, other than the driver, has a role in reducing SPADs? *RSSB T368*.

Rail Safety and Standards Board (RSSB) (2007a) Understanding multi-SPAD signals and the effects of line identifiers on driver behaviour: an investigation into multi-SPAD signal D301. *RSSB T632*.

Rail Safety and Standards Board (RSSB) (2007b) Research into whether 'Check AWS' signs have a beneficial impact on driver behaviour at stations. *RSSB T631*.

Rail Safety and Standards Board (RSSB) (2010) Rail industry standard on the use of mobile telephonic equipment in driving cabs. *RIS-3776-TOM*. Issue 1.

Rail Safety and Standards Board (RSSB) (2010a) *Causes, risks and mitigation of station stopping incidents: project summary report*.

Rail Safety and Standards Board (RSSB) (2010b) Lineside signals, indicators and layout of signals. *Railway group standard GK/RT 0045*. Issue 1.

Rail Safety and Standards Board (RSSB) (2011) The application of leading and lagging indicators in the rail industry (measuring safety performance).

Rail Safety and Standards Board (RSSB) (2012) Managing fatigue – a good practice guide. *RS/504*.

Rail Safety and Standards Board (RSSB) (2013a) Rail industry standard for train driver selection. *RIS-3751-TOM. Issue 2*.

Rail Safety and Standards Board (RSSB) (2013b) *Managing occupational road risk associated with driver fatigue: a good practice guide.*

Rail Safety and Standards Board (RSSB) (2014a) Code of practice for management of operational risk and SPAD avoidance strategy. *RSSB COP0100 issue 7*. Accessed 24 May 2016. www.rssb.co.uk/rgs/oodocs/COP0100%20Iss%207.pdf

Rail Safety and Standards Board (RSSB) (2014b) *RSSB Board meeting final: 06 March 2014. Signals passed at danger. Agenda Item 02*. Accessed 17 June 2016. www.rssb.co.uk/Library/about-rssb/2014-03-06-strategic-board-spad.pdf

Rail Safety and Standards Board (RSSB) (2015) *Measuring safety performance – how to develop and manage safety performance for Britain's railways.*

Rasmussen, J (1982) Human error: a taxonomy for describing human malfunction in industrial installations. *Journal of Occupational Accidents 4,* no.2: 311–333.

Reason, J (1990) *Human error*. Cambridge University Press.

Reason, J (1998) Achieving a safety culture: theory and practice. *Work and Stress 3*: 293–306.

Reason, J (2008) *The human contribution: unsafe acts, accidents, and heroic recoveries*. Ashgate.

Roop, SS, CA Morgan, TB Kyte, AJ Winfred, AJ Villado and T Beneigh (2007) Railroad crew resource management (CRM): the business case for CRM training in the railroad industry. College Station, TX: *Technical report: DOT/FRA/ORD-07/21*. Texas Transportation Institute.

Rosekind, MR, RC Graeber, DF Dinges, LJ Connell, MS Rountree, CL Spinweber et al (1994) Crew factors in flight operations: IX. Effects of planned cockpit rest on crew performance and alertness in long-haul operations. *NASA technical memorandum #108839*. Moffett Field, CA: NASA Ames Research Center.

Rosekind, MR, RM Smith, KB Gregory and DL Miller (1996) NASA AIRLOG: an electronic sleep/wake diary. *Sleep Research 25*, no.525.

Sagie, A, D Elizur and M Koslowsky (1995) Decision type, participative decision making, and organisational behavior: an experimental simulation. *Human Performance 8*, no.2: 81–94.

Shorrock, ST and B Kirwan (2002) Development and application of a human error identification tool for air traffic control. *Applied Ergonomics 33*: 319–336.

Schneider, B and A DeNisi (1991) Communication with employees following a merger: a longitudinal experiment. *Journal of Academy of Management 34,* no.1: 110–135.

Terry, DJ and N Jimmieson (2003) A stress and coping approach to organizational change: evidence from three field studies. *Australian Psychologist 38*: 92–101.

Tsang, MT and HJ Hoermann (2009) Adaptation of CRM training for the railway industry: operational safety benefits. Paper presented at the *15th International Symposium of Aviation Psychology*, April 2009, Dayton/OH.

Wanberg, CR and JT Banas (2000) Predictors and outcomes of openness to changes in a reorganizing workplace. *Journal of Applied Psychology 85*: 132–142.

Weick, KE (1991) Organizational culture as a source of high reliability. *California Management Review 29*: 112–127.

Weide, R, H Frieling and D Bruijn (2012) (Why) are Dutch cargo trains 2.6 times more often involved in SPADs compared to passenger trains? *Human Factors in Rail Conference 2012.*

Wright, LB (2002) The analysis of UK railway accidents and incidents: a comparison of their causal patterns. PhD dissertation. University of Strathclyde, Centre for Applied Social Psychology.

Zanoni, P and M Janssens (2007) Minority employees engaging with (diversity) management: an analysis. *Journal of Management Studies 44*: 1371–1397.

Annex BA: Hazards identified in the RSSB SPAD mitigations database

Table BA.1 Risk mitigation strategies from the SPAD mitigations database

Issue	Hazards
Signal sighting	
Distractions on approach to signals	Signal multiple reminder aids
	Temporary materials/equipment
	Lineside information hard to see
	Signal after traction gap
	Complex track layout
	Non-operational lineside distraction
	Driver preoccupied with controlling speed
	Driver distracted by DOO
	Incorrect signal aspect
	Limited sighting
Signal is difficult to detect and/or view	Signal misaligned
	Signal obscured by foliage
	Signal beyond bridge / tunnel
	Signal occluded
	Signal obscured by OLE
	Signal close to tunnel exit
	Reduced signal intensity
	Stop sign position
	Stanchions occlude approach
	Stopping position
	Vision obscured by gangway
	Signal beyond curved approach
	Lineside clutter
	Temporary materials/equipment
	Signal at non-standard height
	Semaphore visibility
Signal is difficult to read	Sunlight on signal lenses
	Another signal-like light
	Small backplate
	Hatched background
	Dark or complex background
	Signage near lenses
Signal is difficult to associate with the line	Signal height inconsistent
	Irregular signal spacing

Issue	**Hazards**
	Signal layout recently altered
	Signal less bright than others
	Number of lines differ to number of signals
	Signal unusual location
	Signal staggered on gantry
	Identical profile to adjacent signals
	Parallel signal in curved approach
	AWS horn with another signal closer
	Track obscured by vegetation
	Unusual routing on parallel tracks
	Recent changes
Signal is difficult to interpret/respond to	Flashing aspects on approach
	Gradient profile change
	Speed limit increases
	Leaving a station
	Driver misjudges train speed
	Different aspects configuration
	AWS unusually close to signal
	AWS disconnected
	AWS in cab not working
Signal design/background is non-standard/inconsistent	Signal at non-standard height
	Signal height inconsistent
	Irregular signal spacing
	Signal layout recently altered
	Number of lines differ to number of signals
	Identical profile to adjacent signals
	Different aspects configuration
	AWS unusually close to signal
	Fitted AWS
	AWS disconnected
	SPAD indicator
Route design layout	
Driver workload and error	Route change
	Complex track layout
	Cab passes
Timetabling and regulations	
Timetable pressure	Time pressure
Adhesion/weather/conditions/vegetation	
Low adhesion	Low adhesion not allowed for

Annex BB: Human factors principles for signal sighting

Table BB.1 Human factors principles for signal sighting

HFP no.	Human factors principles for signal sighting	Driver information processing stages
1	Speed signs and their associated AWS magnets should be placed 275m before a platform starter or a stop signal.	Source of distraction
2	Avoid positioning stop signals immediately beyond a converging or crossover junction on multiple parallel lines.	
3	Any signal-like lights that may be confused with the signal in the driver's field of vision on approach to the signal should be shielded from view, eg from a nearby facility with strong lighting, streetlights, station lighting. Special attention should be paid to this distraction at night, or in dark conditions.	
4	Position the signal where the driver is unlikely to be distracted by other duties, eg setting up train radio, arming ATP, operating TASS visual indicator, responding to lineside signs.	
5	Signals should not be positioned beyond a curve that restricts minimum required reading time of the signal on approach	Signal detectability
6	Signals should not be positioned behind any obstruction such that minimum required reading time immediately in rear of the signal is interrupted	
7	Signal height along particular stretches of route should be consistent.	
8	Avoid positioning signals beyond a tunnel exit where visual adaptation could be a problem. This includes covered stations and covered ways.	
9	Platform signals should be positioned so that the signal aspect, or repeating element (eg OFF indicator or banner repeater), is visible to platform staff and from the at rest position of all trains that use that platform.	
10	Lineside signals should be located within the driver's visual field of ±8° at the normal stopping position (s).	
11	Signals should not be positioned in front of a complex, or cluttered background (eg a combination of background lighting, lineside and overhead structures	Signal perceptability
12	Avoid positioning signals against a dark background, eg a bridge, such that the signal backplate is indiscernible.	
13	Line identifiers or other signal signage should not be positioned too close to signal lenses such that they could be misread as signal aspects.	
14	Ensure that the potential for trespass and vandalism problems is considered.	
15	Use extended signal hoods if direct sunlight could be a problem.	
16	Avoid the transition from colour light to any other signal type with a different light intensity.	
17	Ensure that the signal can be clearly associated with its line at the point of its associated AWS horn sounding.	Association of signal with route
18	The association of a signal with its line should be immediately apparent at the initial sighting point.	
19	Signals should be easily distinguishable from adjacent signals of the same group.	
20	The signal post should be distinct from other lineside structures to aid	

HFP no.	Human factors principles for signal sighting	Driver information processing stages
	signal conspicuity and association with line.	
21	Ensure a junction signal is positioned as close as possible to the points it protects without compromising the overlap.	
22	On approach, signals should appear parallel until the association of signal with line is unambiguous.	
23	Maintain equal or similar spacing between consecutive signals to help the driver judge stopping distance.	
24	Avoid the use of approach controlled junction warning signals if possible to avoid generating driver expectation of signal clearance.	
25	Signals should be positioned on the left hand side of the line in the direction of travel, unless readability is significantly improved by placing signal elsewhere.	
26	Light intensity of all signal aspects of a single signal head or a group of signals should be consistent, set and maintained to the correct level.	Interpreting signal
27	Signal beam must be properly aligned so that it appears to be brightest at the commencement of and throughout the minimum required reading time.	
28	Signals should not be positioned where stanchions could repeatedly obscure the signal on approach, such that a flashing illusion could occur, especially during the minimum required reading time.	
29	Provide drivers with visual cues such as markers or small lights in tunnels where perception of speed and distance may be a problem.	
30	Route indicators should be positioned so as to present a clear and unambiguous message to the driver of the route set.	
31	Avoid the use of flashing aspects at junctions where the running line is not cleared through the signal beyond the junction.	
32	AWS magnets should be positioned at 180m on approach to the signal. For line speeds of 100mph and above, the distance should be increased to 230m.	
33	Avoid positioning stop signals on points of significant change in gradient on approach.	
34	Avoid positioning controlled stop signals at known sites of poor railhead conditions.	
35	Avoid the transition from different signal types, eg changes from three to aspect signalling, semaphore to colour light signalling, or fibre optic to multi-aspect signalling.	

Appendix C: Glossary

ATP	automatic train protection
ATSB	Australian Transport Safety Bureau
AWS	automatic warning system
CRC	Co-operative Research Centre
CRM	crew resource management
DOO	driver only operation
DRA	driver reminder appliance
EMU	electrical multiple unit
ERTMS	European rail traffic management system
ETCS	European train control system
FAID	Business decision support tool used in Australasia that can be used to limit hours of work-related fatigue exposure
FRA	Federal Railroad Administration
GB	Great Britain
GPS	global positioning system
HF	human factors
HFP	human factors principles
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IFALPA	International Federation of Airline Pilots' Association
ITSR	Independent Transport Safety Regulator (Australia)
Lean management	an approach to running an organisation that supports the concept of continuous improvement, a long-term approach to work that systematically seeks to achieve small, incremental changes in processes in order to improve efficiency and quality
LED	light emitting diode
MaPSaF	Manchester Patient Safety Framework (UK)
NASA	National Aeronautics and Space Administration (USA)
NHS	National Health Service (UK)
NRS	national rail system (New Zealand)
NTC	National Transport Commission (Australia)
NTS	non-technical skills
NTSB	National Transportation Safety Board (USA)

ORR	Office of Rail Regulation (UK)
PA	preliminary assessment
RDT	route driveability tool
RM^3	Rail Management Maturity Model (UK)
RRM	rail resource management
RSSB	Rail Safety and Standards Board (UK)
SPAD	signal passed at danger
SMS	safety management system
TASS	tilt authorisation/speed supervision
TPWS	Train Protection and Warning System
Transport Agency	New Zealand Transport Agency
UK	United Kingdom