MAGIC BULLET OR SWISS CHEESE? DEVELOPING SPAD MITIGATION MEASURES FOR NEW ZEALAND.

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This paper describes a project commissioned by the Rail Safety Regulator, New Zealand (NZ) Transport Agency and undertaken by Interfleet Technology with input from NZ rail organisations and network access providers KiwiRail, Transdev and Dunedin Railways. The impetus came from the rise in the recorded number of Signals Passed At Danger (SPAD) in NZ in recent years. SPAD risk is already a focus for NZ Rail Participants who are implementing a range of SPAD risk reduction programmes. A SPAD Strategy Evaluation was developed to establish a framework for rail participants to explore their current strengths and weaknesses for SPAD risk reduction and to provide the Rail Safety Regulator with an overview of the rail industry as a whole. The tool and associated user guide will be available via the New Zealand Transport Agency's website "Research and Reports" category. This paper describes the development of the tool and application of the tool in New Zealand.

The New Zealand Context

The NZ National Rail System (NRS) is characterised by:

- Wellington and Auckland have high density metropolitan passenger operations; locomotive hauled passenger and freight trains operate across the entire NRS; and the Dunedin Railways' services operate on both the NRS and a private branch line that only has signals at the point of connection to the NRS.
- On the NRS, locomotive hauled passenger and freight trains share the network with metro services. This mix of traffic results in heavy freight trains operating amongst agile multiple unit and carriage stock with very different braking capabilities.

- Train separation on the NRS is managed with colour light signalling and Track Warrant Control, a paper based Limit of Authority (LOA) system.
- Operational procedures (KiwiRail, 2010) and traditional railway engineering controls such as signal overlaps, catch points, mechanical train stops and track circuit interrupters have been deployed to mitigate against SPAD risk.
- On most of the network Driver Only Operation (DOO) is in place, without any form of Automatic Train Protection (ATP).
- The European Train Control System (ETCS) has been deployed across the Auckland metropolitan network. The cost of ETCS is a significant barrier to its application on the remainder of the NRS in its current three current levels of system application (International Union of Railways, 2007).

This operating model demands high levels of human performance, necessitating careful consideration of the cognitive risk factors when designing the human-machine interface and associated driver training. The system dynamics mean that the SPAD reduction strategy must be tailored across the various networks; it cannot be a simple one size fits all magic bullet.

Project Objectives

The Rail Safety Regulator was keen to understand whether the different SPAD reduction approaches being implemented by each Rail Participant (rail organisations and the network access provider) were effectively addressing the wide range of contributory factors to SPADs that span organisational, engineering, operating systems and human performance dimensions. The aims of the SPAD Strategy Evaluation Tool were to:

- Provide clear descriptions of excellence and describe a mature SPAD risk reduction programme
- Establish a common framework for use both by the regulator and duty holders
- Allow rail participants to identify their current strengths and weaknesses against each of the dimensions in the model
- Allow rail participants to make comparisons across different areas of their organisation in approach to SPAD risk reduction
- Help drive continuous improvement
- Support shared best practice.

Method

There were two distinct work packages to the project; a review of international best practice and the development and application of the SPAD strategy evaluation tool. Due to the amount of literature on SPADs, the review focused on the range of SPAD interventions that have been developed, their success and limitations. The *SPAD Resources* section at the end of this paper list those that were most useful. The literature review identified the wide range of factors that

contribute to driver error and SPAD risk, and consequently the need for a broad spectrum of SPAD reduction strategies that provide and maintain layers of protection. Understanding the suite of reduction strategies was useful in enabling a holistic strategic approach to SPAD reduction rather than tackling it in a piecemeal fashion and provided a good basis for the tool development.

Development and validation of the SPAD Strategy Evaluation ToolThe tool was developed through several stages of iterative improvement:

- specialist expertise in human factors, rail safety management and assurance, operational management, rolling stock and signals engineering
- review of the SPAD Reduction Strategies of KiwiRail and Transdev
- external validation by project stakeholders.

The underlying concepts used to develop the tool were threefold: the Swiss Cheese Model, the Railway Management Maturity Model (ORR, 2011) and the Manchester Patient Safety Framework (MaPSaF, 2006).

Swiss Cheese and a Systems Approach: The 'Swiss Cheese Model' is a commonly used model of accident causation and is widely known within rail and other safety critical industries (Reason, 1990; RSSB, 2004). The SPAD Strategy Evaluation Tool is based on 'layers of protection' in the form of critical dimensions that fall within four categories: Organisational; Work Practices and Processes; Work Environment; and Individual.

- **Railway Management Maturity Model (RM^3)**: RM^3 is a tool for Great Britain railway inspectors assessing duty holders' safety management systems against the requirements for the Railways and other Guided System Regulations, 2006. Excellence is described by means of a five-point maturity scale for key elements of an organisation's safety management system (SMS) and it provides a useful tool for setting the standard for an SMS and measuring improvement. The SPAD Strategy Evaluation Tool adopted the format of the RM^3 within an Excel spreadsheet:Dimensions such as organisational culture were adapted to better fit the context of SPAD risk reduction
- Many RM^3 dimensions were excluded as not relevant to SPAD risk reduction
- Additional dimensions were developed specific to SPAD risk reduction, e.g. train management systems and timetabling.

The Manchester Patient Safety Framework: MaPSaF (2006) is a tool developed in the UK to help healthcare organisations and teams assess and develop a positive safety culture. It describes five levels of increasingly mature organisational safety culture and so has parallels with the dimensions in the RM^3:

- Commitment to overall continuous improvement
- Learning and effecting change

- Priority given to safety
- System errors and individual responsibility
- Recording incidents and best practice
- Evaluating incidents and best practice
- Communication about safety issues
- Personnel management and safety issues
- Staff education and training
- Team working

MaPSaF is applied in workshops, led by a facilitator to generate collaborative relationships and insightful discussion. It is this participative, self assessment feature that we wish to retain within the SPAD Strategy Evaluation Tool rather than establishing it as a tool that can be used by a single person to generate a numerical score. Like the MaPSaF framework, it is envisaged that the SPAD Strategy Evaluation Tool can be used to bring people together and facilitate reflection on the maturity of different aspects of the organisation that impact SPAD risk. It can also stimulate discussion about the strengths and weaknesses of the organisational processes and potentially reveal differences in perception between staff groups that can lead to sustainable and effective solutions.

The SPAD Strategy Evaluation Tool

The key features of the tool are a User Guide and an Excel spreadsheet containing a Risk Assessment Matrix and Summary Profile. As the tool is designed as a self-assessment tool, rather than an external audit tool, the User guide contains information regarding the process by which the tool should be applied to generate most benefits in terms of:

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

The Risk Assessment Matrix presents sixteen critical dimensions or 'layers of protection' within the system, akin to the Swiss Cheese Model (**Error! Reference source not found.**). For each dimension, there is a description of how effective or 'mature' that dimension is, on a scale of 1 to 5. Participants read and discuss which description best fits their organisation. An example for one of the dimensions is provided in Table 2.

Table 1 Critical Dimensions

Organisational	Work practices and processes
Planning and implementing SPAD risk reduction strategy	Communication of safety critical information
Organisational culture	Timetabling

Incident response and investigation	Operational procedures
Managing change	Driver strategies
Leadership	
Work environment	**Individual**
Design and management of route and infrastructure	Competencies
	Teamwork
Train management systems	Fatigue management
Train cab design	Workload

Table 2 Example of a critical dimension with five levels of excellence

Category	Planning and implementing SPAD Risk Reduction Strategy
Level 1 – ad hoc	There is no SPAD risk reduction strategy or it exists but is out of date or has not been communicated within the organisation. There is no evidence of employees being consulted.
Level 2 - standardised	The SPAD risk reduction strategy is up to date and is communicated within the organisation, but local managers and supervisors have inconsistent approaches or interpretations. This results in the strategy being applied in different ways across the organisation. The strategy is not seen as vital to maintaining railway safety.
Level 3 - managed	The SPAD strategy encompasses accident investigation and analysis, route and signal design and management (infrastructure managers only), train systems and crew management (Train Operating Companies only). The SPAD risk reduction strategy is used as a focus for managers, which results in them being interpreted in the same way by all staff. Employees are actively involved in reviewing and revising the SPAD risk reduction strategy and how it is applied.
Level 4 - predictable	The SPAD strategy encompasses accident investigation and analysis, route and signal design and management (infrastructure managers only), train systems and crew management (Train Operating Companies only). The SPAD risk reduction strategy is consistent with the actions of everyone acting in the management chain. There is evidence of extensive collaboration throughout the management chain. The SPAD risk reduction strategy includes a realised commitment to continually improving the efficiency and effectiveness of risk controls. There is measurement of the efficacy of SPAD interventions. The SPAD strategy has a risk based approach.

Category	Planning and implementing SPAD Risk Reduction Strategy
Level 5 - excellence	The SPAD strategy encompasses accident investigation and analysis, route and signal design and management (infrastructure managers only), train systems and crew management (Train Operating Companies only). The SPAD risk reduction strategy is used to challenge the organisation to achieve business performance that is in line with the best-performing organisations. There is proactive monitoring and measurement of the SPAD risk reduction programmes, the results of which are used to effect continual improvement of the strategy. The SPAD strategy has a risk based approach. There is a consistent method for risk ranking SPADs, interventions that target high risk SPADs are prioritised.

There will be different opinions within the group and sometimes no box entirely fits. In this case, one that is closest to the organisation is chosen and evidence recorded along with the improvement opportunities. Participants are also asked to consider and record:

- Existing measures in place
- Whether/how they monitor the effectiveness
- Assumptions/judgements used to assign criteria.

The improvement opportunities are used to develop implementation plans for SPAD risk reduction and to steer future SPAD risk reduction strategy.

The levels identified in the matrix (1: Ad Hoc to 5: Excellence) represent the maturity of the management systems. Figure 1 illustrates how scores are displayed as a summary graph.

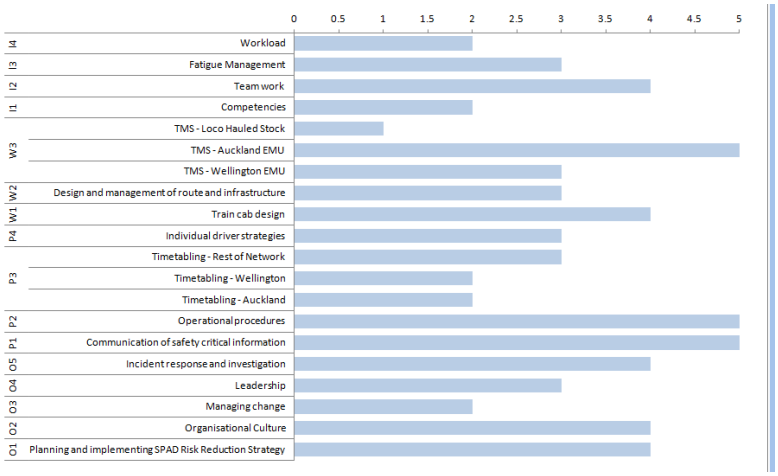

Figure 1 Example SPAD Risk Reduction Profile Summary Chart

It should be noted that the descriptions of each dimension are qualitative. Values are not equivalent across dimensions; a 2 on workload is not equal to a 2 in fatigue management in any quantitative way. The purpose of the snapshot is to highlight areas of weakness and excellence and to prompt discussions around potential risk reduction strategies.

Outcomes

This approach successfully takes the focus away from 'single' events and places the emphasis on a range of contributory causes and mitigation strategies. In the example profile above, which is a representation of our workshop with KiwiRail, we can see that the organisation has assessed itself as strong in **planning and implementing their SPAD risk reduction strategy.** They believe they have a well developed strategy that encompasses improved incident investigation and analysis, driver management, signalling systems and technological solutions and it has high commitment from senior management. Unsurprisingly **organisational culture** is also seen as positive by KiwiRail – something that will inevitably be required both to develop and implement the SPAD risk reduction strategy. Organisational culture is linked to the high values for **operational procedures** and **communication of safety critical information**. The profile reminds us that no one single mitigation will impact on SPAD rates if addressed alone.

The model considered the KiwiRail SPAD reduction strategy actions and identified the areas where these were likely to deliver positive benefit. This approach is very useful as it enables KiwiRail to have confidence that appropriate change initiatives are either underway or are being considered for future deployment. These include consideration of technical interventions such as:

- ETCS for the Wellington metro network
- how ETCS or another ATP solution might be applied to the remainder of the NRS
- GPS derived monitoring and intervention of train speed approaching worksites, GPS position monitoring and in-cab LOA approach warning and automatic braking when a paper-based LOA is overrun.

And procedural strategies such as:

- risk triggered commentary driving
- development of stabilised approach procedures (by train class).

Dunedin Railways found it less relevant to their organisation which is much less complex, having just four locomotive engineers, a simple timetable and single track operations with predominantly track instructions rather than signalling. That said, the discussions did leave them with some insights and some improvement points which they were willing to pursue. For example, it

highlighted the importance of the second man in the cab and the reliance on teamwork to recover from error by the locomotive engineer. This led to a discussion of how they could ensure good in-cab communications and flatten any hierarchy gradient between locomotive engineer and second man.

Some lessons learnt

Key ingredients of the workshop sessions that delivered success:

- Participants were up for it as a learning opportunity and they were unflinchingly honest
- All contributed
- Allowed enough time – typically three hours and would have benefited from a follow up session
- Right people in room (a variety of experience, driver representation, safety, operational knowledge, sufficiently senior for subsequent follow up)
- Involving different people allowed responsibility and ownership of the problems and solutions to be openly and equally shared
- Good note-takers to capture discussion without interrupting the flow.

Difficulties encountered with the sessions were that videoconferencing rather than face to face workshops limited the scope to a straightforward application of the tool and prevented more interactive exploration of improvement plans. However, the conversations were frank and open and did not require special facilitation. Our session with Dunedin Railway was limited to a teleconference with just one representative from the organisation. This did not give the opportunity to get different perspectives and confirmed that the tool is best applied in a workshop setting with different participants. The tool supports the consideration of all the causal and contributing factors of a SPAD occurring, e.g. between driver performance, company support to drivers and the wider design choices for the technology and equipment.

Opportunities for Improvement to the Tool

There were sometimes different scores for different parts of the organisation, for example, timetabling for freight was thought to have different characteristics to metro trains. However, highlighting this difference was in itself a useful finding. This is overcome easily by adding rows to the spreadsheet so it is still useful for the organisation.

The feedback on usability presented a very mixed picture, with the large rail participants finding the tool very user friendly and its content very relevant to their organisation. This contrasted with the small tourist rail participant who found the tool difficult to use as there was a lot of information that was considered to be irrelevant to their small scale operation. The tool would benefit from minor modifications to remove less relevant points for small operators to

improve applicability. These small operators may not have the opportunity to learn from near misses in the way that larger operators do. The open nature of the tool allows for proportionate SPAD mitigation measures to be acceptable.

Use of the Tool

Both KiwiRail and Transdev found the tool and the process useful and are using the outputs to guide their future SPAD risk reduction strategy. In its present form the tool should be very applicable to other large rail participants; with minor modifications it is also applicable to smaller organisations. Although aimed at New Zealand, the concepts and critical dimensions should be relevant to other countries although some alignment of wording, with specific signalling systems and technology, may be necessary.

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

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

Conclusion

Companies and regulators need to be actively examining systems and output performance to identify common patterns across events and the more systemic issues. The tool enables this to occur and can be further enhanced by matching the tool outputs with detailed causal and contributory factors data to deliver a very strong triangulation of 'real' data and staff perceptions of key causes. This would provide weight to decisions for SPAD mitigation solutions, which can be both costly and resource intensive.

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

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SPAD Resources

SPARK - UK database of research managed by the Rail Safety and Standards Board (RSSB) which includes the HF library *http://www.sparkrail.org*

OPSWEB - On line resource centre designed for the rail industry to access and share information and resources on operational safety. *www.opsweb.co.uk*

AITSR - Website for the Australian Independent Transport Safety Regulator. http://www.transportregulator.nsw.gov.au/

RHF - Proceedings of the International Rail Human Factors Conference (2005, 2007, 2011 and 2013)

REA, 2013, Resilience Engineering International Symposia Proceedings. http://www.resilience-engineering-association.org/

NZTA - New Zealand Transport Agency. Best-practice international solutions for mitigating human factor causes of Signal Passed at Danger (SPAD) ART 14/48. http://www.nzta.govt.nz/roads-and-rail/rail/resources/