INDEPENDENT TRANSPORT SAFETY REGULATOR

Managing signals passed at danger

ITSR

Safe transport for NSW

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1 Introduction

1.1 The importance of signals passed at danger (SPAD) management

Train drivers pass many tens of thousands of signals every year uneventfully. In a very small percentage of cases, a signal passed at danger (SPAD) event may occur. In many of these instances, there are other protections for the train. Only a small percentage of SPADs result in a serious accident such as a collision or derailment.

Investigation of SPADs and analysis of SPAD data can be a powerful way of diagnosing weaknesses in the safety system that, if left untreated or not managed, could lead to serious accidents. Because of this, SPADs can be categorised as precursor events as they may indicate undetected or unassessed safety risk and more serious incidents to come.

The reasons why SPADs occur are complex. Few occur because of a single error or deliberate action by the driver. Most SPADs occur as the result of a combination of operational factors, environmental conditions and factors associated with human performance. This involves multiple aspects of rail operations such as infrastructure, train performance, crew performance and signaller performance. Therefore, initiatives to reduce SPADs need to be wide ranging, taking into account many parts of a railway organisation and, often, action by more than one railway operator.

Effective investigation and management systems for SPADs that involve all relevant systems and parties should help improve an organisation's safety management system (SMS) as well as enhance reliability, safety and efficiency of the overall rail network.

Collecting and analysing SPAD summary statistics over time is important for tracking trends in safety performance where there is sufficient data for the analysis to be meaningful. Additionally, high-quality investigations can yield important insights that are not necessarily revealed by the data analysis approach.

Thus, the adoption of two complementary and equally important approaches - **investigation** and **data analysis** - is critical for establishing truly effective SPAD management.

1.1.1 Aims of this information paper

The approach to SPAD data collection, investigation and management differs greatly for rail transport operators (RTOs) across Australia and even within NSW. In recognising that a degree of consistency and improved data collection would be desirable, this information has been prepared to outline better practices used by some NSW RTOs and the UK overland rail network.

ITSR has previously published an information paper on SPAD management in 2009. *Management of signals passed at danger* contains additional data on SPAD performance in NSW and enhanced materials on investigation of organisational fatigue factors and their relevance to SPADs.

The concept of an information paper was generated from an international review of railway safety practices, including SPAD management, which was commissioned by the Independent Transport Safety Regulator (ITSR) in 2008[1]. This review identified successful initiatives in SPAD management in the UK whereby railway organisations work together in SPAD reduction and mitigation groups[2]. The collaborative approach was said to lead to much greater understanding of the human factor causes of SPADs, particularly interaction between driver error and poor infrastructure. The resultant actions taken by the groups were considered to be the key to improving SPAD performance.

The approaches discussed and checklists presented in this paper represent ideas for potential adoption or customisation to local conditions and needs. Some aspects may be valuable for some organisations, while others will have limited applicability. While greater consistency in investigation and collection of data is important, the SPAD management process needs to be tailored to reflect the insights yielded from data as well as the equipment, operating environment and culture of each railway organisation.

ITSR acknowledges the work undertaken by the United Kingdom Rail Safety and Standards Board (UKRSSB) that is cited extensively in this paper.

A range of examples of practical tools appear in the appendices. These include generic checklists developed in conjunction with rail organisations in the UK and Australia.

This paper has also drawn from information on SPADs from the UK website OPSWEB (http://www.opsweb.co.uk). OPSWEB contains content submitted by a wide range of rail industry organisations including railway operators, safety organisations and regulatory bodies. The website content is reviewed by an editorial group comprised of operational experts.

RTOs need to understand that this is intended to be an informative document and must be used in the context of the specific SPAD risks of each RTO's operating environment.

1.2 Preliminary explanation of concepts

1.2.1 What is a SPAD?

The definition of a SPAD under the current *Guideline for the reporting of notifiable occurrences: Occurrence notification standard one* (ON-S1) is where a train passes without authority a signal displaying a stop indication or stop aspect.

[1] Lloyds Register, *International review of railway safety practices*, Independent Transport Safety Regulator, 2008

[2] Further information can be found at http://www.opsweb.co.uk

In order to understand how SPADs occur, it is necessary to look at the operational environment of trains driving to wayside signalling systems. An illustration of the spacing of signals and how they accommodate the different braking performance of various trains for NSW is shown in Figure 1.1

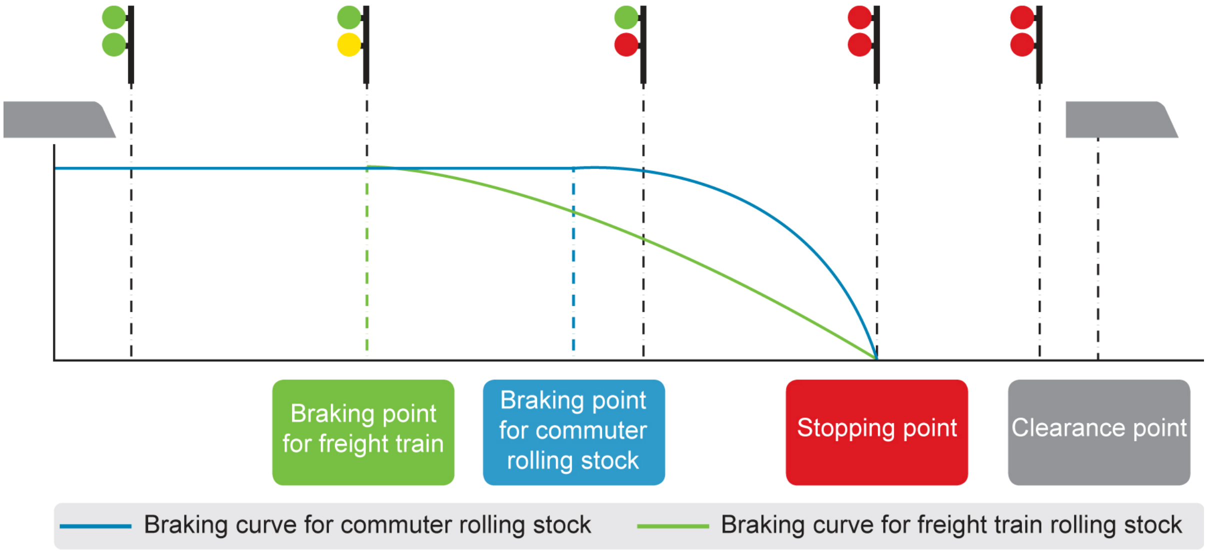


Figure 1.1 - Signal spacing and train braking performance

In Figure 1.1, the green over green aspect provides the driver of the train on the left the authority to proceed into the next block. The two sets of double red signals are protecting the train on the right with an overlap until it passes the clearance point. The green over yellow signal is the medium aspect indicating more restrictive signals ahead and green over red is the caution aspect indicating a stop signal ahead.

The signals are spaced so that all types of trains can be safely brought to a stop once a medium aspect (green over yellow) is sighted. A heavily-loaded freight train (the green curve) may need over a kilometre to stop, so its driver needs to start braking at the point of reaching a medium signal (green over yellow aspect) so it can safely stop at the stop signal (red over red). A lighter train, such as a commuter train (the blue curve), can delay braking until it is closer to a caution aspect (green over red). This relationship between signal spacing and the braking performance of the train means drivers require comprehensive, lengthy training to build up their knowledge of the gradients, likely adhesion levels between train and track, and braking characteristics of the trains they operate.

Misjudgement or misunderstanding of these factors can lead to the driver braking too late and subsequently overshooting the stop (red over red) signal. Likewise, if the driver fails to observe the information provided by signals or fails to observe the information correctly they may also pass the stop (red over red) signal. Since this signal is at stop because the train in front has yet to pass the overlap clearance point, the signal has been passed at danger.

1.2.2 Types of SPADs

There are a variety of different types of SPADs due to the variety of circumstances that can lead to SPADs. Understanding SPADs by general types is an important starting point for SPAD management.

It is common practice to categorise and separate SPADs at a high level according to the nature of how the SPAD occurred, such as:

- crew/train performance SPAD
- returned in face of driver (RIFOD) SPAD
- runaway SPAD.

Crew/train performance SPAD

The most frequent type of SPAD is where driver error occurs in reading the information displayed by signals or misjudging when to brake. Factors such as infrastructure design, and operational and environmental conditions often contribute to these errors. This type of SPAD can also involve train braking equipment not performing when required or as well as expected. For the purpose of this information paper, such SPADs are referred to as crew/train performance SPADs (termed Category A SPADs in the UK). Within this category of SPAD are further subcategories such as *starting against signal* SPADs (SASSPADs).

Crew/train performance SPADs have a greater potential to lead to a high consequence derailment or collision than RIFOD SPADs (defined below). SPAD management strategies discussed in the following sections focus on crew/train performance SPADs in order to address the area of highest risk.

Returned in face of driver SPAD

Another type of SPAD with a completely different range of causes is referred to in this information paper as a RIFOD SPAD. In this case, the train approaches a signal with a clear authority to proceed but the signal returns to stop at distance where the train could not possibly stop. In many cases, although the train passes a red signal, it does not pass it at danger, as the route for the train was already set and the path ahead of it was clear of conflicting movements.
There are, however, cases where the track has become suddenly obstructed or broken and the signal is passed at danger. RIFODs may occur for a number of reasons including:

- track circuit failures
- loss of points detection

- signal electricians conducting maintenance in relay huts disturbing signal components such as circuit cards, fuses, relays, etc., which causes them to fail safe (that is, return to red)
- electricians switching power off at substations to allow maintenance works or power supply failures
- signaller error (incorrectly reset signal previously not at stop)
- signaller returns signal to stop as a safety measure, to prevent trains entering a particular area of track where there may be an emergency situation ahead.

Although the safety risk from RIFODs is typically low, they still cause train drivers much concern. As emergency braking is required, drivers will not be sure as to why the signal has returned to stop and whether or not there may be an emergency situation ahead, such as a broken rail. These types of incidents still require investigation to find the underlying causes and determine what can be done to reduce RIFODs. Corrective action may include improved maintenance procedures in signal relay huts and electrical substations.

Runaway SPAD

There is potential for an un-crewed train or uncoupled rolling stock to run away and pass a signal at danger. In this paper, this type of SPAD is differentiated from other SPADs because quite different errors and circumstances are involved. Where a crew/train performance type SPAD may be brought under control by signallers radioing the train crew, the runaway SPAD is harder to control and mitigate.

The following sections are devoted to management of crew/train performance SPADs as these present a higher risk to railway operations.

1.2.3 Why do SPADs occur?

SPADs can rarely be attributed to a single cause and are better understood by looking at the full range of possible contributing factors. In general, a SPAD can occur because someone (a driver, signaller or controller) made an error or violation, or because of a technical deficiency associated with rolling stock or infrastructure. These are sometimes referred to as immediate causes because they are the trigger for the SPAD.

In many cases, the immediate causes provide a description of what happened but do not provide an explanation for why the SPAD occurred. To do this, it is necessary to look at a broad range of contributing factors which often increase the risk of human errors.

1.2.4 Errors and violations – unsafe acts

Errors and violations are unsafe acts by train crew that may lead directly or indirectly to a SPAD including:

- beginning to brake a train too close to a signal
- incorrect braking technique
- failing to react to cautionary aspects
- failing to communicate correctly
- using a train radio or mobile phone when running up to a signal at danger
- acting on an expectation that the signal will clear
- distraction from external or internal factors
- misreading the signal aspect
- referencing the wrong signal
- accepting a right of way from a guard without looking at the signal
- reading through to a subsequent signal.

Some current procedures used by RTOs to investigate SPADs stop at this point. This has an outcome of focusing corrective action - such as counselling, disciplinary procedures, deduction of points, re-training - predominantly on the driver. While these processes may be important components of a SPAD management process, many of the underlying factors that contributed to the SPAD may remain undetected and therefore unchanged.

In order to manage SPADs effectively, it is essential to also identify and address those factors that impair human performance and make driver error more likely. It is also necessary to understand organisational factors that contribute to violations such as a poor safety culture, poorly designed procedures and inadequate monitoring or supervision.

Some of the reasons that workers violate include:

- rules lacking in appropriateness
- relevance and practicality
- operational pressure and prevailing culture

- unusual circumstances
- routine shortcuts
- ineffective supervision.

Commonly cited factors[3] which impair human performance and have been found to contribute to SPADs are listed in the following sections.

1.2.5 Work environment/operational factors – unsafe conditions

An unsafe condition occurs where a particular factor associated with the operating environment has a negative impact on human performance and therefore may be a major contributor to a SPAD incident. Examples of unsafe conditions include:

- signal/sign attributes such as size, contrast, shape, border, back plate, signal lens dirty, near signals dimmer then far signals
- signal location such as behind a bend, directly after tunnel, over crest of hill
- equipment interface and workplace layout such as cab design, layout and design of controls and displays
- infrastructure features and track layout such as bridge/building obstruction, complex junction, complex or cluttered background, curve, overhead line equipment obstruction, parallel lines, significant change in gradient, stanchion or station furniture obstruction, trees and foliage obstruction, tunnels
- ambient environment such as temperature, noise, vibration, ventilation
- time of day/month of year
- weather conditions such as wind, fog, sun glare, rain, sleet and snow.

1.2.6 Individual/personal factors

Individual/personal factors refer to a physical or cognitive condition of a person which increases the likelihood of error. Those factors include:

- alcohol/drugs
- fatigue/alertness
- health-related condition
- physical limitations

[3] Adapted from those factors listed by UK OPSWEB http://www.opsweb.co.uk/TOOLS/common-factors/PAGES/intro_faq.html

- motivation/attitude
- preoccupation
- stress/anxiety
- experience and route knowledge
- expectations and habituation.

1.2.7 Organisational factors

Organisational factors are a range of conditions associated with business and operational systems that may impact on working conditions and workforce performance. They often occur further back in time from the actual SPAD event, and are usually only identified in systemic investigations. Examples include:

- safety/risk management (how SPAD risk is controlled and integrated within the overall SMS)
- monitoring and review processes
- ongoing competence assurance
- task demands/workload (underload or overload)
- adequacy of rules, procedures and standards
- design (driver's cab, new equipment, infrastructure, train control systems, etc.)
- workforce management (shiftwork system, teamwork, supervision, staff support etc.)
- training and selection
- communication/dissemination
- safety culture
- maintenance and asset management
- executive safety leadership.

Many of the contributing factors presented above and their relationship to SPAD performance are discussed further at http://www.opsweb.co.uk under *SPAD management tools - Common factors in SPADs.* (http://www.opsweb.co.uk/tools/common-factors/PAGES/QA.aspx).

Contemporary models of accident and incident analysis allow categorisation of contributing factors within a systemic framework. The Australian Rail Safety Regulators' Panel developed a simple framework to provide guidance to investigators on how to code systemic factors contributing to rail safety occurrences.

Information on the Contributing Factors Framework and a copy of the manual can be downloaded from http://www.transportregulator.nsw.gov.au.

1.2.8 Continuous improvement cycle

SPAD management follows the concept of continuous improvement common to many management systems such as the *ISO 9000* standards series for quality management.

This improvement cycle applied to SPAD management in its basic form is presented as Figure 1.2. The improvement cycle closely adheres to the 'measure in order to manage' concept that emphasises the importance of ongoing data collection and analysis.

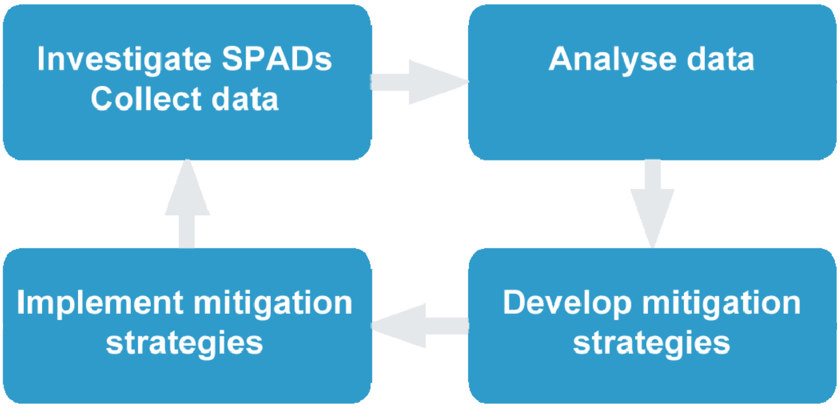


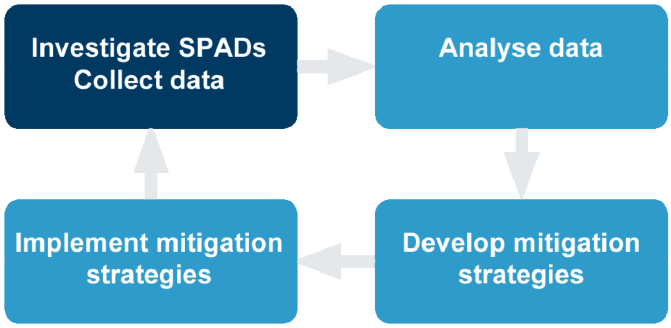
Figure 1.2 - SPAD management continuous improvement cycle

This information paper discusses in detail what is occurring at each of these stages of the cycle in the following sections. Data analysis is integral to this approach and strategies are formed on the basis of what the data is revealing.

2 Data collection and investigation processes

This section discusses what processes can be used to collect and categorise SPAD data.

Effective SPAD management is data driven, as data is used to guide decisions, monitor performance and reduce uncertainty[4].



All SPADs require an initial information gathering process to determine the basic facts of what happened and allow a coarse sorting of the type of SPAD that has occurred. This initial sorting of SPAD type allows different investigative processes to be undertaken relevant to the type of SPAD. This is illustrated in Figure 2.1.

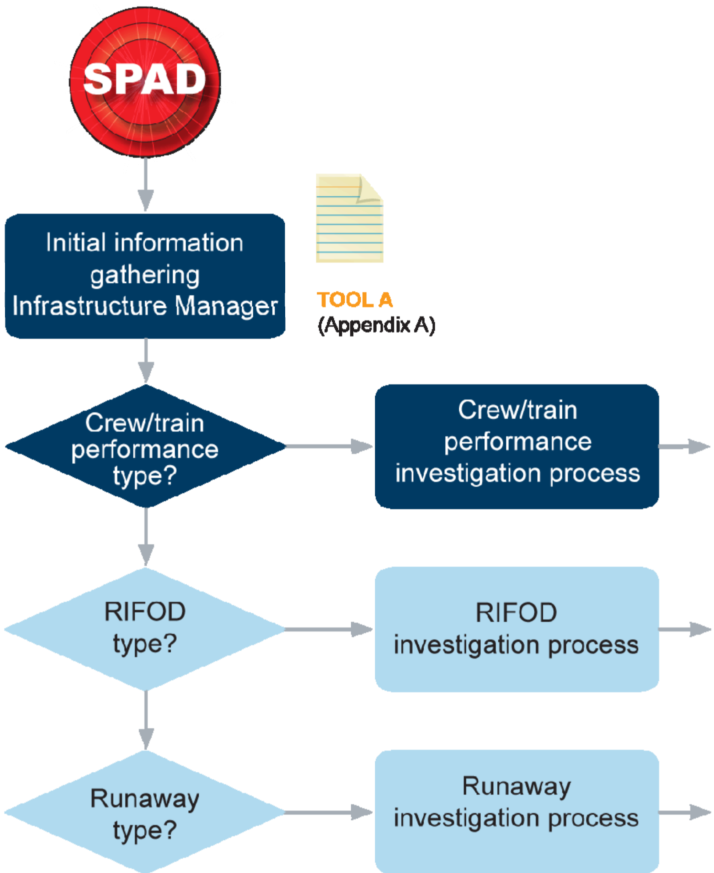


Figure 2.1 - SPAD types and associated investigative processes

[4] OPSWEB, *Good practice guide*, UK

The type of general information that needs to be captured on the day of the event includes, but is not limited to, the following:

Details of the SPAD incident

- date of incident
- time of incident
- location of SPAD
- line
- identity of signal passed
- type of signalling/safeworking system
- train run number
- distance passed
- injuries
- damage
- initial delay/cumulative delay.

Details of the rolling stock involved in the SPAD incident

- operator
- train type (passenger/freight EMU, DMU, locomotive hauled)
- load and length of train
- number of locomotives
- whether a trip valve is fitted to the train
- whether a form of automatic train protection is fitted
- results of brake tests.

Basic driver details

- driver name
- employer name
- depot at which the driver is based
- alcohol/drug test results.

A sample tool that captures more detailed information about the circumstances of the SPAD, and helps to determine the type of SPAD, is presented in Appendix A.

2.1 Investigating crew/train performance SPADs

Crew/train performance SPADs can rarely be attributed to one single cause. They are usually the result of a combination of human, technical, organisational and environmental factors, such as errors by the driver, factors associated with infrastructure design, poor performance of train systems as well as weather or unclear procedures.

Sound SPAD investigation provides information about errors, contributing factors and surrounding conditions as well as possible recovery strategies. A study that reviewed the quality of SPAD investigations across the UK was undertaken by the UKRSSB predecessor, Railway Safety[5]. This study included a review of all SPAD investigation reports and resulted in the development of good practice guidance for SPAD investigations. The main findings of the review were that:

- SPAD investigations have played a valuable role in reducing the occurrence of SPADs
- despite examples of good practice, there is a wide variation in the quality, and hence the value, of individual investigations
- there is evidence to suggest that more serious SPADs should be investigated independently
- competence levels should be established for investigating teams and panels, especially in their understanding of human factors
- a shortage of signal-sighting experts is preventing full investigation of some SPADs
- the benefits of the SPAD risk-ranking methodology should be reinforced.

To gain information (data) on these contributing factors, further investigation is required on both the train-operating organisation side and the infrastructure management side. This is shown as Figure 2.2.

[5] Railway Safety, *SPAD investigations special topic report*, 2002, UK

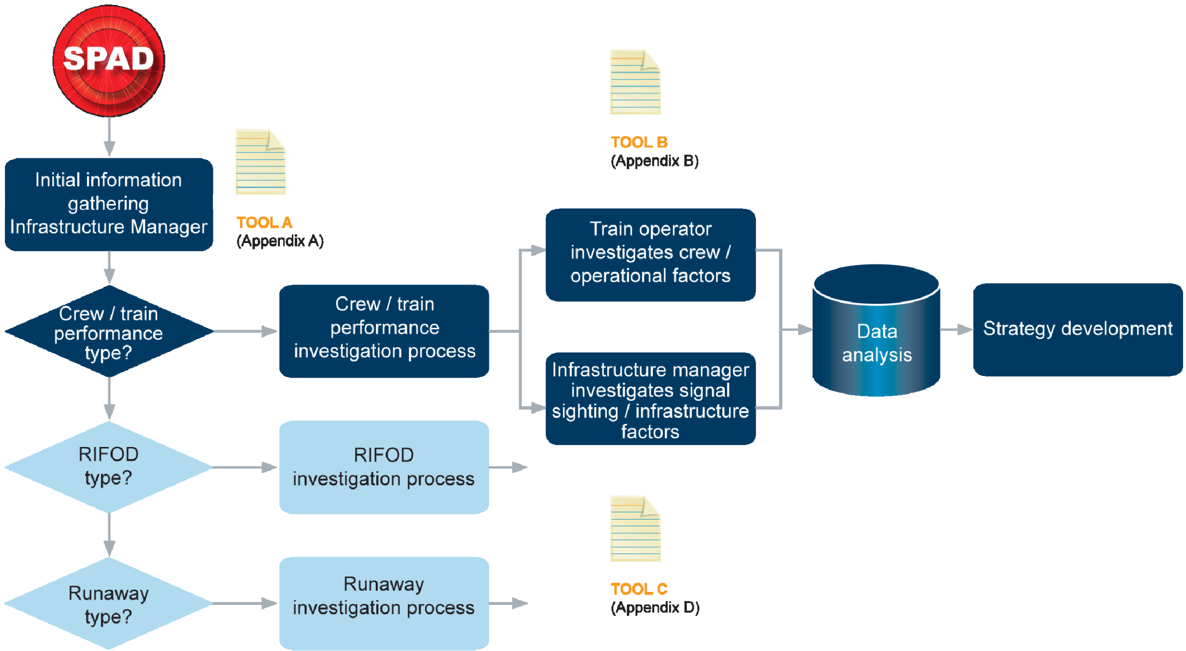


Figure 2.2 - Investigation processes for crew/train performance SPADs

2.1.1 Investigation – rolling stock operator

Once general data on the SPAD has been collected on the day of the event, further investigation into driver-related, operational and organisational factors that may have contributed to the SPAD is performed to gain data and understanding.

Appendix B contains a sample checklist that captures detailed information on:

- driver factors associated with the driver's history
- driver factors associated with the driver's physical and mental state
- operational factors that may have affected driver performance such as:
  - unusual or unfamiliar circumstances
  - in-cab distractions
  - external distractions
  - driver's view of signal obscured
  - effects on the driver's perception of the signal
  - early assumptions made about the signal aspect
  - changes affecting driver braking behaviour or judgement
  - attending to the wrong visual cues as evidence that they could proceed.

Correct use of the checklist requires an approach to the investigation by the rolling stock operator that is based on the principles of just culture through interviews, corroboration of evidence, site inspections, inspection of training records, and driver records. In this regard, it is important for the driver to be aware that the investigation is looking broadly at potential impacts on performance.

2.1.2 Investigation – rail infrastructure manager

Once general data on the SPAD has been collected on the day of the event, further investigation into infrastructure factors that may have contributed to the SPAD is performed by the rail infrastructure manager to obtain further data and insights.

Appendix D contains a sample checklist for investigating infrastructure factors that captures detailed information on:

- factors associated with the design of the route
- factors associated with the approach to the signal passed
- factors associated with the signal itself
- verifying information provided by the rolling stock operator.

As the focus of the investigation is the infrastructure, a key step is a site inspection of the signal sighting and surrounding environment to detect factors impacting on human performance. Another important step is checking the signal's performance over time to determine if it is a multi-SPAD signal. In the UK, Network Rail publishes information on multi-SPADed signals and multi-SPAD strategy on a dedicated multi-SPAD website[6] which provides information about the signal, why it has been passed at danger, risk aspects, actions taken, further actions planned, etc. Information on multi-SPAD signals in NSW is presented in section 3.2 of this paper. It is important to share the results of this part of the investigation with the driver involved in the SPAD so that they are aware of any infrastructure factors that may have contributed to the SPAD, as well as seeing that a wider process is happening to investigate all potential contributing factors.

2.1.3 Investigating fatigue factors

At present, some rail operators note a biomathematical model output score in conjunction with SPAD investigations and may overlook fatigue as an organisational factor if the work schedule score is within company guidelines. However a biomathematical model output score that is based on average data is not a valid indicator of fatigue in an individual, or that the work schedule allowed sufficient opportunity for sleep. If investigators utilise a fatigue model, they should obtain confirmation that the particular model output has been validated for investigation purposes, and understand what cautions apply in interpreting results.

[6] http://www.multispad.co.uk

Investigating fatigue factors requires thorough examination of individual circumstances. This requires a just culture approach and cooperation from the driver and any other worker whose actions may have contributed to the incident or recovery. This should include detailed consideration of factors associated with roster patterns, commute times, sleep patterns, sleep deficits, health and lifestyle issues. It should also include factors during the shift that might influence alertness, including food and fluid intake, cab environment, time since a break and workload. Where errors are made by signallers/network controllers, examination of fatigue factors should extend to these roles.

Investigators should be aware of rostering dimensions that are thought to be associated with SPADs. These are outlined in section 3.2.1 and include night hours, length of time on task (greater than 4.5 hours), consecutive shifts (greater than 6 hours), and single rest days. Although it is impossible to avoid night work, schedules should endeavour to reduce the number of consecutive night shifts so far as is reasonably practicable and ensure adequate recovery following it.

If workers report poor quality or quantity of sleep, it is important to investigate whether their sleeping environment is optimum and that they have received training or information on fatigue management and good sleep hygiene (habits). In addition, investigators should ascertain if there are procedures in place to risk-manage fatigued drivers and encourage drivers to self-declare if they have not received enough sleep.

NTSB fatigue investigation methodology

The United States National Transportation Safety Board (NTSB) has developed a methodology for investigating fatigue in transportation accidents. The steps involved in the process are equally relevant to analysis of close calls such as SPADs. A useful part of their methodology is that they propose use of initial screening questions that can be used to determine if further analysis is needed.

The initial NTSB screening questions are as follows:

If any of the following is true, proceed with the detailed methodology:

- does the operator's 72-hour history suggest little sleep, or less sleep than usual?
- did the accident occur during times of reduced alertness (such as 0300 to 0500)?
- had the operator been awake for a long time at the time of the accident?
- does the evidence suggest that the accident was a result of inaction or inattention on the part of the operator?

The detailed NTSB methodology involves determining:

(a) If the operator was susceptible to fatigue, for example:

  – reduced sleep length

- fragmented/disturbed sleep
- circadian factors
- sleep disorders, health or drug issues
- long time awake.

(b) If the operator’s performance contributed to the accident and their behaviour was consistent with fatigue effects, for example:

- attentional lapses or inappropriate attention strategy
- slower reaction time
- errors
- impaired decision making
- signs of fatigue/sleepiness.

A complete version of the NTSB fatigue investigation tool appears at http://www.ntsb.gov/info/fatigue_checklist_V%202_0.pdf.

While the NTSB investigation tool provides a methodology for examining individual factors associated with fatigue, it does not address investigation of failures in organisational SMS defences in relation to fatigue.

Organisational model of fatigue

Reason[7] developed a model to describe how an accident trajectory could pass through holes in layers of organisational defences and safeguards. The model is commonly referred to as the Swiss cheese model.

[7] Reason, J, *Managing the risk of organisational accidents*, 1997, Ashgate Publishing Limited

ITSR adapted the principles of the Reason model to demonstrate the organisational layers of defence for fatigue-related incidents. The ITSR model draws upon earlier work of Dawson and McCulloch[8]. If initial screening questions such as those used by the NTSB suggest that fatigue may have played a role, the ITSR model can be used to assist investigators to systematically identify failures in organisational defences to fatigue. The model appears in Figure 2.3.

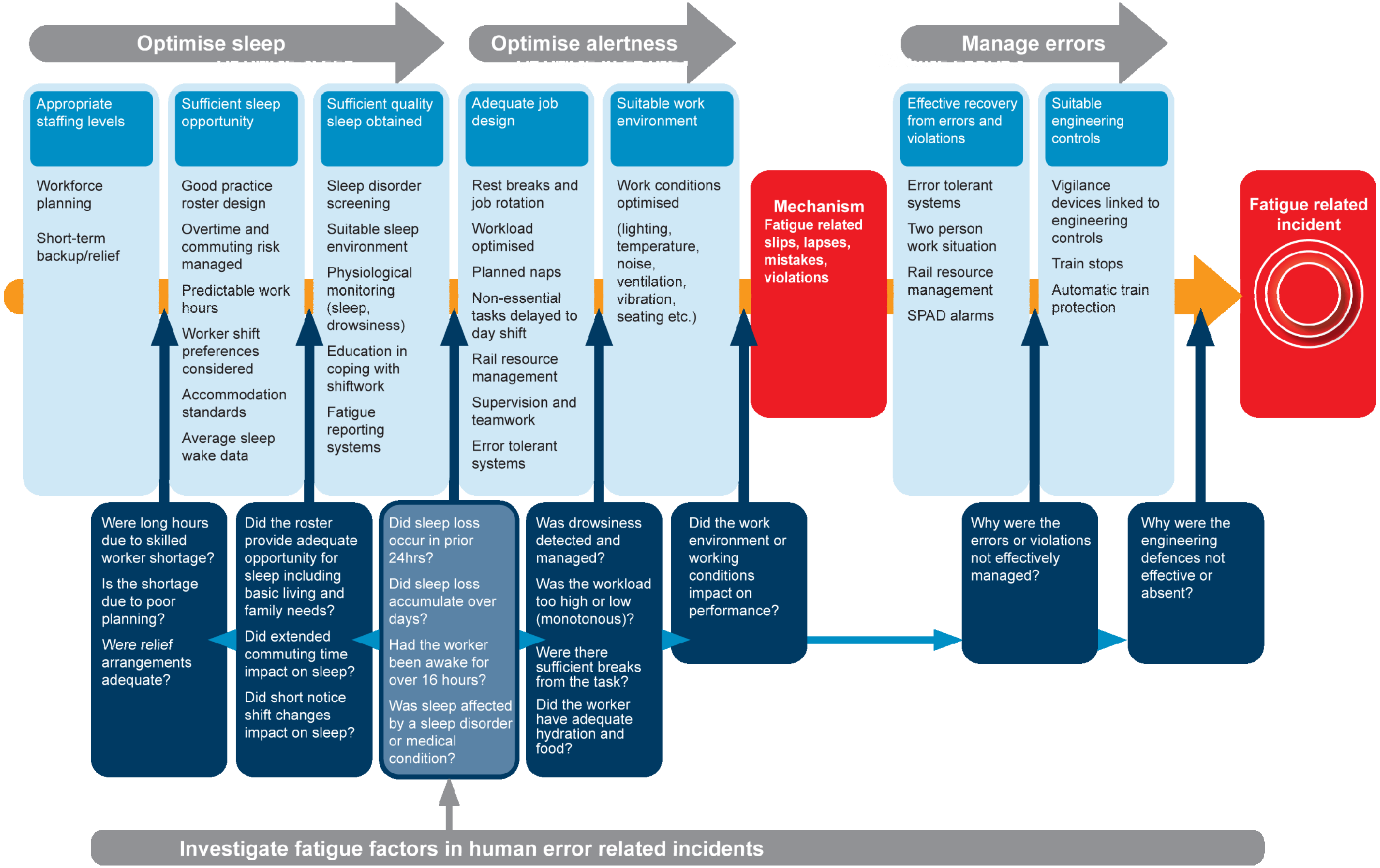


Figure 2.3 - Organisational model of fatigue

[8] Dawson, D & McCulloch, K, 'Managing fatigue: It's about sleep', *Sleep Medicine Reviews 9*, 2005, pp 365-380

2.2 SPAD categorisation

SPADs have a wide range of consequences, from the extreme of collisions and derailments, to damage to infrastructure from events such as running through points. Others have relatively minor consequences, such as overshooting a signal by a few metres, that may cause delays and lost productivity.

There is a need to be able to distinguish the more severe SPADs from the less severe, in order to better appreciate the underlying risks of SPADs (that is, higher rates of more serious SPADs are likely to mean higher underlying risks).

2.2.1 Categorisation of crew/train performance SPADs

Due to the greater potential for accidents such as collisions and derailments, subcategories have been developed for crew/train performance SPADs.

Australian classification systems

Australian rail regulators have produced ON-S1 and a guideline for classification of occurrences, *Guideline for the top event classification of notifiable ocurrences: Occurrence classification guideline* (OC-G1). ON-S1 clearly identifies a SPAD as a notifiable occurrence. Under ON-S1 and OC-G1 SPAD incidents are reported and categorised into five sub-classifications:

- *driver misjudged*
- *completely missed while running*
- *signal restored as train approached*
- *starting against signal*
- *other.*

Crew/train performance SPADs are categorised by OC-G1 under the categories *driver misjudged*, *completely missed while running*, and *starting against signal.* RIFOD-type SPADs are coded as *signal restored as train approached*.

Coding to these categories is normally done on the basis of the overrun distance and the occurrence description, but there are problems with this approach. Overrun distance does not account for the influence of protective systems such as train stops, automatic train protection (ATP) and catch points. For example, with train stops and ATP, a completely missed SPAD may occur with a relatively short overrun leading to incorrect categorisation as driver misjudged.

Another issue is that the current classification system does not cater for a common SPAD cause type that occurs when a driver reads the wrong signal. It is unclear if this should be classified as completely missed or another subcategory.

Due to the problems with the OC-G1 categories, a review commissioned by Transport Safety Victoria (TSV) of national SPAD data classification[9] recommended use of a severity-based approach such as used in the UK. The TSV report noted that an earlier ATSB-commissioned report that reviewed Australian rail-related data previously made the same recommendation. The authors of the TSV report considered that a severity-based approach would increase capacity to develop more reliable benchmarks within jurisdictions.

2.2.2 The UK SPAD severity index

Until recently, UK railways categorised SPADs according to their severity. This involved a scale of the consequences of the SPAD, ranging from an overrun within the signals overlap under 25m to a collision or derailment involving injuries and fatalities. The full categorisation is shown in Table 2.1.

The UK severity index has the advantage of being easy to use and does not require as much detailed information to be gathered as other categorisation methods. It also provides a reasonable separation of minor SPADs from more serious SPAD accidents. Having SPAD data categorised by severity provides a number of distinct benefits. It:

- allows the railway to communicate that the majority of SPADs are relatively minor events - total number of SPADs can be alarming to the lay person
- provides data that can be used to compare SPAD performance with other railways, provided suitable normalising data is available
- provides SPAD managers with the ability to monitor trends in more serious SPADs which may not be apparent in the total number of SPADs.

Severity 1	Overrun 0 to 25 yards, overrun not exceeding overlap, and no damage, injuries or deaths
Severity 2	Overrun 26 to 200 yards, overrun not exceeding overlap, and no damage, injuries or deaths
Severity 3	Overrun greater than overlap, plus all overruns greater than 200 yards and no damage, injuries or deaths
Severity 4	Track damage only with no casualties
Severity 5	Derailment with no collision and no casualties
Severity 6	Collision (with or without derailment) and no casualties
Severity 7	Injuries to staff or passengers with no fatalities
Severity 8	Fatalities to staff or passengers

Table 2.1: The UK SPAD severity index

[9] Transport Safety Victoria, *Signals passed at danger (SPADs) - analysis of national spad data*, August 2007

However, there are weaknesses of the severity index in some instances. For example, some severity 3 SPADs, where a train has passed a yard signal with no overlap, are perhaps not as equally serious as when a train has gone completely beyond the signal overlap on the main line. Such inconsistencies could be dealt with by altering definitions of the categories.

Another disadvantage of the UK severity categorisation is that it does not sufficiently differentiate between some types of SPADs. For example, a SPAD exceeding an overlap when the train ahead is in close proximity, versus the same SPAD where the train ahead is a long distance ahead. These would be categorised at the same severity. However, the UK SPAD risk categorisation (see section 2.2.3) would give the case of the train ahead in close proximity a higher risk, and so make a better distinction between the seriousness of SPADs.

To provide an example of what proportions of SPADs fall into the severity categories, a report by the UK Health and Safety Executive[10] provides seven years of SPADs reported according to severity. These data are summarised with Figure 2.4, which shows very few occurrences of severity 5 and above.

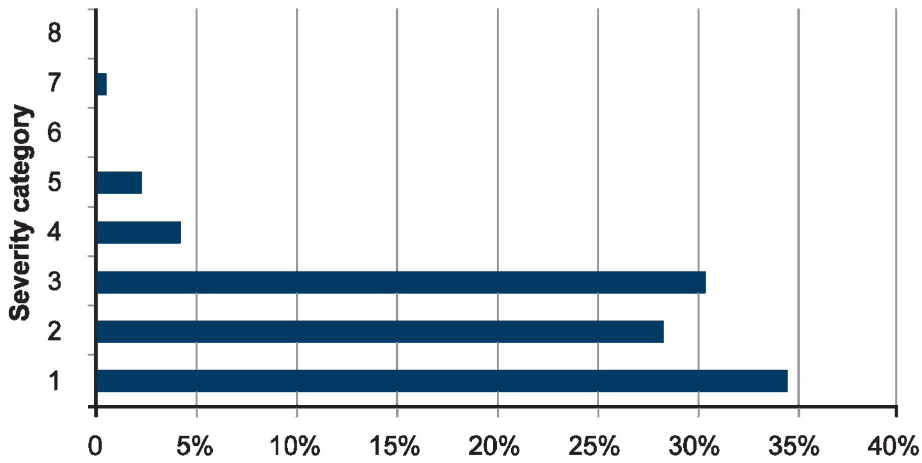


Figure 2.4 - Average occurrence of SPAD severity categories in the UK, 1996-2003

2.2.3 UK SPAD risk categorisation

The approach in the UK has since moved on from use of the severity index. Rather than categorising SPADs according to degree of severity, a more sophisticated approach is to categorise according to the risk of a more serious accident. The SPAD risk ranking tool (SRRT) approach involves rating a SPAD on a number of criteria related to the likelihood of an accident and its potential consequences. It thereby provides a better measure of the potential risk of each SPAD. The risk ranking result is made up of three elements:

Part 1 - an initial collision potential assessment

Part 2 - an accident vulnerability ranking

Part 3 - the risk ranking score.

[10] Health and Safety Executive (2002), *SPAD (signals passed at danger) report for June 2002*, 31 July 2002

SPAD risk categorisation requires a lot of detailed information to be gathered about the SPAD. There were some discussions as to whether the risk ranking tool is too complex or cumbersome. However, between the first and second editions of this information paper, ITSR received feedback from an Australian rail operator that has used the SPAD risk ranking tool since 2009. This rail operator indicated that the tool only takes about 10 minutes to categorise each SPAD, so long as all the data has been collected by the investigators. Their experience is reported below:

Feedback from an Australian rail operator about the SPAD risk ranking tool
I just recently came across the attached paper produced by ITSR. [Our company] has adopted and are using the SPAD risk ranking tool. We have adapted it to suit our rolling stock, etc. based on subject matter expert input, and have used it for all SPADs that have occurred since 2006. We introduced the tool in early to mid 2009, but went through some of our old SPAD reports as well. *The [ITSR SPAD information paper] says that the SPAD risk ranking tool process may be too cumbersome - it actually only takes about 10 minutes to do for each SPAD assuming a decent investigation has been done (with all the relevant info collected). We have now included the risk ranking as a mandatory aspect of SPAD investigation so it is done in conjunction and has made investigators think a bit more too, so a double benefit!*

Appendix F contains more details on using the SRRT.

2.2.4 Hybrid SPAD severity/risk ranking categorisation scheme

With the problems of both the severity index and the SRRT in mind an example of a classification system that is used by a large Australian integrated rail operator is presented with Table 2.2. This table borrows from both the UK severity index and the UK SRRT to form a practical solution to the problem, while avoiding the weaknesses of both schemes.

Classification	Description	Example/details
A	Collision or derailment affecting a passenger running line	Collision between two trains, with infrastructure or road motor vehicle
B	Rail traffic has entered a potential conflict zone Collision or derailment on freight-only running line	Rail traffic has progressed to a point where a conflict could occur Collision between two trains, with infrastructure or road motor vehicle derailment at catch points.
C	Rail traffic has passed the signal by more than 100 metre, but remains within the signal overlap	System controls worked to maintain safety but were tested by the incident - for example, train is stopped by an infrastructure control (train-stop)
D	Rail traffic has passed the signal by less than 100 metres	System controls worked to maintain safety. Train was under driver control and being braked at the time

E	Within shunting yard, maintenance centre or possession and not affecting a passenger running line	If not wholly within the yard, depot or possession then A to D above
F	Signal returned in face of driver	Caused by deliberate or unintentional human error, or equipment failure Route previously clear so probability of collision or derailment negligible

Table 2.2: Hybrid SPAD severity/risk ranking categorisation scheme[11]

2.2.5 SPAD precursor classification

It is useful to develop classification schemes for immediate causes and contributing factors of SPADs to provide insight into the most common precursor events and preconditions, and to provide a means to link SPAD occurrence rates to underlying risks of collisions and derailments.

It should be noted that SPADs are not exclusively a train driver issue. There are many operational personnel (for example, train dispatch staff, signallers, network controllers, managers, instructors, infrastructure maintainers) whose actions or inactions can lead to a SPAD occurring. In most cases, a single condition will not cause a SPAD. It is the compounding of several conditions that leads to the SPAD incident.

An example of a driver error classification scheme is provided in Table 2.3. In order to be able to categorise SPADs to such a precursor listing as presented in this table, more information than that collected in the initial report of the occurrence is required. Further investigations into contributing factors help to identify the precursor events or preconditions related to human error. Tool B (Appendix B) and tool C (Appendix D) will support the collection of this data.

Group	Description
1	Ambiguous or incomplete information given Correct information given but misunderstood Information not given Wrong information given
2	Anticipation of signal clearance Failure to check signal aspect Failure to locate signal Failure to react to caution signal Ignorance of rules/instructions Not monitoring for a signal Violation of rules/instructions

[11] Source: Human Engineering Australia developed for an Australian rail operator

3	Misread previous signal Viewed correct signal but misread aspect Viewed wrong signal
4	Misjudged environmental conditions Misjudged train behaviour

Table 2.3: Immediate cause classification list for crew/train performance SPADs[12]

As can be seen in the table above, all these immediate causes relate to human error.

2.2.6 Conclusions on SPAD categorisation

The following conclusions are drawn about the various SPAD categorisations described in this information paper:

- There are some problems associated with data reliability with use of the coding system of the OC-G1. The primary issue is that categorisation is usually undertaken prior to completion of the investigation process. For example initially it may not be possible to determine if a category is driver misjudged or completely missed due to the influence of train protection systems or the nature of errors. The other problem is that the categorisation system is not comprehensive and some events may not be captured adequately by any category.

- The UK SPAD severity index provides a reasonable categorisation for SPADs but the definition of category 3 SPADs allows a wide variation of severity within the category, suggesting sub-categorisation is needed. Another negative is that there is a precedent for the scheme being abandoned in favour of the SPAD risk ranking method.

- The UK SPAD risk ranking method addresses some of the problems with the severity index, but is complex and resource intensive to use, as it requires a great deal of situational data around the SPAD to be gathered.

- A hybrid/severity risk ranking method combining the UK SPAD severity index and the UK SPAD risk ranking method used by a large Australian integrated railway is a practical way to represent SPAD statistics by drawing from the strengths of both methods while avoiding their weaknesses.

- The UK SPAD precursor classification provides a useful way of categorising types of human errors and can be used in conjunction with hybrid severity/risk ranking categorisation. Such a classification is supported by the investigation tools provided in appendices A, B and D.

Statistics based on schemes such as the hybrid severity/risk ranking categorisation and the UK SPAD precursor classification will provide useful data on overall SPAD performance, as well as human error problem areas. Looking at methods of analysis of such statistics leads to the next stage of the overall continuous improvement cycle.

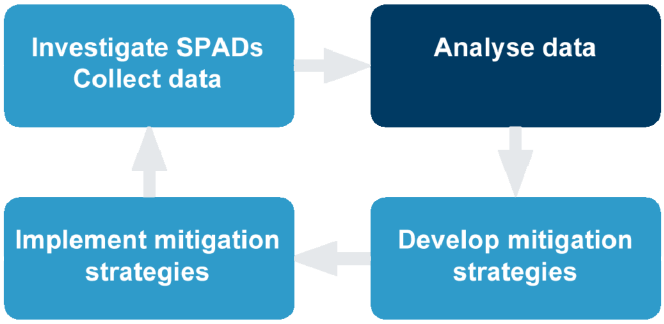
[12] Rail Safety and Standards Board (2006), *Category A SPAD Report Q2 2006 (1 April to 30 June)*, 2006, p 33 http://www.rssb.co.uk/pdf/reports/Category%20A%20SPAD%20Report%20Quarter%202%202006.pdf

3 Data analysis

Once data has been collected, various forms of analysis can be performed. This provides insight into problems related to the causes of SPADs and guides strategy development.

In this way, raw data that often has little meaning is analysed to generate useful information for guiding SPAD reduction strategies.

Common types of SPAD data analysis are presented here for information.



Data for NSW is presented where available. NSW data is based on occurrence notification records submitted to ITSR by NSW RTOs as required under rail safety legislation.

3.1 SPAD severity

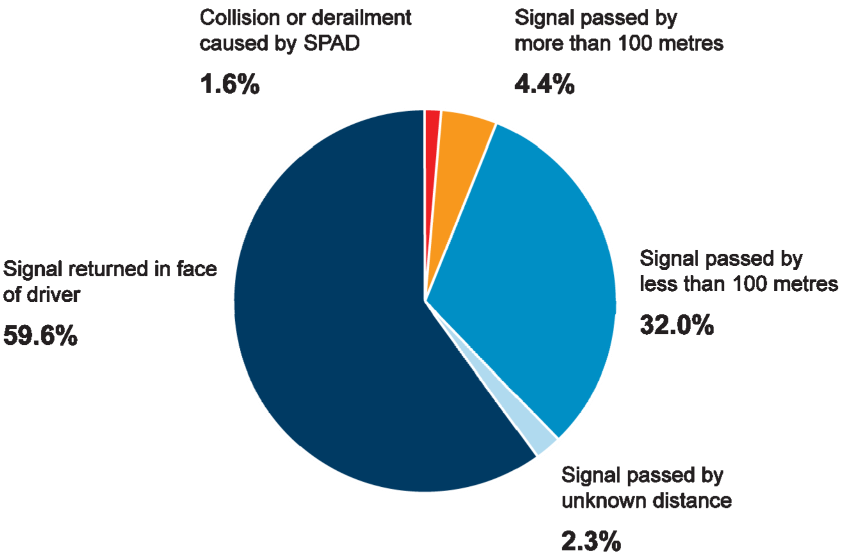


Figure 3.1: Severity of SPADs NSW rail network in the two years to December 2010

Between January 2009 and December 2010, there were 991 SPADs on the NSW rail network. Figure 3.1 shows that a majority of these SPADs were low severity, with only about 1.6% (16 SPAD events) resulting in a serious incident such as collision or derailment. The principle category is signal *returned in face of driver*. These SPADs are also known as technical SPADs and do not pose a collision risk as the route ahead of the signal will be cleared for the train. They may pose a relatively lower risk of passenger falls or load shift if rapid deceleration occurs due to emergency braking. The second largest category, *signal passed by less than 100 metres*, is also low severity because the train remains within the signal overlap.

3.2 Multi-SPAD signals

As has been discussed in previous sections of this paper, unfavourable infrastructure characteristics can have a significant impact on human performance. Where multiple SPAD events have occurred at one signal, the likelihood of such factors being present is high.

Determining multi-SPAD signals is useful as an indicator that a signal may need adjustment or enhancement. This relatively simple form of analysis leads to effective improvements in SPAD rates if the required infrastructure upgrades are made. The number of SPADs each signal has experienced in its current operating arrangement (since upgrade) is determined. Signals with the most SPADs are then assessed for possible upgrades and improvements.

In setting priorities for upgrades, a higher degree of importance may be given to the more serious SPADs that have occurred for a particular signal than the number of less serious SPADs. This provides a way of identifying those signals where intervention is almost certainly required. Such signals are sometimes referred to as bad actors.

Identifying multi-SPAD signals can be based on a statistical calculation that establishes how many SPAD events need occur at a particular signal beyond the point where the repeat events are likely to be due to chance[13]. The analysis will identify signals with a SPAD rate higher than the general signal population. Depending on data available, analysis may also take account of uncertainty in estimating the expected rate as well as differences in exposure, for example signals on lines with a greater frequency of trains would tend to generate more SPAD events than signals on quieter lines.

The UKRSSB determined that four or more SPADs recorded at a signal cannot be attributed to chance[14]. This threshold is, however, dependent on the number of years of operation in the period of analysis and may not be relevant for clusters of signals in high traffic areas that may be passed more frequently.

Once a signal has been identified as a multi-SPAD signal, it can be put into a prioritised signal upgrade program. To view an example of a program for multi-spaded signals, go to http://www.multispad.co.uk.

An example of the types of signal features that have been analysed for multi-SPAD signals in the UK is presented as Table 3.1.

[13] RailCorp identify multi-SPAD signals on the basis of two SPADs in five years but apply further criteria such as degree of protection

[14] Robinson B, *Special topic report focusing action on preventing SPAD incidents*, UKRSSB

Signal feature	Line feature	Signal location	Infrastructure/ environment feature	Safety device
Parallel signals	Curved approach	Signal orientation	Background type	TPWS fitted?
Temporary signal	Severity of curve	Side of track (L/R)	Signal obscuration	AWS fitted?
Type of signal (running/shunting)	Left/right curve	Signal position (ground/gantry)	Signs before signal	
Signal type (traditional or LED)	Track slope (up/down/flat)	Starting at station	Read-through	
Signal type (stop signal or stop board)	Actual line speed		OLE clutter	
Signal height	Line speed below or above 100mph		Close to level crossing	
Number of signal heads/aspects	Type of line			
Added furniture (theatre box)				
Signal control type				
Flashing aspects				

Table 3.1: Features of multi-SPAD signals[15]

In order to identify the most effective mitigation strategy for a specific signal, a tool such as the one presented in tool C (Appendix D) can be used to support a detailed assessment of infrastructure related to human factors issues.

3.2.1 Multi-SPAD signals on the NSW network

The NSW rail network consists of the Metropolitan Rail Area network (MRA), the Defined Interstate Rail Network (DIRN), the Hunter Valley network and the Country Regional Network (CRN).

An analysis of multi-SPAD signals was conducted for the MRA and the remainder of the NSW network separately. The review threshold adopted for the MRA was two or more SPADs in two years. A threshold of two or more SPADs in three years was adopted for the remainder of the network to compensate for far less operational density.

[15] Human Engineering (2004), *Human factors support to SPAD management in the Southern and Scotland zones - summary report*, UKRSSB, Bristol UK

The maps in Figures 3.2 and 3.3 show signals where two or more SPADs have occurred on the DIRN, CRN and Hunter Valley (Figure 3.2) and the MRA network (Figure 3.3).

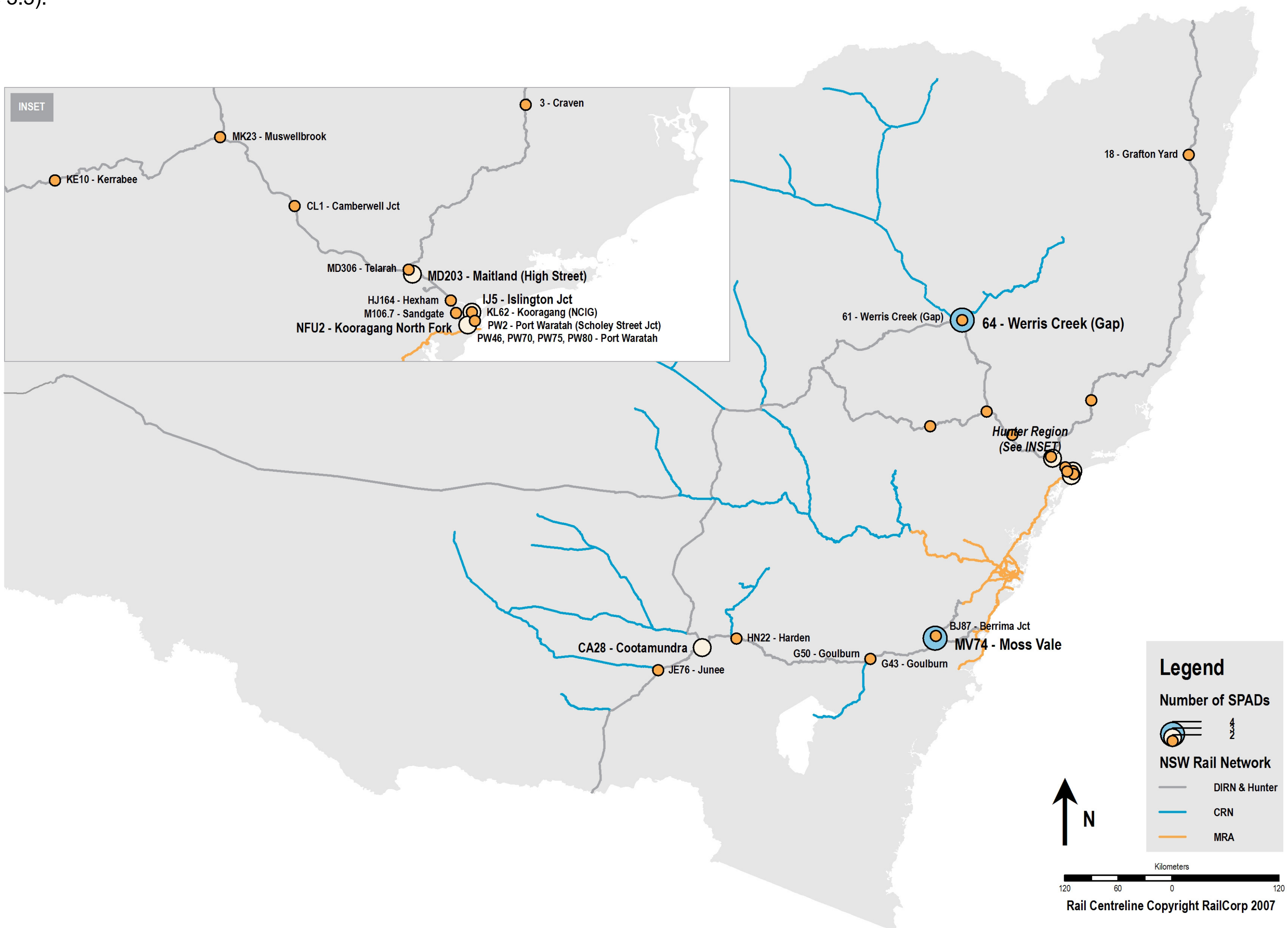


Figure 3.2: Signals with two or more SPAD events during the three years to December 2010 on the DIRN, CRN and Hunter Valley network (inset)

The following Table 3.2 shows more detailed information on the location and characteristics of the signals involved.

Signal number	Signal type	Location	Line	Kilo-metrage	Date of latest SPAD	Number of SPADs 1/1/2008 to 31/12/2010
64	Absolute	Werris Creek	Northwest	416.440	29/06/2010	4
MV74	Shunting	Moss Vale	Down Main	146.060	02/02/2010	4
NFU2	Absolute	Kooragang	Kooragang	170.047	02/12/2010	3
IJ5	Absolute	Islington Jct	Down Relief	164.000	28/10/2010	3
MD203	Absolute	Maitland	Down Main	191.519	14/05/2010	3
CA28	Absolute	Cootamundra	Down Main	429.650	19/03/2009	3
M106.7	Absolute	Sandgate	Down Main	171.649	10/12/2010	2
G43	Shunting	Goulburn	Down Main	225.144	21/10/2010	2
JE76	Absolute	Junee	Main	488.619	03/07/2010	2
KE10	Absolute	Kerrabee	Ulan	363.500	02/06/2010	2
KL62	Absolute	Kooragang	Departure	174.996	23/04/2010	2
G50	Absolute	Goulburn	Up Main	224.737	22/03/2010	2
BJ87	Absolute	Berrima Jct	Down Main	141.100	03/02/2010	2
PW2	Absolute	Port Waratah	Arrival Road	164.950	21/12/2009	2
HN22	Absolute	Harden	Up Goods	385.345	11/12/2009	2
MD306	Absolute	Telarah	North Coast		22/09/2009	2
HJ164	Absolute	Hexham	Up Coal	174.192	25/06/2009	2
PW46	Shunting	Port Waratah	Arrival Road		26/04/2009	2
PW75	Shunting	Port Waratah		169.487	06/03/2009	2
PW70	Shunting	Port Waratah		167.079	24/02/2009	2
3	Absolute	Craven	Main	289.388	24/11/2008	2
MK23	Shunting	Muswellbrook	Down Main	288.047	08/11/2008	2
PW80	Shunting	Port Waratah	Departure		28/10/2008	2
CL1	Absolute	Camberwell	Down Main	243.301	03/09/2008	2
61	Absolute	Werris Creek	Branch	415.720	01/07/2008	2
18	Absolute	Grafton Yard	Storage	699.000	26/06/2008	2

Table 3.2: Signals with two or more SPADs in the three years to December 2010 on the DIRN, CRN and Hunter Valley network

Note: Some signals have been reconfigured since the last recorded SPAD

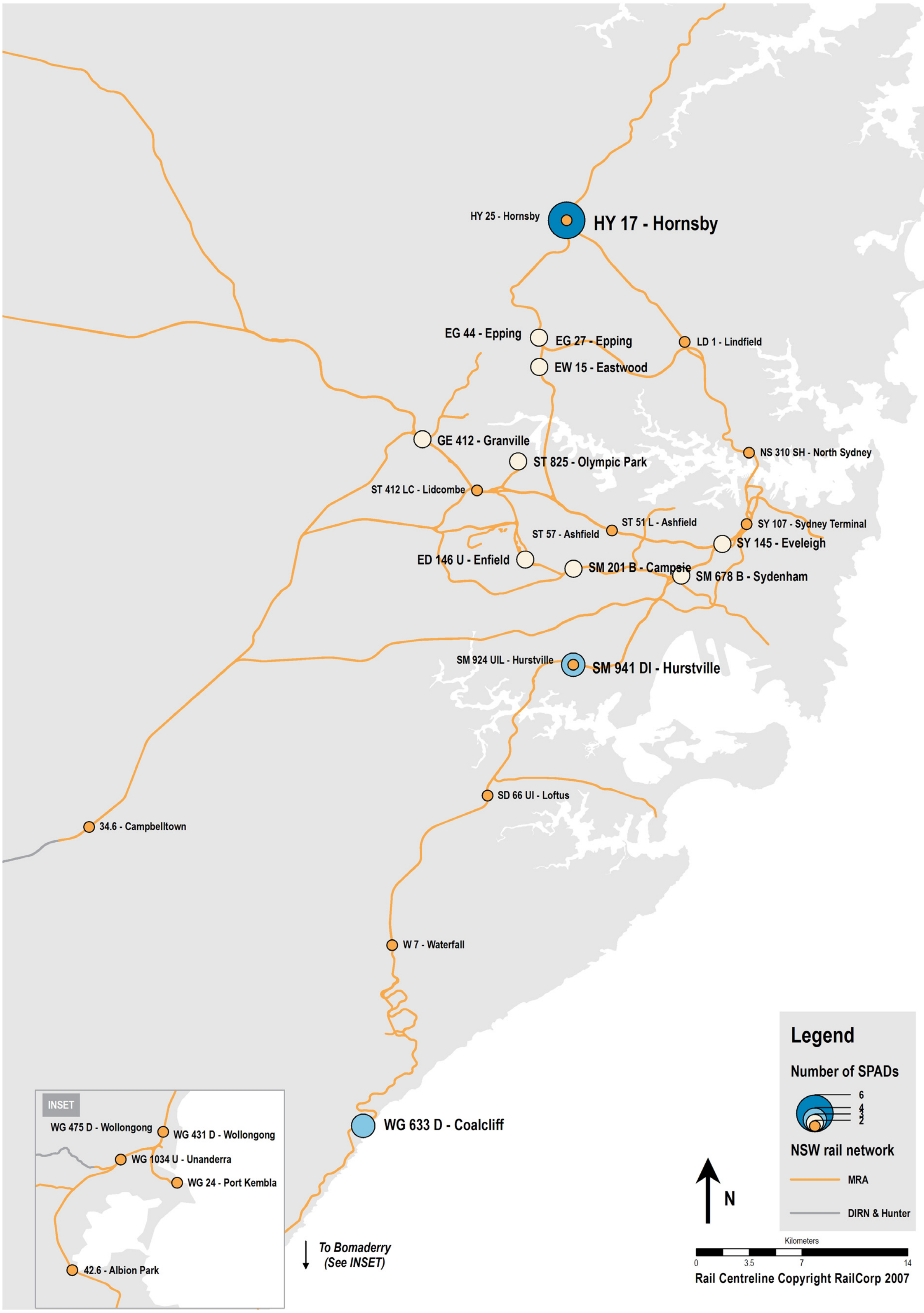


Figure 3.3: Signals with two or more SPADs in the two years to December 2010 on the MRA network including South Coast (inset)

The following Table 3.3 shows more detailed information on the location and characteristics of the signals involved.

Signal number	Signal type	Location	Line	Kilo-metrage	Date of latest SPAD	Number of SPADs 1/1/2009 to 31/12/2010
HY 17	Absolute	Hornsby	Down Main	32.642	15/10/2010	6
WG 633 D	Absolute	Coalcliff	Illawarra	60.220	17/06/2010	4
SM 941 DI	Absolute	Hurstville	Down	15.398	17/12/2009	4
ST 825	Absolute	Olympic Park	Down	16.930	18/12/2010	3
SY 145	Shunting	Eveleigh	Western	1.715	17/12/2010	3
SM 678 B	Absolute	Sydenham	Up	5.773	21/11/2010	3
EG 44	Absolute	Epping	Up Main	24.120	30/10/2010	3
EG 27	Absolute	Epping	Down Main	22.861	30/06/2010	3
ED 146 U	Absolute	Enfield	Up Main	14.940	21/06/2010	3
EW 15	Absolute	Eastwood	Down Main	20.550	14/05/2010	3
SM 201 B	Absolute	Campsie	Down	10.682	24/03/2010	3
GE 412	Absolute	Granville	Up West	21.925	10/12/2009	3
ST 57	Absolute	Ashfield	Down Local	8.462	13/12/2010	2
WG 1034 U	Absolute	Unanderra	Up	90.471	10/12/2010	2
SD 66 UI	Absolute	Loftus	Up Illawarra	25.761	04/12/2010	2
NS 310 SH	Absolute	North Sydney	Up Shore	5.605	12/11/2010	2
SY 107	Absolute	Sydney	Down	0.661	05/11/2010	2
WG 475 D	Absolute	Wollongong	Down	82.550	29/10/2010	2
34.6	Absolute	Campbelltown	Up Main	55.860	14/09/2010	2
ST 412 LC	Absolute	Lidcombe	Up Main	17.215	12/07/2010	2
SM 924 UIL	Absolute	Hurstville	Up Illawarra	14.698	11/07/2010	2
ST 51 L	Absolute	Ashfield	Down Local	8.280	03/04/2010	2
42.6	Absolute	Albion Park	South Coast	103.450	08/02/2010	2
LD 1	Absolute	Lindfield	Down Shore	14.053	20/09/2009	2
WG 431 D	Absolute	Wollongong	Down	83.250	18/08/2009	2
HY 25	Absolute	Hornsby	Down Main	33.415	17/06/2009	2
W 7	Absolute	Waterfall	Down	38.230	16/06/2009	2
WG 24	Absolute	Port Kembla	Port Kembla	89.733	08/04/2009	2

Table 3.3: Signals with two or more SPADs in the two years to December 2010 on the MRA network

Note: Some signals have been reconfigured since the last recorded SPAD

RailCorp has these signals under active management. Mitigating actions taken include review of signal sighting and placement, signal redesign and replacement, installation of LED lights, signal repositioning and removal of obstructions such as vegetation.

RailCorp has a range of programs in place to improve driver performance such as route knowledge risk assessments, multi-SPAD alert boards, professional driving technique training, DVD education programs and SPAD notices and briefings. RailCorp utilises a range of communication and stakeholder consultation strategies to enhance understanding of SPAD risks.

3.2.2 Multi-SPAD drivers (drivers with more than one SPAD incident)

In a similar way that multi-SPAD signals provide an indication of an underlying problem, so can drivers with multi-SPAD histories. In NSW, there are around 200 non-RIFOD SPADs per year for a population of around 2000[16] drivers which means that, if all drivers are performing consistently, they can expect to SPAD once every 10 years. Driver performance, however, varies and so some drivers may never have passed a signal at danger in their driving career while others may have had a number of events.

There is a similar question to multi-SPAD signals with multi-SPAD drivers by asking how many SPADs a driver has to experience for it not to be random experience. This is less amenable to statistical analysis of the type applied to multi-SPAD signals. As a general principle, the UKRSSB study suggests that where a driver accrues two or more SPADs, increased management attention is warranted. However, this may depend on the driving territory as some drivers will pass more signals than others due to differences in signal density and proportion of time driving in dark territory. It is important that actions concerning the driver consider the driver's overall performance record.

The advice given by OPSWEB on this topic is:

> It is however important to bear in mind that SPADs are just one of the many types of safety related incidents that a driver may be involved in. As such, any review of driver performance needs to conducted in the context of overall driver performance over time, without unnecessary focus on a singular event which may just be a one off e.g. an initial SPAD by a driver without a history of other safety related incidents could be considered as a one off or statistical aberration and not warrant any further attention. However, the same driver with an initial SPAD who has also been involved in a number of other safety related incidents may warrant a more detailed investigation.

This type of analysis is most effective if managed using a just culture approach.

[16] Hansard and Papers Legislative Assembly 1 December 2005 Minister Watkins indicates RailCorp has 1351 train drivers who account for approximately 68% of train kilometres in NSW. This scales up to an estimate of 2000 drivers for the state

Examples of multi-SPAD driver data that has been collected by the UKRSSB is presented as Tables 3.4 and 3.5[17]. The data shows relatively few drivers with more than one SPAD in the last five years (there are approximately 14,700 drivers in the UK) and the rate is falling, probably due to the overall improved SPAD performance in the UK.

	2004	2005	2006	2007
Driver with more than one SPAD in last five years	41	38	44	12
Drivers with more than one SPAD as a percentage of all SPADs	11%	11%	13%	9%
Drivers with more than one SPAD (in current five years) at multi-SPADed signals	10	7	13	3
Drivers with more than one SPAD (in current five years) at multi-SPADed signals as a percentage of all SPADs	3%	2%	4%	2%

Table 3.4: UK multi-SPAD driver data

	2004	2005	2006	2007
Driver with more than one SPAD in whole career	86	89	91	26
Driver with more than one SPAD in last 10 years	69	66	81	20
Driver with more than one SPAD in last 5 years	41	38	44	12

Table 3.4: UK multi-SPAD driver data

3.2.3 Freight versus passenger train driver SPADs

Currently the SPAD rate for freight trains in NSW is around 30% higher that of passenger trains.

Figure 3.4 shows the rate of non-technical SPAD events (i.e. RIFODs excluded) per million kilometres for passenger and freight trains. The SPAD rate for freight trains was about 50% greater than passenger trains over the earlier part of the period. However, the difference in SPAD rates between freight and passenger trains has decreased over time. In 2010, the rate for freight trains was about 30% higher than passenger trains (3.2 and 2.5 SPAD events per million train kilometres, respectively). Freight trains travel in areas with fewer signals. This means that, if the rate was calculated per signal passed, the performance gap between freight and passenger trains would be even greater.

Some potential contributing factors to a higher rate of freight train SPAD events include increased mass and velocity of freight trains and differing mental workload conditions associated with the freight and passenger train driving task.

An assumption of the analysis is that passenger and freight trains have an equal probability of encountering a signal at stop. This information, not currently extracted from train control systems for all parts of the network, would provide more effective means of normalisation, enabling actual difference in SPAD rate to be determined.

[17] UKRSSB, *SPAD performance report Q2 2007*, UK

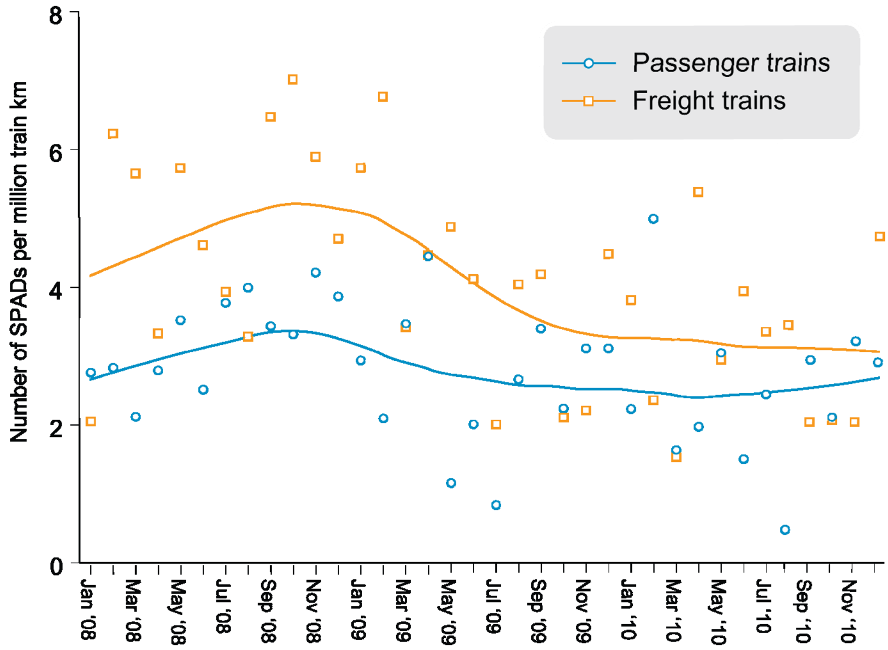


Figure 3.4: Non-technical SPAD rate (count per million kilometres) by train type on the NSW network for the three years to December 2010

3.3 Analysis of work scheduling and time of day factors

Research has linked accident risk, including industrial and motor vehicle accidents, to dimensions of work schedules such as time of day and number of consecutive shifts worked. The UKRSSB completed a series of research projects that looked at working patterns of train drivers and dimensions of work schedules associated with SPADs[18,19]. Dimensions analysed with respect to their relationship to accident risk are as follows:

- time of day
- time on task (i.e. continuous duty without a break)
- time on duty
- consecutive shifts
- number of rest days.

The UKRSSB undertook research using aggregated industry data to ascertain if these trends are found to be associated with SPADs in the UK. In addition to a description of the SPAD incident, the data set contained, for each individual involved, details of the timing of the duty period of the SPAD, the timing of breaks, and the shift pattern of the previous 12 days.

[18] UKRSSB, *T059 Human factors study of fatigue and shiftwork Appendix 1 - Working patterns of train drivers: Implications for fatigue and safety*, 2006

[19] UKRSSB, *T699 Fatigue and shiftwork for freight locomotive drivers and contract trackworkers: implications for fatigue and safety*, 2010

Measurements of a factor such as time of day or consecutive shifts will depend on how often the activity is occurring (termed here as exposure). Statistics gathered need to be normalised to account for differing levels of exposure.

The UKRSSB emphasises the importance of controlling for exposure to risk in this sort of data analysis approach that looks at accident risk associated with dimensions of work schedules. In addition, for analysis of trends relating to accident risk to be meaningful, there needs to be:

- sufficient data for statistical analysis
- consideration of other known risks that may mask trends
- data that describes the shift system operating so that risks associated with exposure (for example, the number of drivers that are driving trains at the time) can be estimated.

Without this adjustment process, trends such as time of day will most likely reflect peak times for train traffic, rather than the risk of an individual driver being involved in a SPAD at a particular time of day.

The first step that the UKRSSB used to estimate likely exposure was to obtain the probability that a driver would be on duty at any particular time of day. This estimate was derived from the distribution of duty hours of the SPAD drivers during the 12 days prior to the SPAD. The UKRSSB also adjusted for rest periods (breaks), since these corresponded to times when the driver would not be at risk. This was possible because information on rest breaks was collected for the duty periods in which the SPAD occurred. The final factor corrected for was duty frequency, on the basis that the amount of traffic is directly proportional to the number of drivers on duty.

3.3.1 Work schedules and risk of SPADs

Collecting and analysing data on work history prior to SPADs and other human factors incidents may help determine aspects of work schedule design that are associated with increased risk. The results can help to optimise schedules to reduce risk of SPADs. Careful analysis of work history data is needed to control for exposure.

The results of the UKRSSB analysis of SPAD risk controlling for exposure is presented in Figures 3.5, 3.6 and 3.7. These graphs, based on UK SPAD data for passenger trains, suggest a high number of consecutive shifts, long time on task, and driving between midnight and 4am, are associated with elevated SPAD risk. Note that the data in all graphs reflects relative risk as it has been normalised with respect to an average risk of one.

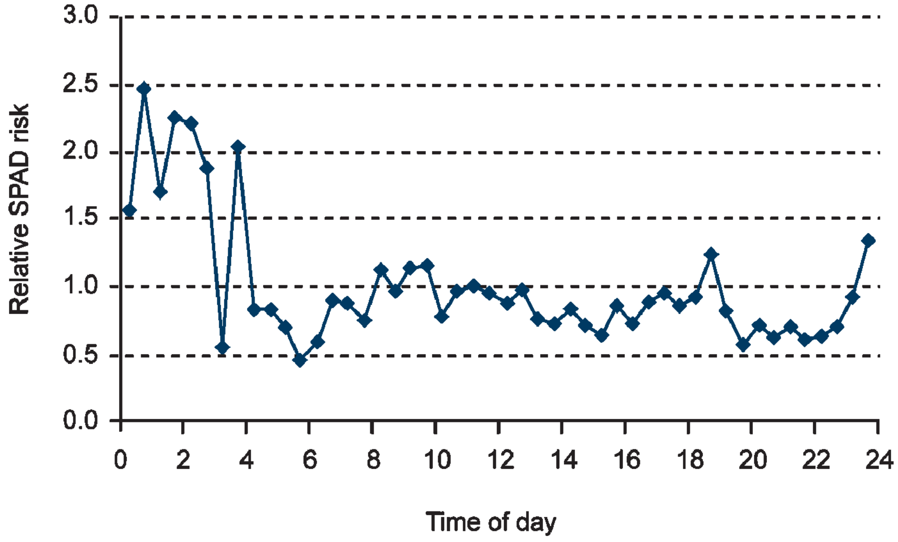


Figure 3.5: Relative SPAD risk - time of day[20]

The shape of the graph in Figure 3.5 is influenced by the methods used to control for exposure to risk and associated assumptions. The UKRSSB notes that the absolute risk of a SPAD is highest during the day because more trains are in service during the day. Alternative graphs that depict time of day factors and further details of how the UKRSSB controlled for exposure to risk can be found in the UKRSSB report: *T059 Human factors study of fatigue and shift work Appendix 1: Working patterns of train drivers - Implications for fatigue and safety*. http://www.rssb.co.uk/research/allsearch.asp.

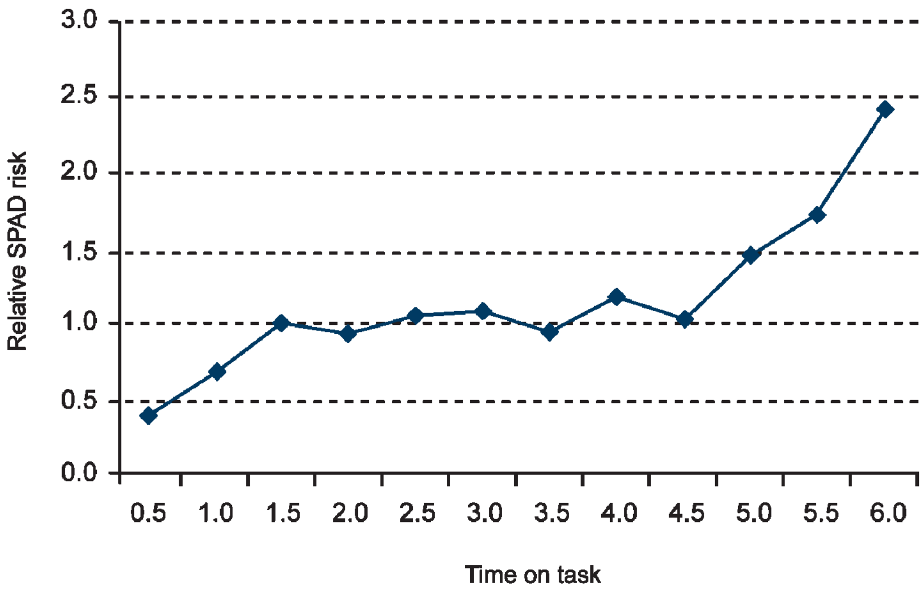


Figure 3.6: Relative SPAD risk - time on task[21]

[20] UKRSSB, *T059 Human factors study of fatigue and shiftwork Appendix 1 - Working patterns of train drivers: Implications for fatigue and safety*, 2006, UK

[21] Ibid

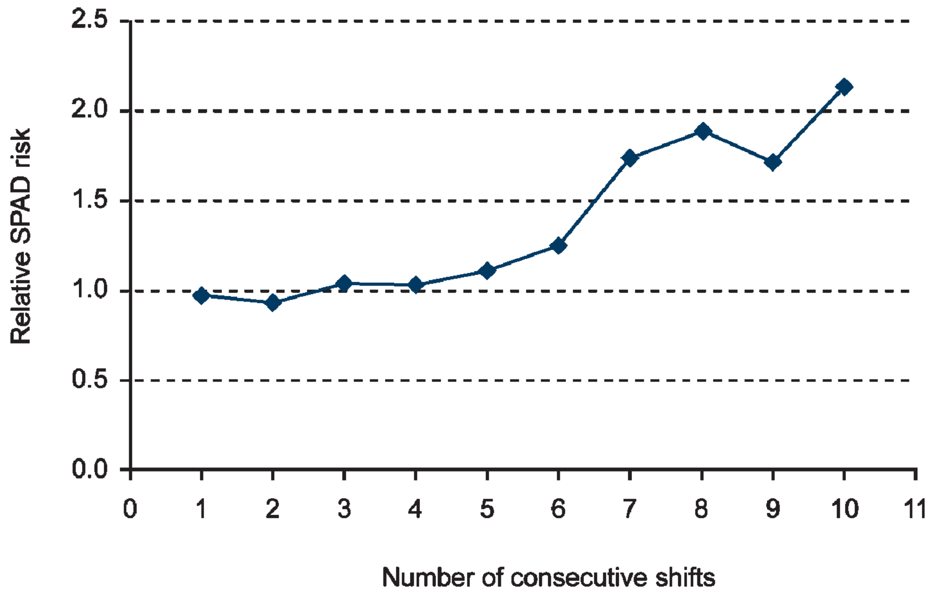


Figure 3.7: Relative SPAD risk - consecutive shifts[22]

Trends in work schedules associated with SPADs by train type

More recent work published by the UKRSSB includes analysis of SPADs by freight trains and infrastructure maintenance companies. The analysis is based on 1728 SPAD events during the five years from 2003 to 2007.

The following graphs show relative risk of a SPAD based on a normalisation process that considers the number of drivers of the same group on duty at a given time, and the total number of drivers on duty at a particular time (for freight and passenger trains).

This normalisation process is an attempt to obtain an estimate of relative risk controlling for likely exposure to a red aspect. It is based on an assumption that more trains on the network leads to more red aspects. For further information on the data analysis and associated assumptions refer to the original UKRSSB report.[23]

TOC - train operating company (passenger trains)

FOC - freight operating company

IMC - infrastructure maintenance company

[22] Ibid

[23] UKRSSB, *Research programme operations and management fatigue and shiftwork for freight locomotive drivers and contract trackworkers Appendix F: Analysis of data from signals passed at danger*

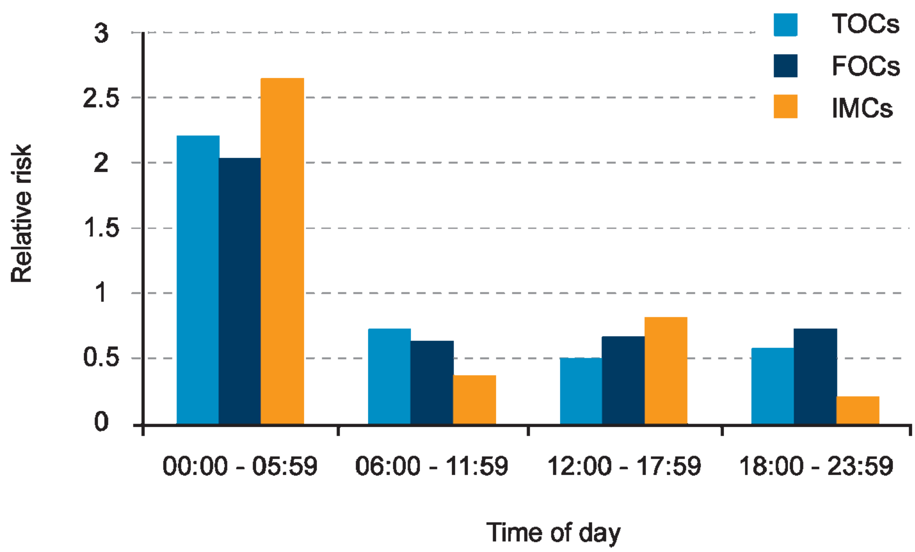


Figure 3.8 Relative SPAD risk by time of day[24]

Figure 3.8 shows that estimated relative risk of SPAD is much higher during night hours midnight to 05:59.

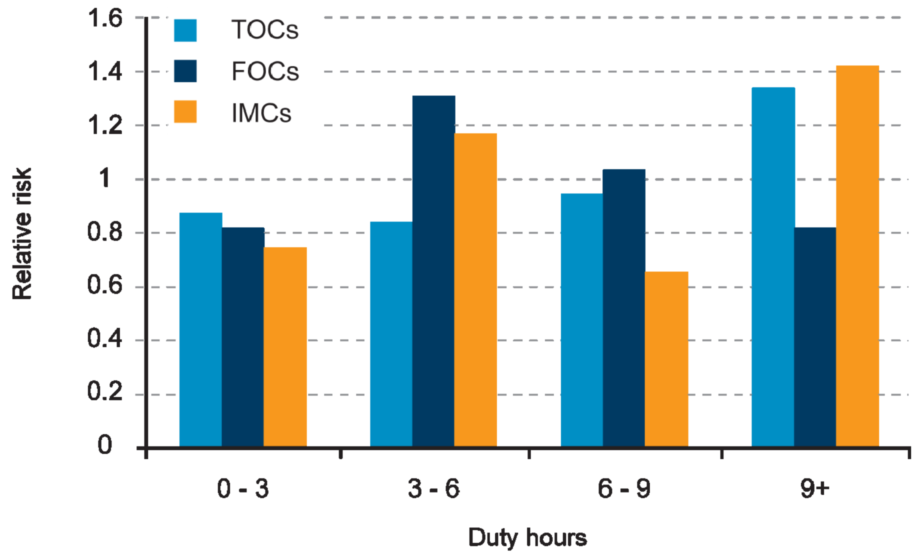


Figure 3.9 Relative SPAD risk by time on duty[25]

Figure 3.9 shows differing trends in estimated relative risk of SPAD associated with time on duty. For freight trains, the risk was highest from three to six hours into the shift. For passenger and maintenance trains, the relative risk was highest after nine hours or more.

[24] Ibid

[25] Ibid

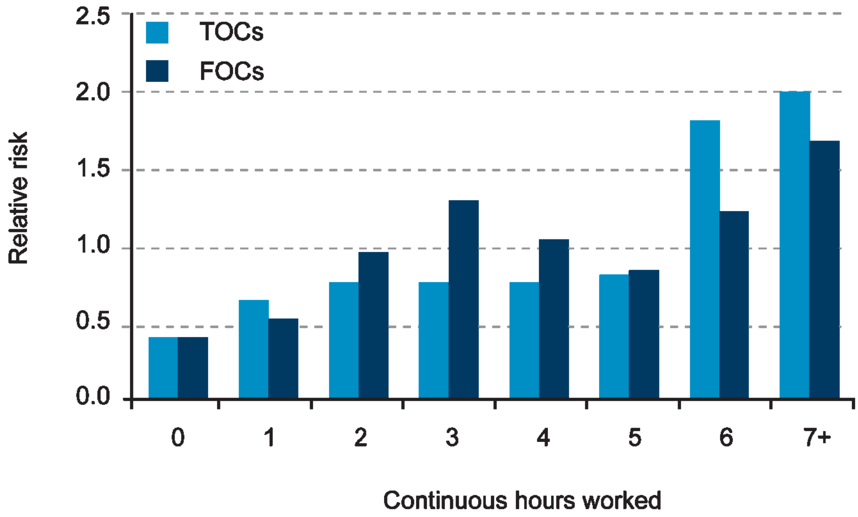


Figure 3.10: Relative SPAD risk by time on task

Figure 3.10 shows relative risk of SPAD by time on task (continuous time worked without a rest break). The data is based on information on rest breaks in the duty period on the day of the SPAD. Time on task is defined as the time from the start of a duty period to until the time of the SPAD or, if the SPAD occurred after a rest period, time on task was the time from the end of the rest period to the time of the SPAD.

There was a clear increase in relative risk of SPAD for passenger drivers at six or more hours without a break. For freight trains, there was evidence of increased relative risk after seven or more hours without a break. There was not sufficient data for meaningful analysis of this dimension for infrastructure maintenance trains. However, the UKRSSB indicate that only one break per shift was recorded in the database and suggest a possibility that the increase in risk has been masked by unrecorded breaks.

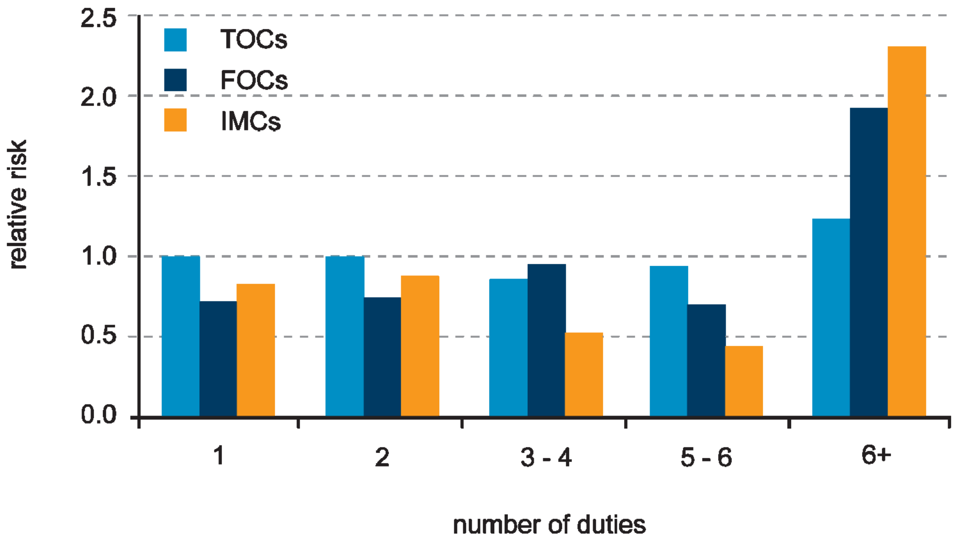


Figure 3.11: Relative SPAD risk by consecutive duties

Figure 3.11 shows that relative risk of a SPAD appeared to remain relatively steady over the first six consecutive duties after which it increased in all groups. The increase was greatest for freight and infrastructure maintenance where it was approximately double the average level.

SPADs and the distribution of rest days

Another study by the UKRSSB and reported on OPSWEB[26] found an increased risk of SPADs when drivers have only a single day's break, a decrease in SPAD risk for breaks between three and seven days, and an increase in risk following a break of seven days or more.

Work schedule design to reduce accident risk

The UKRSSB research concluded that shift designs should take into account scheduling dimensions that have the potential to reduce accident risk. They encourage the UK rail industry to improve the current approach to roster generation in relation to freight and infrastructure train operatons and identify a number of specific areas where new guidelines related to work and rest need to be considered in the risk context of each rail operation[27].

These include:

Duration of the shift: Limiting shift duration to 12 hours, with further restrictions on duties involving nights and early starts that impinge on normal hours of sleep.

Consecutive duties: Limiting consecutive duties to around six and a lower limit where duties impinge significantly on the normal sleep hours such as consecutive night and early shifts.

Weekly hours: Consideration of a duty hour limit based on a seven-day rolling period and is limited to about 55 hours before a rest day is scheduled.

Days off: Providing for a full night's sleep in the schedule particularly following night shifts where a single rest day may not be sufficient.

Rest periods: Minimum rest period of 12 hours between consecutive shifts advisable.

Travel time: Consideration of alternative arrangements such as transport or accommodation if workers are doing long shifts in association with commuting over one and a half hours. Guidance for workers on the risks of long periods spent driving, particularly when driving home after the night shift.

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[26] http://www.opsweb.co.uk/tools/common-factors/PAGES/QA.aspx?id=32 (Refer to tab entitled shift patterns)

[27] UKRSSB, *Research programme operations and management fatigue and shiftwork for freight locomotive drivers and contract trackworkers Appendix F: Analysis of data from signals passed at danger*

Other areas that need to be addressed that are not directly covered by the guidelines outlined above include:

Rostering practices: Improvements to roster design to reduce day-to-day variation in timing and duration of shifts, and include greater contingency within the roster. Staff involved in planning and managing rosters being trained in good roster design and factors that impair sleep and alertness. Consideration of individual worker shift preferences where practical.

Breaks within the shift: Greater consideration to timing of breaks within shifts. Breaks scheduled at a suitable time with respect to the task activities, ideally towards middle of shift. Break of at least 15 minutes recommended after four hours of work, particularly for freight drivers.

Napping policy: For freight drivers, it would be beneficial to implement a napping policy to allow rest to be taken in the cab assuming that controls are in place to assure safety.

'How to manage shiftwork problems - a research perspective' is a table of principles for the design of shift work developed by the UKRSSB, based on their incident data analysis and research on good practice. It can be found in *Understanding human factors: A guide for the railway industry* at http://www.rssb.co.uk/SiteCollectionDocuments/pdf/understanding_human_factors_a_guide_for_the_railway_industry.pdf.

3.3.2 Analysis of human factors data

As previously discussed, information regarding the driver and other relevant operational and organisational factors can be collected using the suggested checklists (tools A, B and C, appendices A, B and D). Compilation of this data will provide some insight into human factors and organisational factors contributing to SPADs.

Some types of data analysis that can be performed are:

- different age groups and experience (for example, UK SPAD data by driver age - Figure 3.4)
- SPADs where drivers reported unusual or unfamiliar circumstances (potentially also related to driver experience)
- SPADs following extended time off (for example, prolonged sickness or leave)
- time into the shift that the SPAD occurred and shift time remaining
- SPADs with internal or external distractions as a contributing factor
- SPADs for different types of signals or specific routes.

3.3.3 Age factors

Figure 3.12 presents UKRSSB data normalised by ITSR to represent SPAD incidence (rate per 1000 drivers) by driver age over four consecutive years. In this example, it can be seen that each of the age groups is performing at a similar rate when normalised as SPADs per 1000 drivers in the each group. The drop in rate for 2007 is due to the reduction in total number of SPADs, probably due to the influence of the implementation of the train warning protection system.

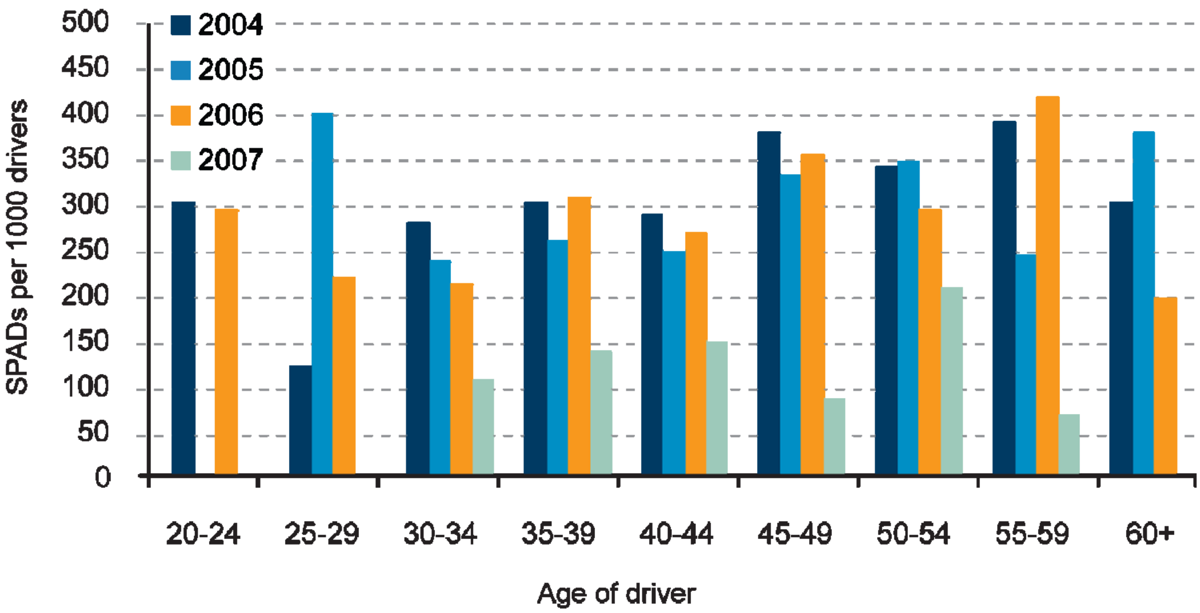


Figure 3.12: UK SPADs per 1000 drivers by age, 2004 to 2007

3.3.4 Driver experience

UKRSSB also provides data on SPADs by driver experience. This has been normalised by ITSR as a rate per 1000 drivers and presented in Figure 3.13. It clearly shows poor SPAD performance in experience bands one to five years especially for drivers with one to two years experience.

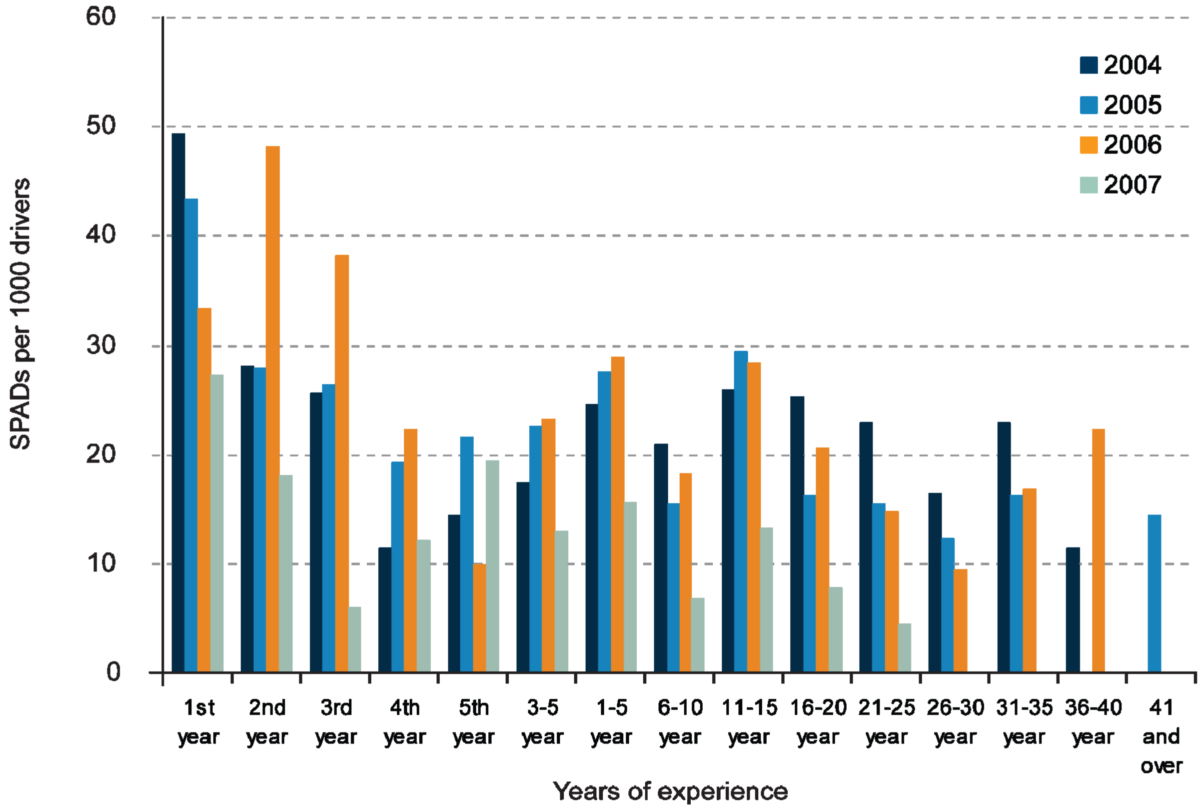


Figure 3.13: UK SPADs per 1000 drivers by years of experience, 2004 to 2007

3.3.5 Human error

Data on precursor categories can be analysed to determine the greatest contributors to SPADs and the relationship with other factors, such as multi-spad signals. The UK UKRSSB provides an example with Table 3.10 that lists the human error precursor categories. The categories in the table match the immediate cause classification presented earlier as Table 2.3. The second and third columns show each category of error precursor as a percentage of all SPADs, and as a percentage of SPADs that occurred at multi-SPAD signals.

Precursor	% all SPADs	% SPADs at multi-SPAD (4 or more SPAD) signals
Misjudge train behaviour	9%	21%
Failure to react to a caution signal	26%	19%
Failure to check signal aspect	19%	15%
Misjudge environmental conditions	8%	10%
Viewed wrong signal	6%	9%
Failure to locate signal	9%	7%
Anticipation of signal clearance	6%	6%
Violation of rules/instructions	6%	4%
Viewed correct signal misread aspect	3%	3%
Misread previous signal	1%	3%
Ignorance of rules/instructions	1%	1%
Wrong/ambiguous/incomplete information	4%	1%
Correct information, but misunderstood	1%	1%

Table 3.10: Precursor contribution to SPADs and influence of multi-SPAD signals

The data in Table 3.10 suggest that SPADs at multi-SPAD signals are more likely to involve the category *misjudge train behaviour* than SPADs at all signals. Otherwise, the proportions in each of the other error precursor categories appear to be similar for SPADs at multi-SPAD signals and SPADs at all signals. However, it is important to note that investigators need high-level competencies in the human factors aspects of investigations to be able to differentiate between precursors. In many cases, the driver is not aware of the factors that influenced his or her performance and it takes a skilled human factors investigator to ensure that precursors are as accurate as possible.

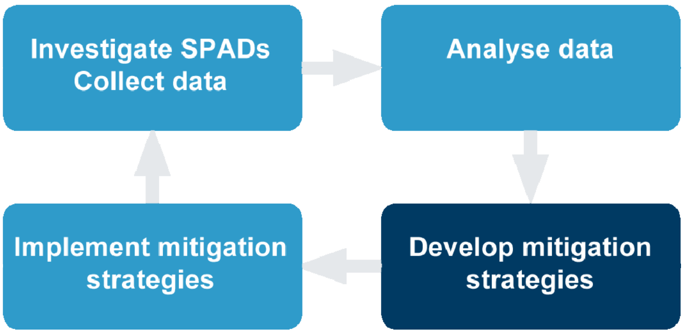
In presentations regarding SPAD strategy, the UKRSSB has identified the following priority issues and factors that have been identified through UK data. As such, they may provide worthy starting points for consideration in Australian SPAD investigations and data analysis:

- perturbed operation
- unusual moves
- mobile telephones
- diabetes

- prescription as well as prohibited drugs
- *starting against signal* SPADs
- starting from yellow
- 3-4 aspect transitions
- train stop reliance/cues
- poor communication
- signals to right.

The data from the UK presented above shows how a deeper understanding of contributing factors to SPADs can be gained. For example, Figure 3.12 suggests driver age does not appear to be a significant factor, whereas Figure 3.13 suggests driver experience to be a contributing factor. Such information is invaluable in developing strategies for SPAD reduction, as it provides direction in which areas to target. However, railways differ considerably in terms of signalling, associated infrastructure and rolling stock, so it is best to look at what local data is revealing and form associated strategies.

4 Mitigation of identified SPAD problems



Through data collection, investigation and analysis, contributing problems to SPADs can be identified, allowing strategies to address such problems to be developed. This section provides examples of a number of strategies and programs that can be used to address particular problems that contribute to SPADs. They are not necessarily the best way for every organisation to deal with the problems, but are put forward as ideas on what may be done in the area.

4.1 Mitigation measures linked to investigation tools

Appendices D and E contain example mitigating measures that link to each item of the investigation checklist tools at appendices B and C. These generic mitigating measures were developed in conjunction with Human Engineering based on work for rail industry clients in the UK and Australia. The relationship between the checklist tools and mitigating measure tools is shown in Figure 4.1.

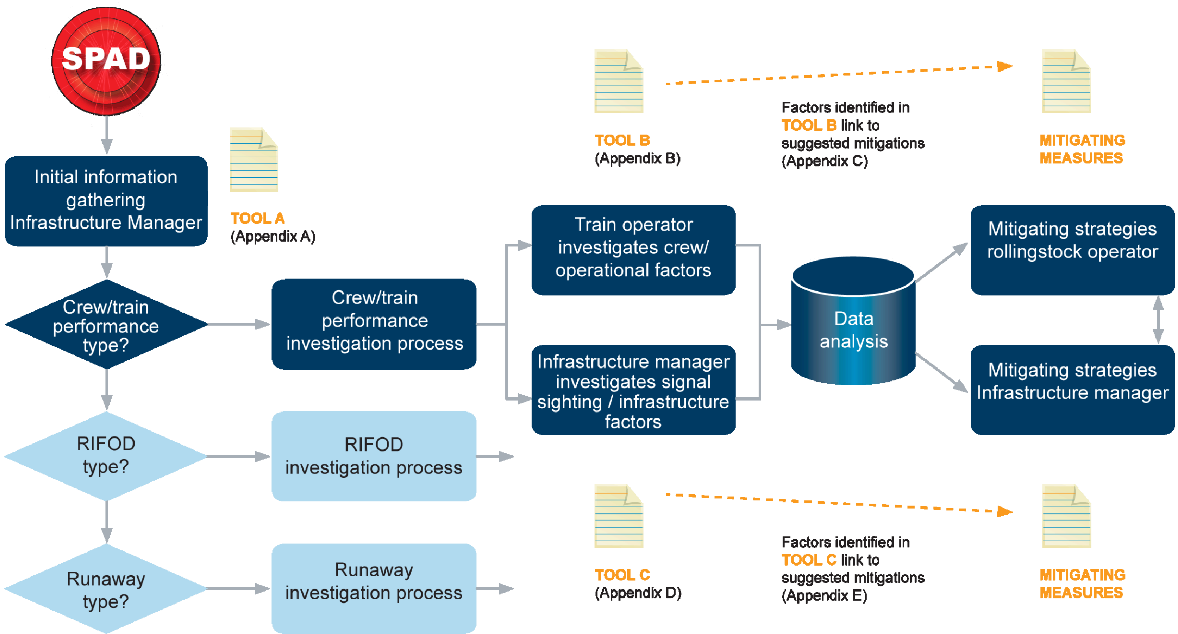
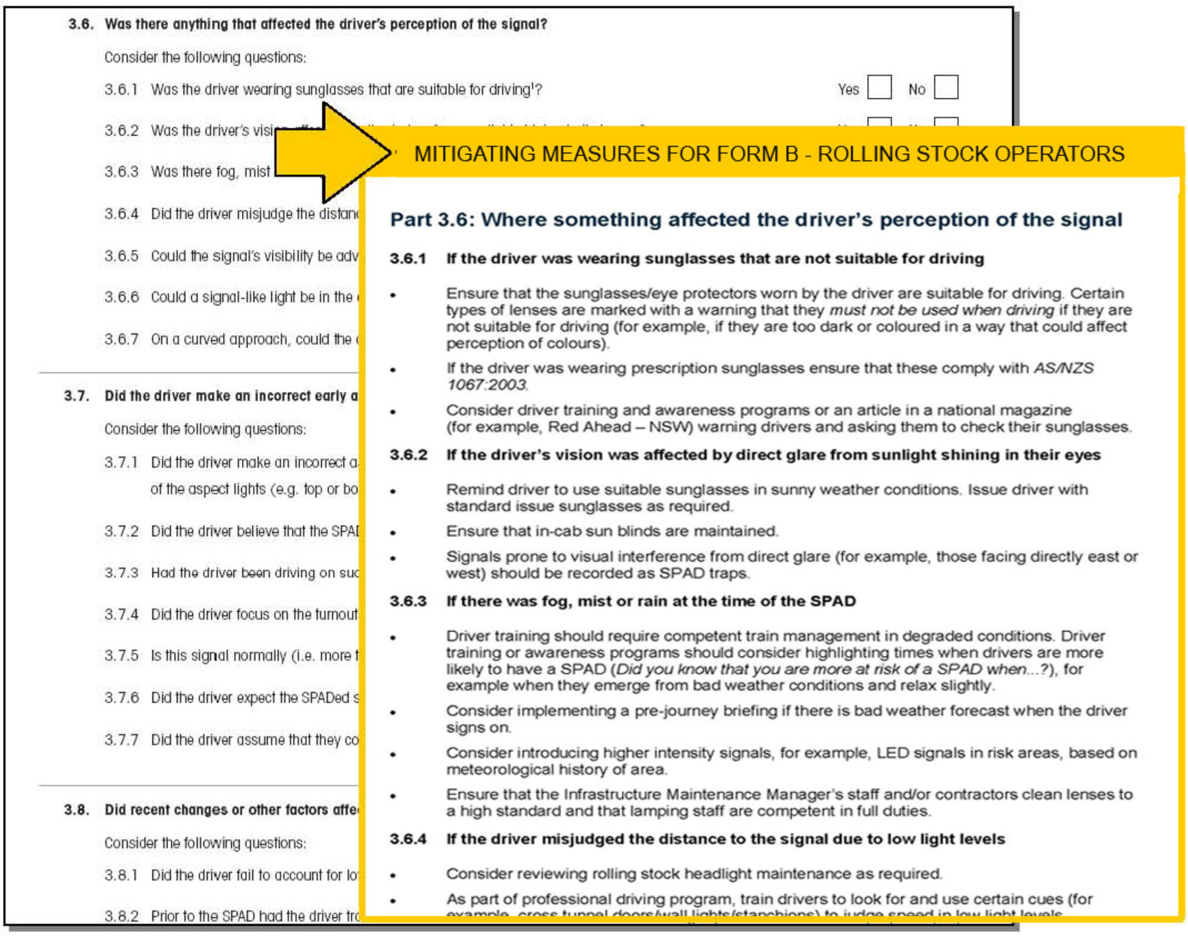


Figure 4.1: Link between investigation tools and possible mitigations

An example of the suggested mitigation measures that are linked to the rolling stock operator human factors investigation tool is presented as Figure 4.2.



3.6. Was there anything that affected the driver's perception of the signal?

Consider the following questions:

3.6.1 Was the driver wearing sunglasses that are suitable for driving'? Yes ☐ No ☐

3.6.2 Was the driver's visi

3.6.3 Was there fog, mist

3.6.4 Did the driver misjudge the distan

3.6.5 Could the signal's visibility be adv

3.6.6 Could a signal-like light be in the

3.6.7 On a curved approach, could the

3.7. Did the driver make an incorrect early a

Consider the following questions:

3.7.1 Did the driver make an incorrect a of the aspect lights (e.g. top or bo

3.7.2 Did the driver believe that the SPAI

3.7.3 Had the driver been driving on suc

3.7.4 Did the driver focus on the turnout

3.7.5 Is this signal normally (i.e. more t

3.7.6 Did the driver expect the SPADed s

3.7.7 Did the driver assume that they co

3.8. Did recent changes or other factors affe

Consider the following questions:

3.8.1 Did the driver fail to account for lo

3.8.2 Prior to the SPAD had the driver fro

MITIGATING MEASURES FOR FORM B - ROLLING STOCK OPERATORS

Part 3.6: Where something affected the driver's perception of the signal

3.6.1 If the driver was wearing sunglasses that are not suitable for driving

- Ensure that the sunglasses/eye protectors worn by the driver are suitable for driving. Certain types of lenses are marked with a warning that they *must not be used when driving* if they are not suitable for driving (for example, if they are too dark or coloured in a way that could affect perception of colours).
- If the driver was wearing prescription sunglasses ensure that these comply with *AS/NZS 1067:2003*.
- Consider driver training and awareness programs or an article in a national magazine (for example, Red Ahead – NSW) warning drivers and asking them to check their sunglasses.

3.6.2 If the driver's vision was affected by direct glare from sunlight shining in their eyes

- Remind driver to use suitable sunglasses in sunny weather conditions. Issue driver with standard issue sunglasses as required.
- Ensure that in-cab sun blinds are maintained.
- Signals prone to visual interference from direct glare (for example, those facing directly east or west) should be recorded as SPAD traps.

3.6.3 If there was fog, mist or rain at the time of the SPAD

- Driver training should require competent train management in degraded conditions. Driver training or awareness programs should consider highlighting times when drivers are more likely to have a SPAD (*Did you know that you are more at risk of a SPAD when...?*), for example when they emerge from bad weather conditions and relax slightly.
- Consider implementing a pre-journey briefing if there is bad weather forecast when the driver signs on.
- Consider introducing higher intensity signals, for example, LED signals in risk areas, based on meteorological history of area.
- Ensure that the Infrastructure Maintenance Manager's staff and/or contractors clean lenses to a high standard and that lamping staff are competent in full duties.

3.6.4 If the driver misjudged the distance to the signal due to low light levels

- Consider reviewing rolling stock headlight maintenance as required.
- As part of professional driving program, train drivers to look for and use certain cues (for

Figure 4.2: Example mitigation measures for rolling stock operations

4.2 Areas of operational management to target

SPAD management spans a number of areas of the management of a railway operation. According to the UK-based OPSWEB *SPAD risk management guide* key areas to target when developing SPAD mitigation strategies are:

- behaviour and performance management of safety critical staff
- managing the working environment on the train operations side
- route design
- infrastructure management.

4.2.1 Behaviour and performance management of safety critical staff

Initiatives that help shape behaviour and support performance of staff involved with train driving, signalling and train control are key to reducing SPADs. Staff involved in these areas can be considered to be safety critical due to the risks associated with SPADs. In the context of SPADs, safety critical staff include:

- train drivers/guards/second persons
- track machine drivers
- signallers/train controllers
- shunters
- platform staff
- worksite protection officers
- signal technicians.

Managing behaviour and performance of staff covers a number of areas of a safety management system. The OPSWEB *SPAD risk management guide* highlights the following areas of focus:

- **Recruitment and selection** - How well does the process check the applicant's physical ability to perform roles such as driving? Are mental abilities and aptitudes required for the role defined? How well does the process check for these requirements?
- **Training and competence** - How effective is training in areas such as driving and signalling? Is it followed by an assessment of competence to ensure individuals are competent and that this competence is maintained? Are SPAD awareness and the steps that can be taken to prevent SPADs occurring, a constant feature?

- **Health and fitness** - Are health and fitness issues affecting the performance and behaviour of staff such as drivers and signallers? Areas for possible improvement include diet, coping with stress, personal life/work balance, and exercise.
- **Fatigue** - Research by the UKRSSB indicates a link between aspects of work schedules and SPAD performance (see earlier section 3.3 - Analysis of work scheduling and time of day factors). Improvements in fatigue management should therefore improve SPAD performance.
- **Safety critical communication** - How well do drivers, signallers, track workers and other frontline staff talk to each other using the correct protocols? How does this affect the risk of misunderstandings and subsequently SPADs?
- **Briefing** - How well are staff briefed in areas such as:
  - causes of SPADs (both in general terms and directly after an incident)?
  - high risk locations?
  - changes to infrastructure and the operating environment?

Rail resource management and simulation

A promising area to improve safety critical workers performance and behaviour is rail resource management and use of simulation.

Rail resource management is a type of applied human factors training (crew resource management) that has been responsible for reducing errors and their consequences in industries such as aviation. Investigations of accidents and serious incidents in the transport industry have shown that many safety occurrences could have been prevented by people making better use of their available resources, such as team members, equipment, information and procedures. Effective resource management not only helps to reduce human error but enables operators to detect and deal with those errors that have occurred so that they can be contained and their consequences mitigated. As such, it is well suited to SPAD management practices.

Simulation involves artificially creating the train driving environment. As well as allowing new drivers to train in a safe environment, it allows the training of unusual events and conditions and system malfunctions in a safe environment. Simulation can become an important part to driver training and assessment.

The techniques of rail resource management and simulation are particularly effective if used in combination, such as joint signaller and driver training. This enables signallers and drivers to experience each others' tasks and understand how to assist each other in detecting potential threats and errors. Rail resource management can also improve the training of guards/second persons and drivers by facilitating a team-based approach to error minimisation (that is, one part of the team watches and supports the other part of the team).

ITSR has published guidance and training materials on rail resource management. Further information can be found at www.transportregulator.nsw.gov.au

4.2.2 Managing the working environment

There are a number of work environment factors that can influence the performance and behaviour of safety critical personnel, in turn affecting the risk of a SPAD.

Driving performance can be impaired by factors such as extremes in temperature, poor ventilation noise, vibration, poor equipment design or layout. Performance can also be impaired by distractions such as people on and around the train, platforms and rail corridor, radio messages, mobile phones, PDAs, and other personal electronic devices.

Following the multiple casualty event due to a SPAD at Chatsworth, California, in 2008, the US Federal Railroad Administration made a ruling to restrict the use of personal electronic or electrical devices, and the California Public Utilities Commission unanimously passed an emergency order to temporarily ban the use of cellular communication devices by train crew members. Following this, the US Congress passed the *Rail Safety Improvement Act of 2008*, which requires the Secretary of Transportation within a year to complete a study on the safety impact of the use of personal electronic devices, including cell phones, video games, and other distracting devices, by safety-related railroad employees. Railways such as the Massachusetts Bay Transportation Authority in the US have banned such devices from the cab altogether. Clearly, managing distractions is important in relation to SPADs.

4.2.3 Route design and management

There are a number of factors that affect how difficult a route is to drive, which in turn influence SPAD risk. These include:

- signal sighting
- route design/layout
- timetabling
- adhesion /weather conditions.

Problems with signal sighting will be revealed by performing signal sighting checks after SPADs using tools such as the investigation tool for infrastructure managers presented as tool C (Appendix D) and signal sighting standards. Such checks can also be done proactively, without having a SPAD, if a particular type of signal is found to be problematic. The infrastructure managers tool C contains links to possible mitigations relevant to the particular infrastructure factor in question. These mitigations are compiled as Appendix E. Examples of signal sighting mitigations are:

- removing excess lineside information
- removing obstructions
- increasing signal brightness by using LEDs
- installing back plates on signals to screen out visually complex information behind it.

Problems with route design/layout can be revealed by using signal sighting standards, as well as the checklist items in tool C and associated links to the possible mitigating measures in Appendix E.

Another factor to consider with route design/layout is assessment of the likely path or trajectory of a train following a SPAD, including where catchpoints (derailers) may be directing a train. Designs need to ensure that catchpoints are not directing trains into stanchions, lineside structures or off embankments.

The timetable can have an influence on the pressure and workload of safety critical personnel, including drivers, signallers and platform staff. Humans are more likely to make errors when under conditions of high workload, thereby increasing SPAD risk. Processes can be followed to identify and mitigate timetable related SPAD hazards.

Planning for adverse conditions

Extreme weather (intense rail, fog, etc.), dust, insect swarms and leaf fall can make driving difficult and have an influence on train performance. In addition, planning is required to maintain the visibility of signals within stopping distances. Procedures should map out how operations are to be performed safely in such conditions.

4.3 Implementing and evaluating strategies

Once potential mitigation measures have been identified and strategic priority target areas have been determined, the next step is to implement strategies and evaluate the impact.

Combining some of the details of each of the steps of the continuous improvement cycle is presented as Figure 4.3 that summarises the overall SPAD management cycle.

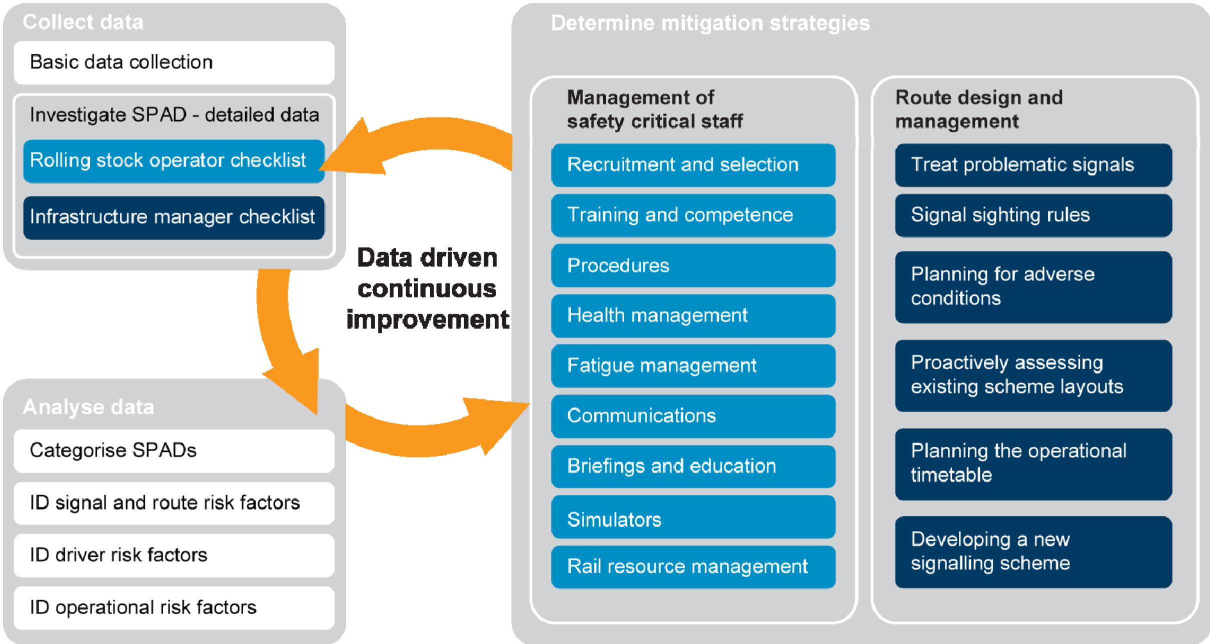
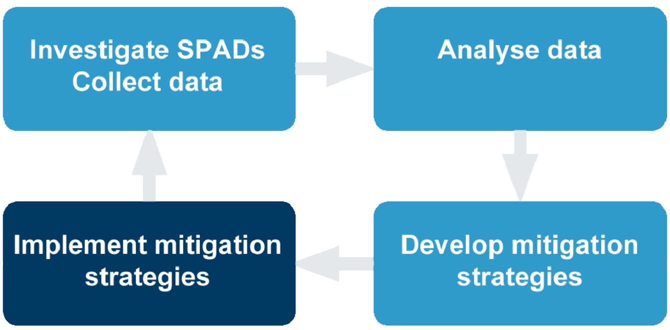


Figure 4.3: SPAD management continuous improvement cycle.

4.4 Getting the message out on SPAD management



Good SPAD management practice depends on action by people across different operational areas and divisions and often more than one organisation. Because of this, mechanisms for information sharing and dialogue are critical. Forums and newsletters are common ways to disseminate good practice and collaboration between organisations, however web-portals with on-line content are increasingly used to bring ideas and people together. A number of useful tools and references on SPAD management are available on line. Some examples from the UK are:

OPSWEB internet portal - http://www.opsweb.co.uk

This UK initiative started as SPADWEB. Due to the success of the initiative, it expanded and re-branded as OPSWEB in recognition that SPAD risk is interconnected with other operational risks intrinsic to the rail network.

OPSWEB aims to communicate operational risk issues and provide a platform for sharing of good practice. Content includes material from a wide range of organisations from operators to regulatory bodies. Although the site has a UK focus, 50 of the 300 organisations (as at April 2008) are represented by users from outside the UK.

OPSWEB provides an opportunity for users to contribute examples of good practice that relate to risks in train operations. Content is vetted via an editorial review panel.

The site provides an important avenue for dissemination of aggregated data and reports. For example, the UKRSSB provide a weekly report on multi-spad signals, and SPAD incident reports each month, quarter and year.

Network Rail multiple SPAD signals – http://www.multispad.co.uk

This website contains maps of the UK rail network with information on multi-SPAD signals in various sections of the network. The Network Rail SPAD policy and strategy also appear on the site.

User information is provided on the benefits of incorporating multi-SPAD information into driver training programs and local SPAD management initiatives, including incorporation into route knowledge, training and safety briefings for divers/trainers, and incorporation into risk assessments.

Halcrow Rail operational safety and SPAD project

Various risk and human factors consultants contribute to development of practical tools on SPAD management. Halcrow UK host a website devoted to their work in this area.

For a number of years, 38 UK railways have jointly funded the Operational Safety Risk and SPAD Project on an annual contract basis. Halcrow UK is currently fulfilling this role. As part of their work, Halcrow host a website (http://www.halcrowspad.com) and produce a SPAD newsletter, *RedAlert*, as well as hosting an annual Operational safety risk and SPAD conference.

Adhesion Working Group (AWG) - http://www.awg-rail.co.uk

AWG is a non-profit making, cross-industry focus group with the sole objective of researching and developing initiatives to combat the effects of low wheel/rail adhesion.

As well as developing new concepts, the group stimulates the sharing of information through regular conferences, events, informational videos and a twice-yearly newsletter.