SPAD Dashboard: A tool for tracking and analysing factors influencing SPADs

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Abstract. Signals Passed At Danger (SPAD) continue to be a key risk in railway operations, particularly in areas where safety systems such as TPWS are not yet implemented. This paper discusses the investigation of SPAD events on the Irish railway network and proposes a taxonomy and dashboard for tracking the factors influencing human performance in this context. The dashboard allows the performance shaping factors influencing different error types to be explored and analysed, enabling the development of more effective, systematic recommendations and the communication of human factors to key stakeholders.

Keywords. Rail human factors, SPAD, performance influencing factors, safety dashboard

1. Introduction

The investigation of accidents and incidents is a critical part of safety management. In the rail industry, Signals Passed At Danger (SPADs) represent the leading cause of fatal accidents across Europe between 1980 and 2009 (Evans, 2011) and they continue to be a key industry risk (Gibson, 2016). SPADs are defined as situations where the train proceeds beyond its authorised movement, i.e. where signals have been passed when a stop aspect (or end of movement authority) was displayed correctly and in sufficient time for the train to be stopped safely. Although most SPADs do not result in an accident, the potential for serious consequences means that each event should be thoroughly investigated. Traditionally, preventing SPADs has relied exclusively on the train driver's ability to perceive and correctly react to the trackside signals, although more recent technologies such as Automatic Train Protection (ATP), Train Protection Warning System (TPWS), and tripcocks provide system safeguards in support of driver performance. However, these technologies are not in widespread use on all networks and, even where they are in place, they do not completely eliminate the threat of SPADs.

Research into SPADs stretches back to Buck, who in 1963 discussed the different types of errors possible in the perception of railway signals. In addition to the mechanisms by which the driver may fail to perceive or react to a signal, research has also focussed on investigating the factors that may influence performance in this regard. Naweed and Rainbird (2015) found that driver attention and distraction are key themes in SPAD events while other research has suggested that SPADs may be more likely when drivers have returned from a break of a single day (Gibson, Shelton & Mills, 2007). Poor cab layout and ergonomics may also contribute to a higher SPAD rate (Pasquini, Rizzo & Save, 2004). Naweed (2013) conducted workshops with train drivers in Australia to define SPAD scenarios and identified three factors contributing to a majority of the envisaged scenarios:

1. Time pressure – pressure to keep or recover time;
2. Station dwelling – distractions or incorrect cues to depart the station;
3. Sighting limitations – relying on route knowledge and the role of expectancy bias.

The existence of 'multi-SPAD' signals demonstrates recognition that the design of the railway is a factor in SPADs, for example in terms of the level of train exposure, poor visibility of the signal, or high densities of signals in a particular location (Naweed, Rainbird & Dance, 2015). However, such organisational or system level influences are not as well acknowledged and investigated as driver errors. Another factor potentially influencing SPAD rates is an increase in approaches to cautionary aspects (Naweed & Aitken, 2014; Naweed, Rainbird & Dance, 2015). Congested networks may result in single or double yellow aspects being routinely experienced by drivers across a route, with danger signals rarely encountered. The long-term effect of this will be to change the meaning of a yellow aspect in the mental model of the driver from anticipation of a stop signal to expectation of a continued movement authority, i.e. drivers may become desensitised to the traditional meaning of the caution aspect and thus the cautionary aspect is devalued. Such degrading of safety features can be characterised as a normalisation of deviancy, or organisational drift (Dekker, 2014). Other industries have started to explore ideas such as normalisation of deviance and how a system can become stressed, for example through technological change, changing regulatory practices, or competitive environments (Naweed, Rainbird & Dance, 2015) but very little research in this vein has yet emerged in the rail domain.

A recent review of 257 SPAD investigation reports in the UK (Gibson, 2016) found that SPADs feature multiple causes, and there is no silver bullet that can fix the issue. The review also found a bias in the reports towards investigating driver performance rather than underlying factors and recommended improving the investigation process to place a stronger focus on the underlying causes of SPADs. It also recommended tracking trends in SPAD incidents in addition to managing each incident and involving front line staff in SPAD reviews.

Naweed & Rainbird (2015) note that most SPAD investigations tend to identify a single, often judgemental, factor as the cause and the investigation rarely progresses beyond 'human error'. Wright, Embrey & Anderson (2000) described the overall approach to accident analysis in the rail industry as characterised by:

- A focus on individual failings or inadequacies underlying human errors;
- Collection of limited information on the context of the incident;
- The search for a single root cause;
- No incentive to identify systematic, recurrent causes.

This is supported by the recent research by RSSB (Gibson, 2016), who also recommend a wider focus on identifying trends. However, Marsh and Bearfield (2004) discuss the difficulty of identifying underlying organisational factors in incidents without significant input from senior managers. They suggest that part of the difficulty is the tendency to investigate incidents as event sequences; deep organisational factors are rarely a direct event in the sequence leading to the accident, and thus are not routinely identified in the investigation.

The human factors community has developed a number of tools that attempt to overcome the focus on the individual by including wider systems issues that may have contributed to the event. Specific tools for SPAD investigation include the SPAD hazard checklist (Lowe & Turner, 2005) which covers eight areas that may have influenced the drivers' ability to correctly perceive the signal. However, this tool does not delve into deeper aspects of system performance. Wright et al. (2000) developed a Model for Assessing and Reducing SPADs (MARS) based on human information processing (Wickens, 1992) and incorporating performance influencing factors that may prevent successful processing of information. The method uses influence diagrams to structure data collection and investigation. Accident classification tools such as HFACS (Shappell & Wiegmann, 2000) and TRACEr (Shorrock & Kirwan, 2002) can be applied to SPAD events to help identify and classify performance shaping factors.

This research drew on the tools above to develop a classification system to support the investigation and analysis of SPAD events but rather than create a stand-alone human factors tools, this work was designed to fit within the existing investigation methods. The aim of the work was to identify trends within the events to provide focus for future improvements.

2. Methods

Eighty-three internal investigation reports of SPADs occurring between 2005 and 2015 on the Irish rail network were reviewed. Only reports where the immediate error leading to the SPAD was wholly or primarily on the part of the driver were included in the analysis.

The researcher reviewed each investigation report twice. A classification taxonomy was generated in the first pass using grounded theory to categorise the performance influencing factors identified by the report authors. This was then refined with reference to existing taxonomies in the literature (e.g. SPAD hazard checklist, MARS, HFACS, TRACEr, etc.) to create a bespoke classification system focussed on SPADs applicable to the Irish rail network. The revised taxonomy was then consistently applied in the second review of the incident reports. The final taxonomy used six broad categories to code the data:

1. Individual – factors pertaining to the specific driver involved in the SPAD and their driving style e.g. medical condition, fatigue, knowledge/skill, overspeed;
2. Team communication – a list of other roles who may have provided misleading, incorrect or unclear information;
3. Environmental – factors ino the environment in which the SPAD took place (e.g. visibility, weather, low rail adhesion, etc.);
4. Technical – factors in the design, operation or maintenance of railway equipment of systems e.g. train, signalling, infrastructure, warning and communications systems;
5. Organisational– factors in the support provided by the organisation e.g. competence management, procedures;
6. Task – factors in the specific movement or task being performed e.g. distraction, expectation biases, additional cues, time pressure.

An Excel-based database was created and populated with the SPADs coded against the classification taxonomy along with general information on the SPAD including time of day, overrun length, signal type, movement type, location type. The type of error i.e. slip, lapse, mistake, violation (Reason, 1990), was also coded for each event, based on the description of the incident in the investigation report and Reason's definitions. A dashboard was created within the workbook using a series of Pivot Charts and data slicers to display and explore the data across all incidents.

3. Results

A screenshot of part of the SPAD Dashboard is shown in Figure 1. The data slicers along the top allow the data to be viewed by year, type of operation, location type, movement type, error type and whether the SPAD was classified as a start against signal (SAS) i.e. passing a red signal when starting from a station stop, or a start on yellow (SOY) i.e. passing a red signal after starting from a station on a yellow.

Figure 1: SPAD Dashboard Screenshot

The use of these data slicers allows trends to be investigated across different types of operations and different types of SPADs. For example, Figure 2 shows the distribution of error types across all SPADs in the database. Lapses are the most common error type here, followed by mistakes and slips. Only a single violation was coded across all 83 incidents. In comparison, Figure 3 displays the error types for those incidents that occurred under degraded conditions i.e. when the railway system was not operating in a normal configuration. The errors here are almost exclusively mistakes. Figure 4 shows the error types for passenger trains, where lapses are even more dominant than in Figure 2 (all incidents). Finally, Figure 5 describes the error types during Shunt Movements, where no particular error type is dominant. Such comparisons can be achieved at the touch of a button using the data slicer functionality, and other slicers can be generated to distinguish between different types of SPAD (e.g. by length of overrun, type of movement, etc.). Space constraints in this paper mean that the examples of the dashboard functionality will focus on the error types and performance influencing factors.

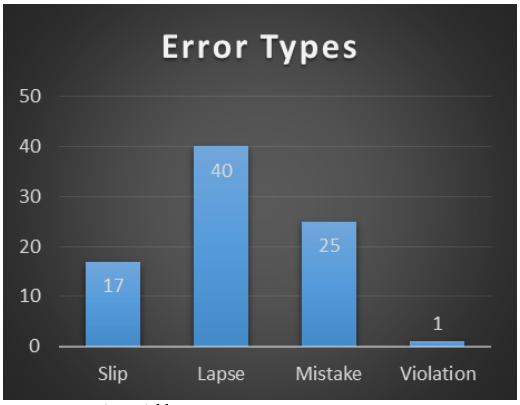

Figure 2: All error types

Figure 3: Error types - degraded conditions

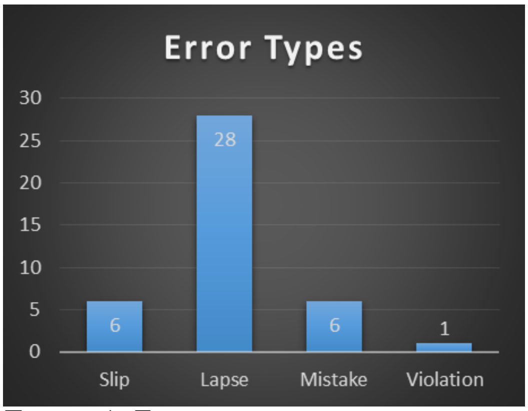

Figure 4: Error types - passenger movements

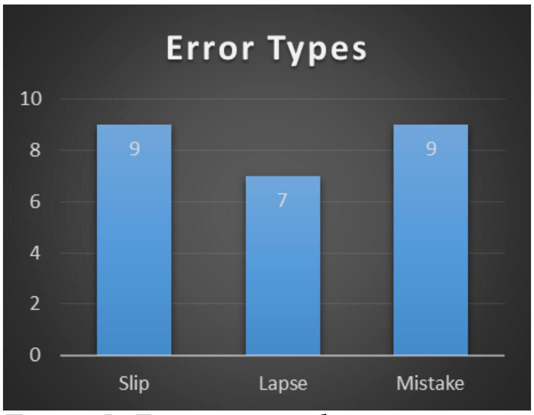

Figure 5: Error types - shunt movements

As well as error types, the factors associated with each incident are coded in the database using the taxonomy described earlier and can also be analysed. Figures 8 and 9 show the distribution of high-level influencing factors for lapses and mistakes. Task factors dominate lapses, which is unsurprising given that additional workload or distractions are likely to increase the opportunity for a lapse. Task factors are also the largest group for mistakes, but by a much-reduced margin. Communication between the driver and other roles takes a larger role, as does the state and knowledge of the individual driver.

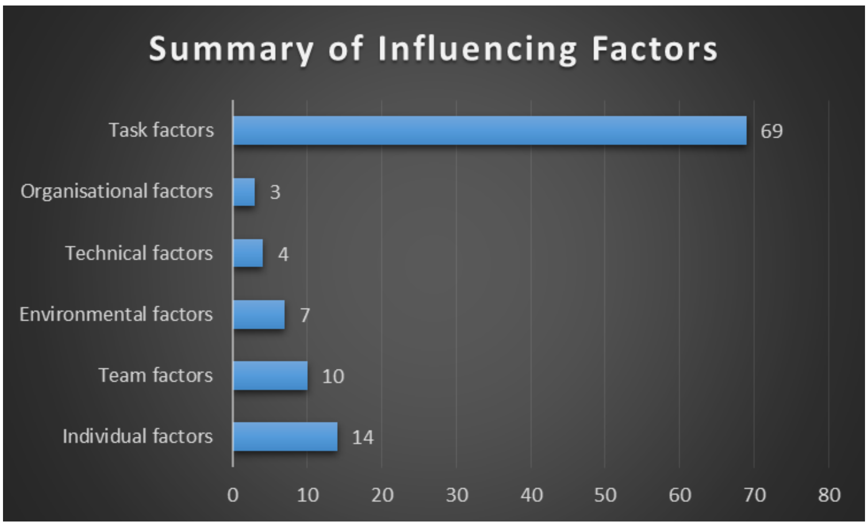

Figure 6: Summary of Influencing Factors for Lapses

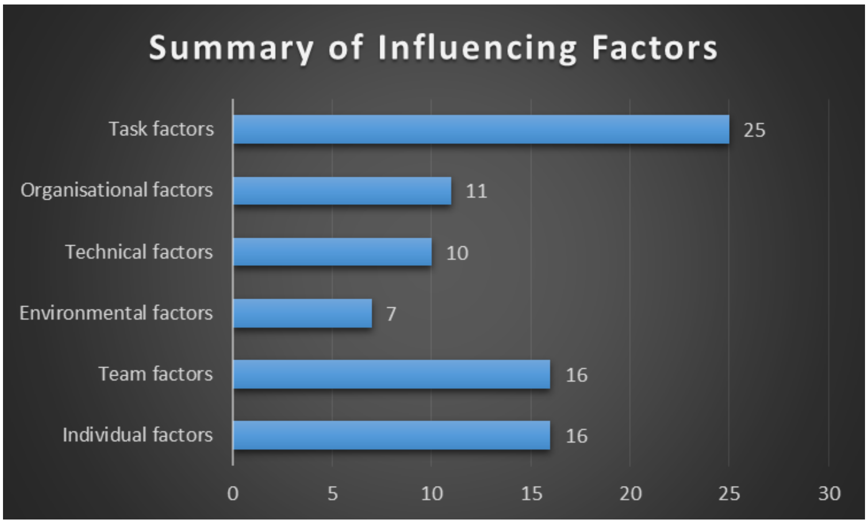

Figure 7: Summary of Influencing Factors for Mistakes

Each of the sets of factors can be broken down and viewed in more detail to determine whether there are particular factors influencing certain incident types. Examples of these breakdowns can be seen in Figures 8 and 9. Here the difference between the task factors influencing lapses and those influencing mistakes can be seen, i.e. lapses are associated with distractions and expectation biases whereas mistakes are more associated with complex, new or unusual movements and the presence of an additional cue.

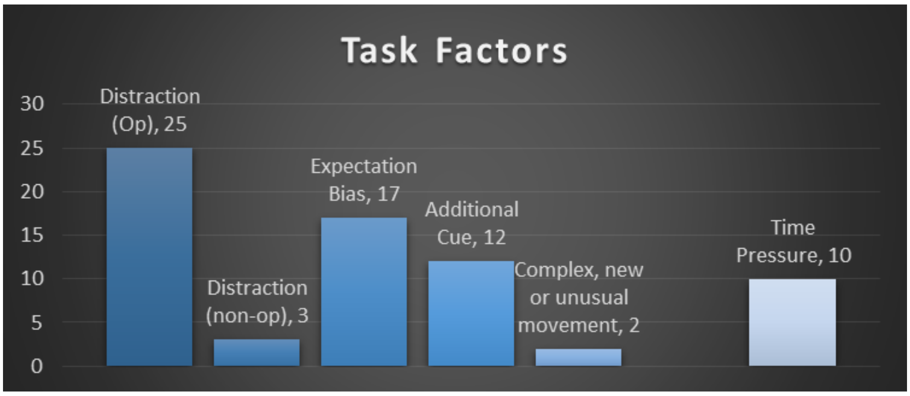

Figure 8: Task factors associated with lapses

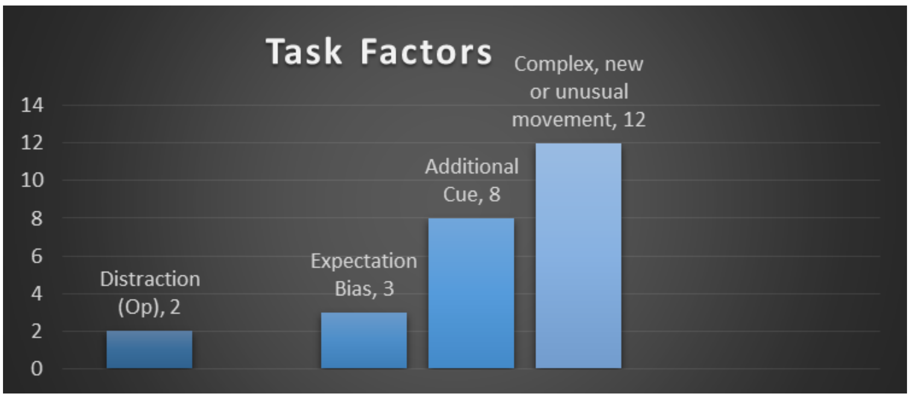

Figure 9: Task factors associated with slips

4. Discussion and Conclusion

As SPADs continue to be a key risk for railway operations, there is a need to move beyond the investigation of individual events and the provision of recommendations associated with single events (Gibson, 2016). This is also true for other safety events in a variety of industries where individual reports may not reveal the performance influencing factors prevalent in general. The SPAD Dashboard has been developed to support the longitudinal analysis of SPAD incidents and to place a greater weight on the identification and analysis of factors that may be influencing the overall incident rate. The data input is based on the internal investigation reports for each event, and the individual investigation continues to be of great importance. However, the SPAD dashboard aims to identify trends across all incidents, and therefore create recommendations that will be more globally effective. The strength of the approach is in utilising information already gathered by the organisation i.e. investigation reports, but documenting it in a single database to provide a more holistic analysis. By exploring the data held in the dashboard, a greater understanding of the systemic factors influencing incidents can be achieved, and stakeholders can explore influencing factors without the biases that may exist in relation to individual incidents. The dashboard is, however, dependent on the investigations of the incidents to correctly identify and document the influencing factors. To support this, a summary sheet containing a tick list of influencing factors is proposed with the aim of both summarising investigation data for entry into the database and to raise awareness among investigators of the possible influencing factors. Further work is necessary to integrate the dashboard in practice, and in particular to link the analysis resulting from the dashboard with a process for identifying and adopting recommendations. However, even without this link, the dashboard can still serve to highlight the role of factors beyond the specific error mechanism and raise awareness of a more systematic approach to improving safety and performance. The approach is also applicable to other types of safety incident within and beyond the railway industry, where existing information can be combined with appropriate taxonomies to provide a more systematic analysis.

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