SPAD – reducing timetable related risk

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Abstract

This paper will address an important railway safety issue – Signals Passed at Danger (SPADs) – and set out how timetable simulation can be used to give a reliable assessment of how often drivers will see red signals and hence enable railways to manage changes in risk brought about by changes to the timetable.

Changes to timetables are known to be a factor in SPAD risk, as a poorly designed timetable can lead to more trains approaching signals at red than a timetable devised with SPAD risk in mind. Typically, the more times trains approach signals at red, the more the possibility of them being passed at danger. Changing the timetable can introduce new 'problem' signals (problem in the sense that they are more likely to be at danger when a train approaches) and driver over-familiarity can lead to more SPAD incidents at these signals.

RWA Rail has developed a software tool that uses timetable simulation to produce data to enable a quantified assessment to be made of potential timetable-related SPAD risks. The tool achieves quantified assessments by calculating how often each signal in the modelled area is approached by a train whilst it is showing a red aspect. A unique advantage of using simulation is that it can also estimate the number of red signals seen by drivers under normal operating circumstances, when some trains are running late.

The statistics produced highlight changes in red signals that will be seen by drivers and where there are significant instances, these can then be investigated and, where practicable, the timetable (or the infrastructure configuration) can be changed. Where this is not possible, the results can be used for driver briefing.

A case study will be presented, setting out how the tool has been used in practice.

Keywords: safety, signals passed at danger, SPAD, operational simulation.

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1 Introduction and methodology

Signals passed at Danger (SPADs) are an important railway safety issue. Documentation [1] and severity classification of SPADs in the United Kingdom has improved as a result of the Ladbroke Grove Rail accident in 2003 and a number of measures are in place to reduce the number of SPADs:

- Signalling is heavily reviewed for visibility and clarity during the design stages
- All SPADs are investigated and measures taken to avoid repetition where risks are identified
- The Train Protection and Warning System (TPWS) has made a significant reduction in SPADS and has now been reviewed in an effort to further reduce incidents, e.g. due to an override by the driver

Most current methods focus on the infrastructure elements (visibility of signals, position of train protection systems and installation of warning systems) as well as driver's alertness (Fatigue Index) [2]. None of these approaches considers the timetable or integrates the impact of the timetable and infrastructure taken together. In cooperation with Chiltern Railways, RWA Rail has developed a methodology to fill this gap and audit timetable changes prior to their implementation for any change in the likeliness of SPADs occurring. In the following paper this is described as 'SPAD risk'.

2 Methodology

2.1 Background

Most SPADs occur as a result of either technical faults (defective brakes, signalling system faults) or human error (misjudgement of braking distance, momentary lapses of concentration by the driver, signaller error) when a train approaches a signal at danger. While these fault and error causes can differ, all SPADs have one contributory factor in common: the train is approaching a signal at danger. To estimate how the timetable contributes to SPAD risk a quantitative assessment of the frequency of approaches to signals at danger is required.

2.2 Modelling and analysis

In order to forecast the timetable related element of SPAD risk, RMCon's timetable planning and performance system RailSys Version 6 has been used as a signal berth level timetable simulation tool. With RailSys timetables can be simulated for several hundred days, perturbed based on historic delay data.

RailSys logs all decisions made by the in-built train dispatcher at signals (this dispatcher effective mimics the interventions of signallers and drivers). For the SPAD risk assessment, the method compares how often a train has to either stop at signals or the departure of a scheduled stop is delayed because of a signal aspect. For the analysis the data has been extracted and cleaned to exclude simulations that have led to deadlocks and other duplicate records and the data has then been imported into a database for faster access.

2.3 Modelling driving techniques

Different train operators train their drivers to use different driving techniques (known in the UK as ‘professional driving’ techniques). The current methodology has been tested on two different professional driving practices:

1. Scheduled run times: Trains are run ‘on time’, departing the station on time and arriving where possible on time and coasting on route where run time allowances exist.
2. Minimum run times: Trains are run at minimum run times, departing the station on time and arriving where possible early at the next station.

In UK circumstances the first driving practice may overestimate the impact for trains following services with large allowances, especially in the approach to terminal stations where a performance allowances is often added. If trains are running on minimum run times this impact may be underestimated due to trains running unrealistically quickly into these terminals.

3 Modelling and analysis

3.1 Timetable comparison and calibration

Like much performance modelling, the SPAD risk estimation is most reliable if undertaken as a comparative assessment. Both a base case with historic data and an option/future case with new data are compared. This is important as it allows the user to get an understanding of improvements or worsenments as well as allowing a detailed analysis of changed per train to highlight those areas where the timetable change results in potentially increased risk.

Table 1: Total number of signal stops and dwell time extension on the simulated Chiltern Railway network.

	On Time Running		Minimum Running Time	
	May 2007	Dec 2007	May 2007	Dec 2007
Chiltern Services	81.3	60.9	182.2	185.2
Other TOCS	74.0	61.1	105.2	95.1
Number of Stops	155.3	122.0	287.4	280.3

Table 1 shows the result of simulations of the Chiltern Railways network before and after timetable and infrastructure changes between the May 2007 and December 2007 timetables – these changes have reduced the overall number of predicted signal stops. However the improvement is less marked on the assumption that drivers drive to achieve the minimum running time between stations.

3.2 Train by train analysis

It is also possible to undertake comparative analysis train by train, with the change in average daily signal stops per train compared between the models. We find that relatively small timetable changes can have significant impacts on the SPAD risk. Depending on the professional driving method, few trains exceed 1.5 average approaches to a signal ‘at danger’ using coasting compared with 2.5 when running flat out. We have then, using RailSys, been able to investigate the reasons for higher than average incidence.

Causes for a change in timetable-related SPAD events can vary, but unsurprisingly the most significant impacts are due to either the obstructing or the obstructed train directly having been retimed.

3.3 Small scale timetable changes

Existing timetables typically do not allow for significant changes to be made to reduce the SPAD risk. But small timetable changes can have a large impact – for instance moving pathing allowances to more appropriate locations is a key area of flexibility.

When creating timetables, these allowances are often placed in the approach to a junction with conflicting movements. The UK Rules of the Plan are the guideline rules for timetable construction. Below figure 1 shows two following trains approaching a junction. The Rules of the Plan in some cases allow the headways between two following trains to be smaller than the actual signalling headways.

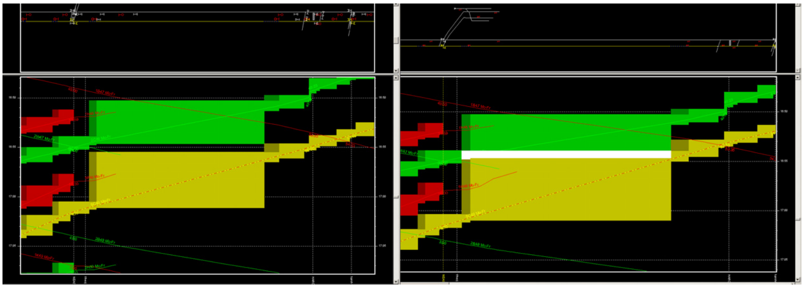

Figure 1: Impact of changes to pathing allowance: early application of pathing allowance (left), late application of pathing allowance (right).

Cases like these where no or very little buffer time between trains is available, can be reduced by changing the location where pathing allowances are applied. In above figure the critical area for compliancy with the Rules of the Plan is the junction on the left of the screenshots. If a pathing allowance is applied immediately before this junction however, then there is still a headway conflict remaining. If a pathing allowance is applied earlier on route this spreading of train paths reduces the number of times a train will approach a signal at danger.

In areas with low punctuality and a less regular sequence of train services it can be beneficial to investigate trains based on the number of signal stops caused rather than those incurred and to investigate if this can be reduced.

3.4 Signal analysis

Similar analysis has been undertaken looking at individual signals. In the Chiltern Railways network model most signals at danger when approached are in the approach to London Marylebone terminal station, with two critical areas:

1. Neasden Junction: Two separate lines into Marylebone join here and some outbound services cross the line of main line inbound services.
2. Marylebone Station Throat: Inbound trains and outbound trains are crossing.

Different timetable variants and station platforming variants have a large impact on the location of the signal where number of approaches at danger is highest. Figure 2 shows the simplified inbound infrastructure:

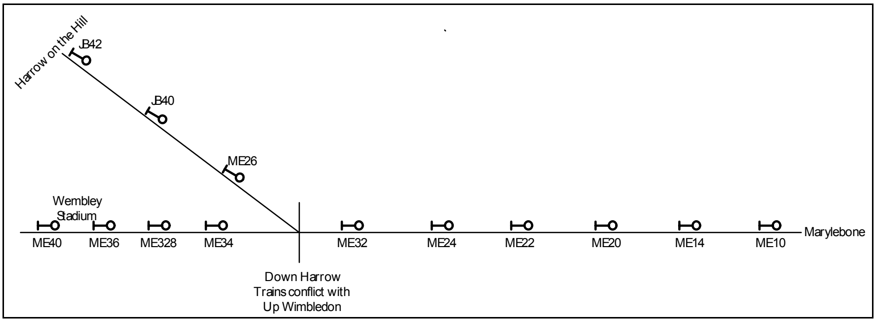

Figure 2: Station approach to London Marylebone.

Key signals at Marylebone are ME10, ME22 and ME26. At ME22 the headway is effectively longest due to performance and pathing allowances being applied in the final approach to Marylebone. ME10 is limited due to conflicting station movements with outbound train services and ME26 is affected by delayed services not being 'in sync' when joining the main line.

We concluded that making minor changes to the time and driving practices could lead to significant reductions in the number of signals seen at danger.

3.5 Use of SPAD risk estimation

The data produced has currently only been used for consideration of timetable issues and an assessment of critical areas. The information could further be used to brief drivers. But caution has to be taken that by increasing awareness at certain signals this information may lead to reduced cautiousness of drivers approaching less critical signals.

4 Outlook

The project has shown that the method is a good indicator of how often and where drivers will see signals at danger and provides a wealth of information that can be used to improve the timetable and reduce the number of stops of a train on route. The methodology has however a number of limitations which we intend to refine further.

4.1 Signal classification

Analysing individual changes to trains or at specific signal is a slow process and overall figures can be hard to interpret.

If both timetable and signals are jointly regarded a better indicator for the risk may be identified. We have started producing output graphs showing the spread of the approach at danger by train.

Figure 3 shows an example highlighting these different characteristics. Signals, as signal A, which are only (and more regularly) at danger for a small number of different train services are more likely to be a SPAD risk as drivers may not expect to see the signal at danger. Being only affected by a small number of services, changes to the timetable are expected to be more effective at these signals.

Signals, as signal b, which through their position on the network are at danger for a large number of different train services, can often only have the frequency reduced through costly changes to infrastructure or signalling. At these signals it is often more likely that drivers expect a restrictive aspect and therefore despite a larger number of signal stops the risk may not be higher.

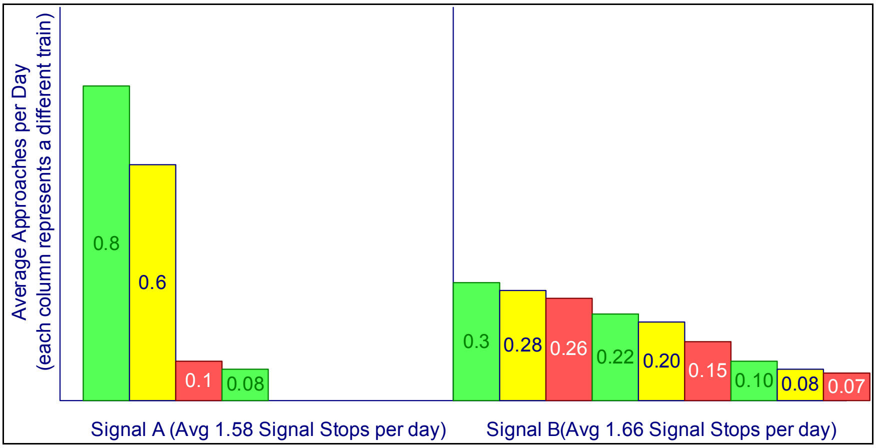

Figure 3: Comparison between alternative signals.

It would be desirable to use these characteristics to devise a measure that could indicate for each signal a risk measure based on the level of expectation that the signal is at danger and the actual frequency of the signal being at danger, so that it allows for a true risk assessment for individual signals.

4.2 Inclusion of freight trains

Passenger service timetables have little variation throughout the week and the methodology is a good indicator for the SPAD risk both caused by and affecting passenger services. Freight timetables vary significantly from day to day. The modelling software used is not yet sufficiently sophisticated to provide a good assessment of the impact of varying freight schedules when modelling a multiple simulation over several perturbed days. Freight services can also run significantly early but the underlying performance data can only be modelled for trains that run on time or late. This leads to a number of shortcomings:

- Freight schedules vary each day with a large number of long term planned trains being only conditional or cancelled and therefore leaving clear paths in the timetable which can in practice be used as buffer time
- Short term planning timetables use some of these paths in the timetable but some remain unused each day.
- Freight services are less punctual than passenger services.

RailSys does not yet have the capability to incorporate in a multiple simulation varying timetables with a pool of available freight services and early running cannot be incorporated at all. Modelling a typical day will overestimate the impact of those services that run only on some days but would be included in the simulation on all days. The simulation may also miss some days which, because of a heavy freight path requirement, perform particularly badly. These factors make the analysis of passenger on passenger delay more difficult on routes where there are significant freight volumes.

4.3 Multi aspect signalling

Multi-Aspect signalling requires trains to reduce speeds in the approach to signals at danger several blocks in advance. RailSys is fully capable to model these reduced approach speeds per block section but current UK standards and implementation is still incomplete in this area. Therefore current modelling is often based on approach to the signal at danger at full line speed. While this overestimates the number of events where a train is required to stop, the methodology would need to be enhanced to incorporate trains that had to reduce their speed in the approach to a signal but were not required to stop.

4.4 Calibration

For performance modelling in the UK the base timetable for all models is now calibrated against punctuality values. This calibration is replicated for the SPAD analysis. However, train movements on the UK railway network are not recorded to a level of detail that provides data that can be used to calibrate the frequency of stops in approach to signals at red. Unfortunately therefore no quantitative evidence is available to confirm the modelling analysis represents reality. Having said this, driver managers and timetablers at Chiltern Railways have confirmed that, qualitatively, results are plausible and largely as expected.

5 Conclusions

The project has proven that operational simulation can be used as a qualitative method to estimate the frequency of trains approaching signals at danger. The analysis indicates the impact of infrastructure modifications and timetable changes and the outputs can be used to both optimize these modifications or to introduce further preventive measures such as issuing driver warnings or introduction of line safety equipment.

Improved results are expected from more recent developments of the RailSys system and simulation runs taking into account professional driving and multiple aspect signalling.

We are further developing a system to classify signals allowing to better distinguish between the location and timetable as a cause of SPAD risk in order to improve the identification of critical signals and remedial actions.

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