Managing and Mitigating
SPAD Risk in Rail Operations
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Synopsis:
This report comprises the key milestone deliverable for R2.116 Managing and Mitigating SPAD-risk. This study set out to explore how the SPAD failure mode was being managed and mitigated by rail operators delivering passenger services in Australia and New Zealand. Broad aims were to determine key risk factors/determinants for SPAD-risk, and behavioural strategies adopted by train drivers to mitigate risk, and to develop a cogent understanding of the issue from the organisational/systems-view.

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Executive Summary

The Cooperative Research Centre for Rail Innovation (CRC for Rail) commissioned this project to explore how SPAD risk was being mitigated at an organisational-managerial level, with some second-hand accounts of the ‘unpublished strategies’ being used by drivers. Following a considerable show of support, the methodology was revised to accommodate first-hand accounts from train drivers and a systems investigation of the issue using novel techniques.

Consequently, this project used a participative data collection methodology to collect situational insight of the signal passed at danger failure mode from passenger train drivers. The first phase was to undertake focus groups across the industry. This was done in eight different organisations in Australia and New Zealand. The second phase was to undertake large scale national and international Future Inquiry Workshops to represent these data from the systems level and provide propositions for each organisation to take away.

Key moderating factors and determinants for SPAD-risk identified from focus groups included time pressure, station dwelling, sighting restrictions, and controller interactions. Four specific codes were used to classify and describe the process of inattention and distraction to show that various aspects of service delivery and the all-important dynamic with the signal was being destabilised to substantially increase the likelihood of a SPAD outcome. Growing anxiety, multi-tasking, and/or disengagement from three or more of these moderators was found to intensify the experience of distraction. The study also identified a number of important behavioural strategies that were being used to mitigate SPAD-risk at the driver level. These were covert (i.e. personally and informally adopted), volitional strategies that helped the driver self-regulate by building habitual behaviours.

An analysis of organisational factors was also performed. A summary of the aims and findings that relate to this project are as follows:

**Aims:**

1. Identify the SPAD-risk factors that underpin challenging SPAD scenarios, as perceived by train drivers in Australia and New Zealand.
2. Identify the key countermeasures and behavioural strategies that train drivers use personally and professionally to manage and mitigate SPAD-risk.
3. Develop a model of SPAD-risk and determine fit against risk mitigation strategies.
4. Determine key organisational factors that govern how safety and performance are regulated, particularly in the context of the trend for maximising network capacities.
5. Establish common ground and explore SPADs from a systems perspective to complement train driver accounts using the Future Inquiry Workshop process to present the past and present of the problem, and explore pragmatic options for the future.
6. Identify future research avenues.

**Summary of findings/highlights:**

- Most challenges in passenger train driving were defined as issues with inattention and distractions.
- Time pressure, controller interactions & station dwells are key determinants for SPAD-risk.
- In some scenarios, driver attention is best described as ‘misappropriated’.
- Train drivers have a highly personal relationship with railway signals.
- Train drivers use a variety of covert and volitional behavioural strategies to self-regulate.
- Cautionary signals in some rail networks are being perceived as devalued.
- Maximised rail capacities may be resulting in a normalisation of deviance.
- The ‘fit to continue’ post-SPAD inspection of the train driver is counterintuitive.

The study identified compelling relationships between several moderating factors, however consideration is needed of potential solutions to this problem, and the hypothesised relationships associated with the moderating factors need to be tested.
Research Awards

This research has received the following awards:

Awarded CQUniversity Australian Opal Award for Excellence in Engagement for ‘SPAD-risk Management & Mitigation’ Project (2013).

Awarded best poster paper prize for ‘The Case of the Crooked Clock and the Distracted Driver,’ 10th World Congress on Railway Research (2013).

Publications and Presentations

Research from this report has been published in, or presented at:

Naweed, A 2013, ‘Psychological factors for driver distraction and inattention in the Australian and New Zealand rail industry’, Accident Analysis and Prevention, 60, pp.193-204.

Naweed, A 2013, ‘Hurry up and wait: danger signals in the rail environment’, Ergonomics Australia, 3, p. 1


Naweed, A & Rainbird, S 2013, ‘Give me a sign: Reflections on the driver-signal relationship’, [Signalling & Communications], Rail Express, 1,April, pp. 52-53.


Translation of Research

Industry Guidelines:

Working Groups:

Australasian Railway Association (2014). *SPAD Categorisation Working Group*. This project has helped the rail industry in Australia and New Zealand establish and develop a common and standardised SPAD categorisation scheme for both passenger and freight rail operators allowing them to benchmark, identify trends, share information and learn from each other.

Australasian Railway Association (2014). *SPAD Working Group*. This project has had a strong presence in the general SPAD working group in Australia and New Zealand. The group, comprised of SPAD and Safety experts provides a dedicated and consultative forum to discuss systemic issues and recommended effective industry solutions to decrease the number of SPAD incidents.
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Abbreviations and Acronyms

Note: Effort has been taken to spell-out acronyms in full whenever they are mentioned in this report. In several instances this was not possible as the acronym was part of the collected data. These are listed below.

AWS  Automatic Warning Systems
ATP  Automatic Train Protection
ETCS  European Train Control System
ERTMS  European Rail Train Management System
NCO  Network Control Officer
RSSB  Rail Safety Standards Board
SISAR  Safety Information System for Australasian Rail
SPAD  Signal Passed at Danger
Managing and mitigating SPAD risk in rail operations

1. Report Overview

1.1. Background

Signal Passed at Danger (SPAD) events are a major safety issue for both passenger and freight operators. The term ‘SPAD’ is used to describe a scenario where a train has exceeded its limits of authority, conventionally by running through a stop signal aspect. Whilst not all SPAD events result in collisions or accidents, they do represent situations where the safe working system has broken down and thus signify a high-risk failure mode in railway operations. Use of SPAD mitigation technologies in Australia and New Zealand varies, though most territories currently run their services with very limited protection. Whilst those technologies that are installed reduce the potential for serious accidents, they are designed to intervene only after a SPAD event has occurred, and thus do not prevent trains from encroaching onto unauthorised track.

A number of international engineering solutions have been devised to manage SPAD events at the driving activity level and mitigate the risk of movement authority violations (e.g. Automatic Warning System, Automatic Train Protection). The Australian rail industry currently employs these devices in certain corridors, but the piecemeal manner in which they have been implemented prohibits the feasibility of an engineering solution. As events that typically originate out of operator errors of commission or omission during task activity, SPADs advocate the use of human factors solutions that can identify and address the underlying substantive issues.

Rail research has yet to compile a detailed knowledge base of the SPAD mitigation strategies adopted by different rail operators. More importantly, it has yet to identify the unexplored strategies that are not contained in scientific literature and are inaccessible to the academic domain. To that end, the project presented in this report was conceived as an industry consultation exercise that aimed to focus on sharing best practice and facilitate the compilation of all SPAD risk mitigation strategies currently used by rail operators.

1.2. Aims, Objectives & Scope of Study

The overall purpose of this study was to use ‘out-of-the-box’ methods to gain a better understanding of how SPAD risk is managed and mitigated by the rail industry in Australia. Very little, if any, research has been performed in this area, and the aim was to undertake a general exploratory study to lead to new knowledge about this research gap and the identification of important variables for future research. This aim was broadened to include rail operations in the North and South islands of New Zealand to elevate the dataset and represent the issue at the Australasian level. The project adopted an exploratory and ‘bootstrapped’ research approach in that research questions used to drive findings were informed by the findings as they emerged. The overarching research question was: How do rail operations in Australia and New Zealand manage and mitigate SPAD-risk? As the research unfolded, this research question was broken down into the following objectives:

1) Identify the SPAD-risk factors that underpin challenging SPAD scenarios, as perceived by train drivers in Australia and New Zealand.

2) Identify the key countermeasures and behavioural strategies that train drivers use personally and professionally to manage and mitigate SPAD-risk.

3) Develop a model of SPAD-risk and determine fit against risk mitigation strategies.
4) Determine key organisational factors that govern how safety and performance are regulated, particularly in the context of the trend for maximising network capacities.

5) Establish common ground and explore SPADs from a systems perspective to complement train driver accounts using the Future Inquiry workshop process to present the past and present of the problem, and explore pragmatic options for the future.

6) Identify future research avenues.

1.2.1. What is Out of Scope?

This project began as a $20k scoping study to explore how SPAD risk was being mitigated at an organisational managerial level, with some second-hand accounts of the ‘unpublished strategies’ being used by drivers. Through opportunity, networking, and considerable industry support, the project scope widened to accommodate first-hand accounts from train drivers, and a systems investigation of the issue in a large-scale international workshop. Following yet more support, the project scope widened still further to accommodate a total of five workshops, with participation from 300+ additional subject matter experts.

Originally, the scope also included representation from the freight and heavy haul rail sector, but this focus changed when the influx of new support was passenger oriented. To optimise the project, and provide research where it was needed most, the focus changed to understanding SPAD risk in passenger rail. However, despite the expansion to the project, it is important to recognise that the definition of work did not stray beyond the exploratory nature of the original scoping proposal. Consequently, this project does not profess to know all the answers to SPAD causation or mitigation, nor does it offer a single solution. It does, however, offer important insights that may guide rail operators to better manage and mitigate the issue in their organisations.

As the research was conducted, clear themes emerged to focus and refine the project, as part of the bootstrapped approach. One of these was the issue of ‘task-related distractions’ to train driving as SPAD-risk factors. To enhance the readability of this report, the subsequent sections will provide substantive literature related only to the findings that emerged.

1.2.2. Study Method

This project pursued fundamentally participative lines of inquiry. This involved focus group-based interviewing techniques, observations, and workshops with subject matter experts. Additionally, the project drew on rich and imaginative generative tools developed in the course of other like research (e.g. R2.112 Capturing Driving Strategies; R2.113 Route Knowledge Acquisition). To summarise, the research adopted the following core investigation methods in its study method:

- Focus Groups
- Informal Cab ride observations
- Scenario Invention Task (adapted from Route Invention Task)
- Future Inquiry Workshops
- Mind-mapping.
This study adopted scientific research methods to collect and analyse data. Whilst the study has been presented using the conventions of a technical report, the terminology has been balanced to be readable by an industry and academic audience.

1.2.3. Report Structure

The remainder of this study is organised into a series of chapters with subsections, as follows:

- Chapter 2 presents an extended background to the research and focuses on the topic of distraction, as a SPAD-risk contributor that emerged as a critical element in the train driver focus groups. This section concludes with a series of aims and objectives that frame the next few chapters.
- Chapter 3 provides a detailed breakdown of the methodology that was designed and followed in this study. Important design considerations are discussed before presenting the suite of methods that were converged to both collect and analyse data.
- Chapter 4 presents the findings associated with the risk factors that gave rise to distraction and inattention during train driving. This chapter concludes with a risk-based model of SPAD likelihood/distraction as a key finding from this work.
- Chapter 5 presents the findings associated with the countermeasures and behavioural strategies that were used to manage and mitigate SPAD-risk at the driver level. This chapter concludes with a ‘fit’ of the elicited strategies against the goal-shaping criterion in the model of SPAD likelihood/distraction presented in the previous chapter.
- Chapter 6 presents the findings associated with the organisational behaviours for managing and mitigating SPAD-risk.
- Chapter 7 presents key data associated with the SPADs Future Inquiry Workshops.
- Chapter 8 presents a cohesive and extended discussion of the findings from Chapters 4-to-7 systematically.
- Chapter 9 discusses the strengths and limitations of the study, and provides an account of prospective research.
- Chapter 10 concludes the study, and offers a discussion of the overall findings.
2. **Introduction**

A SPAD is a mode of high risk and a situation where safe working in the system has failed. Rail industries use a variety of technology-based engineering initiatives to mitigate violations of movement authority. In the European context, these include various perception-action devices, such as the Driver Reminder Appliance, an operator-initiated memory aid (e.g. GK/RT0091 1997), or the Automatic Warning System, which requires the driver to cancel an alarm triggered on approach to cautionary signals (McLeod et al. 2005). Engineering initiatives also include train protection devices, such as the Automatic Train Protection system (Simpson 1994), and the Train Protection & Warning System (Fenner 2002). Both of these systems apply train brakes if the train passes a signal, or if its speed significantly exceeds line speed parameters. Deficiencies in the design of these systems, such as the Automatic Warning System, have been criticised (Cullen 2000), and under some conditions, they are said to offer little guarantee (Edkins & Pollock 1997). Whilst some of these systems, such as the Train Protection & Warning System do invariably reduce the baseline risk level of having a SPAD, they do not address the underlying causes, that is, what gave rise to the errors that result in the SPAD in the first place.

The rail industries in Australia and New Zealand have adopted a range of technologies used in Europe to mitigate SPADs risk. Several territories have Automatic Train Protection and some use the Automatic Warning System, whilst others have no automatic safety systems at all, and there are also differences in the use and integration of safety systems for operators that share networks. While some of the technologies are similar to those that have been described, the main issue is that the piecemeal implementation of these technologies and inherent system reliability issues hinder SPAD prevention from the perspective of a single engineering solution. This is evidenced by SPAD statistics that continue to rise (ATSB 2012; KiwiRail 2013). A better understanding of SPAD risk requires further analysis of root causation and a grasp of the substantive psychological factors for challenging scenarios, particularly as train driving is an ostensibly complex task underpinned by a specialised skill-set, and considerable expertise is required to navigate railways proficiently (Branton 1979; Naweed 2013b).

During train driving, drivers are often engaged with strategy and future state prediction, even in periods of observably low workload. Thus, skilled rail navigation relies on an in-depth knowledge of the route and its signalling system(s), coupled with a good awareness of future states (Naweed et al. 2013). Much of the theoretical underpinning for these cognitive dynamics is backed by the theories of applied attention and situation awareness (Endsley 1995; Wickens & Hollands 2000). Essentially, train drivers need a strong baseline for sustaining attention and route knowledge but this increases their susceptibility to certain types of information processing disturbance. Information loss from working memory can occur from the amount of time the driver spends on task, or from displacement by new and competing information (Stanton & Walker 2011). Train drivers are particularly vulnerable to these factors, given the demand for prior knowledge and situational assessment, thus SPADs are frequently attributed to inattention and distraction (Edkins & Pollock 1997).

Driver distraction has been defined as the ‘diversion of attention away from activities critical for safe driving toward a competing activity’ (Lee et al. 2009, p. 34). The implication is that inattentiveness gives rise to distraction, but there is some disagreement on what is actually meant by inattention. Those viewing distraction differently from inattention assert that a competing activity (i.e. an event, object, person) has to trigger distraction for attention to be redirected (Treat 1980), and that this activity is typically exogenous to (the mind of) the driver (Hoel et al. 2010). Those viewing distraction as a subset of inattention emphasise the trigger (Stutts et al. 2005) and suggest that inattentiveness can occur without being distracted (Pettit et al. 2005). More recent research has started to focus on the relationship between inattention and distraction.
instead of the differences. Here distraction has been redefined as ‘Driver Diverted Attention’, and a ‘diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving’ (Regan et al. 2011, p. 1776). Thus, research has begun clarifying what gives rise to distraction relating to driving-activity.

Activities that compete for attention can be task-related (e.g. responding to a warning indicator) or unrelated (e.g. composing a personal text message), as can inattention caused by endogenous thoughts (Regan et al. 2011). Industry-led research has tended to emphasise control and mitigation of SPAD-risk from non-task related distractors (e.g. mobile phones (RSSB 2010).) Where task-related, research has concentrated on exogenous mechanisms more closely associated with signal visibility constraints, and action failures such as cab ergonomics (Lowe & Turner 2005; Newman et al. 2007). Research has also explored how awareness may be elevated to minimise distraction (Luke et al. 2006; RSSB 2008) but more study into the nature of distraction beyond sighting restrictions and situation awareness is required. Whilst emotional and cognitive distraction has been explored (e.g. anxiety, boredom), research has yet to examine the distraction-inattention relationship when attention is diverted by activities intrinsically part of train driving.

Determining the nature of distraction in task-related train driving activities is important, for example, the pressure to perform is a distractor that may allocate attention to one aspect of the task whilst drawing attention away from another (Lewis & Linder 1997). Given train driving complexity and the paradox of managing safety with performance, it is difficult to define how train drivers should distribute or divert their attention between activities that may all be construed as critical to the task. Thus, human error in certain SPAD modes may involve a variety of factors that impact the driver’s ability to self-regulate. The point of view adopted in this paper is to look beyond the differences between distraction and inattention to the ir relationship, particularly from the perspective of driving relatedness. Consequently, rail research needs to examine psychological factors for SPAD-risk that divert attention but may also go undetected (e.g. as organisational norms), and the relationships that these share with external distractors need to be better understood if SPAD-risk is to be reduced.

2.1. Complexity in Maximising Rail Network Capacities

In recent years, complexity theory had advocated a systems- or complexity view of systems where complexity is becoming a defining characteristic of high technology (Hsu 2007; Huberman & Miles 1994; Naweed 2013c). This theory describes how failure may emerge opportunistically from the systems put in place to prevent it. It also explores notions of a normalisation of deviance to explain how compliance could give rise to hazards through deviant behaviours, and erode to a level that effectively reduces the risk afforded by the system. Considering how signal passed at danger events are managed from the systems view may provide insight to the people involved with the issue, and explain how complexity may arise between the immediate and/or remote components of the signal passed at danger failure mode. The intersection of different approaches and perspectives used to manage these events may have a tendency to blur the issue, and in some respects the failure remains ‘unmanaged.’ As an overarching theoretical framework, complexity and systems thinking may be used to provide insight into safety decision making.

In the Australian and New Zealand rail industry, rail operators still tend to use judgmental single factor accounts of failure to human actions or inactions (e.g. ‘distraction’) to explain signal passed at danger events, and seldom look beyond the train-signal conflict point to the wider rail-system to explain causation. Rail research has started to trace the path of signal passed at danger events for causality beyond single factor accounts (e.g. Stanton & Walker 2011). Research has also started to examine the dynamics and context-shaping features of the wider-organisation to develop multi-factorial and convergent accounts of failure and signal passed at danger likelihood (Australasian Railway Association Inc. 2008). However, few studies have
researched the unseen factors that shape how the signal passed at danger event is managed from a systems thinking perspective. In Australia, New Zealand, and the wider Asia-Pacific region, rail is undergoing job growth; Australia alone has seen exponential increases in the patronage of their passenger operations since 2008 (Dekker 2011; Ministry of Transport 2005). The increase in demand has led to an increase in recruitment of new drivers and may have also had an impact on the level of initial training and retraining used to maintain skills. Beyond this however, the increase in demand has created a push for rail operators to maximise the capacities of their networks (Ministry of Transport 2005) and these increases are being accompanied by a concomitant increase in SPAD numbers (ATSB 2012; Naweed 2013d).

It is therefore important to determine how the trend for maximising capacities could be impacting the train driving task and the incidence of the signal passed at danger failure mode. It is also important to explore other related issues, such as the impact on training. These considerations are particularly important in rail networks such as those in Australia and New Zealand where train driving is largely still performed using basic train state features (e.g. speedometer) and traditional navigational parameters (e.g. route knowledge). In these networks, few organisations have safety systems that enforce braking if train speeds exceed prescribed limits and no organisation has signalling communication technologies that manage train separation from other trains (Australasian Railway Association Inc. 2008). To some extent, this poses the question of what safety management systems rail operators have in place to manage how train separation distances are maintained. Researching this issue under the overarching theoretical framework of complexity may explain these issues, and provide insight into the systems and organisational behavioural mechanisms underlying safety decision making and signal passed at danger causation.

2.2. Aims and Objectives

The overarching aim of the study was to investigate SPAD risk in the Australian and New Zealand rail industry and to better understand how the failure mode may be managed and mitigated. In meeting these aims the objectives were three-fold:

2.2.1. SPAD Risk Factors

To examine SPAD-risk factors that diverted attention and impacted task regulation in train driving. The objectives used to achieve this were to: (1) collect and thematically analyse SPAD-scenarios created by train drivers, and (2) use these data to develop a conceptual model of distraction-based SPAD-risk, to help RTOs develop a better understanding of these sorts of SPADs, and provide a guide to analyse these types of SPADs during SPAD investigation.

2.2.2. Countermeasures and Behavioural Strategies

To investigate the behavioural strategies used by train drivers to manage SPAD-risk, optimise safety and performance, and maintain effective self-regulation. The objectives used to achieve this were to: (1) compile, categorise, and thematically analyse behavioural strategies created by train drivers in challenging SPAD-scenarios, and (2) ascertain the relationship between these behavioural strategies and SPAD-risk factors.

2.2.3. Organisational Factors for Managing & Mitigating SPAD Risk

To determine key organisational and systems issues that could be impacting the train driving task and the incidence of SPADs. The objectives used to achieve this were to determine how train movements and safety risk were managed from the perspective of the train driver, and the implications of this behaviour on the rail organisation. This research objective was driven by the research question: ‘Given the trend for maximising network capacities, how is rail safety and performance regulated in the rail domain?’
3. Materials and Methods

This study is based on 12 months of qualitative fieldwork undertaken in Australia and New Zealand from 2012 to 2013. Access to the train drivers and regions of interstate rail network was granted by contacts in the CRC participating organisations. The author was afforded behind-the-scenes access to various rail operations, and had the opportunity to observe a number of candid SPAD committee meetings. The study methodology reported was consistent with the qualitative and ethnographic proponents of the scientific method.

3.1. Design

The approach was designed using the interview and observations family of methods for eliciting knowledge. Direct methods of talking with experts and watching them at work helped conceptualise the issue in the problem domain (Cooke 1994), in this case, SPAD-risk. Data were collected in a focus group setting but several methods were combined to maximise knowledge elicitation (Hoffman & Lintern 2006). Table 1 categorises the class of questions in the protocol. Examples were ‘what are your views on the different categories of SPADs?’ and ‘what sort of things would you consider to be distracting during driving?’ The protocol obtained views of SPAD categorisation and causation, and the strategies used to mitigate risk and ameliorate safety. However, the focus groups were actually a primer for an invention task that combined the principles of scenario retelling and timeline verification from the Critical Decision Method (Klein et al. 1989), and the intuitive and generative properties of a visualisation technique (Monk & Howard 1998) to evoke and record insight into a SPAD scenario, and gain an accurate understanding of all the contributing factors.

Table 1. Overview of the semi-structured focus group protocol

<table>
<thead>
<tr>
<th>Class of question</th>
<th>Typical content</th>
<th>How does your organisation react to a SPAD?</th>
</tr>
</thead>
<tbody>
<tr>
<td>General experience</td>
<td>Background, organisational issues</td>
<td></td>
</tr>
<tr>
<td>Impressions of SPAD</td>
<td>Management, classes of SPAD</td>
<td>What are your views on the different categories of SPAD?</td>
</tr>
<tr>
<td>causation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prospective SPAD causation</td>
<td>Awareness, distraction, fatigue</td>
<td>What sort of things would you consider to be distracting during driving?</td>
</tr>
<tr>
<td>Task Influence</td>
<td>Service delivery, sustained attention</td>
<td>How much do you think fatigue contributes to the risk of a SPAD?</td>
</tr>
<tr>
<td>Impact of equipment design</td>
<td>Cab environment, safety systems</td>
<td>Does your train have any special equipment to help you stop at signals?</td>
</tr>
<tr>
<td>‘Invention task’</td>
<td>SPAD-scenario drawing &amp; walkthrough</td>
<td>Invent a scenario and driving conditions that may result in a SPAD...</td>
</tr>
<tr>
<td>SPAD Mitigation</td>
<td>Personalised strategies</td>
<td>What strategies have you developed or used to help you stop at red signals?</td>
</tr>
<tr>
<td>Driver-signal relationship question</td>
<td>Areas of improvement, training</td>
<td>Describe your relationship with the signal.</td>
</tr>
<tr>
<td>Broader issues</td>
<td>How could a driver be better prepared for a SPAD event?</td>
<td></td>
</tr>
</tbody>
</table>

The scenario invention task elicited knowledge by simulating a SPAD scenario, and placing participants into the event. The task probed participant knowledge, stimulated situational insight and generated pictorial data (i.e. drawings of scenarios on sections of track). These drawings externalised their mental representations and knowledge of the failure mode. The task was designed to elicit intuitive knowledge in a way that drew on the drivers’ own diagnostic processes. In train driving, drivers use forward-thinking and future state prediction to operate the train. This is based on their knowledge of train dynamics, the rail environment, and the evolving situation. The invention task related to study aims because it drew on the same type of collision avoidance...
cognition, and required drivers to think how a SPAD could occur based on a set of driving conditions. The following excerpt taken from this study supports the similarity between cognition in the actual driving task:

[Train drivers] are expected to do what I call ‘crystal ball-gazing.’ You’re expected to make a decision on something that’s going to happen [in the future], which is only a guess, it’s only a judgment, it’s all the mathematics come into your head, spat out in an outcome. There’s nothing written on how to do it, it’s all these judgments coming in and you know, that’s what you have to do.

Various interpretations of the drawing technique used in the invention task have been developed. For example, the rich picture soft systems approach has formalised sketch elements (e.g. symbols, cartoons) to assemble relevant information and encapsulate influences, relationships, and cause-and-effect (Checkland 1980; Monk & Howard 1998). The scenario invention task was adapted from the ‘route invention task’ technique that was created to elicit knowledge from train drivers in the CRC for Rail Innovation’s Capturing Driving Strategies (R2.112) and Route Knowledge Acquisition (R2.113) projects (Naweed & Balakrishnan 2012b; Naweed et al. 2012a). Figure 1 illustrates a SPAD-scenario that was created as part of an instruction to draw a critical incident of a challenging train driving scenario in the aforementioned projects.

Studies comparing the accuracy of sketch maps with spatial knowledge have demonstrated high reliability (Aginsky et al. 1997). Integrating an approach that engaged drivers by escaping the limits of conventional focus groups also had the effect of extracting knowledge built through experience (Shadbolt 2005). The general aim was to obtain a representative cross-section of passenger train drivers but this was invariably
Managing and mitigating SPAD risk in rail operations

driven by logistics. Selection criteria included driving experience (i.e. novice and experts), level of unique insight (i.e. position on the organisation’s signal-sighting\textsuperscript{1} committee), and prior experience with SPAD outcomes (i.e. SPAD history). A focus group typically included a new train driver (less than one year’s driving experience) and two-to-three experienced drivers (more than 10 years’ driving experience). Observational cab-rides were undertaken at participating organisations prior to focus groups as an ethnographic means of framing the ensuing focus group and better understanding the idiosyncrasies and/or peculiarities of the different rail networks (i.e. signalling conventions, risk countermeasures). The bearing of the cab ride within the methodology was to support the elicitation of knowledge that went on to inform the model.

3.1.1. Future Inquiry Workshops

Specialised Future Inquiry Workshops were performed after data associated with train driver perspectives of SPAD-risk management and mitigation had been collected. The Future Inquiry Workshop is a large group plenary and participative process that aims to have ‘the whole system’ in the room at the same time (Blewett & Shaw 2008). This is to find common ground amongst the stakeholders in the development and attainment of a desired future. The process is used to develop action plans for interventions at the organisational level. In this research, the Workshop was used to present our findings from the train driver focus groups we had conducted, and then use the findings as a starting point to focus on developing actionable steps to address some of the identified issues. The intention was to perform state-level workshops to provide individual organisations with information about their own rail networks at the local level, and a final international Future Inquiry Workshop to determine common ground and actions for the industry as a whole. The Future Inquiry Workshop process produced reports (effectively a minuted account of the workshop activities). These were checked by the people that attended each workshop in order to generate an accurate account of workshop activities. Informed consent was obtained from all participants. The specific aims of the Future Inquiry Workshop were:

1. to give the industry partners information about initial findings from the research
2. to identify workplace-specific issues impacting on SPADs
3. to develop strategies for interventions at the workplace that mitigate the incidence of SPADs and improve their management.

The Workshop was conducted with a four-step, goal-oriented process exploring the past, present, future, and actions to get to the future, as follows:

1. The past was addressed through a short, formal presentation of the literature on SPAD research, and preliminary research findings. Examples of data were also provided. The past sought to answer the question, ‘What do we know now about the incidence, management and mitigation of SPADs?’
2. The present was addressed by asking participants to work in stakeholder groups to identify what works and doesn’t work in relation to managing and mitigating SPAD risk in the here and now. As a plenary group, participants developed a large, group mind map of the trends existing now that influence (positively and negatively) SPAD mitigation. Stakeholder groups then determined how they respond (or don’t respond) to priority trends.

\textsuperscript{1} Signal sighting committees comprise a group of individuals that advise on the ideal placement of new signals, and relocation of signals identified to be ‘multi-SPAD hotspots.’
3. Attention was turned to the **Future** after having heard and discussed the past and examined the present as stakeholders and as a plenary group. Participants were asked to imagine an ideal future for SPAD-risk mitigation.

4. In order to **Get to the future**, the whole group discussed the areas of ‘common ground’ from the day’s work to determine what they commonly want and what they would be prepared to work towards. There was commitment by participants to strategies that had not previously been a consideration, and the formation of new alliances.

The Workshop was designed to engage the diverse stakeholder groups, which represented ‘the whole system’, in identifying how to mitigate and manage SPADs.

### 3.2. Participants & Recruitment

#### 3.2.1. Organisational Profile

The study was undertaken within eight rail organisations in Australia and New Zealand, effectively representing all passenger operations in the trans-Tasman region. Five organisations delivered metropolitan passenger services, while three extended to regional service delivery. Four of the participating organisations delivered their operations using train guards. Guards performed passenger service duties aboard the train, such as platform work, wheelchair assistance and station announcements. The other four did not employ guards, thus train drivers also performed these duties in addition to their routine driving operations.

Use of the advanced automatic safety systems (described in the Introduction) varied: two operators had Automatic Train Protection deployed on one or more of their networks; one had integrated the Train Protection Warning System; four used mechanical trip-arm devices (attached to the trackside signal to activate on contact with a passing train); and one had no advanced automatic safety systems. Further, use of driver-initiated memory aids varied: two operators employed the Automatic Warning System, and two used the Signal Alert system. The latter was a timed device that alerted the driver after they had travelled a set distance, typically 600m following activation². Lastly, none of the participating organisations used integrated in-cab signalling technologies or displays that previewed the route to the driver (e.g. speeds, gradients, curves). Thus, train driving was performed with basic train state features (e.g. speedometer) under very traditional navigational parameters (i.e. in-depth knowledge of the route and its signalling system) (Naweed 2013b).

#### 3.2.2. Participant Profile

A focus group was conducted within each organisation and a total of 28 participants (male = 26; female =2) gave informed written consent to participate. The average age was 45.67 (SD = 8.52), with a median of 48, mode of 53 (four separate individuals), and age range of 24 to 58 years. The majority of participants (n = 22) possessed more than 10 years of train driving experience, satisfying the accepted minimum period for attaining expertise (Ericsson et al. 1993). Table 2 shows the composition of participants in the 8 focus groups. Train drivers participated voluntarily, but in all cases, contacts within the organisation were needed to facilitate access. This involved advertising the research and distributing information articles published in rail magazines (e.g. Naweed 2012), so that data collection with interested parties could be rostered appropriately around their shifts.

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² This device had to be physically activated by the driver each time it was used. Use of this device was also unenforced, thus its usage was entirely dependent on individual driver work practices.
Table 2. Composition of Focus Groups

<table>
<thead>
<tr>
<th>No. of people</th>
<th>Gender</th>
<th>Age range (y)</th>
<th>Driving experience (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>24-34</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

Five Future Inquiry Workshops were held across the Trans-Tasman region. The composition of the workshops is shown in Table 3. The participants were drawn from different roles within the rail organisations that directly related to signalling in some form. They were formed into stakeholder groups:

- users of signals
- designers/builders of signals, infrastructure and rail safety
- policy influencers
- policy developers
- policy designers
- front line supervisors
- employee representatives
- controllers of signals
- industry representatives.

Depending on the combination and number of participants in each workshop, some of these stakeholder groups were conflated into fewer categories.

There was considerable diversity in the room and the researchers were confident that ‘the whole system’ was represented. Participants worked persistently throughout the Workshop and there were useful actionable outcomes from the day.

Table 3. Composition of Stakeholder Groups in Future Inquiry Workshops

<table>
<thead>
<tr>
<th>FIW</th>
<th>Stakeholder groups</th>
<th>No. Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>48</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>39</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>54</td>
</tr>
</tbody>
</table>
3.3. **Ethical Considerations**

Management contacts in each organisation were necessarily aware of the employees who were participating in the study, thus confidentiality and anonymity within the dataset was paramount. Data were de-identified and the names of stations, depots, organisations, etc. were removed and any idiosyncratic remarks were not reported. During focus groups, personal details were sought (e.g. work history) but participants were not (intentionally) pressured to provide them. Participants were not required to answer questions they felt uncomfortable discussing, and any potentially upsetting topics (e.g. fatalities) were avoided. The cab rides were cleared by attending authorities (e.g. Driver Safety Managers) and undertaken in accordance with guidelines concerning the observation of behaviour performed in the private domain.

The ethics for the Future Inquiry Workshop had some important differences from the ethics process that was adopted for the rest of the research. The Future Inquiry Workshop relied on debate, discussion and engagement between experts sharing different perspectives. A minuted account of the content in each workshop was also compiled into a report and disseminated to each person that participated, as a means of validating the work that was carried out. The process was therefore not de-identified but participants could control what did and did not get captured simply by withholding or omitting it from being written down. As part of the process, the researchers took photos of the people at work, so as to provide a picture board of the activities in the disseminated report. This process received special dispensation as far as ethics was concerned. Given that this is also an industry report, some of these photos have been included to illustrate the process and aid in the communication of findings. The study met the requirement of the human ethics committee of Central Queensland University (Ethics approval no: H12/03-033).

3.4. **Procedure**

The focus groups lasted approximately 120 minutes and briefing-debriefings were given before and after. The structure of the focus group followed the overview shown in Table 1. The invention task was introduced halfway into the overall procedure and required each participant to ‘invent a scenario and driving conditions that may result in a SPAD for even the most experienced of drivers.’ This could come from previous (i.e. real) experiences with SPADs or based on general driving experience (i.e. what a SPAD event could potentially involve). Drawing conventions were unconstrained and interpreted by the participant based on the instructions provided. Drawings were depicted schematically on A3-sized paper with felt-tip marker pens (yellow, red, green, black). Once the scenarios were invented, each participant was asked to ‘imagine being in that scenario,’ and to ‘highlight and record the key areas of interest.’ These areas referred to significant decision points, shifts in situation assessment, anomalies, violated expectations, and so on. This process was also unconstrained and involved notational remarks and callouts, and further illustrations.

Participants were then asked to ‘write down the strategies or changes’ they would adopt to mitigate the SPAD from reoccurring. This was done with a different coloured pen to differentiate this part of the process and facilitate analysis of retrospective comments. Once this was complete, each participant took turns to ‘walk through’ their scenario in the vernacular with the rest of the group. This was used to verify the timeline of events. Each scenario was then repeated back to the participant, in order to identify gaps, conceptual leaps, ambiguous cues with the aim of understanding the nature of the scenario and all aspects of the driving situation presented. Each of the scenarios was reviewed as part of the group, involving discussion of causal factors, driving challenges, and the operational disturbances.
3.5. Data Analysis

Thirty SPAD scenarios\(^3\) and eight focus group transcripts were systematically analysed using NVivo (version 10, developed by QSR), a qualitative data analysis software tool for organising, searching, and coding data. Data within the transcripts included verbal elaborations of the pictorial data. Themes and conceptual groupings for risk amelioration strategies were inductively drawn from phrases, comments and features of the transcripts, which grounded findings in the data (Huberman & Miles 1994). The initial findings were then refined into overarching groupings and discussed by the researchers using the Delphi method, allowing them to agree to coding definitions (Hsu 2007; Powell 2003). Analysis was undertaken in multiple rounds and included constant comparative analysis (Charmaz 2006). The drawings were analysed separately but compared against the verbal elaborations through a process of data triangulation, or ‘cross-data validity check’, to determine consistency and allow for further refining (Patton 2002). The analytical process was designed so that findings could be repackaged into a succinct model of explanation.

Although the analytical framework was specifically derived for this study, qualitative path analysis methods are commonly used to analyse rail accident data (e.g. Naweed et al. 2012b; Stanton & Walker 2011). The data reported in this study were systematically collected and analysed by a single individual (the author). They were then presented to a reference group comprised of a variety of subject matter experts (e.g. risk, safety and SPAD managers) at the participating organisations, as a means of verifying and validating the findings with their existing SPAD data trends.

3.5.1. Risk and Causation Factors

Figure 2 presents an overview of the coding and categorisation schemes used in the study. The categorisation scheme represented the sole deductive aspect of the framework and captured a schematic of human factors-based causation in each scenario (see ‘risk factors’ process in Figure 2). The risk factors were identified deductively with a predefined process and analysed following a four-step scheme to elicit the causation factors and classify the scenario. These were: (1) defining driving challenges; (2) establishing operational disturbances; (3) eliciting causation factors; (4) and classifying the SPAD scenario. Example codes are shown in Figure 2, thus driving challenges included attention, train control, and route knowledge. For operational disturbances, codes described the impacting direction, such as low situation awareness (downwards arrow), high workload (upwards arrow). For causation factors, codes were assigned primary and secondary causation, with descriptors such as speaking to controller and station delay. For scenario classification, one or more codes were developed and assigned to describe how driving goals were impacted and distraction occurred. These were: distortion, where distraction was identifiable from a deformation of driving goals (e.g. by incorrectly assigning urgency to an activity/goal not critical for safe driving); disruption, where disruption to the driving task itself from a new and competing activity (e.g. an incoming call from the controller) gave rise to distraction; disconnection, where a broken link or gap in a cued task gave rise to distraction, though the physical driving task itself remained uninterrupted (e.g. forgetting the colour of the previous signal); and dislocation, where a complete separation of driving cue, (e.g. forgetting the location of a signal), and/or replacement of one cue with another (e.g. misreading one signal for another) gave rise to distraction.

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\(^3\) Although 28 drivers participated in the study, two generated an additional scenario
Figure 2 - Coding and categorisation scheme used to derive SPAD-risk factors (left-side) and risk amelioration strategies with example codes (note: the codes shown in the scheme contextualise the scenario given in Figure 5).
3.5.2. Countermeasures and Amelioration Strategies

The codes and categories in the risk factors causation pathway were checked against the countermeasures and strategies that were considered to mitigate risk in each of the scenarios (see ‘Strategies’ process in Figure 2). The countermeasures and strategies identified as ameliorators were described and checked against the risk factors in each of the classified scenarios using four steps. The process was to: (1) extract the strategy; (2) identify the type of strategy being used; (3) classify the nature of the strategy; (4) and then finally define the task context in which the strategy was applied. This process was applied to findings from the first three steps of each scenario and determined best fit against the contextualising elements of the task (i.e. service delivery and driver-signal dynamic). Example codes for a scenario are given in Figure 2, thus the type of amelioration strategies extracted for some of the driving challenges encountered in one of the scenarios was to slow or stop and to prioritise the task. These were covert and/or overt types of strategies, thus to slow or stop was overt and to prioritise the task was covert. Both of these strategies were classified as decision making as both were underpinned by decision making of some sort. Thus, errors and causation were attributed to disruption, distortion, disconnection, and/or dislocation to decision making. However, both of these strategies were applied in the context of service delivery; therefore, it was likely the strategies were designed to mitigate risk likelihood and consequence of error from time pressure and controller interactions. Thus, the strategies for operational disturbances were to use short-term recall, and to stand up after the caution signal, and the strategies for some of the causation factors were concentration and prioritise the task, and each of these were analysed for type, classification, and definition in the same way. In this manner, each strategy was investigated at each of the steps and triangulated against the risk factor model.
4. **Factors that give rise to Distraction & Inattention in Train Driving**

Four main themes emerged from the findings; the most common were (1) sighting restrictions, which featured in 80% of scenarios, (2) time pressure, in 60% of scenarios, (3) station dwells, in 50% of scenarios, and (4) controller interactions, in 26% of scenarios. The results section will present the outcomes of the analysis first by reporting the themes that gave rise to distraction, then by supporting each of the themes with sample data from the study. The latter will delve deeper into the data, reframe the themes to moderating factors and draw on excerpts from the whole dataset to expand on the points. Scans of the drawings associated with each moderating factor will be given to evidence the depth, individuality, and nuances of the participants in the study. Note that the drawings used in this paper are raw versions (i.e. as they were drawn minus identifying information). The drawings given in this paper are exemplars from the dataset and representative of the overall findings.\(^4\)

4.1. **Sighting Restrictions**

Figure 3 illustrates a SPAD-scenario coordinated primarily around sighting restrictions. The density of infrastructure (e.g. level crossings, overhead bridges) emphasises a high event rate, but also the importance of route knowledge and appropriate driving strategies when upcoming information is out of sight. In this scenario, the train departs the station to encounter a cautionary signal ahead of an overhead bridge. The next signal, set to danger, is located further down the track beyond a second bridge. Both of the bridges are described as ‘visual obstructions,’ which means that the danger signal is situated on a blind corner. The danger signal is also described as ‘interlocked,’ meaning it only clears and provides movement authority when the level crossing is activated and road traffic had been adequately separated from the rail corridor. The level crossing has been placed a ‘very short distance’ (approximately one train-car length) away from the danger signal, emphasising the safety critical nature of a SPAD outcome at this location. Ordinarily, the train driver would decrease the speed of the train at the caution signal, and prepare to stop at the danger signal. However in this scenario, they do not, and produce a SPAD outcome.

In Figure 3, the danger signal was located on an automatic signal. This meant that in most cases, the signal would have cleared (to a proceed aspect) by the time the driver reached the overhead bridge. In this scenario, the signal did not clear, and the driver went ‘sailing through the stop signal.’ A number of factors impacted the resulting SPAD. First, the invented scenario effectively pre-loaded an anxious driving state: ‘Just before the platform there is a level crossing that is often breached by passengers...boom’s down, lights going, you know, cyclists will ride through the damned thing [and] people will run across it...’ The passenger loading at the departing station was also described as a mechanism that gave rise to distraction: ‘A lot going on. Always something – all the smokers hang up this end, all the certain types of society get up this end...’ In both cases, the resulting anxiety served to disconnect the driver from their attention and safe working requirement, and to some extent, their route knowledge (i.e. proponents of the driver-signal dynamic): ‘My understanding is it takes 8-seconds or so of looking at a signal to commit it to memory, otherwise drivers forget’; ‘If you don’t essentially train yourself to switch-off to some of those outside distractions, those outside distractions really do eat at your attention.’

\(^4\) More exemplars from these data can be found at: (Naweed 2013a)
The scenario in Figure 3 was also influenced by a tendency to over-rely on default conditions and the expectation for a clear signal: ‘Quite often you almost inevitably depart from this location with that signal being on yellow.’ This was based on experience and from practice, increased acceptable levels of risk: ‘If you’ve seen something happen 99 times, you expect it the 100th time;’ ‘we’ve devalued the yellow.’ The last contributing factor was the pressure for on time running: ‘...the driver is accelerating away from the platform, trying to maintain a schedule...’ Sighting restrictions was of thematic interest because by itself, restricted visibility is a rail domain norm. This is a key feature that separates the rail-driving task from the heavy vehicle/light-rail (e.g. tram) driving task on roads. The majority of train driver training is about developing route knowledge and driving strategies to compensate for this lack of visibility: ‘when you’re pulling into stations or you’re thinking about what’s ahead of you, you’re using your landmarks to tell you where you are and how you have to react.’ For this reason, train drivers have the requisite knowledge and skill to regulate throttle and braking for information that has yet to arrive into view. Thus, sighting restrictions were a moderating factor that augmented risk, but in combination with other elements, elevated a high emotional response (i.e. anxiety) and risk acceptance. In Figure 3, this was largely from task-related distraction but included complacency, workload and time pressure.

4.2. Time Pressure

Time pressure was a ubiquitous theme and critical moderator for risk acceptance. Although time keeping was contextualised as a goal-directed activity, the experience of time-keeping pressure was considered to be a distraction: ‘Well, that’s your job. That’s your job. As a train driver your job is to get the train in on time;’ ‘[There is] a push for, you know, it’s got to be on time, on time, on time...’ The drawing in Figure 4 illustrates a SPAD-scenario invented around time pressure. In this scenario, the driver is about to pass a caution aspect at speed, with the next signal located on a blind curve and set to danger. The driver receives a radio call as they pass the caution zone, and over the course of the radio conversation, does not adjust throttle or brake to correct appropriately for the danger signal, resulting in a SPAD. Compared with Figure 3, the scenario in Figure 4 is depicted with fewer sighting restrictions and far less infrastructure. However, the duration of the radio conversation has been highlighted, and a vignette of the driver engaged in the act of losing focus has been given.
A key moderator for the SPAD outcome in Figure 4 was time pressure. While a radio conversation was noted as a mechanism for inattention, the analysis implicated task-related distraction from time pressure as a mechanism that elevated acceptable levels of risk: ‘There was a focus on quick turn around of train due to timetable running late.’ In the scenario, a call from the controller for an explanation to the delay also increased the pressure to perform. This disconnected the driver from their route knowledge (i.e. there is a signal around the bend) and their awareness of the aspect (i.e. the signal is at danger): ‘[The driver] might be thinking about the time and so that’s distracted you from the actual route knowledge that you have.’ However, it also distorted service delivery by emphasising performance: ‘If you’re running late coming down the hill, the other [train’s] waiting there and if you’re running late and your crossing’s late, it makes the whole line late, so some drivers will, you know, they’ll see the yellow, the next one’s going to be yellow, and they think I’ll just go for it.’

Figure 4 raises the issue of risk from multi-tasking during critical activities, but also the issue of distraction related to service delivery. While the driver was focused on recovering delay, answering the call impacted response times by elevating performance anxiety (i.e. they want to know why I’m running late) and creating a psychological and biomechanical disadvantage (i.e. attentional and physical load diverted to a non-critical task). The scenario in Figure 3 noted that the ‘loss of focus left no time to react to red signal,’ revealing a dichotomy in the way it was speculated. The majority of driver attention was directed to another competing activity to leave behind residual levels for competing driving tasks (i.e. safe working, train operation, route knowledge, and situation awareness). But while the call could be considered the trigger for distraction, the underlying time pressure is likely to have motivated the breach of safeworking (i.e. answering the call in unsafe working conditions): ‘When you push [time keeping] and make that the focus of everything that you do all of the time, whether you like it or not, it’s what starts to dominate people’s thought process.’ Thus, the focus was arguably misdirected in the first place. In Figure 4, attention was diverted to a routine goal, but
under the moderating factors (time pressure, sighting restriction) created SPAD-risk. Controller interaction emerged as a specific theme and is presented next.

4.3. Controller Interactions

The speculation that driver distraction also originated from controller interaction issues was a recurring theme. The driver typically called the controller to alert signaling anomalies or query issues with train running, whereas the controller called the driver for an explanation to train delays. An example of this was ‘[Control] wants to know why you lost four minutes in that section,’ though the length of time prompting an explanation varied. Participants indicated that in some networks and under some conditions (e.g. peak hours), calls could be initiated after a one-minute delay. This aspect of controller interactions was perceived as problematic and distracting, particularly where there was a culture of accountability for delay minutes: ‘[Control] is constantly asking ‘why are you late driver?’ and that wears you down after a while;’ ‘The [controller] at train control is annoying me wanting to know why rah rah rah...all of these things contribute to making mistakes.’ In many cases, participants thought explanations for time delay were unnecessary and in most cases, explanations could be deduced without calling drivers, for instance when following a late train, going through a temporary speed restriction, or driving in a peak period: ‘[The driver is] always going to end up late into [this station] because it’s just the way it is. [Control] give you one minute to get passengers off and then you’re running late and they want a ‘please explain driver.’”

Figure 5 - SPAD outcome involving moderating factors that disconnected/dislocated the driver from the signal, and distorted/disrupted service delivery.

Figure 5 illustrates a SPAD scenario where an issue at a station results in time delay. The driver departs the station on a caution signal, and then calls the controller to notify the delay and explain time loss. The next signal, set to danger, is situated around a corner and obscured by trackside vegetation. The scenario includes a relatively complex chain of events, but represents a situation where the driver has experienced a loss of awareness of the departing signal. In similar scenarios, the driver may misread the departing signal for a clear-

5 Note that the term ‘controller’ can vary. Those who interact with the train driver during driving and/or control train movements are also referred to as dispatchers and signallers in different states and in different countries.
normal speed aspect, but it is important to note that that does not happen in this scenario: ‘[The driver] got out of the seat and had to deal with something and then when he got back into the seat and the doors closed, he took off, he looked, he saw the caution...’ Note that unlike Figure 4, the driver in this scenario elects to initiate the call to explain their delay. The SPAD is invariably impacted by the inopportune time chosen to interact with the controller, but several moderating factors are involved in the decision and elevated the risk.

Sighting restrictions and perceived time pressure were important moderators in the scenario shown in Figure 4: ‘So [the driver] is talking to the [controller] saying whatever information he had to relate, still powering, came around the bend which was obscured by a lot of vegetation;’ ‘from when you clear that vegetation to when you see the signal is really no more than about 15-20 metres.’ Much like the scenario in Figure 4, the restricted view and pressure to perform disconnected the driver from their knowledge of the departing signal aspect, and similarly their awareness of the upcoming signal. Whilst interacting with the controller distorted the task by emphasising time keeping, the service delivery dimension was already distorted as a result of the inordinate time delay at the station. Thus the driver was operating in an already anxious, inattentive (and distracted) state, and the decision to call the controller may have been a preemptive attempt to mitigate further anxiety from an incoming call to explain the delay: ‘[Drivers] still get hammered on [their] side about losing time all the time.’ Beyond the emotional distraction, the view of the upcoming danger signal was also restricted by track foliage, but once sighted, response times were exacerbated by poor cab ergonomics: ‘It can be very difficult to talk to [Control] on the phone while controlling the train;’ ‘We’re bound to the dead man, you have to have your arm on it, so you’ve only got one arm to operate all the other equipment;’ ‘Particularly difficult if you’re right handed and you tend to use the phone with your right hand...’

It is important to note that the SPAD scenario shown in Figure 5 involved a station stop that was longer than usual: ‘[The driver] pulls into the station on a caution and something happens on the train...a door issue or something like that...’ The dwell at the station was required to address an issue, which diverted the drivers’ attention and contributed to pressure. Though the danger signal was located some way away from the station, the additional activity required to address the issue disrupted the driving task, and disengaged the driver from their primary activity (i.e. safe working). Under these circumstances, the inordinate length of time and problem-solving load disconnected the driver from the caution signal but also dislocated it, meaning that the driver effectively departed the station still engaged on the door fault task (i.e. relaying it to the controller). The next section will present more data on the issue of station dwelling, which emerged as an additional theme.

4.4. Station Dwelling

Over half of the scenarios invented in this study featured SPADs at or very near stations. Participants generally considered the point of departure to be a high-risk area from the perspective of distraction. Figure 5 illustrated how a prolonged station dwell impacted SPAD-risk. Whilst the main reason for enduring the dwell was a faultfinding scenario, dwelling with nothing to do but wait for the signal authority was also considered distracting: ‘keep the caution up in the top of your head [at the station] as opposed to filtering it out with all the other rubbish that goes on...’ Figure 6 illustrates such an example. In this scenario, the train is stationed on a platform and the driver’s signal is set to danger. However, this signal is restricted from the driver’s line of sight (i.e. the signal is not directly visible to the driver from their side window). The next signal shows a proceed aspect, but this is for the parallel line. The driver misreads this signal as their own and drives away from the platform to have a SPAD event, potentially derail at the points and collide with another train: ‘We’re

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6 The ‘dead man switch’ is a colloquial term for a fail-safe system that is automatically operated if the driver is incapacitated. In this example, the throttle handle must be twisted and remain in this position during driving.
talking about a flank collision which is the most dangerous you can have really for trains. Trains are very strong in the ends but weak in the sides. If you hit one in the side, you’ll rip it apart.’

Figure 6 - SPAD scenario involving a station dwell and moderating factors that disconnected and dislocated the driver from their signal dynamic

Ordinarily, the driver would have completed their platform work with the train guard (if present), and then departed the station when their signal changed to proceed. In Figure 6, the driver departed the station when platform work was completed, but did so on entirely the wrong signal. The station dwell served to dislocate the driver’s attention from the primary task and safe working. Inattentiveness was deemed to arise primarily from the consequence of disengagement (i.e. from an active driving state), which gave rise to the process of distraction and reduced situation awareness. Much like the earlier examples, the sighting restriction and time pressure (or motivation to avoid it) exploited the effect of the dwell, contributed to the outcome, and disconnected the driver from their signal dynamic: ‘The train is running late, the driver changes ends quickly, the station staff make announcement ‘train will be departing,’ the level crossing booms are down and the driver sees they are down, doesn’t check signal properly, takes off…’ The station dwell was an important moderator for SPAD-risk, regulator of competing activities, and shared a relationship with other moderating factors, such as controller interactions: ‘[Control] will ask you if you’re sitting at a platform for too long, when are you going to move?’ Dwelling was a norm for passenger train driving and around 30 seconds of dwell time were reportedly built into timetabling. However, increases in dwell time were atypical, anxiety inducing, and unplanned station dwells bred concern for accumulated time delay for the entire network.

Train drivers managed their driving behaviours around the stopping pattern. Time-of-day effects, peak running, and time pressure affected station arrival and departure. Widely documented examples of human error related to station stopping include station overshoots (i.e. stopping beyond the end of the platform) and overruns (i.e. missing the station altogether). At the other end of the scale, a false start (i.e. departing a station against a stop signal) is also a common occurrence. The majority of false start scenarios in this study explored the circumstances in which this would happen. While SPAD-risk from station dwelling may be caused by time pressure, anxiety and/or high workload, any inattention and disengagement may attract error from a schema-based response to train crew: ‘you’ve got platform staff making announcements…it’s ridiculously loud
Observations of drivers during station dwelling evidenced highly ritualised behavior. Drivers were observed performing a series of physical tasks and/or invoking personal commentaries whilst waiting to depart. Physical tasks ranged from standing up or pacing with a reminder object for cured recall (e.g. keys), through to very specific train control interventions (e.g. reverser in neutral, full brake on, park brake on). Commentary dialogue included repetition of current system state (e.g. ‘I’m departing on a yellow stick’). These patterns of behaviour suggested a conflicted state of driver workload perception; on the one hand, the driver recovered from not needing to drive but assumed a greater attentional load for maintaining situation awareness.

4.5. Novel Events

During data analysis, a fifth element emerged as a SPAD-risk contributing factor. This was the novel event, defined in the context of this study as a peculiar, uncommon, and/or unexpected occurrence that was task-related or unrelated and converged with other factors to divert attention and elevate risk. Under this definition, the scenarios in some of the Figures contained novel events. The scenario in Figure 3 contained a danger aspect that did not clear (and match expectations) by the time the train reached the signal. Figure 5 contained the event of a door-issue that elevated workload and prolonged the station dwell. In Figure 6, the position of the train and signal effectively rendered the danger aspect invisible to the driver. Whilst signal restrictions in rail are commonplace, this exact positioning engendered a novel event. In each of these scenarios, one or more of the four intrinsic moderating factors played a role in a SPAD outcome, but in some cases, a novel event contributed to driver distraction and inattention. The utility of distinguishing novel events from intrinsic moderating factors is returned to in the discussion.

4.6. Summary

In summary, the vast majority of SPAD-risk challenges were attributed to driver distraction, specifically from task-related factors that: (a) diverted attention away from critical work activities; and/or (b) misappropriated management of service delivery goals. These were: time pressure; controller interactions; station dwells; and sighting restrictions. These factors gave rise to distraction through mechanisms that distorted and/or disrupted key parameters for service delivery, and disconnected and/or dislocated correspondence in the driver-signal dynamic. Taken together, these factors reflected issues with self-regulation, and when converged, increased the experience of distraction and the likelihood of a SPAD outcome. The next section will extend these factors into a succinct model of explanation and consider them within the context of SPAD-risk management in the rail industry. The discussion will touch on the theoretical/taxonomical implications for driver distraction.

4.7. Discussion

4.7.1. Conceptualising Distraction & Inattention-related Factors for SPAD-risk

The aim of the study was to examine SPAD-risk factors that diverted attention, and provide a better understanding of the factors impacting train-driving regulation. The first objective was to collect SPAD-scenarios and analyse them thematically, and to derive substantive relationships between inattention and distraction. Based on data collected, four intrinsic themes and moderating factors were identified which: (1) diverted attention away from work activities critical for safe driving to task-related activities that were less
critical, and/or (2) reflected problems with the ability to self-regulate in response to competing activities. The second objective was to develop a model of SPAD-risk for further thinking and research.

Figure 7 conceptualises the findings into a succinct multi-factorial model of distraction in the context of rail collision avoidance and service delivery. The codes used to describe how distraction and inattention came about have been embedded. Thus, distraction and inattention was identifiable through growing anxiety, multi-tasking load, and/or disengagement in the moderating factors, and these appeared to distort, disrupt, disconnect, and/or dislocate the driver and their attention from activities critical for safe driving. Although the model is based on speculative data, these findings support other rail research that has shown train driving to be inherently skilled, ostensibly complex, and comprised of many work activities. Consistent with underpinning theories of attention, the risks from a single moderating factor were considered easier to regulate against competing activities than with multiple factors. The effect of converging multiple factors elevated the intensity of distraction (from anxiety, attentional load, etc.) and intensified SPAD-risk.

The model (see Figure 7) describes the psychological processes that gave rise to inattention and distraction, and describes the nature of the relationships found between the four intrinsic factors of time pressure, sighting restrictions, station dwells, and controller interactions. Although a novel event could be task-related or unrelated, it was best explained as a factor situated outside the intrinsic factors, and shown in the model, this was a dynamic pressure point that increased the experience of distraction when present. The relationships between each of the factors and the way they gave rise to distraction varied. The model conceptualises these interactions within two hemispheres illustrating how one or more risk factors destabilised service delivery and/or the signal dynamic. These are discussed in the next three sections.
4.7.2. Psychological Mechanisms: Distortion and Disruption to Service Delivery

On its own, potential distraction from controller interactions destabilised service delivery, including instances where the driver overheard conversations between the controller and other drivers over the radio. When distractions from controller interactions were experienced with time pressure, the two factors appeared to over-emphasise on time running by misappropriating service delivery and essentially distorting safety-performance regulation. Thus, distraction manifested itself not only from diverting attention through misprioritisation and neglect, but through a kind of subversion of the task itself, that is, the driver continued to perform what they considered was the overriding goal and/or critical activity at the time. Whilst the focus of performance over safety is a feature of the task, the moderating factors associated with service delivery propagated an admission of unacceptably high levels of risk. When distractions from controller interactions were experienced with station dwelling, the factors disrupted the task. Thus, in the scenarios given, interacting with a controller during a station dwell potentially disrupted work activities and the effort to remain engaged, and gave rise to time pressure (i.e. distortion). The implication from these patterns of distortion and disruption to service delivery is for normalised deviance, where compliance attracts new hazards, and the risks associated with these factors have become or are in danger of becoming organisational norms (Dekker 2011).

4.7.3. Psychological Mechanisms: Disconnection & Dislocation in the Signal Dynamic

Distraction from sighting restrictions destabilised the driver-signal dynamic by impacting the drivers’ awareness of their movement authority. A large number of SPAD-scenarios with blind corners were invented in the study, indicating that whilst sighting restrictions were a normative feature of the rail environment, using route knowledge to overcome this limitation was brittle and broken easily under the right conditions. When experienced with time pressure, sighting restrictions disconnected the driver from the signal though the driver remained engaged with the driving task itself. When distractions from sighting restrictions were experienced with distractions from prolonged station dwelling, the driver was disengaged from driving but also dislocated from the signal, and identifiable through cursory checks and/or forgetfulness. Dislocation gave rise to distraction by replacing an awareness of the correct signal with other movement authority cues (e.g. station announcements, incorrect signals, time), most likely through a schema-based response. When experienced with time pressure and station dwells, the sighting restriction gave rise to both processes, and was likely to have mobilised distraction through disconnection and dislocation.

4.7.4. Risk Likelihood from Converging Factors

The model draws attention to increases in the experience of inattention and distraction, and therefore SPAD-risk, when factors converged. At least two of the moderating factors were used to define a challenging SPAD in all the scenarios gathered. Participants experienced inattentiveness and distraction from two factors simultaneously on a daily basis, and some were naturally paired (e.g. station dwells with controller interaction, time pressure with sighting restrictions). Many of the drawings converged risk from three factors, indicating that whilst drivers allowed for (and had adapted to) an elevated baseline level of multi-tasking and performance pressure, it was increases in this baseline that raised SPAD-risk. Thus, converging demand from three or more of these factors would leave little residual attention for the task in high SPAD-risk situations (e.g. driving in a caution zone; starting against a caution in a station). These notions support the argument that train drivers have particular susceptibility to operational disturbances, born from sustaining attention and using route knowledge. Experiencing distraction from time pressure, dwelling unrest, and the controller dynamic (or equivalent) feature in most work domains coordinated by the on time running requirement. To
some extent, these factors comprise rail system culture, but these work norms are also moderators that may subvert the task in certain combinations. Clearly, the effect of fatigue or other biological factors on SPAD-risk should not be ignored; however, none of these restricted states were overtly projected into the scenarios and so have not been represented in Figure 7.
5. **Countermeasures and Behavioural Strategies**

Data analysis identified two themes associated with covert behavioural strategies in the context of (1) service delivery and the (2) driver-signal dynamic. In all, six strategies were identified, each implemented with the intention of preventing SPADs and/or mitigating related risk and, in doing so, ameliorating safety. Three of these related to service delivery (Engagement, Internal Dialogue, and Decision Making), and three were related to signal dynamics (Task Focusing, Proprioceptive and Multisensory). A third theme associated with overt strategies was also identified. The results from each of these themes and subcategories follow and illustrative excerpts are used to support the points where relevant.

5.1. **Overt Strategies**

Overt countermeasures were organisation-approved, endorsed by standard operating procedures or driving policies, and associated with different dimensions of SPAD-risk. The identified countermeasures were divided primarily into *hard* or *soft* categories, each of which had separate sub-classifications. A third category captured *systems* related countermeasures, which were attributed to SPAD-prevention, even if not by design.

5.1.1. **Hard Countermeasures**

Hard countermeasures comprised technology that was built into the train in an effort to mitigate the risk of a SPAD or dampen its effect. By and large, this technology was purpose-built and formed part of the driving task, but the category also included equipment that was designed for other purposes but promoted to SPAD-risk management through policy and practice. The key point for a hard countermeasure was that it was a tangible part of the train and driver’s interaction with a direct influence on train performance. Whilst the basic principles underlying purpose-built safety technologies have already been touched on in the Introduction (Section 1) and the Organisational Profile (Section 2.2), a description of these in the context of the study is given here, particularly as the design parameters of these technologies vary across the world.

The Automatic Train Protection system observed in the study provided a flashing warning light when the train travelled 5- to-9km/h over the speed limit, to prompt the driver to apply the brakes. If the driver did not reduce the speed of the train, the system applied the brakes automatically and very conservatively, and the train had to be brought to a complete stop in order for the driver to reset the system and continue:

‘It prompts you to put the brakes on earlier then, so where it might have prompted you to put on the brakes 700m from the curve in wet mode, it will prompt you to put it on earlier, maybe 900m. And it monitors that you do that’.

The Automatic Warning System observed in the study was a perception-action device that triggered when the train entered a caution or stop zone of movement authority. The driver was required to rest the button, usually within a few seconds in order to ‘acknowledge’ the caution and prevent the train brakes from coming on. The perception-action imperative was also applied to the Vigilance device or button, which emitted audio and visual stimuli if the driver had not manipulated throttle/braking controls and other features (e.g. horn) for longer than 60 to 90 seconds. The primary check was to ensure the driver had not been compromised.

The last subset of hard countermeasure was primarily positioned as memory aids to mitigate SPAD likelihood, but the initiatives also enabled the driver to have influence over train performance. An example of this was
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the practice of ‘centring the reverser,’ which was analogous to putting a road vehicle into the neutral gear position. Some operators encouraged drivers to do this as a reminder of the current signal aspect, but the action also served to lock the status of the train to ensure it was not unintentionally overlooked:

‘If you’re sitting at a signal, red at a platform, whatever – centre your reverser. So if they give you the – in those days the guards used to give you 2 bells, so if you got 2 bells to take off you go, oh hang on, oh signal’s red. So then you realise, oh that’s – even though your mind was thinking of something else, when you went to open up, it didn’t happen. And then you look, oh, that’s – yeah, signal’s red.’

The psychological imperative reflected in this practice is to construct a schema-based response to managing false starts, and some operators had instantiated initiatives to establish this in the driving culture. An example of this was dubbed ‘the triangle,’ illustrated in Figure 8, which captured a sequence of procedures that intended to maximise SPAD-risk mitigation.

![Figure 8 - Illustration of 'the triangle' sequence posted in an organisation and adopted into standard operation procedures as an aid to memory and SPAD-risk mitigation strategy.](image)

**IF YOU DO THIS**

**FULL BRAKE**

**NEUTRAL**

**PARK BRAKE ON**

**YOU WON'T DO THIS**

**SPAD**

5.1.2. Soft Countermeasures

Soft countermeasures comprised SPAD-mitigation initiatives (technology and/or driving policies), which whilst overt, were not an automated part of the task and once activated, did not directly influence train performance but relied on the driver to interact with them in a manner conducive to mitigating the effect or risk of a SPAD.

The Signal Alert device was an example of a countermeasure that fell between hard and soft coding categories. At first glance, it appeared to work in a manner conducive to other perception-action devices, but the closest analogy to the device was that of a rudimentary cooker timer. That is, it was entirely up to the user to activate the device, and whilst it emitted an auditory alert once the cycle was complete, it had no direct
influence on the speed of the train. The Signal Alert device primarily functioned as a memory aid, and the drivers that used it treated it as such:

‘It takes away the possibility of passing [a caution] and going, ‘oh well, I’ll brake’, you know, another 500m down. But then if something catches your attention and you forget, then all of a sudden a SPAD is more available to happen’.

However, the data also suggested that the device was used lackadaisically. Some drivers elected not to use it at all, despite the organisational endorsement. This was associated with the parameters under which the device worked. Once activated, the device was triggered after the train had moved a set distance (usually 600m). This was perceived as problematic given that many signals were situated well outside the distance envelope (and therefore require multiple-activations) and more importantly, some were placed within it. Although the device was built into the train and served as a memory aid or prompt for action, it relied exclusively on the driver to remember to activate it in the first place, and did not exert any influence on train performance or speed one it was triggered. For this reason it was closer to the definition of a soft countermeasure.

Another soft countermeasure was the basic ‘Slow or Stop’ strategy. This was the practice of consistently reducing train speed following a caution signal by applying a minimum reduction (e.g. 25%), regardless of the allowable speed limit. This countermeasure extended the basic practice of using track knowledge to intuitively reduce train speed in preparation for possible caution and to significantly reduce speed prior to answering a call from train control and come to a complete stop whilst talking.

A formalised extension of the Slow or Stop countermeasure was the ‘40 km/h speed restriction.’ This initiative mandated that the speed of the train be reduced to a blanket 40 km/h. This was immediately upon encountering a caution signal, till such time that the section had been cleared. In practice, it was considered to work as a memory aid as well as a preventative measure:

‘It keeps it in my head that you’re at 40 because of the reason there’s that signal in front of you that said stop’.

Consistently driving at a lower speed wherever there was a caution was considered to remind the driver that the next signal is a stop, however it was still a soft countermeasure as it relied exclusively on driver action. This measure was also extremely conservative and invariably unsustainable in the long run.\(^7\) Given the impact on delays and time loss, it was also likely to elevate time pressure.

5.1.3. Systems-driven countermeasures

The final subcategory of overt strategies was the Systems-driven countermeasures. These were adopted as part of the wider domain to manage the idiosyncrasies of the driving task. Examples were the use of two-drivers, where the co-driver would independently observe and call the signal to ensure the main driver was acting on their current status:

‘If I didn’t pick up that signal, my mate would. My mate would say ‘Ay, ay, ay the signal!’ So he was making you aware when you might have been ‘off with the fairies’.

\(^7\) The operator that implemented the 40 km/h speed restriction adopted the initiative as a response to inordinately high SPAD rates
5.2. Covert Strategies in the Context of Service Delivery

Three covert strategies implemented in the context of service delivery were identified (Engagement, Internal Dialogue, and Decision Making). These strategies were particularly conducive to overcoming SPAD-risk associated with controller interactions and time pressure (see Figure 1). Generally speaking, they were personally and informally adopted to minimise disruption and/or distortion, and meet the basic requirements of the service, that is to keep time while driving safely.

5.2.1. Engagement Strategies

Drivers carried out a process of engagement prior to driving. For some, this involved a visual inspection of the train and mental preparation of the task to follow. This was considered to form an intimate knowledge of potential mechanical issues that may affect the performance of that particular train. For example, one driver carefully examined the brakes because if ‘I know these brakes are getting warm, I know I have to put more effort into it,’ during the shift. Thus, the driver aimed to mitigate the likelihood of a SPAD by adjusting their driving to the braking needs of the train. Although this strategy was based on train mechanics, drivers also engaged with the task in other ways. Often these were verbally invoked statements or mentally formalised intentions. For instance, one driver always said to themselves, ‘it’s not your turn (to have a SPAD) today dickhead,’ before starting a shift. Ritual engagement was also obtained through prayer where another driver reported feeling spiritual support throughout the shift, providing focused engagement and calmness. Another engagement strategy was to visualise the track, which was considered to provide additional time and space prior to commencing the shift:

‘Always get to my trains way earlier and that, sit down and relax a bit before I take off on the journey, think about where I’m going, what I’m going to do and where are my first stops, what stops I’m going to be going past and that and just try to get it in my head what I’m going to be actually doing the whole way through, like work it through’.

Envisaging the journey that lay ahead allowed the driver to consider what difficulties may be encountered, allowing a calm state of mind to continue throughout the shift, particularly in view of service delivery demands:

‘Then by that time you say, okay getting ready to go and go off, I know, nothing surprises me – shit, I’ve got to stop at the next one, you know, I try to have it all set in my head what I’m going to be doing’.

Consequently, an engagement strategy was applied by some drivers prior to starting a shift, to ensure they were in the correct state of mind to mitigate the possibility of a SPAD.

5.2.2. Decision Making Strategies

Strategies associated with informed decision-making were cognate, self-regulatory and implemented with the intention to apply safe driving. There were two features to this type of strategy: self-assessment and task prioritisation. Self-assessment enabled drivers to evaluate the extent to which emotional distraction or fatigue was likely to impact their capacity for safe driving. Drivers commented that in order to mitigate SPAD-risk, they needed to be one hundred per cent fit for the job in order to meet the requirements of service delivery.
For some, this meant that a self-assessment of their ability to drive safely needed to be made prior to starting their shift. If their self-assessment found that they were ‘not up to it’ they would report themselves as unwell. Drivers cited fatigue and personal issues as factors that would lead them to take a ‘sickie,’ though officially, they would report ill health. Making decisions based on their capacity to drive safely was considered to address real SPAD-risk. The example was given of some personal issues that distracted the driver from safe driving and led to a SPAD. Other drivers explained that calling in sick was:

‘A hard thing to get in my mind to actually say, okay I’m going to have a sickie because I’m not right for the job today. Any other time I would have gone into work but you just can’t do that with this job’.

The second critical element of decision-making was task prioritisation, characterised by the decision to temporarily dismiss competing tasks in favour of those that were deemed imperative for safe driving. This strategy was most frequently used to manage the risks associated with time pressure conflicts and controller interactions. ‘Concentrating on my train’ and ‘driving the thing safe’ meant that disruptions such as incoming calls could be blocked out at safety critical times: ‘If they call you up, that’s alright. Talk to them when you’re prepared to talk to them,’ ‘You don’t have to report that immediately, do it when it’s, you know, safe to do so.’ Where this task prioritisation conflicted with the timetable, more experienced drivers believed their best strategy was to prioritise safety because: ‘It’s not about speeding up to get your times back and that, because then all of a sudden you’re going to start breaking speed limits and then something can go wrong.’ Another driver concurred:

‘I use whatever time I need to use. I prioritise from the most important thing to the least important. Least important for me is worrying about anything but the signals. Signals and train safety is first everything else comes from thereafter.

Drivers who implemented task prioritisation as a decision making strategy were likely to be more experienced drivers who recognised that time delays (e.g. from ‘picking a wheelchair up’) could be reported to train control once it was safe to do so. As a self-regulatory strategy, decision-making shifted pressure away from the conflict of on time running, and allowed drivers to safely concentrate on the task in hand.

5.2.3. Internal Dialogue Strategies

As a strategy, internal dialogue referred to drivers’ self-reported thoughts in relation to driving and non-driving tasks. Whilst previous research into internal dialogue (i.e. thoughts) has rendered the activity as explicitly distracting in the road context (Regan et al. 2011), the findings revealed that internal dialogue during train driving could be harnessed as a way of resolving issues or enhancing engagement techniques (Naweed & Rainbird 2013). A number of drivers described unresolved incidents with passengers as a threat to concentration, and some referred to a strategy of internal dialogue where they were able to suppress, compartmentalise, or exclude these distractions. This activity was referred to as being able to ‘practise your skill,’ where the distraction was intentionally evaluated and dismissed: ‘Identifying the issue, finding out what it is, thinking about the obvious outcomes, you know, if, if, if, what if, what if, what if and then ignore it.’ In this way, the distraction was acknowledged: ‘I identify it, I try and go through the possible outcomes and then just say, I’m not going to get into it and I don’t. So I deal with it that way.’

Thus, the perception from some was that the issue did not have the potential to become an obtrusive thought at a later point because the issue had in one way been resolved. Another driver called it ‘internal chatter’ and put in place physical hand signals or verbal calls to refocus and ‘control my own brain chatter, okay – to try and calm that down.’ Drivers referred to this strategy as gaining the experience to: ‘force everything out of my
mind except what the job I’m doing at this moment is.’ Drivers acknowledged that this was not always easy but the proficiency grew with experience: ‘you will increase your concentration span the more you work on that.’

The findings also revealed that drivers would intentionally engage internal thoughts to assist them with troubleshooting problems or remaining focused. Creating, listening and responding to their own internal dialogue helped drivers to re-focus, remind them what they needed to focus their attention on, or acknowledge what they did not want to experience. One driver described the kind of internal dialogue that was useful: ‘you think ‘Okay, […] it’s all about driving the [train] safe, it’s not about speeding up to get your times back.’’ In this way, remaining aware of their priorities re-affirmed safety.

5.3. Covert Strategies in the Context of the Driver-Signal Dynamic

Three covert strategies that were implemented in the context of the driver-signal dynamic were identified. These were: proprioceptive, task focusing, & multisensory strategies. These were particularly conducive to overcoming SPAD-risk associated with sighting restrictions and station dwelling (see Figure 1). Generally speaking, they were reflective of higher-order train driving skills, and associated with maintaining connectedness to the signal (location and aspect).

5.3.1. Proprioceptive Strategies

Participants described a cognitive process based on awareness and instinct that assisted them to ‘automatically’ register signals and when a signal aspect had changed. Broadly referred to in the literature as a proprioceptive awareness of external information sources (Naweed 2013b), this strategy appeared less aligned with conscious thought and more closely with subconscious processes, route knowledge, and accumulated experience. One driver suggested that ‘it becomes sort of instinctual, a bit like an animal […] you sort of get this gut feeling because you’ve seen this thing out of the corner of your eye and you know you’re in the right sort of area and you’ve got to act otherwise you know something will go wrong.’ One way of enabling this strategy was relayed as ensuring the driver’s ‘mind-set was correct for [their] journey.’ This process was also described as a precursor to concentration in the driver-signal dynamic under demanding situations, for example with a change from a clear to caution signal: ‘…[you] turn on a switch and then you focus, you don’t switch off, you keep remaining focused on the yellow and the red.’ Thus a proprioceptive strategy was considered to provide signal intuition and help drivers remain aware of signal status. In practice, a proprioceptive strategy was essentially an approach to train driving that fostered a keen awareness of signal-to-signal based running and developed the capacity for self-regulation. A related aspect of this was the task focusing strategy.

5.3.2. Task Focusing Strategies

Optimising focus was identified as a vital feature of train driving, and task-focusing strategies were considered critical for ameliorating SPAD-risk from sighting restrictions and distractions during station dwells. In this context, the participants’ descriptions of concentration were those of being ‘zeroed in’ where they were ‘one hundred per cent […] eyes forward and I don’t get distracted by anything.’ Many participants referred to this state of concentration as a ‘switch’ and a way of ‘staying switched on,’ whilst others referred to it as the ability to ‘switch off’ from external distractions or put ‘blinders on’ to non-critical tasks. The effectiveness of task focusing strategies was conveyed by one driver using the example of distraction from another person in the cab:
'They can talk to what they like, but it goes in one ear and out the other. They can tell me their life story and if somebody said to me ‘What have we just talked about?’ I wouldn’t have a clue. It’s just, I don’t know, I just put my blinkers on because I’m concentrating on what’s in front of me’.

Much like proprioceptive strategies, participants referred to accumulated experience as a basis for the ability to remain focused, suggesting that this strategy was based on building the capacity for self-regulation. Some driver trainers referred to the ability to remain focused on signals as a fundamental part of the trainee driver’s skill set.

5.3.3. Multisensory Strategies

Finally, drivers also used covert strategies that encompassed physical movement, verbal and auditory cues, and physical objects as aids to memory. These multisensory strategies were primarily used to overcome sighting restrictions, retain signal awareness, and act as reminders during station dwells. For example, participants described kneeling or actually standing while driving as a physical reminder that they were driving through a caution zone. This change in driving stance, whilst prohibited by most organisations, was considered to be a highly reliable reminder that something was different, and eliminated the possibly of forgetfulness. In some stations, departing signals were either not located on platforms or could be obscured by the train’s position. This meant that during a station dwell, the driver relied on their memory of the preceding signal to inform the appropriate approach, and a physical change was commonly adopted to ensure signal recall. For instance, a driver commented about the difficulty of remembering a caution signal during a station dwell:

‘You’re thinking about your next speed board and all that sort of thing, so I now stand up whenever I leave a platform on a caution, I’m standing up. And that’s my memory’.

Participants also reported using physical gestures to acknowledge that a signal had been sighted, for example: ‘I’ll point at the light and I’ll point down if it’s a yellow or I’ll point up if it’s a green.’ Verbalising signal status was also a common strategy amongst participants. One driver considered this to commit signal aspects to memory faster than visual cues. Calling out each signal three times was said to help ensure the signal status was committed to memory. Another driver described how this not only aided with signal recall, but also interrupted distracting thoughts: ‘I will verbalise it and that’s to control my own brain chatter.’ The underlying principles of verbalisation were consistent with the risk triggered commentary approach (RSSB 2008), though the nature of what was said differed: ‘Whenever I go through a caution I always whistle Mellow Yellow.’

Participants also reported using physical objects as memory aids in order to remind them of signal status and movement authority. For instance, participants spoke of holding a pen, or a bottle in their hand when going past a caution signal as a reminder that they were in a caution zone. Others placed keys or other objects on the dashboard through a caution zone. At stations, one driver indicated that they would pull the blinds down in the cab so that on departing, they would know that the signal was at stop or caution. Another driver recalled being issued with a red and green bottle as a SPAD-risk reduction initiative: ‘that was a SPAD bottle. As soon as you went past a caution signal you turned it from green to red – a lot of people laughed at it, but it saved a lot of people from having SPADs too.’ One driver had also indicated they had created and used a small desktop electronic device with lights that could be changed to reflect the status of the signal which they have just passed (i.e. a manually managed in-cab signalling device). Whilst the use of objects as a strategy to mitigate SPADS was effective for many participants, it is important to note that the initiative was
not error proof. One participant reported that having used a reminder object for many years, they experienced a SPAD, despite holding the object.

5.4. Summary

Taken together, the identified strategies (overt and covert) were put in place by the organisation and drivers to remain focused, safe, and mitigate SPAD-risk. The covert strategies were applied in different combinations and in varying contexts and workload pressures. These strategies were context specific and individually tailored to achieve safe driving or develop the self-regulatory capacity in order to do so. They were internally informed and often involved deviating from prescribed procedures. Consequently, they may be challenging to synthesise into rulebooks or embed into driving standards, but despite this, there was considerable overlap between the overt and covert strategies meriting discussion and evaluation of which covert strategies could be effectively operationalised. In either case, knowledge of the identified strategies can inform the development of countermeasures to address SPAD-risk factors. The discussion will extend these results to determine their fit with the SPAD-risk model (see Figure 7), and the implications of the findings.

5.5. Discussion

It is clear that train drivers have a huge responsibility for ensuring the safe transit of passengers and goods. In order to mitigate the risks associated with this work, drivers have put in place their own covert behavioural strategies. These strategies revealed a meta-awareness of tasks, particularly those tasks which were opaque and therefore able to be addressed, and which in turn were attended to in complex ways. For instance, in preparing for possible route eventualities, drivers were aware that this required considerable cognition, therefore the strategies in place, such as proprioceptive ones, were equally cognitively based. The behavioural strategies outlined above clearly highlighted the self-regulatory aspect that drivers intended and implemented under their own volition. Figure 9 illustrates the self-regulatory nature of behavioural strategies that are implemented to mitigate the risks associated with service delivery and the signal dynamic.

As depicted in Figure 9, the engagement, decision-making and internal dialogue strategies all address SPAD risks associated with service delivery and were primarily about effective self-regulation of the task, aims, objectives, and perspectives. To address the risks associated with sighting restrictions and station dwell and those risks associated with the signal dynamic, the strategies of task focus, proprioceptive and multisensory were principally about facilitating self-regulatory capacity to maintain connectedness to the signal and the awareness of its location. For this reason, these were more intuitive and analogous to train driving skill. These self-regulatory strategies are effectively self-enforced habits that link situational and environmental cues to a specific response. Eventually, some, such as proprioceptive strategies, become automatic and habitual triggered by a situational or environmental cue. These habits are a specific mode of ritualistic behaviour characterised by repetitive and systematic use by a driver to prevent a SPAD. Further research into this repetitive behaviour may be useful in determining personality traits that can be incorporated into recruitment processes.
The covert strategies highlighted some aspects of service delivery and signal dynamics that could be addressed to optimise SPAD mitigation. For instance, drivers referred to task focus strategies as a part of decision-making that block out distractions at critical safety points. Distractions were referred to as calls from train control. Making communication when drivers know it is safe to do so highlights the potential and unnecessary risk that some service delivery protocols may be detrimental to safe driving. Similarly, proprioceptive strategies draw attention to the synergies that drivers must draw from route knowledge and keen signal awareness. This suggests that for proprioceptive strategies to be most effective, drivers would best benefit from being at the forefront of consultation processes with regard to signal and track reviews.

Some of the strategies clearly evidenced redundancies in the driver-cab interface. For example, some multisensory strategies were applied to maintain signal awareness in the environment where the Automatic Warning System was used. Given that this automatic system is designed to communicate the same information in a multisensory manner (i.e. AWS sunflower and auditory alert/chime), the decision to use a volitional strategy was highlighted that AWS was simply not used for the purpose for which it was designed. The next section in the report extends this theme more generally into an analysis of the organisational factors for managing and mitigating SPAD-risk that were revealed in the study.
6. Organisational Factors for Managing & Mitigating SPAD Risk

The data collected provide critical insights into how the signal passed at danger event was being managed in Australia and New Zealand and how this influenced the way safety and performance were being regulated. Analysis revealed three themes concerned with: (1) notions of colour and signal meanings being devalued, (2) the intimate nature of the relationship between a driver and the signal, (3) and the disconnect of asking a driver if they were fit to continue driving after passing a signal at danger. These themes and the main categories are shown in Figure 10. Each of these themes will be discussed and examples from the dataset will be provided to support them where necessary.

![Figure 10 - Diagrammatic summary of the key thematic findings](image)

6.1. Devaluing the Meaning of Cautionary Signals

The first theme concerned the prevalence of cautionary signal aspects in day-to-day operations. The perception was that the meaning behind cautionary signals had changed. On some journeys it was said to be routine to never see a clear aspect, but despite this, the expectation was for on time running: ‘That’s the way we have configured the network. We have devalued that yellow.’ ‘We still get hammered on our side about losing time.’ ‘[Control asks] why are you late? Because there’s like four cautions, I had to go through four cautions between this spot and this spot.’ Thus a combination of task habituation and time pressure...
motivated drivers to treat caution signals as if they were clear aspects and drive at line speeds. ‘If you’ve seen something happen ninety-nine times you expect it will happen the one hundredth time...’ The resulting risk acceptance was the essence of this theme, and from a systemic perspective, pointed to a normalisation of deviance, both in how train movements were managed and the way the task was regulated. This perspective was found in all organisations and evidenced in the frequency of cautionary signals seen during cab ride observations.

![Figure 11 - Example scenario collected during the study depicting safety and performance constraints. Inset storyboard manipulation shows four key steps as the scenario unfolds (note: the direction of travel is from the left to right)](image-url)
Managing and mitigating SPAD risk in rail operations

Managing and mitigating SPAD risk in rail operations

The theme of devaluing signal meaning was related to how safety and performance were being managed. To exemplify this, Figure 11 shows a scenario that was collected in the study. The scenario has also been storyboarded (see inset) to conceptualise the tension between managing safety and performance in the context of rail. Figure 9 conveyed time keeping as the main performance criteria, which attracted train movements that were very risky and counterintuitive, but appeared to evidence on-time running on paper. ‘Why do you start a train directly onto a red light when there’s no way for it to go? You’re setting somebody up to fail … if you have a SPAD there, you’re going to hit something.’ The main reason for granting the train on platform ‘3’ authority to go was so that it could depart the station ‘on time’ even though it would only move several train lengths before stopping. Most rail organisations were considered to emphasise time keeping performance, creating ensuing pressures to perform that ultimately impacted how driving was managed by the driver.

6.2. The Nature of the Driver-Signal Relationship

The second theme provided insight into the nature of the relationship between the driver and the signal, and the implications of driving past a stop signal on this relationship. Participants made a point of conveying the unique characteristics and properties of each signal: ‘Every signal tells you a story.’ It was not uncommon for drivers to see many hundreds (if not thousands) of signals in every shift, but passing a signal at danger, even by a metre, was described in terms of the emotional and physiological response. All participants indicated they were ‘conditioned’ into seeing a danger signal as equivalent to a ‘physical boundary’, and going past such a signal would leave them shaken. ‘Having this incident rocked my world, shattered it, left me in a very bad place for a while.’ ‘I saw the flash of red out of the corner of my eye. Initially I sat there for about 10 seconds just gripping the controls thinking, oh God, life’s over.’ ‘I felt terrible. I went I just want to cry! Because I’d made a mistake, like, I’m not - I take pride in my job so making that mistake was like, oh my God.’ Participants also contextualised their relationships with railway signals in different ways. One group of answers described signals by assigning primacy to their purpose as a ‘top priority’ and as the ‘ultimate collision avoidance system.’ However, most drivers described how they interacted and managed signals in terms of the different types of intimate relationships they held.

One kind of relationship was all about a deep sense of regard and esteem for the signals, with choice words like ‘respect,’ and ‘the most respected thing out there.’ Another kind projected the effects of observing signal authority on security, and signals were described as ‘my life-line’ or ‘my passenger’s safety.’ Some drivers described their relationship in terms of the role of the signal on the broader context of their personal lives, and expressions of signals as ‘my livelihood’ and ‘my bread n’ butter’ were common. Signals were also personified with human or animal attributes and described as ‘my colleague’ and ‘my best friend,’ and in one case ‘a large dog,’ illustrating an inscrutable threat. Lastly, the relationship was also expressed in terms evocative of spiritual ethics or divine law, and signals were described as ‘my religion,’ and ‘God.’ Taken together, these data pointed to a strong, highly intimate and often complex dynamic underlying the driver-signal relationship.

The essence of this theme was that the density of signals and performance dynamics (i.e. on time running) attracted operational errors, such as the scenario in Figure 9. However, the intensity of the driver-signal relationship was such that violating its terms created symptoms of an acute stress reaction (release of noradrenaline, increased heart rate, constricted blood vessels, change in blood pressure), and emotional irregularity (disbelief, fear, panic anxiety). This threatened the performing capacity of the driver by manifesting itself cognitively (e.g. daze, narrowed attention, confusion, distraction, impaired judgement, disorientation, partial amnesia), and biomechanically (e.g. shaking, muscular agitation, delayed response). The intensity was such that the psychological ramifications would continue long after. In terms of risk
management, this translated into personal amelioration strategies that were near-obsessive compulsive in their appearance and adopted to remind the driver that they were driving through a caution zone (e.g. counting backwards, singing songs, standing up).

### 6.3. Are You Fit to Continue?

Study data showed some uniformity in the processes adopted to manage the driver following a signal passed at danger. All events were investigated as part of the organisation’s safety management system. This included an on-site ‘fact finding exercise,’ drug and alcohol testing, and interview with the driver for their recollection of events, train management techniques, and factors that could have influenced decision-making. Details of the signal were captured (e.g. type, protection class, sighting distance), to build a profile of the event. The driver’s fatigue state and shift-work patterns were also recorded. While the fact gathering exercises were relatively comprehensive, there was less uniformity in how operators managed risk on their network after the event. In most, detaining the train at the site of the event was not compulsory, and in the majority of cases, moving the train and relieving the driver from duty at ‘the nearest safest location’ was the preferred mode of managing risk. However, the ability of the driver to continue driving immediately after a signal passed at danger event was typically determined over the radio by a controller with a single question: ‘Are you fit to continue?’

Participants involved in risk management indicated that the ‘fit to continue’ check was used to determine if drivers were ‘physically okay,’ ‘unshaken’ and in a state where they were ‘able to concentrate.’ Participants held views that asking drivers if they were ‘fit to continue’ was confounding and near-preposterous. ‘Once you had a serious near-miss, where you can hear fear in the driver’s voice or they’ve had a SPAD, to me they should be immediately relieved from duty.’ ‘If you had a SPAD the last thing you want to do is drive that train and the driver should say, no, this is where I stop, I do not go anywhere.’ In operations where a train guard was present (crew member responsible for platform work, wheelchair assistance, station announcements), the guard may have been asked to accompany the driver as an ‘extra pair of eyes’ though this control was critiqued. ‘I was not in a good place to drive, even though I had the guard next to me the whole way, all the guard’s doing is looking out the window.’

In operations where the driver was the only crew person aboard the train, the risk was reportedly managed by ‘giving the train priority of way.’ This meant that drivers would continue driving on ‘clear aspects and at a low speed,’ but in practice this did not always happen and drivers considered it a ‘weak procedural control,’ especially with existing network disruption. In both cases, the distance to ‘the nearest safest location’ varied, and could be the next station, or a location many kilometres away. ‘I remember this one driver went from [location A] all the way through to [location B] into [location C] and this guy was rattled.’ In one case, a participant reported they had driven 20 kilometres to the ‘safe location’ following an event. In some networks, the initial radio-based assessment of being ‘fit to continue’ would also be corroborated or verified with ‘a visible inspection by a competent person’ at the next ‘manned location.’ Thus, a duty manager or a staff member at this location would be radioed and asked to inspect and verify if the driver was indeed ‘fit to continue.’

The intersection of ‘management’ from a managerial and a driver perspective was blurred in the event of a signal being passed at danger. Thus the question ‘are you fit to continue?’ reflected a huge disconnect in the safety management system where this check was adopted. This was evident when participants indicated that

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8 The question varied between organisations (e.g. are you alright to continue; are you able to continue) but the essence of what was being asked was generally the same.
answering the question ‘are you fit to continue’ with a ‘yes’ was contrary to what seemed intuitively right or correct, but most drivers were likely to answer it with a ‘yes’ despite how compromised they felt. This was underpinned by strong motives to comply from inward projections of blame, but also because they feared being seen as uncooperative, and believed it could be used against them. This was linked with worries for being ‘labelled as someone who has had a SPAD’, and the notion that ‘a SPAD needed to be paid off’ to recover reputation, ‘There’s a particular scare-factor management put around with SPADs, you know - you do this, you get a bell plug.’ The fear of being seen as uncooperative was particularly apparent when a signal passed at danger was categorised as a ‘technical error’ by the controller (i.e. the signal switched from proceed to danger unexpectedly presenting no opportunity to prevent the outcome), though this elicited the same emotional response: ‘I haven’t had a SPAD yet ... had a few close calls, had false SPADs where you get the same sort of adrenalin rush/feeling.’ Some participants indicated that the question was just a formality, and they were expected to provide no resistance: ‘Train control puts pressure on the driver then to proceed.’

Participants who had experienced passing a danger signal provided accounts of the poor risk controls that were in place, and having violated many driving rules during the post-incident journey. ‘I really shouldn’t have been driving. I made a lot of mistakes driving back to [the location] that I would never normally make. If there’d been management in there with me, they would have done me for half a dozen other things – I won’t go into them, but it’s – it was traumatic.’ Additionally, verifying the radio-based determination of being ‘fit to continue’ with a visual inspection raised concerns of non-objectivity, not only because it occurred after the fact, but because the ‘competent person would then have to manage disrupted passengers.’ From the perspective of organisational behaviour, the contradiction of asking the driver ‘are you fit to continue’ is the essence of this paper in so far as the driver is very unlikely to be in a ‘fit’ state of mind to determine if they are ‘fit’ to continue. From a systems thinking perspective, these findings support the notion of a normalisation of deviance in rail risk management processes. In light of these results, the discussion section will provide a description of what was identified and where to go from here.

6.4. Discussion

6.4.1. Organisational Factors for Managing & Mitigating SPAD Risk

The results presented data for different levels of management associated with or directly influenced by how railway operators managed safety risk on their rail networks. These were concerned with how train movements were managed to maximise capacities, how drivers managed interactions with signals, and how safety risk was managed after a signal passed at danger event. The first and third themes were intertwined with performance, and connected with safety in a highly competitive dynamic. The nature of the driver-signal dynamic was a more personal introspection of this relationship that erred towards safety, but some of this was also influenced by performance (e.g. ‘my bread n’ butter’, ‘my livelihood’).

The first theme indicated that current rail safety management systems could be trying to address signal passed at danger events without fully understanding the cause. Signal integration and redesign practices may not be supporting how drivers should be driving in the wake of maximising operations, and simply adding another signal between existing signals to separate trains safely may not have the desired result. The demand for service delivery had created a drive to maximise network capacity, but few networks appeared to have undertaken a review or analysis of signal infrastructure with the aim to optimise the driver-signal dynamic and timetable design. From the systems management perspective, it may encourage complacent or deviant

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9 A bell-plug is a key that controls the door on trains. Here, the term ‘bell-plug’ is used as a euphemism for demotion, and being redeployed into lower-grade service as a train guard in the same organisation.
behaviours. In a number of scenarios, drivers intentionally broke safeworking protocols, for example by answering or making a call when unsafe to do so. This issue linked back to performance pressure, which destabilised core driver-signal dynamics, such as remembering the colour of the last signal, and retaining an awareness of what the next one is likely to be.

The highly intimate and personal nature of the relationship between the driver and the signal was not altogether surprising, given the importance of signal authority, frequency of signals, and the isolation of the cab environment. Participants described their relationships in different categories but every response evidenced the significance of signals to the driving role, and the gravity of this significance to the driver’s work and life. There was a singular weightiness to this relationship that gave unique insight to the identity of the train driver, but as with most emotionally invested dynamics, participants viewed a cost to breaking the terms of the relationship (beyond safety). The concern for being ‘labelled’ a driver who has had a signal passed at danger event, and the idea that this would need to be ‘paid off,’ bred a culture of taboo in the industry and strong convictions of punitive action to follow. The intimate nature of this dynamic and the potential of disrupting it may have been related to compulsive behavioural traits of the risk amelioration strategies described.

Finally, the theme ‘yes, I am fit to continue,’ reflected negative attitudes towards this aspect of risk management, most of which appeared to be justified. However in practice, there may be several reasons why not moving a train immediately after a signal passed at danger encroached on rail safety. If a signal is passed at danger on open track (i.e. not at a platform), waiting for a recovery team to arrive may breed unrest or disquiet among the passengers, attracting the desire to open carriage doors and disembark directly into the railway corridor. Equally, leaving the driver on their own for a prolonged period before relieving them of duty could also be damaging to their welfare. The key point here is that the intent to move the train to a ‘safe location’ invariably runs parallel to performance, but it is also a safety issue, thus a well specified rail safety management system would need to consider the competing demands specifically for their networks.

As a status check, ‘are you fit to continue’ contains traces of strategic ambiguity; culturally, drivers are rarely likely to admit to being ‘upset’ by an incident, particularly when talking to a controller. It is also critical to understand that a signal passed at danger event is likely to elicit the same acute emotional stress response regardless of whether the driver was at error. The assumption that train drivers should be able continue if the event was caused by ‘technical error’ is ill-advised as it is unlikely to curb the physiological imperative or performance impairment, even if the driver knows they will be absolved in the long run. Considering the response to a signal passed at danger event as a ‘management’ issue with differing needs and viewpoints, it would be useful to ensure that the response is adequately handled from a psychosocial and cultural perspective. A driver should feel able to say ‘no’ when asked if they are ‘fit to continue’ without fear of punitive action or being perceived as an inconvenience. Thus, it is important for rail operators to become more cognisant of these issues.
7. **Future Inquiry Workshops**

7.1. **Descriptive Summary: Exploring the Past, Present, & Future of SPADs**

The Future Inquiry Workshops were extremely effective in engaging the stakeholder groups and eliciting knowledge from the experts present. The four local level workshops were strategically used to present accounts of the data that came out of the first phase of the study (i.e. the focus groups). The broad themes of time pressure, controller interactions, sighting restrictions, and station dwelling were presented, along with illustrative data to convey the image of normalisation of deviancy in the task. Presenting the past was followed by an opportunity for questions and answers, and based on the questions asked there was little disagreement with the data. The last industry level workshop was used to present the actual convergent risk model (see Figure 7). Following some group activities, the next major part of the process was to determine a picture of the present, which culminated in the development of a mind-map.

![Sample photos taken at each of the key stages of facilitation at Industry level workshop](image)

This mind-map captured the key issues associated with SPADs, and how significant the particular issues were for the different stakeholders. The third step in the process involved the Future, and conceptualising how the industry may get to a SPAD-free future ten years from now. The last part of the process was about developing propositions and agreement between stakeholder groups that would go some way to making this a reality.

Whilst the process was designed to generate pragmatic solutions, from a research perspective, it was also designed to see how the industry’s viewpoint engaged or overlapped with the issues gathered from drivers at the focus groups. Thus, it was an opportunity to obtain data that would help represent what was already
gathered. Figure 12 shows sample photos of the workshop. Figure 13 shows less of the facilitation process, and more detail of the level of participation that was expected and came from those who took part in the Workshop. Figure 14 shows example data captured during the Future component from each of the five workshops. As shown in these illustrations, this part of the process required stakeholder groups to design a newspaper cover page with detail and quotes reflecting a SPAD-free railway. The process was very imaginative and harnessed the same sort of creativity as that collected during the scenario invention task in the focus groups (see Section 3.1 Design).

Figure 13 - Sample photos demonstrating the level of participation required from those taking part
Figure 14 - Sample data from Future component of the Future Inquiry Workshop
7.2. Findings

The analysis across the workshops revealed a number of key issues. The following were the most prevalent:

1. Driver workforce
2. Infrastructure and systems
3. Training
4. Collaboration
5. SPAD Investigation
6. Driver procedures
7. Timetable.

These issues are discussed below in order of topic most discussed across all five workshops. Where appropriate, *Proposition Statements* for the Future Inquiry Workshop have been incorporated as these represent common ground that stakeholders were prepared to work together to achieve. That is, there is energy amongst the stakeholders to work towards improvement in these areas that will have an impact on reducing SPAD risk in the rail industry.

7.2.1. Driver Workforce

Having the right people for the right job with the required experience and training was considered vital for ensuring that SPAD risk is mitigated.

The concern was that in a desperate attempt to increase a rapidly diminishing workforce, recruiters lowered the selection criteria and did not follow up trainees with on-the-job testing. Participants were concerned that the standard and experience of new drivers were too low, therefore increasing the likelihood of SPADs. Indeed one of the propositions developed during the workshop highlighted the need for targeted recruitment and staff development.

With experienced drivers being recruited to mining companies, the workshop participants were concerned that this represented a loss of experience to the rail staff. The experienced drivers’ skills are also not being utilised. This experience could assist in training younger drivers in SPAD mitigation. With the diminishing staff, drivers are increasingly presser to work longer hours.

*Proposition agreed to at the Future Inquiry Workshop:*

**Recruiting**

By not recruiting the right people for the driver’s job we are finding that these people are moving on to other areas. Having a standard, that needs to be a National Standard so that recruitment is across the board. Training and recruiting the right person to be a trainer. Training consistent for teaching new trainers and transferring drivers to a new depot is made consistent.

7.2.2. Infrastructure and systems

In cities where there is an increasing population and heavy usage of infrastructure requiring upgrades, rail networks are becoming more complex and congested. Participants highlighted the problem when the infrastructure is not keeping pace with change, leading to trains literally catching up with each other. This congestion puts pressure on on-time running and increases APD risk. Participants agreed that there needed to
be a greater emphasis on system planning, design and maintenance, adaptation, and planning for obsolescence.

Participants were concerned with signal overuse, which was impacting on on-time running and increasing the likelihood of a SPAD. The participants at workshops agreed that there were too many yellow and red signal aspects were being shown to drivers in any given shift. By removing the stopping mode, it was believed that caution signals would have greater value. Participants also identified the need for better signal sighting distances and better processes for identifying signals that were rendered ineffective (and could therefore be removed). The input of end-users as vital part of the design and placement of signals was also established.

*Proposition developed at the Future Inquiry Workshop:*

**Signalling**

We will consolidate the design of signalling and associated systems by way of ongoing review of equipment from a user’s perspective. We will seek to close the feedback loop of potential operational risks that are identified.

Participants highlighted the need for incorporating new technologies such as in-cab signalling, to reduce SPAD risks.

*Proposition developed at the Future Inquiry Workshop:*

**Systems**

- We will develop systems to actively prevent SPADs:
- Use of predictive systems and not relying on active systems
- Utilise STET technology to reduce SPADs. Better technology could include automated trains, in cab signalling and positive train control.
- Fully interoperable systems with other networks within the nation.

However, with these changes comes an increase in the workload of drivers or at least a change in focus. There was also a concern that new technology does not necessarily fix the problem. For example, modern braking systems may not account for the change in weather. ECTS was actually referred to by some participants as not a ‘silver bullet’ solution, and that there were barriers to retrofitting old rolling stock. Whilst the reliance on automated systems is considered to be a SPAD prevention initiative, there is a concern that there is less reliance on communications-based safe working.

7.2.3. Training

Participants expressed the belief that there was not enough training provided in workplace areas where it is most needed. There was a call for a needs analysis of the training requirements of staff including the gaps, risks, job roles, and enterprise requirements.

*Proposition developed at the Future Inquiry Workshop:*

**Training**

We will provide task specific, up to date training, monitoring and mentoring to assist and maintain your competence aligned to industry standards.
It was agreed that training needed to be developed as a national standard. This would require a nationally recognised training pathway and previous experience would be recognised. Participants argued that there needed to be a greater emphasis on mentoring, monitoring and increased supervision. For this to function successfully, the right people need to be recruited and trained to fulfil these training roles.

**Proposition agreed to at the Future Inquiry Workshop:**

**Training**

By not recruiting the right people for the driver's job we are finding that these people are moving on to other areas. Having a standard, that needs to be a National Standard so that recruitment is across the board. Training and recruiting the right person to be a trainer. Training consistent for teaching new trainers and transferring drivers to a new depot is made consistent.

The role of training was thought to need clarifying as one that emphasised an increase in the knowledge base rather than as a compliance issue.

**Proposition agreed to at the Future Inquiry Workshop:**

**Learning**

We will capture meaningful data through a just culture that enables effective learning (e.g. SISAR); we will develop a mechanism for dissemination and improvement.

**Proposition developed at the Future Inquiry Workshop:**

**Training**

We will continue to develop the rail traffic driver capability plan by:

1. Recruiting the right people with the capability to perform the technical and non-technical (behavioural) aspects
2. Retraining existing staff to the same capability level
3. Renewing, developing and delivering training
4. Aligning training to knowledge building as opposed to compliance.

### 7.2.4. Collaboration

For SPAD risk to be reduced, participants argued for a more collaborative approach both as a whole organisation and industry wide. By improving the organisational and industry culture, and creating good communication between work groups, participants believed that systems and operating procedures would be more effective in mitigating SPAD risk.

**Proposition agreed to at the Future Inquiry Workshop:**

**Collaboration**

Australia and New Zealand rail industry will design a system of common operating procedures reporting and standards, involving the end user in their design.

Participants agreed that currently there is no clear communication with government bodies or political pressure about SPADs or information provided to the public about commitment to safety.
Most importantly, participants argued that transparent information about SPADs to workers within rail providers needed to be circulated and made easily accessible.

**Proposition developed at the Future Inquiry Workshop:**

**Collaboration**

We as a SPAD committee will work toward the following points:
1. SPAD committee outcomes to be highly published
2. More open input from key stakeholders including feedback forums
3. Hard copy of the minutes will be made available to drivers
4. Monitoring trends. We as an organisation will be more transparent with consolidating information.

**Proposition developed at the Future Inquiry Workshop:**

**Collaboration**

We will engage our staff in informing the public, our employees and stakeholders of the service, commitment to safety and reliability of our networks.

### 7.2.5. SPAD investigation

Participants expressed concern about the way in which SPADs were investigated. As there are no national or international reporting criteria, SPAD investigations were thought to be inconsistent. The root cause of SPADs was believed to be overlooked due to time pressures of the investigation. In some cases, participants stated that lessons that were learned from the investigation process were often left unshared.

There was also a concern that there was no procedure for SPAD investigation, and instead, a standardised checklist that focussed on compliance rather than on an analysis of root cause was used. Participants called for a system approach that incorporated a defining role and responsibilities and communicating process and provided an analysis of trends and a pro-active rather than reactive approach.

**Proposition developed at the Future Inquiry Workshop:**

**SPAD investigation**

We will apply a consistent process of investigation, analysing all available evidence to ensure the identification of all causal factors. We will use the output of the investigation to facilitate learning and to develop practical and effective suggestions for change. We will use all of this information to enable transparent and accurate reporting within the organisation and to external stakeholders.

### 7.2.6. Driver procedures

Participants described a concern that drivers are becoming desensitised to yellow signals because of their prevalence. This was referred to as poor driver behaviour, and was becoming evident in their ‘lax’ approach to platforms and red signals that were becoming too much like ‘second nature’. Other participants believed that, on the contrary, drivers were constantly on edge, pushing the limits of safety due to increased changes in scheduling. Participants believed that in response to these driver behaviours, there was not sufficient focus on human factors elements that influence these behaviours.
Proposition developed at the Future Inquiry Workshop: Driver procedures

We will undertake to review and continually improve driving procedures to provide safe and efficient railway.

7.2.7. Timetable

Participants reported immense pressure experienced by drivers in achieving on-time running. This pressure has reportedly led drivers to speed in speed restriction zones, leave passengers behind, and leave stations earlier than scheduled in order to maintain their timetable. Participants called for a more realistic timetable that puts safety ahead of punctuality and encourages drivers not to rush tasks or miss comfort stops, and promotes professional driving principles.

Proposition developed at the Future Inquiry Workshop: Timetable

We will build realistic timetables that cater to:
1. Current infrastructure
2. Worst case scenario performance
3. Peak needs
4. Train performance
5. Correct sectional running times
6. Building in station dwell times at ‘busy’ stations for recovery

7.3. Discussion

The findings of the Future Inquiry Workshops indicated re-emerging themes consistent across the four local level workshops. The key themes emerged as areas for action and established common ground in addressing SPADs from a systems perspective. As evident in the findings, establishing a driver workforce that is carefully selected must underpin a safe workforce. Indeed, drawing on the skills of experienced drivers is fundamental in order to ensure that SPAD mitigation strategies are passed on to new drivers. As the driver workforce underpins the rail industry, so too does infrastructure and systems. Stakeholders across the board were cognisant of the rapid changes in network pressures and technologies. Stakeholders agreed that infrastructural and technological improvements had the potential to detract from communications-based safe working and end-user input into signal positioning and over usage. It was believed that developing a better understanding of SPAD-risk and occurrence could be improved by reassessing SPAD investigation procedures and driver procedures. Timetables were also considered a common ground theme that needed to be considered in relation to mitigating SPAD risk.

The findings of the Future Inquiry Workshop provided a further dimension to the findings of the focus groups. The theme of the driver workforce highlighted the time needed to develop skills for fostering covert SPAD mitigation strategies. Indeed, the strategy applied by drivers to remain task focused was applied by experienced drivers and was believed to be a fundamental aspect of a trainee driver’s preparation. Interestingly, both benefits and deficits were emphasised with regard to the infrastructure and system enhancement. Whilst a call for new technologies and infrastructure was welcomed by drivers and management personnel alike, the multisensory strategies applied by drivers that encompass physical movement, verbal and auditory cues, and physical objects as aids to memory were still considered essential in
mitigating SPAD risk. The finding that some drivers who used multisensory strategies used them over technological memory aids points to a need for reassessing the nature of communication and collaboration between these work areas. This is particularly the case where service delivery is being impacted upon, and leading drivers to utilise decision-making strategies so as to maintain safe driving. Consequently, both SPAD investigation procedures and driver procedures need to be considered in light of the covert strategies applied by drivers and the extent to which service delivery imperatives, such as timetables, instigate these strategies.
8. General Discussion

The findings from this project have elucidated the key SPAD-risk factors that feature in challenging SPAD-scenarios, and the strategies that drivers apply to mitigate the associated risks. If we consider the driver strategies alongside the proposition statements identified from a system level perspective, consistent common ground concerns for issues is evident. There is a concern for ensuring that appropriate drivers are recruited using a national standard to ensure consistency across the industry. The task focus, proprioceptive and multisensory strategies used to mitigate risks relating to signal dynamics aligned with the propositional statement that called for signal input from a user’s perspective. Concerns with the impact of timetabling on SPAD risk were supported by the proposition that called for more realistic timetabling that catered for current infrastructure and peak needs. This issue is referenced later in the discussion, but an important point here is that a greater uptake of technology (in order to support systems) was found to parallel the drivers’ needs identified in the focus groups. Training and learning that promoted knowledge building rather than compliance reflect the proprioceptive strategies that drivers utilised to mitigate SPAD-risk. However, propositional strategies completely avoided references to driver strategies that required them to operate independently of normal procedures so that safe driving could occur. For instance, the proposition statement calling for a review and continual improvement of driver procedures to ensure safe railways was found to completely overlook driving strategies such as task focus and decision making that deviate from standard procedure for the sole purpose of maintaining safe driving at critical periods. In not referring to these strategies directly, driver strategies such as these become normalised deviant behaviour.

The following sections are used to extend the findings of this study by illustrating how the SPAD-risk model could be applied as a guide for profiling distraction-related SPAD events. It also provides direction for future research (for academics and industry alike). However, for industry, a separate section exploring new approaches and solutions for managing SPADs is given. Whilst recommendations were outside the original scope of the project, this section has been given to illustrate the sort of options for improvement that can be tested and applied.


The multi-factorial model (see Figure 7) illustrates the impact of the risk factors moderating distraction on driver attention and task performance. As such, the model has a number of applications. First, it may be used to inform training content in driver learning programs, especially modules aiming to develop safety-performance handling skills. Generally speaking, driver training programs in the UK try to develop the skills that enable train drivers to manage risk from the factors shown in Figure 7 (Cullen 2000; RSSB 2008). Given the findings in this study point to problems in the ability for train drivers to self-regulate in response to competing activities, it may be desirable training packages to recognise the specific risks in the moderating factors, and allow managers to address the topic more openly.

Given the representation of rail systems comprised in these data, the model may also be used as a framework to analyse SPAD or near-SPAD events. Rail operators may use the model to explore existing SPAD data trends to define risk, build them into driver training, and develop simulator scenarios. For example, each of the factors gave rise to distraction through one or more impacting processes that bred an inattentive state. In the case of time pressure, these were linked with distortion and/or disconnection, but when risk from two factors contributed to distraction, the experience increased in definition and intensity. For example, distraction from time pressure and controller interaction was likely to be linked with distortion, whereas distraction from time pressure and sighting restriction was linked with disconnection. In a scenario where distraction was
manifested from time pressure, sighting restrictions and controller interactions, the fundamental impacting processes were likely to be distortion and disconnection.

In certain combinations, the SPAD-risk factors invoked driver distraction through a more varied range of impacting processes. This was particularly the case for factors located at opposite ends of the model (i.e. time pressure with station dwells; controller interactions with sighting restrictions). In the case of time pressure and station dwells, distraction was typically manifested via two or more impacting processes, but this was also governed by context (i.e. signal dynamic and/or service delivery). Consider, for example, a scenario where a driver had a SPAD when departing a station. In this scenario, the driver may not have waited long, but having already accrued systematic delays, experienced anxiety from a relative dwell-like situation. Thus the distraction from the station dwell, and time pressure encouraged a false start and a failure to check the signal (situated in plain sight). Under these circumstances the driver would likely be disconnected from the immediate critical task (i.e. ‘check the movement authority’) but dislocated from it too (i.e. ‘I already have movement authority’). The task would also be distorted and the driver would have the impression of safety, but actually be operating under inflated performance needs. The SPAD in this scenario would be contextualised by issues in both signal dynamic and service delivery, with emphasis on the former. Consider, however, that on further investigation, the driver revealed they were anxious to recover time to avoid a call from the controller. This would involve disruption too, and express all impacting processes. Further, consider that the driver always departed this station on a clear signal, and this was the first instance they encountered a stop. This would also make it a novel event in the context of prior experience.

An objective of this paper was to do further research and thinking about driver distraction and inattention, not necessarily to differentiate, but to advance an understanding of the relationship. Driver attention was skewed through internal and/or external emphasis on a single task-related goal to the extent that drivers diverted their attention from activities critical for safe driving and often breached safe working of their own volition (e.g. Figures 3 & 4). The closest definition for this would appear to be ‘misprioritised attention,’ where attention is focused on one driving activity to the exclusion of another, but where both tasks are equally (or near-equally) critical for safe driving (Regan et al. 2011). However, time keeping is not safety critical, and in the data collected, inattention was not so much diverted as subverted from the perspective of goal-directedness. This is a subtle yet significant distinction and in the rail context, inattention may be better described as misappropriated over misprioritised through a form of task subversion, that is, the shift in attention has a subversive (as well as divertive) property.

Task subversion may force manifestations of voluntary or involuntary neglect and/or cursory attention, as defined by Regan et al., implying that these types of inattention may also exist on different levels, or alternatively, misappropriated attention gives way to these types of inattention. It is also important to note that inattention behaviours may also be interrelated, and one form of inattention may give rise to another, such as neglectful attention resulting in cursory checks. A working definition for ‘Misappropriated attention’ in the context of study findings may be: inattention which arises from the voluntary or involuntary subversion of attention away from activities critical for safe driving toward a competing driving-related activity that has little or no safety critical significance. The study findings though were based on untested relationships, and advocate further thinking in the way categories of inattention have been distilled. To reiterate an earlier point, the reviewed driver distraction and inattention taxonomy is designed and exemplified largely in the context of the road sector, thus a more thorough comparison of the content with rail crash, incident and SPAD data is advocated.
8.2. Applicability of Findings for Freight Operations

As the organisations that participated in the first phase of the study were passenger operators, it is important to provide some discussion on what the differences may be for the freight community, and whether the themes identified might be different in that environment. First, the data and themes collected in the train driver focus groups were validated as part of the Future Inquiry Workshops, which had a strong and more even representation of freight and passenger operators. In the workshops, the freight operators, including train drivers, commented on risk factors, and showed recognition and familiarity of the risk factors associated with controller interactions and sighting restrictions. While time pressure and station dwelling were considered to be less relevant, the groups cited that encountering crossing loops, block points (based on train order working) and yard work were analogous to risks from station dwelling, and general performance pressure (e.g. getting payload to the dumpers) was analogous to risks from performance pressure. Based on this work and the verification from participants in the future inquiry workshops, it is suggested that time pressure would amount to performance pressure in the freight environment, and station dwelling would equate to dwelling in passenger loops and waiting for instruction in yards and/or cross-over points.

8.3. Directions for Future Research

The focus group study identified compelling relationships between several themes; however consideration is needed for potential solutions and the hypothesised relationships need to be tested. Future research may test these empirically (e.g. in a simulator) and explore pragmatic mitigation strategies. The perception was that many of the issues permeated through to the driver from the system, thus a systems thinking approach to mitigate the consequences of task conflict is warranted. A key finding was the performance distorting process perceived to exist with the driver-controller dynamic. Subsequent research should continue to explore this issue and garner representative data from both roles in a participative forum. Research may continue to explore performance pressure in the context of passenger driving, identify how safety and performance are regulated, and explore techniques for effective self-regulation in response to competing activities.

The moderating factors revealed in this study (time pressure, sighting restriction, station dwelling, controller interaction) are typically accepted as rail work norms, and aside from sighting restrictions, have received very little attention in the context of SPAD-risk in the rail industry. While anxiety and emotional response in the context of internal cognitive distractions has been recognised, the moderating factors have yet to be researched in terms of the problem of self-regulation. Lastly, whilst these directions for future research are particularly desirable for passenger rail networks that face maximised capacities whilst operating under traditional driving principles, it is important to pursue these directions in Australia and New Zealand, where the industry remains heavily fragmented.

Lastly, some consideration should to be given to the quantification of the data, particularly the model, to determine goodness of fit to actual incidents. This can compare against actual data from event-loggers, or using techniques such as the railway action reliability assessment technique developed by RSSB (Goh et al. 2010).

8.4. New Approaches & Solutions for Managing SPADs at the Organisational Level

This paper reports material that came out of the study. Whilst other prevalent and significant human factors issues can contribute to the risk of passing a signal at danger, such as fatigue (Dorrian et al. 2007), this did not come up in the study and was therefore not reported. Figure 15 presents a model derived from the study that outlines some future research avenues for communities of interest based on findings. As shown, a number of important relationships were synthesised from this study, and the relationships associated with the driver-
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signal dynamic and the signal passed at danger were couched within the broader topic of organisational behaviour. The dynamic between the driver-signal and the incidence of passing a signal at danger was itself highly dynamic, but this impacted on organisational behaviour. Therefore, change and development within the rail organisation may be contingent on understanding the nature of the relationships caught between this dynamic, in this case relationships between safety-performance, the driver-controller, and error producing conditions.

Based on this study, driver-signal research may be best explored through training and pedagogical solutions that focus on self-regulation and targeted training, whereas research of the failure mode may be undertaken through human resources management issues such as crew resources and post-incident risk. As shown in the model, these areas are also dynamic, such that driver self-regulation will impact crew resourcing and so on. The model also proposes key areas where research may use this information to pursue change and development, such as the organisational culture, signal usability, and so on. The aim of the model is to stimulate further thinking and research, but a very brief account of potential human resources and training related initiatives is given.

![Figure 15 - Model outlining key areas for future research](image)

8.4.1. Safety and Performance Training Modules

Currently, the bulk of train driver training in Australia and New Zealand is focused almost entirely on acquiring route knowledge and learning how to operate a train. This then connects with an understanding of driving strategy (also referred to as ‘the methodology’) which is needed to regulate how driving is performed. There’s nothing very wrong with this approach – it’s been the way of the traditional train-driving world for a while. However, with the drive for maximising capacities, it is important to implant content that will render drivers and controllers more aware of the associated ‘big picture’ elements, which personally impact how they view and manage their tasks. Including a ‘safety and performance’ module that openly discusses these issues and conceptualises timetabling design from disparate perspectives may create a better understanding of how performance can be managed in different situations. This may induce a better tolerance to time pressure and engender more intelligent self-regulation, and create more commitment to professional driver training. The
aim would ultimately be to develop a more informed understanding of the synergy in the safety and performance relationship.

8.4.2. Targeted Simulator-based Learning of ‘SPAD’ scenarios

Following on from the previous approach, using more informed techniques of transmitting the actual experience of passing a signal at danger may better prepare the trainee to manage the failure mode. Currently, the safety implication and nature of ‘SPADs’ is transmitted in the classroom environment and acquired through stories and cautionary tales as part of the organisational culture. The adoption of train simulators to enhance learning is a fast going enterprise but they are still very much in their infancy. Indeed there is evidence to suggest they are not being utilised to their fullest potential (Naweed 2013d; Naweed & Balakrishnan 2012b). It is proposed that organisations use the safety of the simulated environment to improve how they emulate the experience of a signal passed at danger event.

![Figure 16](image1)

Figure 16 - Disaggregation of driving strategy elements based on scenario simulation (drawings)

![Figure 17](image2)

Figure 17 - Disaggregation of driving strategy elements based on verbal commentaries (note: includes an additional ‘in-cab warning system’ category).
Using a simulator to convey SPAD scenarios is very much a ‘fringe’ solution, particularly as it involves an element of risk, and necessarily involves some deception to set up the scenario appropriately. However, the essence is to target learning of the signal passed at danger failure mode to provide the most informative learning experience. Simulator-based SPAD scenarios may be most effectively designed using elements that align closest with constituents of route knowledge. Figures 16 and 17 profile those constituents of route knowledge that featured most in challenging scenarios and during actual driving from the CRC for Rail Innovation Route Knowledge and Driving Strategies projects (Naweed & Balakrishnan 2012a). These images suggest that strategies consistent with managing the environment would best complement the design of SPAD scenarios. Thus, a SPAD scenario that includes high event rate, sighting restrictions, error detection and so on, may improve learning and error toleration for SPADs. This sort of data would guide SPAD-scenario development.

8.4.3. Crew Resourcing Management and Supporting the Train Driver post-SPAD

Clearly, one of the most difficult issues to address is the management of post-incident safety risk inherent to the signal passed at danger event. Given what was revealed, better support and/or resourcing to determine if the driver is indeed ‘fit to continue’ driving is advocated. This may be adopted by awareness of the issue in train control, and providing controllers with basic trauma response skills. In environments where the driver is not the only crewmember the train guard may also be taught these skills to better support the driver.

8.4.4. On-time running

Given that on time running was found to be a major performance-shaping characteristic in this study, new methods and approaches for ways that organisations manage timetabling should be explored. One possibility is to investigate if the ‘turn-up and go’ model typically used by bus networks could be applied to rail. This approach is receiving serious consideration in some Australian rail networks and replaces the model of explicit punctuality (e.g. a train will arrive at 13:11) with the indication of service delivery within a certain timeframe (e.g. a train will arrive roughly every 15 minutes). Whilst this initiative would invariably build resilience into timekeeping and potentially change the perception of time pressure, it may not necessarily change the organisational risk profile. From the systems thinking perspective of complexity, the initiative could reduce perceived time pressure for drivers, but it could also result in risk transference and create new issues. For example, the initiative may drive further increases in train services on the rail network, and therefore exacerbate the maximised capacities issue discussed in this paper and create new gaps in training. Understanding the impact of changing present on-time running models is therefore an empirical question that needs to be researched.
9. **Strengths and Limitations**

9.1. **Strengths and Limitations of the Study**

The study adopted a qualitative design and a systems thinking perspective to collect the thoughts and perspectives of train drivers, and approached the issue of SPAD-risk by converging multiple techniques, in order that meaningful data could be elicited. Firstly, the invention task was a core strength that garnered a rich dataset, and encouraged debate and discussion amongst participants. It is important to note that the fit between the model and data collected was exceptional, and the model demonstrated very good stability in the event that the scenarios were to differ. However, all of the relationships reported in the results and encapsulated in the model were based on speculative data, and though most participants qualified as subject matter experts, the data reflected their opinions, prejudices, and nuances. Thus, the ideas and hypothesised relationships associated with the moderating factors need to be tested. However, the model provides a starting point to obtain an informed representation of driver distraction and inattention risk factors in the rail context.

Secondly, the use of hypothetical scenarios to inform a conceptual model could be seen as a limitation, but whilst the remit of the task was to *invent* a scenario, it was not specified if this would come from prior experience or more general knowledge. This was to protect participants, but also because some drivers would not necessarily have their own SPAD experiences with which to relate. In practice, the majority of generated scenarios were not hypothetical but reflexive, which is to say that quite a few drivers drew on their actual SPAD experiences (a point that could be surmised from the language and tenses used to describe the scenario). Figure 2 was a good example of this. Where actual events were reconstructed, the task encouraged discussion from the third-person; thus it was also a key asset of the methodology and a way of dealing with topical sensitivities and protecting participants.

Thirdly, with an average number of 3-to-4 participants per focus group, the number of drivers representing each organisation was relatively small. This was a logistical constraint for a study with train drivers. However, the limitation was traded for the aim to collect data from as many passenger operators in Australia and New Zealand as possible. To that end, these data included representation from *all* passenger organisations currently operating in that region of the world. It is important to note that, despite the differences in the use of safety systems in the organisations, all of the scenarios shared commonalities that transcended the individual differences in the different networks, safe working and use of safety technologies. Although there is a risk of having missed causes and mitigation strategies from the employed methodology, the data reached saturation within the confines of the research question. Post-hoc activity did actually compare the model against a sample of SPADs from actual investigation reports, as part of a national re-classification exercise, and the model held its structure. As indicated in Section 8.2, further research should examine the findings against the actual train driving data from event-loggers.
10. Conclusions

This project used a novel qualitative data collection methodology to obtain situational insights into the signal passed at danger failure mode in passenger rail operations. Key moderating factors for this risk included time pressure, station dwelling, sighting restrictions, and controller interactions. Four specific codes were used to classify and describe the process of inattention and distraction in train driving. These were: disruption, dislocation, disconnection, and dislocation. Driver distraction emerged under certain conditions in the context of service delivery and the driver-signal dynamic. Growing anxiety, multi-tasking load, and/or disengagement from three or more of the moderating factors were found to intensify the experience of distraction and increase the likelihood of a SPAD outcome. The study identified compelling relationships between several moderating factors, however consideration is needed of potential solutions to this problem, and the hypothesised relationships associated with the moderating factors need to be tested.
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References


ATSB 2012, Australian Rail Safety Occurrence Data 1 January 2002 to 31 December 2011, Canberra, ACT.


Branton, P 1979, Investigations into the skills of train-driving, Ergonomics, 22(2), pp.155-164.


Dekker, S 2011, Drift into Failure: From Hunting Broken Components to Understanding Complex Systems, Surrey, UK, Ashgate.


Endsley, M 1995, Toward a Theory of Situation Awareness in Dynamic Systems, Human Factors, 37, pp.32-64.


Huberman, MA & Miles, MB 1994, Data management and analysis methods, In NK Denzin & YS Lincoln (Eds), Handbook of qualitative research (pp. 209-219), Thousand Oaks, Sage.
Managing and mitigating SPAD risk in rail operations


Lee, JD, Young, KL & Regan, MA 2009, Defining driver distraction, In MA Regan, JD Lee & KL Young (Eds.), *Driver Distracton: Theory, Effects, and Mitigation* (pp. 31-41), Boca Raton, FL, CRC Press.


Naweed, A 2013c, Psychological factors for driver distraction and inattention in the Australian and New Zealand rail industry, *Accident Analysis & Prevention*, 60(0), pp.193-204.


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Rail Safety & Standards Board 2008, RSSB human factors research, driver awareness campaign - FOCUS (T677).

Regan, MA, Hallett, C, & Gordon, CP 2011, Driver distraction and driver inattention: Definition, relationship and taxonomy, Accident Analysis & Prevention, 43(5), pp.1771-1781.

RSSB 2008, Good practice guide on cognitive and individual risk factors (RS/232 Issue 1).

RSSB 2010, Development of a train driver education programme on mobile phone risk (T904).


Stutts, J, Feaganes, J, Reinfurt, D, Rodgman, E, Hamlett, C, Gish, K, & Staplin, L 2005, Drivers’ exposure to distractions in their natural driving environment, Accident Analysis & Prevention, 37(6), pp.1093-1101.

Treat, JR 1980, A study of pre-crash factors involved in traffic accidents, The HSRI review, 10(1).
