Operational Safety Indicators Using Real Train Driving Data

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Abstract.

This paper explores the utilization of On Train Data Recorders (OTDR) in monitoring train safety systems use. Train Protection and Warning System (TPWS), Emergency Bypass Switch (EBS) and the Driver's Reminder Appliance (DRA) were used as examples of train safety systems. Using OTDR data to monitor safety systems has to potential to improve compliance with the Rule Book, especially if data can be collected and analysed in real-time. Identification of the deviation from recommended rules that may have safety implications may be useful in the pre-incident investigation.

Keywords. Safety system, On Train Data Recorders, Safety indicators

1. Introduction

Regardless of the importance of train safety systems that can be operated/isolated by a driver, there is no mechanism to continuously reporting its use during train journeys. For example, the initial investigation into an incident near Doncaster on 2nd October 2015, found that the TPWS was fully isolated (Railway Herald, 2015).

A number of train operating companies use in cab assessment to monitor drivers' operational usage of safety system such as DRA (McCorquodale et al., 2002). At research level, digital cameras were implemented to record driver's actions (RSSB, 2004). Both previous techniques (in-cab assessment and in cab-observations) have their own merits in assessing the driver usage of such systems as they supplied comprehensive details about the driver actions. However, drivers may behave differently under observation; furthermore, the time and money cost for both techniques hinders their use for continuous monitoring.

The use of OTDR data, alternatively, offers a continuous cheap source for monitoring the use of safety systems and measure the driver complying level with these safety system rules without distracting drivers. So far, the data related to the safety systems in OTDR are often only reviewed in case of incident or accident.

OTDR data provides a record of the way trains are driven and the state of various train systems including safety systems for each service. Examples include power and brake controller position, driver acknowledgment of signaling system warnings, door status (release/close) and the operation of the brake system. OTDR data have a large potential to support safety management of the railway by continuously monitoring their use during a journey. Based on OTDR data, Green et al. (2001) and El Rashidy et al., (2016) presented a number of performance indicators to facilitate the automatic analysis of driver performance. Balfe (2017) explored the potential of

OTDR data for human factor analysis.

In the operation level, OTDR data have been used to support accident investigations; for example, RAIB (2007) used the data from OTDR to investigate events where two signals were passed at danger at Esher on 25 November 2005. In this instance, OTDR data enabled the investigators to recognise the severe low adhesion conditions that the 1A12 train experienced. This paper introduces a number of indicators to monitor safety systems during a journey using OTDR data.

2. Methods

The method consists of three main phases:

- Safety system rules and processes identification,
- Data processing and analysis
- Application of the developed indicators to a study case to check its applicability.

In the following, more details of each stage are presented.

2.1 Safety system rules and processes identification

The digital Rule Book (GE/RM8000/train driver, 2015) was reviewed to identify safety systems and their rules that the driver should comply with. Cab-rides were also carried out to gain more knowledge about the driver environment and how the driver reacts to different situations. Consultations, in the form of informal interviews, with a driver and a driver manager were conducted to discuss some operational issues and clarify some technical points.
Based on the above method, the following safety systems were chosen:

- Emergency Bypass Switch (EBS),
- the Train Protection and Warning System (TPWS) and,
- the Driver's Reminder Appliance (DRA)

Each train safety system mentioned above has implemented to mitigate or eliminate an operational risk. Table 1 summarises safety rules for EBS, TPWS and DRA. Table 1 also presents the consequences due to non-compliant with these safety systems, and the criterion used to describe the compliance level.

Table 1 Safety systems and its rules.

Safety system	Rule	Consequences	Criterion
EBS	A train cannot enter service (unless travel to a maintenance depot) with the EBS operated in any driving cab	In the case of EBS operated in any driving cab, the driver must: • Notify the signaller immediately; • Not move the train until instructed to do so; • Carry out the instructions given.	• Yes/no
TPWS	TPWS must not fully isolate under any condition according to the Rule Book (GE/RM8000/train driver).	The full isolation of TPWS is considered to be a very serious action.	• Yes/no
DRA	The DRA has to set under different situations, i.e. • When entering the cab, prior to starting the train; • When stopping in front of a signal showing a red aspect; • Coupling and uncoupling activities.	No specific consequences were identified.	• The number of DRA use: ▪ In front of red aspects, ▪ During coupling and uncoupling events, ▪ At the start of a journey.

2.2 Data Processing and Analysis

The initial handling of data stage examines data types and format. Furthermore, closer inspection of data shows a number of deficiencies that can affect the reliability of data analysis such as missing values across all the variables and unexpected character encoding. To automate the correction of data type and format, an R script is written and checked against a manual calculation using Excel.

The OTDR data were examined to identify safety systems monitoring by OTDR and OTDR channels that can be used to identify its status under a certain condition.
A number of algorithms were developed using R software to automate the extraction of relevant scenarios and to calculate the suitable indicators from OTDR data files.

2.3 Case Study

To check the applicability of the developed algorithms, a number of OTDR data files (≈ 200) were used. Relevant OTDR channels were used to identify safety systems status under a certain condition, then the operational safety indicator for each safety system was calculated.

3. Results

Figure 1 shows a number of OTDR channels that have been used to identify EBS, TPWS and DRA status under a certain condition. For example, EBS must not be operated for an entire journey; consequently, train travel distance and EBS channels were used to assess the operating status of EBS, e.g. the status of EBS in the case of travel distance is not equal to zero.

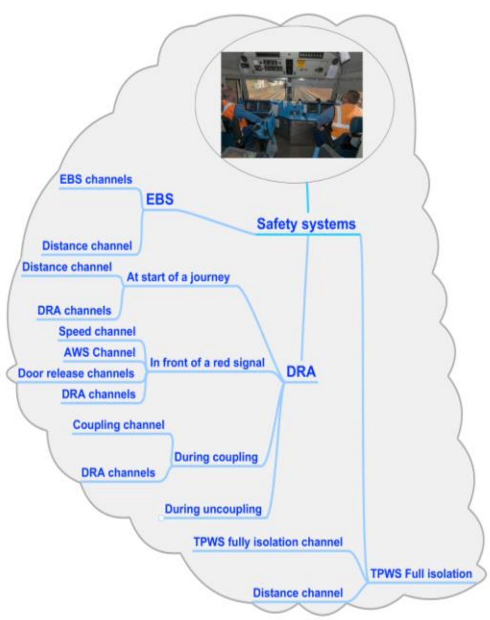

Figure 1 Schematic diagram for OTDR channels under investigation.

3.1 EBS and TPWS

For the OTDR used in the study case, it was found that all drivers considered fully complied with

EBS and TPWS rules. There was no TPWS isolation or operated EBS in the 200 examined journeys.

3.2 DRA

For analyzing DRA activation, Table 2 presents the number of the red aspects drivers experienced during each journey and the corresponding use of DRA. The number of red aspect a driver experienced should be equal to the corresponding use of DRA to achieve complying level equal to 1. For DRA setting at the start of journeys, none of the drivers was in compliance with the DRA setting rule save one. To check the outcomes of DRA setting detection algorithm, an algorithm is developed for plotting the train speed and DRA use against the relative journey time. For example, in Figure 2 the driver complied with the rule as he/she set the DRA at the start of the journey. A similar trend was found for setting DRA during coupling and uncoupling activities.

Table 2: The DRA use and number of red aspects experienced.

Journey number	Red aspect	DRA	Complying level
Journey 1	1	1	1
Journey 2	0	0	NA
Journey 3	2	2	1
Journey 4	2	2	1
Journey 5	1	1	1
Journey 6	4	3	0.75
Journey 7	1	1	1
Journey 8	1	1	1
Journey 9	1	1	1
Journey 10	2	2	1
Journey 11	2	1	0.5
Journey 12	1	1	1

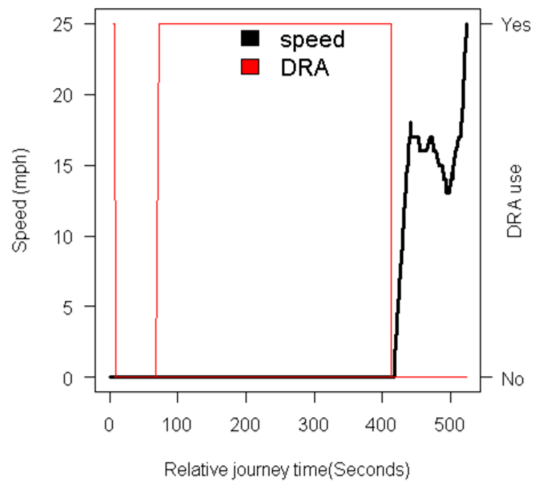

Figure 2 Driver's compliance with DRA setting at the start of a journey.

4. Discussion

The DRA results highlight the variation in complying with DRA use under different situation in line with the literature (McCorquodale et al., 2002; Mcleodet al., 2003). This journey analysis shows that none of the drivers was in compliance with the DRA setting at the start of their journeys save one. A similar trend was found for setting DRA during coupling and uncoupling activities.

Whilst driving, DRA setting behavior is closer to the rulebook requirements. Results presented in Table 2 showed that all the drivers complied with the rule to set the DRA after being stopped at signal showing a red aspect except Journeys 6 and 11. The Journey 6 driver experienced 4 red aspects but set the DRA only 3 times, whereas the Journey 1 driver experienced 2 red aspects but set the DRA once. In these journeys the driver could be using an exception that is used if the train is stopped for a very short time (a few seconds); in that case the driver may ignore DRA setting. Complying with DRA setting in front of a red aspect rule is higher than that at the start of a journey or during coupling and uncoupling activities as shown in Figure 2.

For EBS and TPWS no deviations were found in the dataset. These two system are clearly not open for individual interpretation. These systems demand a more rigid rule following than DRA due to their criticality and direct consequences for the driver. With DRA, which lacks clear consequences for driving and/or enforcement, of the rule is followed less stringent. This could be seen as a drift to danger problem or, at the other extreme, a useless addition to the rulebook.

Continuous monitoring of the safety systems by OTMR allows a better understanding of how the drivers complying with safety systems rules influence the safety of the train. Even with a relatively small sample behaviors becomes clear. Yet we see this case study only as an illustration because the selection is too small for generalizations, even if the results are in line with the reported literature. Using vast amounts of OTDR data to monitor safety systems has the potential to improve compliance with the Rule Book, especially if data can be collected and analyzed in real-time.

A slightly more positive use of the data is that if the complying rate with the safety systems across drivers' population can be determined. A better understanding of driver trust and confidence of such systems is possible; perhaps leading to stronger evidence to modify safety systems rules. Such extensive analysis may also reveals the link between driver complying level and adverse consequences, which, in turn, could allow the development of more effective safety management strategies.

5. Conclusion

This paper proposed a number of operational safety indicators based on real-world driving data extracted from OTDR data files. The use of safety systems such as EBS, TPWS and DRA were considered to illustrate the methodology. It has been found that drivers fully comply with EBS and TPWS fully isolation rules because of their severe operational and enforcement consequences. Even with this high competency level of these indicators, it is still important to monitor them as they are directly related to the safety. DRA seems to be more troublesome in the sense that rule following is less rigid and not very consistent. The lack of clear consequences makes it difficult for driver to decide just how important which leaves it open for personal interpretation. With the techniques described in this paper, a comprehensive study could be made for such rule following and the potential consequences for safety on the railways.

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