RAIB

Rail Accident Investigation Branch

Rail Accident Report

Two signal passed at danger incidents, at Reading Westbury Line Junction, 28 March 2015, and Ruscombe Junction, 3 November 2015

Report 18/2016
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This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where the RAIB has described a factor as being linked to cause and the term is unqualified, this means that the RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident. However, where the RAIB is less confident about the existence of a factor, or its role in the causation of the accident, the RAIB will qualify its findings by use of the words 'probable' or 'possible', as appropriate. Where there is more than one potential explanation the RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, the words 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the event being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of the RAIB, expressed with the sole purpose of improving railway safety.

The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

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Two signal passed at danger incidents, at Reading Westbury Line Junction, 28 March 2015, and Ruscombe Junction, 3 November 2015

Contents

Summary

At 08:22 hrs on 28 March 2015, a freight train running from Acton to Westbury, operated by DB Schenker Rail (UK), passed a signal at danger at Reading Westbury Line Junction, to the west of Reading station. A similar incident occurred at 06:11 hrs on 3 November 2015 when another freight train forming the same service from Acton to Westbury, and operated by the same company, passed a signal at danger at Ruscombe Junction, about seven miles east of Reading. The RAIB began an investigation into both of these incidents following the latter event at Ruscombe Junction, owing to the similarities between them.

Both incidents occurred because the train drivers involved were too fatigued to properly control their trains; both drivers stated that they momentarily fell asleep on the approach to the signals concerned. They were suffering from fatigue because they had not obtained sufficient sleep, which in part was due to the rest facilities at Acton not being fit for purpose, and because the drivers were nearing the end of a long night shift. Neither driver reported as unfit for duty, which was also causal to the incidents. The investigation identified underlying factors associated with supervision and management at the drivers' home depot in Westbury, and with the general approach to the management of fatigue within the company.

The investigation report has identified two learning points and made three recommendations. The learning points concern the importance for preparing for duty and reporting fatigue, and the role of napping (and facilities for such) within a fatigue risk management system. The recommendations cover shift planning at Westbury depot, fatigue management within the freight sector and identification of fatigue risk through data analysis.

Introduction

Key definitions

1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.

2 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B. Sources of evidence used in the investigation are listed in appendix C.

The incidents

Summary of the incidents

3 At 08:22 hrs on 28 March 2015, freight train 7C29[1], which was the 08:25 hrs service from Acton to Merehead Quarry (running about 55 minutes early), passed signal T1729 at danger on the *Up* Westbury line at Reading Westbury Line Junction (figure 1). The train's speed was 13 mph (21 km/h) when it passed signal T1729, and it stopped 24 metres beyond the signal.

4 At 06:11 hrs on 3 November 2015, freight train 7C29, this time forming the 06:22 hrs service from Acton to Merehead (running around 70 minutes early), passed signal T1627 at danger on the *Down* Relief line at Ruscombe Junction, near Twyford (figure 1). The train's speed was 33 mph (53 km/h) when the incident occurred, and it stopped 164 metres past the signal.

5 In both cases, the drivers stated that they momentarily fell asleep before passing the respective signals.

6 Neither incident resulted in any damage or injury.

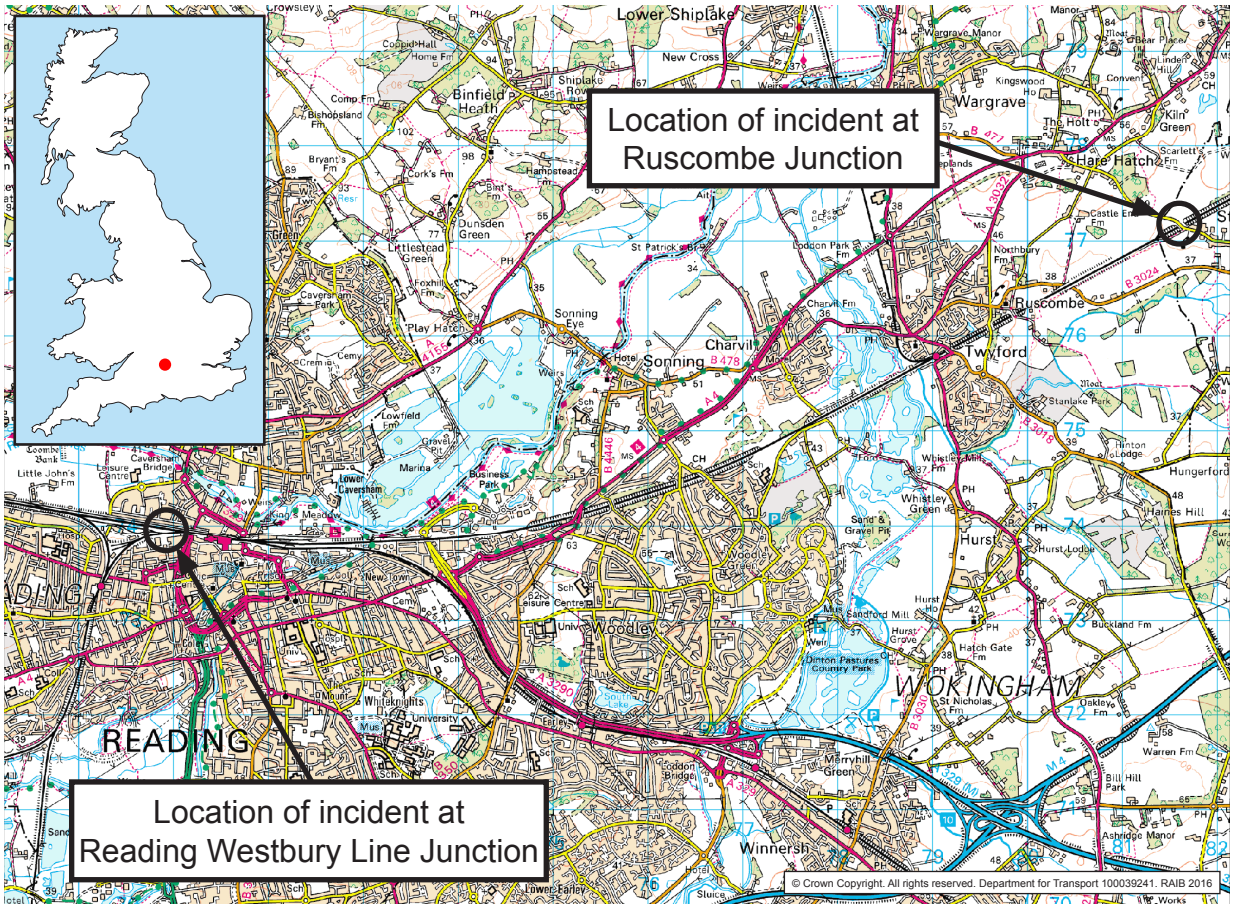

Figure 1: Extract from Ordnance Survey map showing location of the two incidents

[1] An alphanumeric code, known as the 'train reporting number', is allocated to every train operating on Network Rail's infrastructure.

Context

Locations

7 T1729 is a four-*aspect* LED signal located on the right-hand side of the *bidirectional* Up Westbury line at 36 miles 29 *chains*, approaching Reading Westbury Line Junction to the west of Reading station (figure 2). For the path that train 7C29 took on 28 March 2015, this signal is preceded by two similar four-aspect signals. Permissible speed at this location is 40 mph (64 km/h).

8 On the morning of 28 March 2015, signal T1729 was being held at danger because the parallel signal (T1727) was showing a proceed aspect to allow for the passage of passenger train 2K32 (figure 3).

Figure 2: Signal T1729 at Reading Westbury Line Junction (image courtesy of DB Cargo (UK) Ltd)

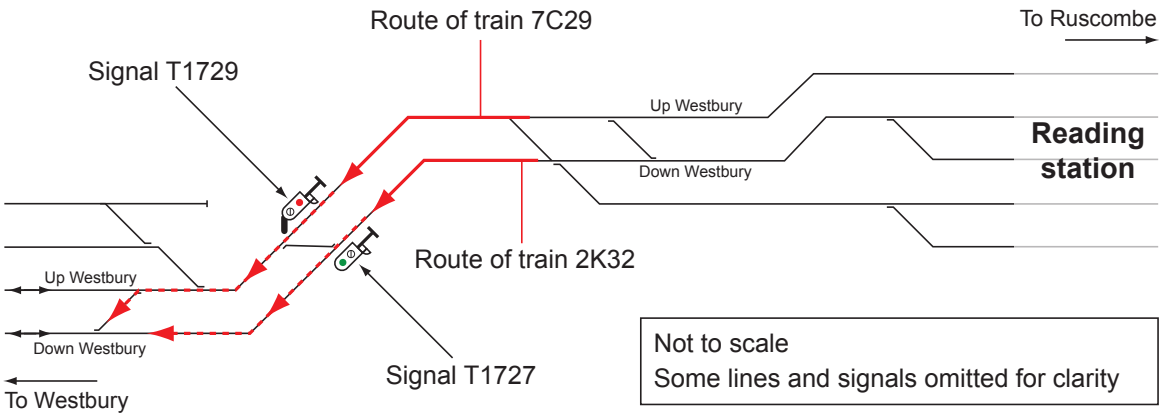

Figure 3: Simplified track layout showing the location of signal T1729 and the intended paths of both trains

9 T1627 is a gantry-mounted four-aspect LED signal protecting Ruscombe Junction on the Down Relief line at 29 miles 16 chains, to the east of Twyford station (figure 4). Its preceding signals are T1623 (four-aspect) and T1611 (three-aspect), meaning that when T1627 is at danger the two signals on the approach to it show green and single yellow respectively. Permissible speed at this location is 60 mph (97 km/h) for freight trains and 90 mph (145 km/h) for passenger trains, although the maximum permitted speed for the train concerned was 45 mph (72 km/h) (see paragraph 15).

Figure 4: Signal T1627 at Ruscombe Junction (image courtesy of DB Cargo (UK) Ltd)

10 When the incident occurred on 3 November 2015, signal T1627 was showing a red aspect, protecting a route which had been set for train 3D16, an empty high speed passenger train (HST), to cross from the Down Main to the Down Relief line at Ruscombe Junction (figure 5).

Organisations involved

11 DB Schenker Rail (UK) was the operator of the train and employer of the drivers. On 1 March 2016, the company changed its name to DB Cargo (UK) Ltd. For the remainder of this report, the company will be referred to as 'DB'.

12 Network Rail is the infrastructure manager and employed the signallers on duty at the time of the incidents.

13 Both DB and Network Rail freely co-operated with the investigation.

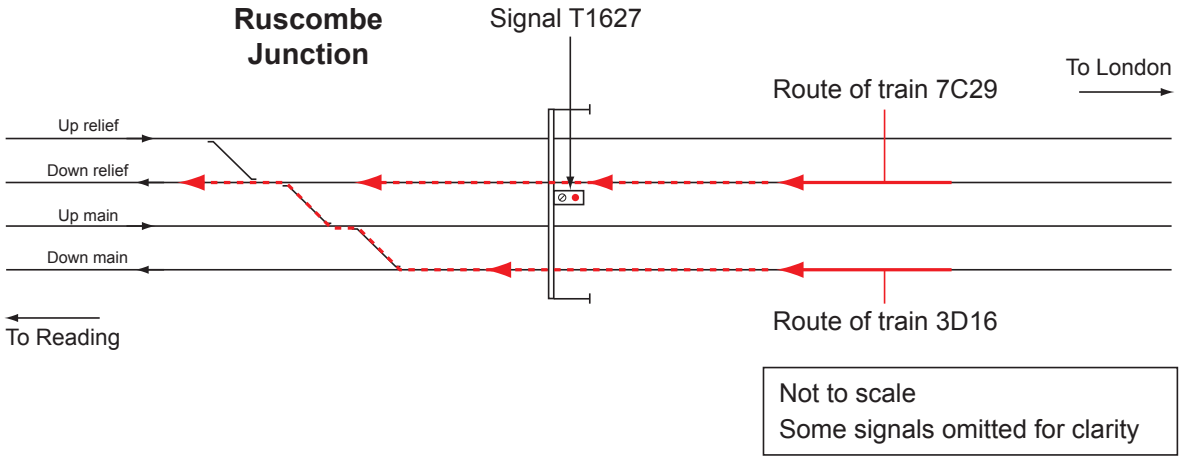

Figure 5: Simplified track layout showing the location of signal T1627

Trains involved

14 On 28 March 2015, train 7C29 was formed of a class 66 locomotive (66184) and 38 empty wagons, with a trailing weight of 907 tonnes. The composition of the train meant that its maximum permitted speed was 45 mph (72 km/h), although the permissible speed at signal T1729 was 40 mph (64 km/h) (paragraph 7).

15 On 3 November 2015, train 7C29 was formed of a class 59 locomotive (59205) and 34 empty wagons, with a trailing weight of 811 tonnes. The maximum permitted speed for the train was 45 mph (72 km/h).

16 In neither case was any fault found nor allegation made against the functioning of the train.

Rail equipment/systems involved

17 T1729 is controlled from the Reading workstation at Thames Valley Signalling Centre (TVSC). The signal is fitted with *train protection and warning system* (TPWS) equipment, and has an *overlap* of 132 metres.

18 T1627 is controlled from the Twyford workstation at TVSC. The signal is fitted with TPWS and has a 180-metre overlap.

19 No faults were found or allegations made regarding the functioning of the signalling equipment in either case.

Staff involved

20 The driver of the train on 28 March 2015 (referred to as 'Driver A' in this report) was 52 years of age at the time of the incident and was based at DB's Westbury depot. He had been working on the railway for 35 years, the last 23 of which were in his current grade as a driver.

21 Driver A frequently drove the route between Acton and Westbury, and was last re-certified as competent on 6 March 2014. His most recent assessment was through a review of his journey on the *on-train data recorder* (OTDR) on 24 October 2014 which he passed.

22 He had been involved in three previous signal passed at danger (SPAD) incidents, on 24 March 1998, 8 January 2001 and 4 May 2002. The circumstances of these incidents were unrelated to the SPAD on 28 March 2015.

23 For about a month prior to the incident, Driver A had been suffering from ill health and was on a range of medications. None of these medications affected his ability to drive trains.

24 The driver of the train on 3 November 2015 (referred to as 'Driver B' in this report) was aged 45 at the time of the incident and had been working as a train driver for 23 years, for all of which he was based at Westbury depot.

25 His last re-certification as a driver was on 3 February 2014 and he had a performance assessment by reviewing his journey on the OTDR on 7 September 2015; both of these assessments were passed satisfactorily. He had most recently driven the route on the day before the incident.

26 Driver B had had one other safety incident in his career, which was a fatigue-related SPAD at East Somerset Junction on 8 February 2006. He was also placed on an action plan on 17 October 2011 to address issues with late attendance at work due to problems he had been having with waking up. However, he was not on any kind of plan at the time of the incident on 3 November 2015.

27 He exhibited some of the risk factors for *sleep apnoea*, but had not been formally assessed for this condition by the company's occupational physician and, based on the physician's medical assessment, was deemed fit to carry out his duties by his manager.

External circumstances

28 The incident on 28 March 2015 took place during daylight (sunrise was at 05:47 hrs that day); weather records in the area indicated cloudy conditions with 10 km visibility at the time.

29 The incident on 3 November 2015 took place 47 minutes before sunrise and weather records indicated a light haze (5 km visibility).

30 Whilst the weather conditions are not considered to have been a factor in the incidents, the lighting conditions and especially the time of day probably had an impact on the drivers' fatigue state (see paragraph 54).

The sequence of events

T1729 SPAD on 28 March 2015

Events preceding the incident

31 Driver A's first shift of the week began at 03:29 hrs on 23 March 2015 and then he mostly worked early morning shifts up to and including the shift on 28 March. His shift start times gradually moved earlier as the week progressed (on 27 March he started at 02:00 hrs), and these shifts ranged in duration from 6 hours and 49 minutes to 10 hours and 22 minutes. The exception was on 24 March, when he attended a briefing in Reading from 07:00 hrs to 14:00 hrs.

32 His health issues (paragraph 23) affected his sleep patterns and, after the incident, Driver A reported having had trouble getting sufficient rest (typically managing about four hours' sleep each day) and difficulty coping with the early starts. Consequently, the duration of his last sleep before the incident was around three hours.

33 On 28 March, Driver A's shift began at 00:48 hrs. He drove train 6A71, the 01:05 hrs from Westbury to Acton, arriving at 03:17 hrs. The journey to Acton was uneventful although after the incident, the driver did report that he had felt tired during this time.

34 He was due to take train 7C29 back from Acton to Westbury at 08:25 hrs. While he was waiting, Driver A tried to sleep in a designated rest facility at Acton train crew depot but was unsuccessful because it was too noisy.

35 At 06:25 hrs, Driver A was asked to begin preparing his train for the return journey and he departed Acton at 07:29 hrs. He reported after the incident that he had felt tired on departure (though he also said that this was no more tired than could be expected at that time of day) and felt progressively worse during the journey.

36 The journey from Acton was mostly under green signals until approaching Reading at around 08:15 hrs, when Driver A slowed the train for a sequence of cautionary signals approaching signal T1729 which was at danger.

Events during the incident

37 At 08:22 hrs, train 7C29 passed the *automatic warning system* (AWS) magnet for signal T1729 at 18 mph (29 km/h). Driver A shut off power on hearing the AWS warning horn and immediately operated the emergency brake. However, the train passed signal T1729 at danger by 24 metres, which also triggered a TPWS brake activation.

Events following the incident

38 The signaller made an urgent call to Driver A using the GSM-R radio system. Driver A told the signaller that he had momentarily fallen asleep and that he was exhausted after having worked long shifts all week. He considered himself unfit to continue as he was too tired.

39 Signal T1727 (paragraph 8) was replaced to danger before train 2K32 reached it. However, the driver of train 2K32 had already seen the SPAD occur and stopped his train.

40 The driver was taken back to Westbury by car to be tested for the presence of drugs and alcohol, the results of which were negative. Due to the non-availability of appropriate supervisors, this process was delayed and the driver was finally allowed to return home at around 17:00 hrs.

T1627 SPAD on 3 November 2015

Events preceding the incident

41 Driver B had worked night shifts from 26 to 29 October 2015, finishing in the early hours of 30 October. His roster then involved providing spare cover for the night of 30 October (although he was not needed) and a rest day on 31 October. His next scheduled shift began at 23:15 hrs on 1 November.

42 Driver B stated that he slept for around four hours on the night of 31 October, waking up at around 09:30 hrs on 1 November. Although he planned to sleep for a few more hours later in the day before going to work that evening, he was unable to get more than about another 20 minutes' sleep.

43 A similar pattern occurred on 2 November after arriving home from his shift at around 06:00 hrs. Driver B slept for about four hours, waking some time between 11:00 hrs and 13:30 hrs. Although he had again planned to obtain more sleep later in the day, he was once more unable to do so.

44 On the evening of 2 November, Driver B's shift began at 23:51 hrs. He drove train 7A91, the 00:03 hrs from Westbury to Acton, scheduled to arrive at 02:55 hrs (3 November). Driver B later stated that he did not feel tired when starting work or on the journey to Acton.

45 He was due to take train 7C29 back from Acton to Westbury at 06:22 hrs. Driver B later reported that the rest facility was occupied during the time that he spent waiting at Acton depot, and that he only obtained limited rest using the other train crew rooms.

46 At about 04:55 hrs, Driver B was asked to prepare his train. He thought it was unusual to leave early and anticipated waiting in his cab for a signal to depart from the yard, which he believed would present an opportunity for a nap. However, the signal was cleared shortly after the train arrived at it and the train departed from Acton at 05:30 hrs.

47 The journey from Acton was uneventful until 05:43 hrs when the train stopped at a red signal at Hayes & Harlington, passing the AWS magnet for the signal at 22 mph (35 km/h). After this, Driver B stated that he started feeling drowsy in the vicinity of Slough, and at 05:54 hrs he braked hard as a late reaction to another set of cautionary signals, consequently stopping considerably short of a red signal at Slough.

Events during the incident

48 On the approach to Ruscombe Junction, train 7C29 encountered signals T1623 at single yellow and T1627 at danger. Driver B cancelled the AWS warnings for both of these signals and applied full service brake after receiving the AWS warning for signal T1627, having passed the AWS magnet at 36 mph (58 km/h).

49 At 06:11 hrs, train 7C29 passed signal T1627 at danger by 164 metres. The train's TPWS made an emergency brake intervention on passing the signal.

Events following the incident

50 Signal T1625 on the Down Main line, which was clear for the passage of an empty HST (paragraph 10), reverted to red when the SPAD occurred. The HST stopped at the red signal.

51 Shortly after train 7C29 stopped, the signaller contacted Driver B using the GSM-R radio system to confirm that he had stopped. At 07:09 hrs, Driver B received further instructions to take the train forward into a nearby loop.

52 Driver B was taken back to Westbury by car at around 11:00 hrs for drugs and alcohol testing (which proved negative), and he returned home at around 12:20 hrs.

Key facts and analysis

Background information

RAIB's investigation

53 The incident at Reading Westbury Line Junction on 28 March 2015 was reviewed by the RAIB, as it had been noted during RAIB's weekly review of national incidents. However, on its own the incident did not meet the normal criteria for a RAIB investigation. When the incident at Ruscombe Junction occurred on 3 November 2015, the RAIB was prompted by the similarities between the two incidents to launch an investigation.

Fatigue

54 The Office of Rail and Road (ORR) defines fatigue as 'a state of perceived weariness that can result from prolonged working, heavy workload, insufficient rest and inadequate sleep' (ORR, 2012). Fatigue results from a combination of the amount of time spent asleep (most people require seven to eight hours of sleep each night), the time since waking up (alertness is significantly reduced after 14 hours of being continuously awake), and the time of day (ie circadian rhythm, or the internal body clock)[2]. The body clock responds to light exposure, while alertness is particularly low in the early hours of the morning, from 02:00 hrs to 06:00 hrs (known as the 'window of circadian low').

55 Fatigue can cause impaired decision-making, degraded task performance, and an increased risk of errors and accidents[3]. Consequently, safety-critical work involving shift work, such as that carried out by railway workers, is at risk of fatigue-related incidents. In a previous investigation into a derailment at Brentingby Junction, RAIB found fatigue to be a precursor in 28% of freight train SPAD incidents (RAIB report 01/2007). More recently, a RSSB[4] research report (RSSB, 2015) identified fatigue as a factor in 21% of incidents (most of which were SPAD incidents).

56 In order to control this risk, regulation 25 of the Railways and Other Guided Transport Systems (Safety) Regulations (2006) states that 'every controller of safety critical work shall have in place arrangements to ensure, so far as is reasonably practicable, that a safety critical worker under his management, supervision or control does not carry out safety critical work in circumstances where he is so fatigued or where he would be liable to become so fatigued that his health or safety or the health or safety of other persons on a transport system could be significantly affected'. Fatigue has also been identified as one of 12 risk priority areas in the industry's recently published health and safety strategy (RSSB, 2016).

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[2] Ingre M, Van Leeuwen W, Klemets T et al. (2014). 'Validating and extending the three process model of alertness in airline operations.' PLoS ONE, 9(10), e108679.

[3] Raslear TG, Gertler J and DiFiore, A. (2013). 'Work schedules, sleep, fatigue, and accidents in the US railroad industry.' Fatigue: Biomedicine, Health & Behavior, 1(1-2), 99-115.

[4] RSSB is a not-for-profit company owned and funded by major stakeholders in the railway industry, and which provides support and facilitation for a wide range of cross-industry activities. The company is registered as 'Rail Safety and Standards Board', but trades as 'RSSB'.

57 Comprehensive guidance is available from both ORR (ORR, 2012) and RSSB (RSSB, 2012) on managing fatigue. Of particular relevance here is the guidance on night shifts, which is more restrictive due to the increased risk of errors being made at night. As such, the guidance suggests reducing the maximum shift duration to eight hours (for shifts starting before 05:00 hrs), reducing the maximum number of consecutive night shifts to three, and increasing the minimum rest period between night shifts to 14 hours. The guidance also recommends that where shift start times vary, this should be in a forward (clockwise) rotation (ie subsequent shifts should not start earlier than previous shifts). Such guidance reflects good practice in other industries.

58 The ORR and RSSB documents go further in describing the elements of a fatigue risk management system (FRMS), embedding a culture of fatigue management within the company's policies, training, monitoring and reporting (including consulting with staff as to whether they find the shift patterns fatiguing). The guidance emphasises the importance of both work-related and non-work-related fatigue, as well as the responsibilities of both employer and employee in managing fitness for work relating to fatigue.

Identification of the immediate cause

59 **Both SPAD incidents occurred because the drivers were too fatigued to properly control their trains.**

60 Both drivers stated that they momentarily fell asleep on the approach to the red signals.

Identification of causal factors

61 Both SPAD incidents occurred due to a combination of the following causal factors:

a. the drivers were not sufficiently rested (paragraph 62);

b. the drivers were nearing the end of a long night shift (paragraph 73); and

c. the drivers did not report as unfit for duty (paragraph 77).

Each of these factors is now considered in turn.

The drivers' rest

62 **The drivers were not sufficiently rested.**

63 Both drivers were sleep deprived in the days prior to each incident and were unable to obtain any additional rest while waiting at Acton train crew depot.

64 This causal factor arose due to a combination of the following:

a. the drivers had not had sufficient sleep (paragraph 65); and

b. the rest facilities at Acton train crew depot were not fit for purpose (paragraph 68).

Each of these factors is now considered in turn.

The drivers' sleep patterns

65 The drivers had not had sufficient sleep.

66 Driver A only managed about three to four hours of sleep before the incident and had experienced difficulty sleeping in the weeks prior to the incident due to ill health. Driver B had about four hours' sleep in each of the two days before the incident because he was attending to domestic issues, and because his plans to split his sleep through the day did not succeed.

67 Although in these cases the drivers' sleep had been curtailed for specific, personal reasons, it is not unusual for workers on night shifts to experience sleep problems. RSSB's guidance on fatigue (RSSB, 2012) cites research that finds the daytime sleep of night workers to be one-third shorter and of poorer quality than when they sleep at night and are awake during the day. Meanwhile, other published research suggests that the performance of individuals is likely to be impaired if they obtain less than five hours' sleep in the previous 24 hours and less than 12 hours' sleep in the previous 48 hours, and if they are awake for longer than the duration of sleep in the previous 48 hours[5].

Rest facilities at DB's Acton train crew depot

68 The rest facilities at Acton train crew depot were not fit for purpose.

69 Although both drivers stated that they had tried to get additional rest during the scheduled layover at Acton train crew depot (paragraphs 34 and 45), neither driver was able to do so because the rest facilities were not fit for purpose.

70 Recent industry guidance[6] highlights that napping is a useful countermeasure for fatigue (although the guidance also importantly notes that napping should not be relied upon in order to control the risks from fatigue; drivers should ideally be well rested and fit for duty at the start of, and throughout, their shift). Research also shows that there is a clear benefit of napping for relieving fatigue and improving performance[7]. Therefore, napping can be used as a mitigation for fatigue risk if necessary.

71 DB has no formal policy on napping but considers it permissible where work scheduling permits. Following the RAIB's investigation into a fatigue-related incident at Shap in 2010 (RAIB report 15/2011), rest facilities intended for napping were set up as part of the train crew facilities at many of the company's depots.

72 Evidence gathered during the current investigation found widespread dissatisfaction with the standard of the drivers' facilities at Acton train crew depot relative to equivalent facilities at other depots. The RAIB's inspection confirmed that the designated rest facility at Acton was not conducive to napping because of the amount of noise, its location (being on a through route between other rooms), and the unsuitability of the furniture for napping (see figure 6).

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[5] Dawson, D. and McCulloch, K. (2005). 'Managing fatigue: It's about sleep.' Sleep Medicine Reviews, 9, 365-380.

[6] RSSB (2016). Guidance on fatigue control options for first night shifts.

[7] Driskell, J. E. and Mullen, B. (2005). 'The efficacy of naps as a fatigue countermeasure: A meta-analytic integration.' Human Factors, 47(2), 360-377.

Figure 6: The rest facility at Acton train crew depot

Shift patterns

73 The drivers were nearing the end of a long night shift.

74 The shifts being worked by both drivers when the incidents occurred involved starting in the middle of the night (00:48 hrs for Driver A and 23:51 hrs for Driver B) and working a relatively long shift (10 hours and 57 minutes for Driver A; 9 hours and 38 minutes for Driver B). Driver A was working a sixth consecutive shift, five of which were similar night duties (paragraph 31).

75 Good practice guidance on shift duration for night duties (paragraph 57) suggests that these shift patterns are likely to cause fatigue. Both drivers' rosters fell outside the guidance in respect of maximum duration for a night shift, minimum rest period between night shifts and clockwise rotation of shift start times.

76 Driver B had been awake for approximately 19 hours at the time the SPAD occurred on 3 November 2015. RSSB's guidance on fatigue (RSSB, 2012). states that after 17 continuous hours awake, car drivers perform as if they had a blood alcohol concentration in excess of the legal UK railway limit.

Fitness for duty reporting

77 The drivers did not report as unfit for duty.

78 DB drivers book on for duty by telephone, which precludes a face-to-face fitness for duty check. DB instead has a process for drivers to report by telephone to their control office if they feel unfit for duty (for any reason, including fatigue). However, evidence from witnesses and records in DB's incident reporting system suggests that fatigue is under-reported in the company, with relatively few fatigue reports recorded on the DB incident reporting system.

79 The reasons for non-reporting are varied. Some drivers are reluctant to cause trains to be cancelled or are aware of the impact on colleagues who have to cover their duties. Others are simply unaware of the process or believe that fatigue is not a legitimate reason to be excused from work; tiredness is seen as the norm on some shifts (due to lack of sleep; paragraph 67). Fatigue is difficult to assess both in oneself and in others[8], so it is possible that some drivers do not report because they do not appreciate the extent to which their performance may be affected.

[8] Martindale, V.E. (2012). Breathalyzer for fatigue: the "Fatigualyzer". 'Aviation, Space, and Environmental Medicine, 83'(1), 70-71.

80 The RAIB also found a perception among some drivers that management are not sympathetic to drivers being fatigued and that controllers might pressurise drivers into continuing working in order to meet operational demands. Driver A stated that he experienced such pressure concerning a turn of duty in September 2015. While such a view may influence a driver's decision to report fatigue, the investigation found no firm evidence to validate these perceptions. Duty managers told the RAIB that fatigue is indeed seen as a safety issue and any drivers reporting fatigue are relieved of duty. The RAIB has seen evidence that this process has been duly followed on at least three occasions since the incident on 3 November 2015.

Identification of underlying factors

Local management at Westbury depot

81 **Insufficient supervision and management at Westbury depot probably led to the depot's poor SPAD performance and lack of fatigue reporting.**

82 Westbury depot has suffered from performance issues in recent years, with an increase in SPAD incidents in 2014 and 2015 compared to the years 2007-2013. In 2015 there were six SPAD incidents involving Westbury drivers (including the two covered in this investigation), representing some 15% of SPAD incidents across the company, even though the proportion of Westbury drivers in DB is less than 4%.

83 This decline in performance coincided with a period of high management turnover at Westbury and, for several years, an absence of qualified driver managers. Consequently, according to witness evidence, drivers have not felt willing or able to discuss issues such as fatigue with their local management (although there is no evidence to suggest fatigue reporting at Westbury differs from the rest of the company, because reporting rates are so low; paragraph 78).

84 Driver resources have also been an issue at Westbury depot. As of February 2016, there were 45 drivers at the depot (five of whom were on restricted duties at the time of the incident, which may include exemption from night shifts), which was six short of the required establishment. Although there was no evidence that the proportion of night shifts (compared to day shifts) worked at Westbury was any higher than the rest of the company, the pressure on driver resources increased overtime and reduced spare cover. Witness evidence confirms that drivers at Westbury routinely worked a lot of overtime, and this was seen to contribute to the poor SPAD performance at the depot.

Fatigue management at DB

85 **Fatigue management at DB was not adequate to control the associated risks.**

86 DB's processes for managing fatigue are distributed across a number of documents, including its safety management system, SPAD prevention policy, and a draft FRMS standard. The company also has a policy statement on fatigue endorsed by its Chief Executive. However, this investigation has identified a number of areas in which DB's fatigue management could be improved.

Shift planning

87 Although the industry's good practice guidance emphasises an integrated approach to managing fatigue, going beyond simple limits on working time (paragraph 58), DB still relies heavily on working hours rules as a primary fatigue control. These rules are in accordance with trade union agreements and are used by shift planning staff in designing rosters.

88 However, designing shifts according to basic time-limit rules can still produce rosters that are fatiguing or that are not in line with good practice. Due to the nature of freight operations, approximately 40% of DB's train driving shifts are at night. Nevertheless, DB's roster rules do not discriminate between day and night shifts, despite good practice guidance recommending that night shifts should be shorter. Although night shifts at DB are, on average, shorter than day shifts, average shift length at Westbury was longer than the company average for both day and night shifts, while around 20% of night shifts at Westbury depot are longer than the 10 hours recommended in industry guidance. The shifts involving train 7C29 (the service involved in the two SPAD incidents in this investigation) are amongst these longer night shifts.

89 Consecutive long night shifts are generally disliked by drivers, but working these shifts also means that drivers periodically have a block week of rest days. A move to a more optimal roster (such as four days on, three days off), would also mean shorter blocks of rest days, which can be less attractive to drivers. The train drivers' union, ASLEF (which represents the majority of DB drivers), supports the principle of reducing fatigue through roster design and has been working with DB management as well as its members to introduce a maximum five-day working week at some depots.

90 Roster design at DB is also still heavily influenced by the *fatigue and risk index* (FRI), with both roster planning and company investigations being guided by indicative threshold scores for fatigue in the FRI. This is despite the fact that the utility of the FRI was called into question in a previous RAIB investigation (RAIB report 15/2011) and the use of such tools is qualified with caveats in the ORR's fatigue guidance (ORR, 2012). In particular, the ORR's position is that users should carefully consider what the FRI values actually mean, rather than assuming that the tool provides an authoritative decision as to whether a roster is acceptable or not. The ORR does not recognise these as safe thresholds and strongly advises that they should be treated with caution.

Briefing

91 DB's safety management system recognises the importance of safety briefings and specifies a twice-yearly 'Business and Safety Communication Day', which provides employees with information about a safety topic as well as company performance. However, witness evidence gathered from a small sample of Westbury drivers in this investigation suggests that they perceive the focus of the briefing to be on company performance rather than safety. DB has stated that these briefing days include information on commercial aspects because many employees have requested such information in company surveys.

92 Other than the Business and Safety Communication Day, and other specific briefings (eg for changes in procedures), safety information (including information about fatigue management) is distributed in a largely passive manner through posters, magazines, drivers' tablet computers, or the company intranet. These media depend on drivers seeking out and digesting the information for themselves. Witnesses stated that there have not been dedicated safety briefings for a number of years at Westbury and there has been little information for drivers on managing their own fatigue.

Monitoring

93 DB produces weekly working time reports to monitor the 17-week rolling averages of its drivers and ground staff[9]. Those who are in excess of a 45-hour per week average for three consecutive weeks are entered onto a fatigue risk register in order to control subsequent overtime or rest day working. However, this monitoring is entirely retrospective; there is little proactive monitoring, or use of controls, to prevent staff working excessive hours in the first place.

94 The RAIB has reviewed the working time reports in the weeks leading up to the two SPAD incidents for this investigation. Although the drivers involved were not on the fatigue risk register at the time of their respective incidents, both were close to DB's 45-hour per week threshold. Besides these drivers, the weekly average for Westbury drivers was consistently high and, relative to other depots, there was a notable number of drivers exceeding the threshold. This is consistent with the evidence that Westbury drivers routinely work a lot of hours (paragraph 84).

Fatigue risk management standard

95 Following the RAIB's investigation into a fatigue-related incident at Shap in 2010 (RAIB report 15/2011), DB convened a fatigue risk management working group in April 2012 with the aim of identifying good practice to input into its own FRMS as well as resources for the company intranet. The group is formed of senior management, local managers and trade union representatives. There is also a separate working group to review rostering practices involving DB and ASLEF representatives.

96 However, from the RAIB's review of meeting minutes and attendance at one of the working group meetings, it is clear that the momentum of these working groups has waned and management attendance at meetings has been poor. Consequently, although DB originally anticipated that its FRMS standard would be implemented in 2012, its latest estimate for publication is autumn 2016. Part of the reason for this is to await the outcome of three RSSB research projects (also in response to recommendations from the Shap investigation) on biomathematical fatigue models, fitness for duty checks and fatigue risk associated with first night shifts, which will inform the company standard.

97 RAIB has reviewed DB's draft fatigue standard and considers it to be an advance on current fatigue management practices within the company. It is comparable with similar policies from other freight operators (where such policies exist) but there remain areas of potential improvement with respect to the latest good practice in this area.

[9] Ground staff are those responsible for shunting and train preparation. Their working time is monitored as such work is deemed to be safety-critical.

Previous occurrences of a similar character

98 The RAIB has reviewed the other four SPAD incidents involving Westbury drivers in 2015 (paragraph 82). In two of these, risk factors for fatigue were present (eg multiple consecutive night shifts, long night shifts, short sleep duration), although ultimately the company investigation reports attributed the incidents to factors other than fatigue.

99 However, one of these incidents, at Southcote Junction, near Reading, on 1 August 2015, was directly attributable to fatigue. At 01:33 hrs, train 6A71 passed signal T2812 at danger because the driver momentarily fell asleep. The incident occurred on the driver's sixth consecutive night shift, which started at 18:55 hrs on 31 July 2015. This was around 5.5 hours earlier than planned due to short staffing. Although he had finished his previous shift early to allow for this, it meant that he only just achieved the requisite 12-hour rest between shifts, during which he managed about five hours' sleep. In total, he had worked more than 47 hours during the week.

100 DB's investigation report for the Ruscombe Junction SPAD on 3 November 2015 specifically highlighted the similarities between that incident and those at Southcote Junction and Reading Westbury Line Junction. The report went on to review the remaining three SPAD incidents involving Westbury drivers in the same year, and concluded that the drivers' shift patterns were potentially causal in two of them.

Summary of conclusions

Immediate cause

101 Both SPAD incidents occurred because the drivers were too fatigued to properly control their trains (paragraph 59).

Causal factors

102 The causal factors were:

a. The drivers were not sufficiently rested (paragraph 62). This causal factor arose due to a combination of the following:

   i. The drivers had not had sufficient sleep (paragraph 65, **Learning point 1**);

   ii. The rest facilities at Acton train crew depot were not fit for purpose (paragraph 68, **Learning point 2**).

b. The drivers were nearing the end of a long night shift (paragraph 73, **Recommendation 1**).

c. The drivers did not report as unfit for duty (paragraph 77, **Learning point 1**).

Underlying factors

103 The underlying factors were:

a. Insufficient supervision and management at Westbury depot probably led to the depot's poor SPAD performance and lack of fatigue reporting (paragraph 81, see paragraph 128).

b. Fatigue management at DB was not adequate to control the associated risks (paragraph 85, **Recommendations 2 and 3**).

Previous RAIB recommendations relevant to this investigation

104 The following recommendations, which were made by the RAIB as a result of its previous investigations, have relevance to this investigation.

Previous recommendations that had the potential to address one or more factors identified in this report

Accident at Brentingby Junction, near Melton Mowbray, 9 February 2006, RAIB report 01/2007, Recommendation 4

105 **The RAIB considers that more effective implementation of recommendation 4 in report 01/2007 would have resulted in a medical surveillance regime capable of identifying the sleep disorder that affected Driver B (see paragraph 129).**

106 This recommendation reads as follows:

Recommendation 4

The RSSB should investigate and if reasonably practicable instigate a change to Railway Group Standard GO/RT3251 so that screening for sleep disorders is required as part of the system of regular medical surveillance applied to train drivers and following incidents/accidents where fatigue has been identified as a possible causal or contributory factor.

107 RSSB responded that the Railway Group Standard concerned was in the process of being withdrawn as part of a strategy to reduce the number of standards. Since medical surveillance of drivers is wholly a concern for duty holders, it is out of scope for Railway Group Standards. RSSB proposed to draw this issue to the attention of train operators and the infrastructure controller.

108 The ORR considered this recommendation to be implemented as of 30 April 2008.

109 The RAIB notes the rationale for the response from RSSB on this recommendation, but considers that the intent of the recommendation has consequently been lost to the industry. Whilst there is detailed information on sleep apnoea and its relevance to fitness for work in a separate rail industry guidance note[10] as well as in the RSSB guidance on fatigue, the RAIB found no reference to screening for sleep disorders in the DB company standards and investigation reports reviewed for this investigation. Given that Driver B exhibited risk factors for sleep apnoea (paragraph 27) and was subsequently diagnosed with this condition (see paragraph 129), earlier detection of this sleep disorder could have prevented the incident on 3 November 2015.

[10] GO/GN3655 'Guidance on Medical Fitness for Railway Safety Critical Workers' (Issue 2, June 2014); specifically Appendix G.

Incident between Shap and Tebay, Cumbria, 17 August 2010, RAIB report 15/2011, Recommendation 1

110 **The RAIB considers that more effective implementation of recommendation 1 in RAIB report 15/2011 could have addressed the factor associated with shift work that led to this accident.**

111 This recommendation read as follows:

Recommendation 1

DB Schenker should, in consultation with its drivers:

a. identify the shifts on which their drivers experience high levels of fatigue, and give particular consideration to the impact on drivers working the first in a series of night shifts;

b. improve the identified shifts, for example by changing the transition to them, their duration and the duties carried out on them, with shifts of the highest risk improved ahead of those of lower risk;

c. assess the findings of drivers on the changed shifts to confirm that those shifts are improved; and

d. share its findings with the Office of Rail Regulation.

112 In its response, DB stressed that the outcome of recommendation 3 in the same investigation report (see paragraph 115) would be crucial in implementing recommendation 1. In the meantime, the company stated that it would continue to use the FRI in its assessment of rosters, to monitor working hours and to inform drivers about the importance of fitness for duty. DB also reported on its activity to convene a fatigue risk management working group and set out its intentions to develop and implement a fatigue risk management standard (paragraph 95).

113 On 11 August 2015, the ORR informed RAIB that it considered DB's actions to have implemented the recommendation.

114 The present investigation found that the night shifts worked by both drivers were likely to have caused fatigue (paragraph 73). RAIB expects that work to identify shifts on which drivers experience fatigue, such as that in response to recommendation 1 of RAIB report 15/2011, should have addressed these shifts, particularly if DB had fully taken into account the feedback from its drivers. RAIB also notes that the DB fatigue risk management standard is yet to be published.

Recommendations that are currently being implemented

Incident between Shap and Tebay, Cumbria, 17 August 2010, RAIB report 15/2011, Recommendation 3

Recommendation 3

The Office of Rail Regulation should arrange for a programme of work to analyse and compare existing mathematical models used to predict fatigue, including the Fatigue and Risk Index, and then provide information to the rail industry on the accuracy of those models.

115 The above recommendation partly addressed the underlying factor of fatigue management identified in this investigation (paragraph 90). So as to avoid duplication, it is not remade in this report.

116 The ORR submitted a research proposal to RSSB and, in response, RSSB commissioned research to understand the relative merits of various fatigue assessment tools that use mathematical models, and to provide guidance to the rail industry on the use of those tools. The project is due to deliver a report in September 2016.

117 The ORR reported on 11 August 2015 that implementation of this recommendation was ongoing.

118 RAIB anticipates that the outcome of RSSB's research, coupled with any subsequent guidance from RSSB or ORR, has the potential to improve fatigue management in the rail industry by promoting more appropriate use of mathematical models and raising awareness of their respective benefits and limitations.

Other recommendations with relevance to this investigation

Accident at Brentingby Junction, near Melton Mowbray, 9 February 2006, RAIB report 01/2007, Recommendations 1 and 2

119 **The RAIB considers that more effective implementation of recommendations 1 and 2 in RAIB report 01/2007 could have addressed the drivers' lack of sleep which was a factor in these SPAD incidents.**

120 These recommendations read as follows:

Recommendation 1

EWS[11] *should include napping within its fatigue management system and implement it as a fatigue counter-measure if the assessed risk of fatigue indicates that it is necessary.*

Recommendation 2

If the assessed risk of fatigue requires napping as a fatigue counter-measure, EWS should provide facilities so that naps may be taken at locations where drivers take breaks and build sufficient time into rosters for taking naps and recovery afterwards.

121 In its formal response to these recommendations, the company indicated that although it considers it is acceptable for drivers to take an occasional short nap, fatigue is primarily managed through the rosters and drivers are provided with lifestyle information emphasising the importance of proper preparation for duty. As such, including napping within the fatigue management system, and the provision of facilities for such, was seen to be unnecessary. Nevertheless, DB told RAIB during the current investigation that although it has no formal policy in this regard, napping is permissible and rest facilities are provided for this purpose (paragraph 71).

122 The ORR accepted the industry's response to these recommendations and considered it to be implemented as of 28 July 2009.

[11] EWS subsequently became DB Schenker Rail (UK) and then DB Cargo (UK) Ltd.

123 Although DB's current position largely meets the requirements of these recommendations, RAIB notes that the facilities provided for napping at Acton depot were not fit for purpose (paragraph 68).

Incident at Llandovery, Carmarthenshire, 6 June 2013, RAIB report 11/2014, Recommendation 4

124 Although not directly applicable to the current investigation, the above recommendation has resulted in actions that have the potential to address the factors associated with fatigue management identified in this investigation (paragraph 85). RAIB is not remaking such a recommendation in this report, but the recommendation and the resulting actions are summarised here to promulgate wider learning.

Recommendation 4

Arriva Trains Wales should conduct a review of its operational risk management arrangements in the light of the findings from this investigation, and make improvements in accordance with the findings of the review. The scope of the review should include:

…

e. the guidance issued by ORR and RSSB about fatigue management, in particular sleep risk assessments when booking-on duty, and a culture of trust and openness in fatigue management

…

125 As part of its response to subsection (e) of this recommendation, Arriva Trains Wales has engaged with Cardiff University to develop new objective measures of fatigue in train crew, for application in its rostering software. The proposed research includes diary studies and simulator trials using mobile applications, eye-tracking, wearable technology and OTDR information to measure fatigue.

126 ORR determined that the recommendation had been implemented on 17 April 2015, based on an earlier response from Arriva Trains Wales. The proposed research is further to the company's original response.

127 From the information supplied by Arriva Trains Wales, RAIB considers that this research has the potential to advance both fatigue science and fatigue management within the rail industry. Although it is a long-term project, its findings could be of direct relevance to the current investigation and applied more widely across the industry.

Actions reported as already taken or in progress relevant to this report

Actions reported that address factors which otherwise would have resulted in a RAIB recommendation

128 DB has reorganised the management structure at Westbury, providing the depot with a clearer management chain both in terms of safety assurance and driver line management. Although these roles are still in a transitional period, initial reports are that the changes have had a positive impact on both staff morale and depot performance.

Other reported actions

129 Both drivers were given development plans involving additional monitoring and assessments. Driver B was disciplined for not preparing for duty. However, since the incident, Driver B has been placed on indefinite sick leave following a diagnosis of sleep apnoea.

130 Since November 2015, if a DB driver reports as unfit for work due to fatigue, this is recorded as a specific 'fatigued worker' instance on the company's incident reporting system, as opposed to a generic absence.

131 DB has moved the train crew facilities at Acton depot, including the designated rest facility, into a refurbished building. The rest facility is now segregated from other rooms such that it is not on a through route between facilities. The refurbished building came into use on 29 May 2016.

132 DB's current cycle of Business and Safety Communication Days focuses on fatigue, including fatigue reporting and the impending roll out of the fatigue risk management standard. There was also a short media campaign on fatigue in the February edition of the company magazine.

Background to the RAIB's recommendations

133 Although the remit of the current investigation has focused on two specific SPAD incidents involving trains operated by DB Cargo (UK) Ltd, there is evidence that the underlying factors associated with fatigue management are present across the rail industry, particularly within the freight sector. The industry's health and safety strategy (RSSB, 2016) identifies several priorities for improvement relating to fatigue that correspond with the findings from this investigation. A review of reports obtained by RAIB from the industry's Confidential Incident Reporting and Analysis System (CIRAS) identified concerns with rostering practices and fatigue reporting. Meanwhile, RSSB research (RSSB, 2010) found similar issues with long night shifts, sleep problems on night shifts, variations in fatigue management and a lack of information and training for employees on fatigue. More recent work by RSSB has shown that many companies' fatigue management systems are still highly dependent on the FRI and out-dated working time limits which are now considered to be insufficiently risk-based, while local practices and working cultures create barriers to reporting fatigue. There is, therefore, justification for making a recommendation on fatigue management more widely to the freight sector.

134 Individual freight services are arguably more susceptible to SPAD risk during the day, because it is assumed that they encounter more red signals as passenger trains take priority on the network. Previous RSSB research has attempted to identify the risk of incidents associated with fatigue (eg RSSB, 2004; RSSB, 2010). Until recently, though, the sources of data in industry have not been sensitive enough to reliably distinguish differences associated with type of service or time of day; this is now possible through research sponsored by RSSB. RAIB has separately analysed DB's SPAD data from 2007 to 2015 in an effort to identify signs of deeper trends associated with fatigue. The analysis showed that a greater than expected number of SPAD incidents occurred when the shift start time was from 04:00 hrs to 08:00 hrs, which overlaps with the window of circadian low (paragraph 54). The statistics showed a similar trend for more SPAD incidents during shifts that began at night, relative to the overall number of night shifts. Furthermore, the RAIB's analysis of the OTDR files from the trains involved in the two incidents investigated here revealed that the drivers' reaction times to AWS warnings were slowest in the moments before the SPAD. Although these analyses were quite superficial, the RAIB believes that there is sufficient evidence to support a recommendation for further analysis in this area (Recommendation 3).

Recommendations and learning points

Recommendations

135 The following recommendations are made[12]:

1 *The intent of this recommendation is to reduce the risk of fatigue arising from the rosters and diagrams worked at Westbury depot.*

DB Cargo (UK) Ltd should review the driver diagrams and rosters at Westbury depot to identify those at highest risk of fatigue and amend the timing, duration and/or operation of these trains in order to reduce the fatigue risk. The review should consider the findings from this investigation, industry good practice, staffing levels and feedback from the company's drivers (paragraph 102b).

continued

[12] Those identified in the recommendations have a general and ongoing obligation to comply with health and safety legislation, and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail and Road (ORR) to enable it to carry out its duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 200 to 203) can be found on RAIB's website www.gov.uk/raib.

2 *The intent of this recommendation is to improve the management of fatigue amongst freight operating companies, in accordance with contemporary research and good practice.*

Freight operating companies should expedite a review of their fatigue risk management systems to ensure that they have sufficient controls (eg policies, company standards) in place which are consistent with published good practice (such as that from ORR and RSSB), including:

- rostering rules and associated staffing levels (such as limits on working hours, overtime and consecutive shifts), especially for night shifts;
- appropriate use of biomathematical fatigue models (such as the FRI);
- training and education on fatigue for safety-critical workers and controllers of safety-critical work;
- fitness for duty checks when booking-on for duty;
- processes for gathering and using feedback, in an open and timely manner, from safety-critical workers on fatigue-inducing shift patterns;
- in consultation with their occupational health advisers, screening and treatment for sleep disorders as part of medical assessments, both routinely and particularly where a worker has been involved in a suspected fatigue-related incident, and requirements on individuals to declare any known sleep disorders to their employer.

(paragraph 103b)

3 *The intent of this recommendation is to improve the industry's understanding of fatigue risk through deeper analysis of available data sources, providing more intelligence on fatigue risk precursors which could feed into fatigue risk management systems (although this should not be a reason to delay the implementation of recommendation 3) and be of benefit to the wider industry.*

DB Cargo (UK) Ltd, in cooperation with other freight operating companies, should submit a research proposal to RSSB with the aim of conducting more detailed analysis on incident patterns using normalised data (eg long shifts, consecutive shifts), revisiting previous research in this area and building on recent advances in SPAD data analysis (paragraph 134).

Learning points

136 The RAIB has identified the following key learning points[13]:

1 Train driving is a safety-critical task and, as such, drivers should be aware of the importance of managing fatigue in preparing for duty, and ensure that they have obtained sufficient sleep before engaging in safety-critical work. Drivers should also be aware of their company's reporting processes in cases where they feel unfit for work due to fatigue, either before or during a shift, or where they are aware of a sleep disorder that could affect their fitness for duty.

2 This investigation highlights the importance of napping as a fatigue mitigation, although its restorative benefits are limited to those staff who are reliably able to nap, and in any case napping should not be relied upon to control fatigue in lieu of preventative measures. Nevertheless, freight operators should ensure that their employees are aware of the role of napping within their wider fatigue risk management systems, including its relative merits as a fatigue countermeasure. In order to maximise the benefits of napping, it is good practice to provide facilities for employees to nap; where such facilities are provided, it is important that they are fit for purpose, minimising light, noise and other disturbances, and providing appropriate furniture to facilitate napping.

[13] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

Appendices

Appendix A - Glossary of abbreviations and acronyms

ASLEF	Associated Society of Locomotive Engineers and Firemen
AWS	Automatic warning system
CIRAS	Confidential Incident Reporting and Analysis System
FRI	Fatigue and risk index
FRMS	Fatigue risk management system
GSM-R	Global system for mobile communications - railway
HST	High speed train
LED	Light emitting diode
ORR	Office of Rail and Road
OTDR	On-train data recorder
SPAD	Signal passed at danger
TPWS	Train protection and warning system
TVSC	Thames Valley Signalling Centre

Appendix B - Glossary of terms

All definitions marked with an asterisk, thus (*), have been taken from Ellis's British Railway Engineering Encyclopaedia © Iain Ellis. www.iainellis.com.

Aspect	The indication of a colour light signal that the driver sees.*
Automatic warning system	A system that provides audible and visual warnings to the driver on the approach to signals.*
Bidirectional	A line on which the signalling allows trains to run in both directions.*
Chain	A unit of length equal to 66 feet or 22 yards. There are 80 chains in one standard mile. Chains are the standard subdivision of miles used in national railway network operations.*
Down	The line normally used by trains travelling away from London.
Fatigue and risk index	A scientifically developed rostering tool that calculates worker fatigue and risk indices based on recorded patterns of working (RSSB definition).
On-train data recorder	A data recorder fitted to traction units collecting information about the performance of the train. This data is recorded to a crash-proof memory and is used to analyse driver performance and train behaviour during normal operations or following an incident or accident.*
Overlap	The distance beyond a signal that is proved clear prior to the signal on the approach to it being cleared.*
Sleep apnoea	A condition which disturbs sleep and increases fatigue caused by intermittently stopping breathing during sleep.
Train protection and warning system	An automatic system intended to reduce the risks arising from trains passing signals at danger and travelling too fast over speed restrictions.
Up	The line normally used by trains travelling towards London.

Appendix C - Investigation details

The RAIB used the following sources of evidence in this investigation:

- information provided by witnesses;
- information provided by other key personnel;
- information taken from the train's on-train data recorder (OTDR);
- information taken from industry incident logs;
- signalling data records;
- recordings of voice communications;
- site observations, photographs and measurements;
- weather reports and observations at the site;
- a review of academic and industry research, standards and guidance;
- a review of industry investigation reports; and
- a review of previous RAIB investigations that had relevance to these incidents.

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