RAIB

Rail Accident Investigation Branch

Rail Accident Report

Derailment of a tram at Bulwell, Nottingham
12 June 2023

Report 02/2024
March 2024

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC
- the Railways and Transport Safety Act 2003
- 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.

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 RAIB has described a factor as being linked to cause and the term is unqualified, this means that RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident or incident that is being investigated. However, where RAIB is less confident about the existence of a factor, or its role in the causation of the accident or incident, RAIB will qualify its findings by use of words such as 'probable' or 'possible', as appropriate. Where there is more than one potential explanation 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 or incident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, words such as '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 accident or incident 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 RAIB, expressed with the sole purpose of improving railway safety.

Any information about casualties is based on figures provided to RAIB from various sources. Considerations of personal privacy may mean that not all of the actual effects of the event are recorded in the report. RAIB recognises that sudden unexpected events can have both short- and long-term consequences for the physical and/or mental health of people who were involved, both directly and indirectly, in what happened.

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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Derailment of a tram at Bulwell, Nottingham 12 June 2023

Contents

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Summary

At around 17:06 hrs on 12 June 2023, a southbound tram, travelling at around 41 km/h (25 mph), approached a set of facing points in an unsafe condition at the north end of Bulwell tram stop in Nottingham. As it travelled over the points, the first and second bogies of the tram were routed in different directions and the tram subsequently derailed.

During the derailment, the tram struck a pole that supported overhead line equipment causing a pane of glass to dislodge and strike a passenger, resulting in minor injuries. The driver of the tram also suffered a minor injury. Significant damage was caused to the tram and infrastructure, with the line reopening on 23 June following extensive repairs.

The set of spring-loaded points were in an unsafe position because they had not reset correctly after the passage of the previous two northbound trams. This can sometimes happen in normal working conditions, but the risk of this happening at the time of the accident had possibly been increased due to the environmental conditions causing the slide plates to be dry or contaminated.

A visual indicator located alongside the points, which was showing that the points were not in the correct position, was not observed by the tram's driver. The driver believed that they would be informed if there were any issues with a set of points but had not been so on this occasion. The driver had probably become conditioned to there being no issues at this location and was also possibly distracted.

RAIB's investigation found that Nottingham Trams Limited did not have an effective policy in place to inform drivers of points failures and had not specifically assessed the risk of a driver incorrectly passing a lineside indicator. RAIB also observed that the process Nottingham Trams Limited used when introducing a new system to the tram fleet had not considered the effect the change may have on its tram drivers.

RAIB has made three recommendations, all addressed to Nottingham Trams Limited. The first recommends a review of control room policy and procedures to ensure that clear and practical guidance is available to manage the response to engineering faults. The second recommendation relates to the improvement of risk assessments in light of this accident. The third recommendation concerns the consideration of human factors when assessing the effects of a proposed engineering change.

RAIB has also identified a learning point to remind tram drivers to not make assumptions about the status of signals or indicators based on their previous experience.

Introduction

Definitions

1 This report uses metric units, with the equivalent imperial value for tram speeds given where appropriate. The report contains abbreviations, explained in appendix A. Sources of evidence used in the investigation are listed in appendix B.

The accident

Summary of the accident

2 At around 17:06 hrs on 12 June 2023, a southbound tram, travelling at around 41 km/h (25 mph), approached a set of facing points which were in an unsafe condition at the north end of Bulwell tram stop in Nottingham (figure 1). As it travelled over the set of points, the first and second bogies of the tram were routed in different directions and the tram derailed.

3 During the derailment, the tram struck and demolished a pole that supported overhead line equipment. This caused a pane of glass to dislodge and strike a passenger, causing minor injuries. The driver of the tram also suffered a minor injury. Significant damage was caused to the tram and infrastructure, with the tram line reopening on 23 June 2023, following extensive repairs.

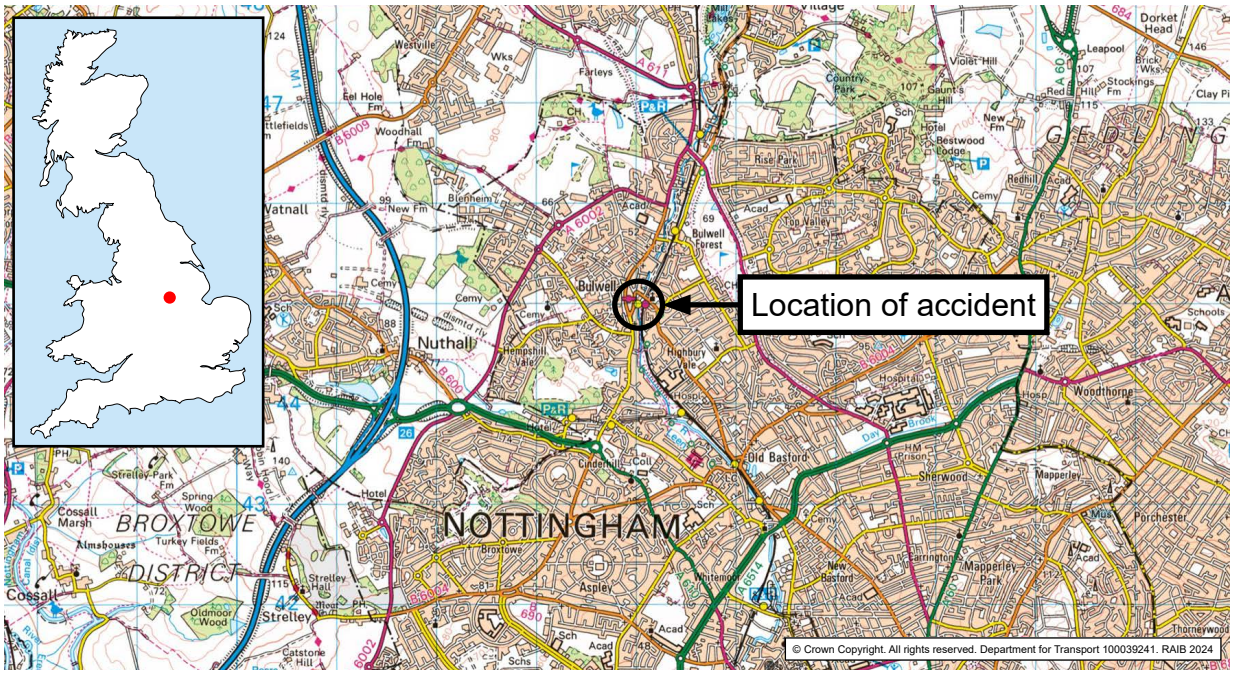

Figure 1: Extract from Ordnance Survey map showing the location of the accident at Bulwell.

Context

Location

4 Nottingham Express Transit (NET) is the tramway system in Nottingham. It operates as two lines, one running between Hucknall and Toton Lane, and the other between Phoenix Park and Clifton South (figure 2). Between Highbury Vale and Sheriff's Way junction, just south of Nottingham Station, the two lines run on the same tracks. The tram maintenance depot is located at Wilkinson Street.

5 Bulwell tram stop is on an off-street section of the route (where the track is wholly separate from the highway) between Hucknall and Wilkinson Street (figure 2). Throughout this section the tramway runs roughly on a north-south axis alongside a main line railway, with the terminus at Hucknall to the north, and Wilkinson Street and the rest of the network to the south.

6 To the north of Bulwell, the tramway runs on a single track, used by trams in both directions, with passing places at each intermediate tram stop (figure 3). The tramway at Bulwell tram stop and further to the south runs on two tracks, one for each direction of travel. The accident occurred at BUP3 points, immediately to the north of Bulwell tram stop, where the single track from the north splits into the two tracks used by the rest of the network. Directly north of BUP3 points, the track passes under Highbury Road overbridge.

7 Bulwell tram stop has an island platform accessed by walkways from a car park to the west. Northbound trams stop to the west of the platform, with southbound trams being directed by BUP3 points to stop to the east of the platform.

Figure 2: Bulwell tram stop in the context of the Nottingham tram system.

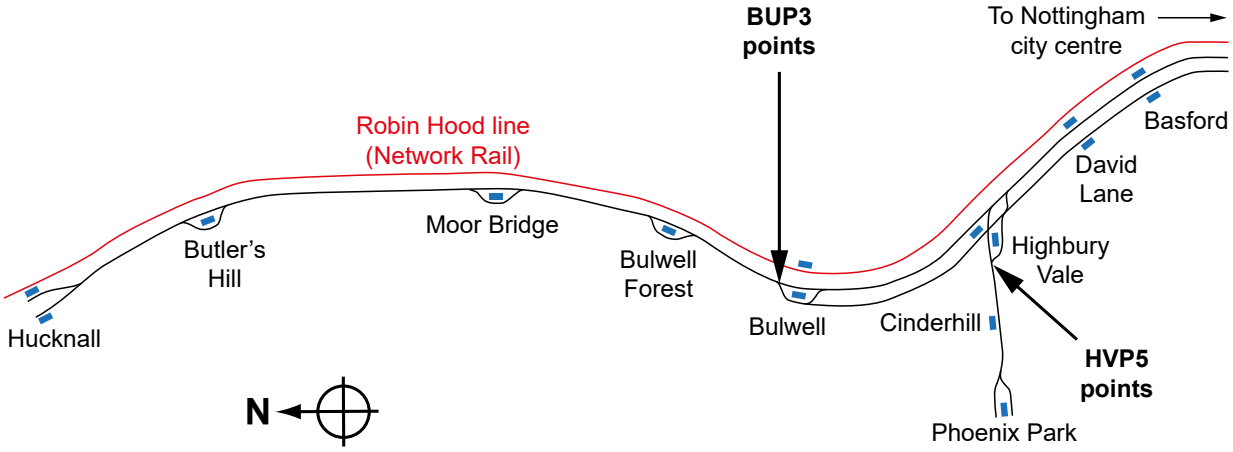

Figure 3: Schematic of the tramway between Hucknall (left) and Bulwell (right).

Organisations involved

8 Nottingham Trams Limited (NTL), part of Keolis UK Limited, operates and maintains the NET system. All the staff involved in the accident were employed by NTL.

9 All parties freely co-operated with the investigation.

The tram

10 The tram involved, tram 232, is an Alstom Citadis type tram. It is around 32 metres long, has a maximum permitted speed of 70 km/h (43 mph) and can carry over 200 passengers. The tram is part a fleet of 37 trams operated by NTL. Of these, 22 are of the Alstom Citadis type and 15 are of the Bombardier Incentro type. All trams are used interchangeably on all routes.

11 The Citadis trams in Nottingham are formed of five modules. The two driving cab modules, one at each end of the tram, have a single sliding passenger door on each side and are supported by a bogie. The centre module has no doors and is supported by another bogie. The two intermediate modules have two double sliding doors on each side and are suspended from the cab and centre modules at either end (figure 4).

Figure 4: Photograph of a Citadis tram.

12 NTL is in the process of installing a new speed control system and an updated driver vigilance system to the Citadis fleet. Although the speed control system was not yet operational at the time of the accident, the driver vigilance system was installed and operating on six of the Citadis trams, including the tram involved in the accident.

NET control room

13 The control room for the NET tram network is co-located with the maintenance depot at Wilkinson Street. The control room is nominally staffed by three network controllers and a network manager. The network controller's role is to communicate with drivers, manage network operations and respond to any service disruption. When a network controller is on a break or is required to perform other duties, and the workload is not unusually high, the control room can be run by two network controllers. While all network controllers can undertake all functions in the control room, under normal circumstances the overall management of the tram service (including communication with trams) is done by one or two network controllers. The third network controller undertakes other tasks such as power distribution, fault monitoring, liaison with engineering staff and general administration. The network manager oversees the network controllers, but has other duties which means they are not always present in the control room.

14 Each network controller has a microphone and speakers mounted on their desk to allow them to communicate with the drivers using a radio system. Each network controller also has a set of monitors on their desk presenting information from the various management systems used on the NET network including the supervisory control and data acquisition (SCADA) system which monitors the operational state of various engineering assets. Among other things, the SCADA system displays and records the status of the majority of the sets of points across the network, including BUP3 points.

The set of points

15 BUP3 points at Bulwell tram stop use a spring-loaded point mechanism to hold the points in the correct position. A feature of spring-loaded points is that a tram can travel through the points in a trailing direction, where two tracks converge into a single track, even if the points are not set in the correct position for that movement. When that happens, the tram's wheels push the points over to the opposite position as they pass and then, depending on the configuration of the mechanism, the points either stay in that opposite position or, as is the case with BUP3 points, spring back to their original position. If a tram travels through the points in a facing direction, where one track diverges into two, it will be routed in the direction the points lie at the time and there will be no positional change of the switch blades.

16 When operating correctly, the switch blades are held in position by a spring acting through a mechanical linkage to apply pressure on the desired switch blade (figure 5). If points fail to swing fully or to spring back, they can be operated manually using a metal bar which is available on all trams and carried by engineering technicians. To check that the points are set correctly, an independent detection system is installed in the points mechanism. In the case of points on the NET system, this is set to show as an 'out of correspondence' fault when the gap between the switch blade and the adjacent stock rail is 3 mm or more. If a set of points is detected as out of correspondence for more than 15 seconds, an alarm is raised on the SCADA system, triggering an audible alert in the control room. This alarm will sound until acknowledged by a network controller.

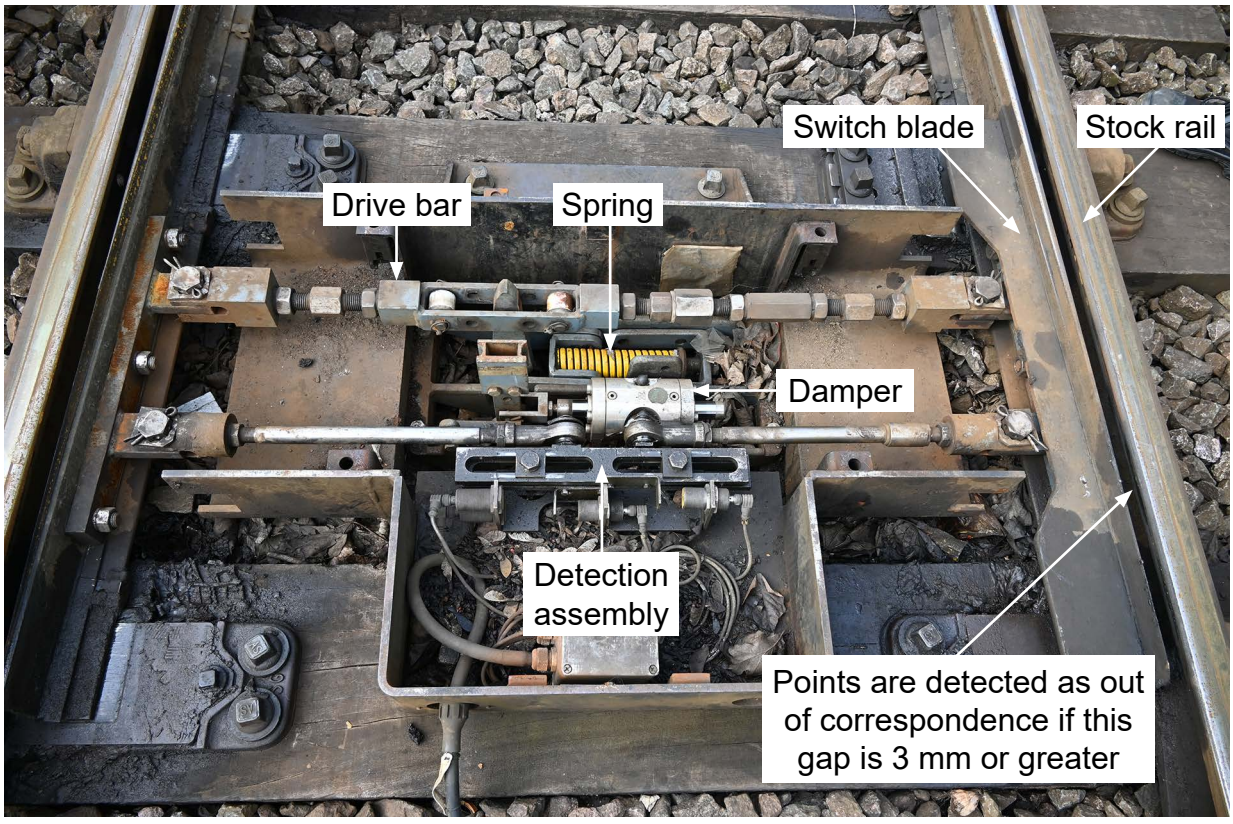

Figure 5: The internal mechanism of BUP3 points (held in the centre position), annotated to highlight important components.

17 The detected position of the points is indicated to tram drivers using a lineside 'facing point indicator' (FPI). For BUP3 points, the FPI displays a 'point left' indication if the points are set correctly for a tram to enter the southbound platform, or a 'bar' indication for any other scenario (figure 6). If drivers observe a bar indication, they should not drive over the points. Instead, they should stop the tram, check the points (normally by getting out of the tram) and operate them manually to attempt to gain the correct indication.

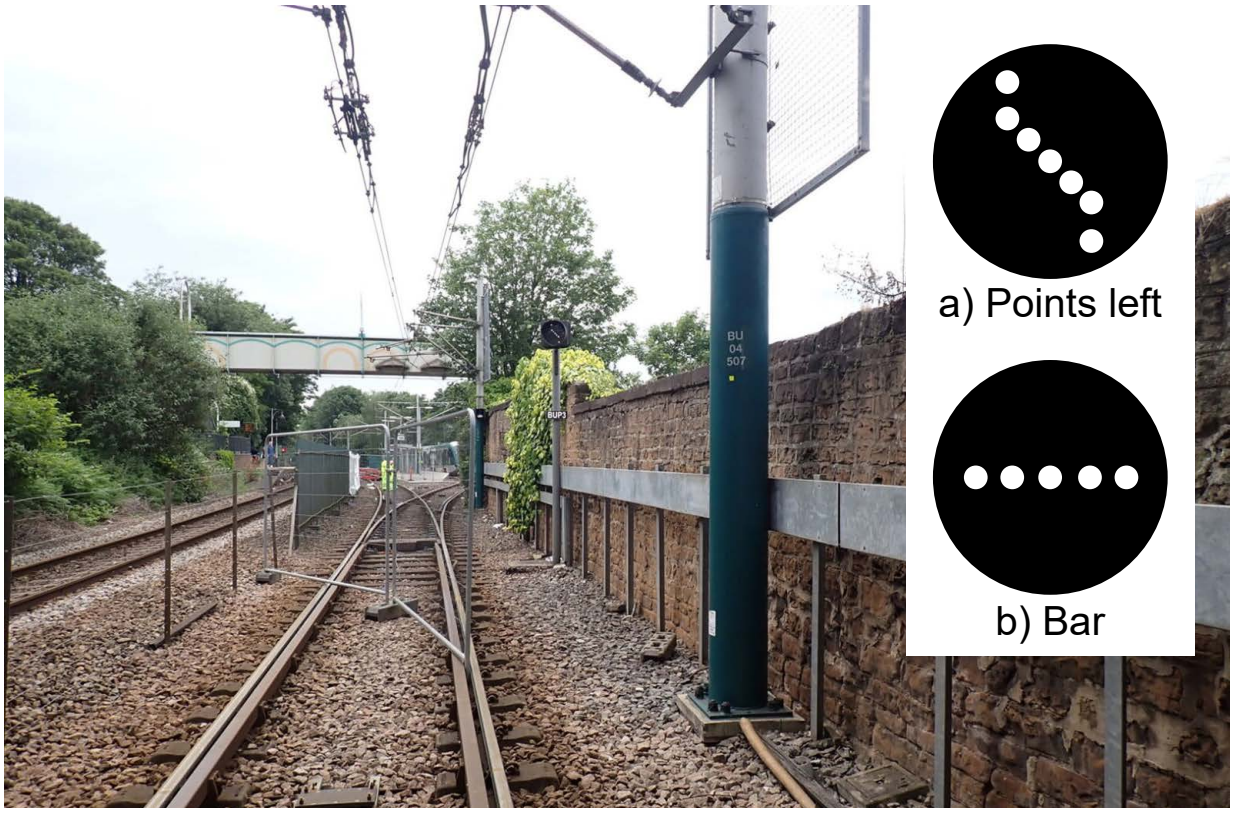

Figure 6: The FPI alongside BUP3 points, and (inset) the two possible indications that the FPI can show to drivers: a) Points left and b) Bar.

Staff involved

18 The tram driver involved in the accident had worked for NTL as a driver for around six years. They were trained and assessed as competent to drive any tram on all parts of the network. At the time of the accident, the driver was working part-time, usually in the afternoon or evenings. The driver stated that they felt well rested before the accident occurred, and analysis by RAIB showed that their roster and working pattern did not contain any duties likely to cause a significant risk of fatigue. The accident happened on the driver's first shift following three day's rest, and around one hour after their shift started. The driver had no recorded safety incidents that RAIB considers relevant to this accident.

19 Two network controllers were in the control room at the time of the accident. These were network controller 1, who had worked for NTL for 20 years, including 17 years in the control room, and network controller 2, who had worked for NTL for 10 years, including 8 years in the control room. Both network controllers were assessed as being competent to undertake their duties.

External circumstances

20 On the day of the accident, and during the two days before it, the weather around Bulwell had been hot and humid with daytime temperatures of around 29°C. At the time of the accident, it was generally overcast with thunderstorms occurring in the area. These weather conditions may have influenced the driver's level of attention (see paragraph 80). Around three minutes after the derailment, it started raining torrentially at Bulwell.

21 Records show that the sun was in the western sky, around 70° to the driver's right. Forward-facing closed-circuit television (FFCCTV) footage and witness evidence showed that visibility of the FPI alongside BUP3 points was not affected by sunlight.

The sequence of events

Events preceding the accident

22 At around 16:00 hrs on 12 June 2023, the driver signed on for their shift at the tram maintenance depot at Wilkinson Street. The driver was rostered on a spare duty, so were not tied to a particular timetable and were used to cover duties based on the arising needs of the tramway operation. Shortly after signing on, the driver was asked to drive tram 232 on a short run from Wilkinson Street to Hucknall and back, taking over the tram at Wilkinson Street tram stop at around 16:35 hrs.

23 At 16:31 hrs, the SCADA system raised an alarm in the control room stating that BUP3 points were out of correspondence. This occurred because a northbound tram passed over BUP3 points in a trailing direction, and the points had not reset to their default position (which directs southbound trams undertaking a facing move into the southbound platform). The alarm was acknowledged by network controller 2. At 16:34 hrs, the SCADA system raised a second alarm for the same fault after a second northbound tram passed over BUP3 points in a trailing direction.

24 At around 16:35 hrs, network controller 2 contacted NTL engineering technicians to inform them of the fault on BUP3 points and ask them to visit the site to address the fault. The technicians were at that time engaged in a maintenance activity at Wilford, on the other side of Nottingham city centre, and had already been informed of another out of correspondence fault with a set of points at Butler's Hill, near Hucknall.

25 Network controller 1 contacted the driver of a tram, number 215, which was then approaching Bulwell tram stop from the north, to inform them of the fault with BUP3 points. The network controller reminded the driver that they would need to stop before the points, get out of the tram and swing the points manually using the special bar that is carried in the driving cab (paragraph 16). At 16:38 hrs, the driver of tram 215 arrived at BUP3 points, reset them to the correct position and, after checking the FPI (paragraph 17) was showing the correct indication, reboarded their tram and continued on their journey. While this was taking place, one of the two network controllers rotated one of the closed-circuit television (CCTV) cameras at Bulwell to view the area around BUP3 points, to check on progress.

26 At 16:43 hrs, tram 232 (the tram which later derailed) reached Bulwell tram stop travelling northbound. After leaving the tram stop, the tram trailed BUP3 points, which on this occasion reset correctly. Between 16:46 and 16:56 hrs, three further trams passed over BUP3 points without incident, including one in the trailing direction, after which the points reset correctly.

27 At around 16:48 hrs, network controller 1 contacted the driver of tram 232 at Moor Bridge tram stop to inform them of the fault with the points at Butler's Hill, the next tram stop to the north. The driver continued to drive tram 232 northbound with this information in mind and stopped their tram on the approach to the points at Butler's Hill. They left the tram and reset the points manually, before travelling into Butler's Hill and then on to the terminus at Hucknall. They then moved to the driving cab at the other end of the tram, and at 16:56 hrs began the journey south back to Wilkinson Street.

28 At 16:58 hrs, tram 232 arrived back at Butler's Hill tram stop. It could not proceed further since a northbound tram was stationary in the single line ahead of them. The driver of this second tram was manually operating the points, as the driver of tram 232 had done earlier. The driver of tram 232 recognised that the other driver was having some difficulty with the points and left tram 232 to assist. By 17:00 hrs, after helping their colleague, the driver was back onboard tram 232 and had resumed their journey.

29 At 16:59 hrs, tram 237 travelling northbound trailed through BUP3 points at Bulwell tram stop, which did not reset correctly. An out of correspondence alarm was raised by the SCADA system in the control room. At 17:04 hrs, tram 222 travelling northbound also trailed BUP3 points, Again, they remained in the incorrect position, triggering another alarm on the SCADA system.

30 At 17:05 hrs, tram 222 arrived at Bulwell Forest tram stop heading north, while tram 232 arrived alongside, heading south. The driver of tram 232 pressed the 'tram ready to start' button to request authorisation to proceed into the single line and over a nearby level crossing. This request was granted by the signalling system allowing the driver to resume their journey southbound from Bulwell Forest towards Bulwell. At this point there were 16 passengers on board tram 232.

Events during the accident

31 At 17:06:29 hrs, around 21 seconds before reaching BUP3 points, tram 232 reached the position along the track where the location of the FPI can first be seen on the FFCCTV footage. Data from the on-tram data recorder (OTDR) recorded the tram as travelling at 56 km/h (35 mph).

32 At 17:06:38 hrs, the driver applied the tram's normal service brake in preparation for stopping at Bulwell tram stop. Around nine seconds later, the tram passed under Highbury Road bridge, now travelling at 45 km/h (28 mph). The FPI is visible on the FFCCTV footage and is displaying a bar indication (paragraph 17 and figures 6 and 7).

33 Three seconds later, at 17:06:50 hrs, while travelling south at 41 km/h (25 mph), the tram reached BUP3 points. The points were still in the incorrect position following the northbound passage of tram 222 at 17:04 hrs. The points directed the first bogie along right-hand route, towards the northbound platform and the front module of the tram lurched in the same direction.

Figure 7: Still image captured from the FFCCTV footage on tram 232, showing the FPI displaying a bar indication (circled in red). (Image courtesy of Nottingham Trams Ltd).

34 After the first bogie had passed over them, BUP3 points reset to their normal position, which then directed the second bogie on the tram's third module along left-hand route. The second module, bridging the gap between the two bogies, was now travelling sideways over the ballast between the two tracks. As the distance between the two tracks increased, the tram reached the point where it could no longer remain on both tracks, and the second bogie derailed by being dragged off the southbound track.

35 At the same time, the first set of double doors on the left side of the tram (in the direction of travel) struck an overhead line structure mounted between the two tracks. This impact deformed the door frame sufficiently to allow a pane of glass to be released, which struck a passenger on the back and head. Other passengers were knocked onto the floor of the tram. Around this time, the driver applied the emergency brake. The OTDR recorded that the tram was travelling at a speed of 25 km/h (16 mph) at the time of the collision with the overhead line structure.

36 The SCADA system recorded anomalies with the overhead line voltage between 17:06:54 hrs and 17:06:56 hrs, which led to circuit breakers being tripped and the overhead line being de-energised.

37 At 17:06:59 hrs, the tram came to a stop with the single passenger door on the right-hand side of the tram (which is located behind the driver's cab) positioned over the walkway between the tram stop and the car park.

Events following the accident

38 An NTL contractor working on a ticket machine at Bulwell tram stop witnessed the accident happen and used the emergency help point on the platform to contact the control room.

39 The actions of the driver and passengers were recorded on the tram's internal CCTV. The driver immediately opened the internal door between their cab and the passenger saloon and began checking on the passengers. Shortly afterwards, the driver released and opened the tram's doors, allowing passengers to begin to alight via the first passenger door onto the walkway. Some passengers alighted from other doors onto the ballast, but then reboarded the tram and walked to the first passenger door and alighted onto the walkway. A passenger informed the driver that one of the other passengers had been injured. The injured passenger was helped off the tram by other passengers, before leaving the scene of their own accord. All passengers were off the tram within three minutes of the accident.

40 Having evacuated the passengers, the driver re-entered the cab and contacted the control room. Around this time it began to rain torrentially. The passengers from the tram, who were now in and around the tram stop's car park, subsequently left the site of the accident.

41 At 17:25 hrs, the fire and rescue service arrived at Bulwell tram stop, having been alerted by the control room. They checked on the driver, who had remained on the tram throughout. NTL staff arrived on site from 17:46 hrs. The driver later reported suffering injuries to their leg and back.

42 The tramway through Bulwell tram stop was closed to repair the damaged track and overhead line, reopening for service on 23 June.

Analysis

Identification of the immediate cause

43 Tram 232 derailed as a result of travelling over BUP3 points when they were in an unsafe condition.

44 CCTV footage from Bulwell tram stop and from tram 232 shows that the points were in an intermediate position as tram 232 approached them (figure 8). Data recorded on the SCADA system confirms that the points were detected as 'out of correspondence'.

Figure 8: Still images from CCTV on a) Bulwell tram stop and b) tram 232 showing the state of BUP3 points immediately before tram 232 travelled over them. (Images courtesy of Nottingham Trams Ltd).

45 Track marks and CCTV show that upon reaching the points the first bogie was incorrectly directed to the right, towards the northbound platform. The points then reset to the correct position, probably due to the forces imparted by the passage of the first bogie. This directed the second bogie to the left, towards the southbound platform. As the distance between the two tracks increased, the second bogie became derailed by being dragged off the southbound track (paragraph 34).

Identification of causal factors

46 The accident occurred due to a combination of the following causal factors:

a. The points did not reset correctly after the two previous northbound trams (paragraph 47).

b. The driver did not observe and react appropriately to the FPI which was indicating that the points were in an unsafe position (paragraph 61).

Each of these factors is now considered in turn.

The operation of the points

47 The points did not reset correctly after the two previous northbound trams.

48 Following the initial failure of BUP3 points (paragraph 23) to return to the correct position, a network controller moved one of the CCTV cameras at Bulwell tram stop to view the area around the points. This footage, supported by SCADA data, shows that the points did not reset correctly after trams trailed the points at 16:59 hrs and 17:04 hrs (paragraph 29).

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

a. Spring-loaded points can stick in normal working conditions (paragraph 50).

b. The slide plates were possibly dry or contaminated (paragraph 55).

c. Staff sent by NTL to attend to the points following a previous failure had not yet had time to reach site (paragraph 58).

Each of these factors is now considered in turn.

Reliability of spring-loaded points

50 Spring-loaded points can stick in normal working conditions.

51 In the off-street section north of Wilkinson Street, there are eight spring-loaded points that see regular trailing and facing movements, including BUP3 points. There are also seven other spring-loaded points that are less frequently used in this section, and three motorised points. The movable switch blades of all these points are supported by metal slide plates. To help free movement of the blade over the slide plate, the interface is cleaned and a biodegradable lubricant applied at regular time intervals as part of routine maintenance. In the case of BUP3 points, this cleaning and lubrication task is scheduled to be done once every four weeks, and was last undertaken on 8 June 2023, four days before the accident.

52 The force imparted by the spring within the points mechanism can be adjusted by maintainers. This adjustment has to be carefully considered. Too low a force and the risk of the points moving under a tram or not resetting correctly increases. Too high a force can lead to the points being difficult for staff, including tram drivers, to operate manually when needed (paragraph 16). Post-accident checks on BUP3 points suggested that the spring force on them was set within the specified range.

53 NTL supplied RAIB with a download from its asset management system relating to the spring-loaded points on the NET system between January and October 2023. This data showed that BUP3 points were recorded as being out of correspondence on 10 occasions, a similar number of times to comparable sets of points elsewhere on the system (figure 9).

54 Points may fail to swing correctly for a variety of reasons, and figure 9 shows that such failures of points are not uncommon on the NET system. In these circumstances, it is intended that safety is assured by the drivers of trams observing the bar indication on the FPI and stopping on the approach to the points. The number of points failures that a tramway considers acceptable can vary based on the criticality of those points to running an effective service, the potential delays and disruption, and what other control measures are in place should they fail. For these reasons, a failure of a set of sprung points to swing correctly is generally seen as a reliability issue.

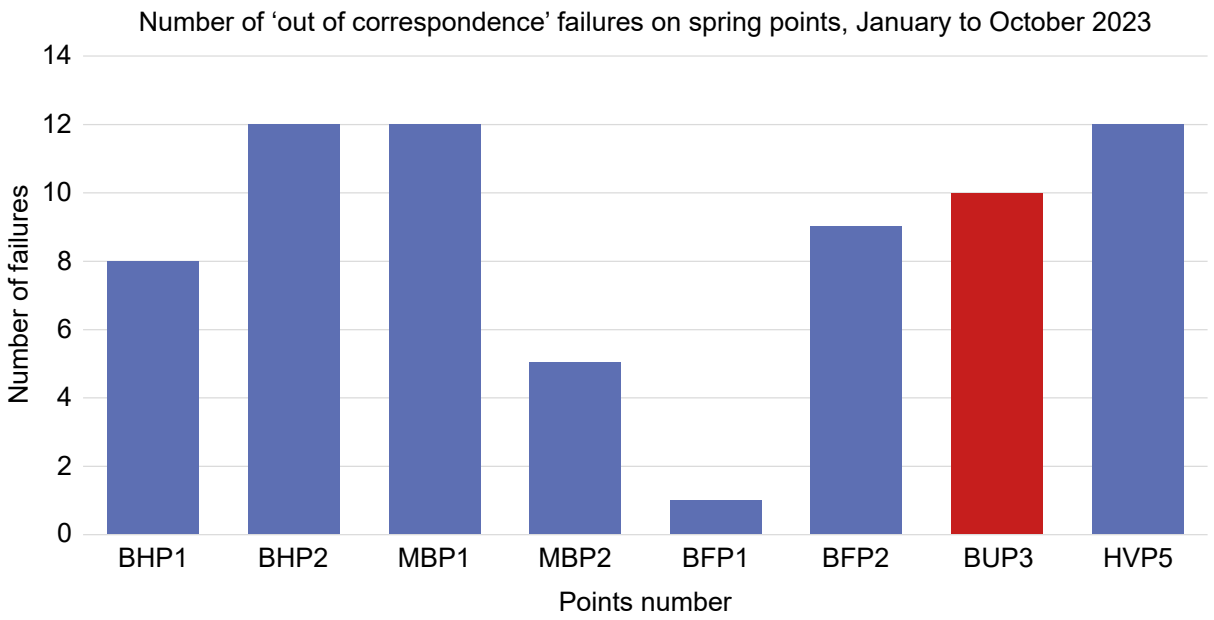

Figure 9: Chart showing the number of recorded out of correspondence failures on BUP3 points (highlighted in red) and other sets of points used in a similar manner.

Condition of the slide plates

55 The slide plates were possibly dry or contaminated.

56 Because of the torrential rain immediately after the derailment, the exact condition of the slide plates before the accident could not be determined during post-accident examination. However, an inspection of the points undertaken by NTL and RAIB in the hours following the derailment showed some organic contamination around the points blades, which may have increased the resistance of the points swinging correctly.

57 This inspection also found that the contact surface between the points blade and the slide plates only had a small amount of lubrication present. NTL's records show that the points had been cleaned and lubricated four days before the accident. There is no record of how much lubrication was applied so it is not possible to say why only a small amount of lubrication remained. It is possible that insufficient lubrication was applied, or that hot and humid conditions had led to the lubrication applied not being as effective as expected. This could have increased the friction within the system, making the points more susceptible to sticking.

Response to a previous failure

58 Staff sent by NTL to attend to the points following a previous failure had not yet had time to reach site.

59 Following the previous points failures at Butler's Hill and Bulwell (paragraph 24), network controller 2 had contacted a team of engineering technicians to investigate and rectify any faults. This team is responsible for undertaking routine maintenance activities as well as responding to any emerging engineering issues on the network. At the time of the call, they were working in Wilford, towards the south end of the network, undertaking a routine track maintenance task. When contacted by the control room, the engineering technicians agreed that they would complete the track maintenance task, and then head to Bulwell and Butler's Hill.

60 Due to the time of day, the technicians were held up in traffic on the journey, arriving at Bulwell tram stop at around 17:45 hrs, roughly 1 hour and 15 minutes after the initial fault was reported and after the accident had occurred.

The actions of the driver

61 The driver did not observe and react appropriately to the FPI which was indicating that the points were in an unsafe position.

62 FFCCTV footage recovered from tram 232 following the accident shows the FPI was displaying a bar indication as the tram approached BUP3 points (paragraph 32 and figure 7). This bar indication was showing that BUP3 points were not in a safe position. Post-accident checks undertaken by NTL and RAIB show that the points detection and FPI were all working correctly at that time.

63 NTL quality procedure QP/OPS/0001 'Points, Crossovers and Turnbacks', issue 13 dated January 2020, defines the operational driving rules at points and crossovers. QP/OPS/0001 states that '*drivers must not pass over points in a facing direction without first ensuring that the FPI indicator is displaying the correct aspect for the movement*'. Knowledge of this procedure is supported by NTL's driver training and monitoring regime and the driver was aware of the rule.

64 The driver of tram 232 should not have continued their journey over BUP3 points with a bar indication showing on the FPI. They should have instead stopped the tram, checked the points and manually operated the points if needed, so that they were safe for the tram to pass over them.

65 Drivers observing and reacting appropriately to these indicators is a critical principle of the line-of-sight operation of tramways. There is no automatic system to intervene should the required action not be undertaken in response to an incorrect FPI indication.

66 After the accident, the driver stated that they did not observe the FPI as the tram approached the points, and so did not see the bar indication being displayed or react appropriately to it.

67 The amount of attention that the driver paid to the FPI was reduced due to a combination of the following:

a. The driver believed they would be informed beforehand if there was a problem with a set of points (paragraph 68).

b. The driver was not informed on this occasion that there was a problem with BUP3 points (paragraph 72).

c. The driver had probably become conditioned to there being no issue with BUP3 points (paragraph 76).

d. The driver was possibly distracted, and this may have reduced their awareness (paragraph 78).

Each of these factors is now considered in turn.

The driver's expectation of fault notifications

68 The driver believed they would be informed beforehand if there was a problem with a set of points.

69 At the time of the accident, the driver had driven trams for NTL for over six years. They stated that, during this time, they could not recall a previous occasion of encountering an FPI showing a bar without being warned by the control room that there was an issue with the points concerned.

70 Tram drivers are trained and assessed against NTL's operating rules and procedures. NTL driver training documents do not specifically state that tram drivers will be contacted in the event of an infrastructure issue. However, NTL's procedures did include a requirement for control room staff to do so (see paragraph 83) and witness evidence suggests that such warnings happened in the majority of cases. This corresponds with the driver's stated experience that the control room would always contact them should there be a problem.

71 The driver's belief that they would be notified beforehand should there be a problem with a set of points was probably reinforced on this occasion because they were contacted by the control room about a separate points failure at Butler's Hill tram stop around 15 minutes before the accident (paragraph 27).

Lack of notification to the driver

72 The driver was not informed on this occasion that there was a problem with BUP3 points.

73 NTL confirmed to RAIB that no contact was made between the control room and the driver of tram 232 regarding BUP3 points being out of correspondence. When the driver approached BUP3 points, they had received no warning that there may be an issue with the points.

74 NTL quality procedure QP/OPS/0011 'SCADA Alarms', revision 4 dated June 2021, defines how staff in the control room should respond to SCADA alarms. QP/OPS/0011 states that control room staff should warn drivers of all points that are automatically reported as being out of correspondence. However, for reasons discussed from paragraph 83, the staff on duty were not aware of this procedure. Despite this, witness evidence indicates that the control room staff aspired to assist tram drivers by warning them of issues with points whenever possible.

75 RAIB has not been able to confirm why the control room did not communicate with the driver in this case. In the minutes leading up to the accident, there were two network controllers on duty as the third was on a break, and the network manager was not in the control room. They were having to handle numerous events, including the ongoing points failure at Butler's Hill tram stop, power supply issues and the onset of inclement weather at various locations on the network. These demands on the network controllers' time and attention may have contributed to them not communicating with the driver of tram 232 about BUP3 points on this occasion.

Driver expectation

76 The driver had probably become conditioned to there being no issue with BUP3 points.

77 The driver reported that, unlike at other locations, they had never encountered an issue with BUP3 points. They could not recall ever being required to manually swing those points, other than during planned movements. Although the driver had driven over these points on many occasions, the low frequency of failure meant that it was credible that the driver had never encountered BUP3 points out of correspondence (paragraph 54). This probably conditioned the driver to assume that there would not be a problem on this occasion, resulting in a reduced level of attention being paid to the FPI.

Possible distractions

78 The driver was possibly distracted, and this may have reduced their awareness.

79 In addition to their expectation as to the condition of BUP3 points, the driver may have been distracted, which reduced the level of attention being paid by the driver of tram 232 to the FPI.

80 While RAIB has not been able to confirm the exact weather conditions immediately before the accident, there was witness evidence and local news reports of stormy conditions at Bulwell as well as the torrential rain that immediately followed the accident (paragraph 20). Witness evidence suggests that, as the tram approached Bulwell tram stop, significant flashes of lightning were visible in front of the tram, which may have taken some of the driver's attention away from the driving task.

81 The tram involved had been recently fitted with a new vigilance system (paragraph 12). The driver stated that this required slight alterations to the way they operated the tram, compared to other vehicles in the fleet. The possible additional cognitive load needed to adapt to this different style of operation may also have been an additional distraction to the driver.

82 RAIB found no evidence to indicate that the driver's level of awareness was affected by other factors such as mobile phone use, fatigue or medical conditions.

Identification of underlying factors

Control room policies and procedures

83 NTL did not have an effective process to inform drivers of points failures; its policy was incomplete, not understood by control room staff and the informal process which was used instead was inconsistently applied.

84 In the event of a points failure leading to a SCADA alarm, the control room receives an audible alert and a highlighted entry appears on a monitor available to each network controller. The policy for responding to alarms is given in NTL quality procedure QP/OPS/0011. Section 5.1 of this procedure contains a table stating the actions to be taken in response to various alarms. The entry for the event of a spring-loaded set of points being reported out of correspondence states that:

> '… *drivers should be warned to use the un-signalled points procedure, technicians should be sent to investigate, and a fault request should be raised in the asset management system*'.

85 Following the accident, it was found that the un-signalled points procedure referred to in QP/OPS/0011 did not exist. Witness evidence also suggests that many control room staff were not aware of the existence of quality procedure QP/OPS/0011, although the steps to be taken should a tram driver encounter a faulty set of points appeared to be well understood by control room staff.

86 RAIB found that there was a long-established informal practice in use whereby the network controllers would contact specific trams concerning infrastructure failures whenever possible and send a message to all trams in the event of a prolonged fault. Witness evidence suggests that this was done out of courtesy, and to keep the tram service to the timetable.

87 As there was no formal process for these communications, and no routine monitoring of when drivers were being contacted, it was not possible to understand exactly how often this informal practice was followed or if it was applied differently by separate teams of control room staff. However, while witness evidence suggests it is likely that trams were being warned of infrastructure failures in most cases, it also suggested that this practice may not have been followed when control room staff were busy with other matters. This led to inconsistencies in the way that drivers were warned of such failures.

Risk Assessments

88 NTL had not specifically assessed the risk of a driver incorrectly passing an FPI. This is a possible underlying factor.

89 NTL uses a suite of risk assessments to assess its engineering and operational activities. These are written by the NTL department responsible for a particular activity, and overseen by NTL's quality, health, safety and environment team.

90 The risk assessments are grouped by function, and itemise each identified hazard, complete with a risk rating which is applied before and after a set of mitigation measures have been implemented. The risk ratings are calculated by assessing the severity of the hazard should it occur and the likelihood of the hazard occurring, both on a scale of 1-5, and cross-referencing the product scores against a table. This table then classes the risk scores as intolerable, tolerable or negligible.

91 The risks associated with a tram being driven over a set of points in an unsafe position is not specifically detailed, nor is the risk of a driver incorrectly passing an FPI. The closest identified hazard to this is listed as ‘points failure’ which is included in the risk assessment ‘RA-DR-On Route Infrastructure’, version 4 dated March 2021. The reported mitigation control measures include a reliance on the line-of-sight driving principles, maintenance, driver training and communication with the control room.

92 The control measures listed are almost exclusively reliant on human performance and do not include the role of the FPI or the broadcast to trams about a points failure. They also do not consider what might occur if the line-of-sight principle is not applied correctly or if the actions of the driver do not meet the requirements of the relevant operating rules. This meant that the risk of a driver incorrectly passing an FPI had not been specifically recognised and assessed and that the provision of potentially effective additional mitigations was not explored. The control measures listed were nevertheless assessed to have reduced the risk associated with points failure from ‘intolerable’ to ‘tolerable’.

Observations

Change Management

93 NTL’s process for assessing the effects of a proposed engineering change did not consider the human factors affecting drivers when introducing the change.

94 Before starting the installation of the new speed control and driver vigilance systems (paragraph 12), NTL used its ‘request for change’ quality procedure QP/QHSE/08, version 6 dated August 2022, to plan and assess the introduction of the changes.

95 As part of this process, a risk assessment was undertaken to understand what additional or amended risks were being introduced by the installation of the new systems. This assessment only identified three hazards, all of which were centred around the failure of engineering systems on the tram, and NTL has not been able to provide evidence that it assessed the effects that these new systems would have on its drivers.

96 Both of the new systems installed included alterations to the cab environment, which in turn required a revised interaction from the driver. Consequently NTL should have assessed what risks were potentially introduced by the change, such as a possible increase in cognitive load during the transition period (paragraph 81). The assessment also did not consider what effect on risk would be potentially created by having only a proportion of the fleet fitted with the new systems, with drivers having to behave differently when switching between the two types of trams.

Previous occurrences of a similar character

Highbury Vale derailment, Nottingham, 2003

97 On 25 May 2003 (before RAIB started operations), a tram travelling from Phoenix Park derailed while approaching Highbury Vale tram stop. The NET system had not yet opened to the public and was operating in a period of testing, commissioning and training. The tram involved was being driven by a trainee under supervision.

98 In a similar cause to the derailment at Bulwell, the facing points (HVP5 points, figure 3) had stuck in the incorrect position, and neither the trainee driver nor the driver instructor observed the FPI which was indicating that the points were set incorrectly.

99 An independent investigation of the accident was undertaken by a consultant which recommended a review of driver training, signal sighting and point machine maintenance. The investigation also recommended the improvement of feedback to the SCADA system to enable the control room to have better awareness of points failures to warn tram drivers about them.

Phipps Bridge, Croydon, 2005/2006

100 RAIB investigated two separate derailments at Phipps Bridge, Croydon on 21 October 2005 (RAIB report 04/2006) and 25 May 2006 (RAIB report 28/2007). On both occasions the tram driver did not observe the FPI (known on the Croydon tramway as a points position indicator, or PPI), which was correctly indicating that the points were in an unsafe position. There were no injuries, and only minor damage was caused by these derailments.

101 Following the derailments, the infrastructure engineering team at Croydon installed a new mechanical roller system to supplement the dry slide plates, and ensured that relevant sets of points received a weekly inspection. These measures have seen the failure rate for spring points reduce significantly, resulting in a much lower failure rate than on the NET system.

Summary of conclusions

Immediate cause

102 Tram 232 derailed as a result of travelling over BUP3 points when they were in an unsafe condition (paragraph 43).

Causal factors

103 The causal factors were:

a. The points did not reset correctly after the previous two northbound trams (paragraph 47, **Recommendation 2**). This causal factor arose due to a combination of the following:

   i. Spring-loaded points can stick in normal working conditions (paragraph 50).

   ii. The slide plates were possibly dry or contaminated (paragraph 55).

   iii. Staff sent by NTL to attend to the points following a previous failure had not yet had time to reach site (paragraph 58).

b. The driver did not observe and react appropriately to the FPI which was indicating that the points were in an unsafe position (paragraph 61, **Recommendations 1 and 2, Learning point 1**). This causal factor arose due to a combination of the following:

   i. The driver believed that they would be informed beforehand if there was a problem with a set of points (paragraph 68).

   ii. The driver was not informed on this occasion that there was a problem with BUP3 points (paragraph 72).

   iii. The driver had probably become conditioned to there being no issue with BUP3 points (paragraph 76).

   iv. The driver was possibly distracted, and this may have reduced their awareness (paragraph 78).

Underlying factors

104 The underlying factors were:

a. NTL did not have an effective process to inform drivers of points failures; its policy was incomplete, not understood by control room staff and the informal process which was used instead was inconsistently applied (paragraph 83, **Recommendation 1**).

b. NTL had not specifically assessed the risk of a driver incorrectly passing an FPI. This is a possible underlying factor (paragraph 88, **Recommendation 2**).

Observations

105 RAIB observes that NTL's process for assessing the effects of a proposed engineering change did not consider the human factors affecting drivers when introducing the change (paragraph 93, **Recommendation 3**).

Previous RAIB recommendations relevant to this investigation

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

Overturning of a tram at Sandilands junction, Croydon, 9 November 2016. RAIB report 18/2017

Recommendation 2

107 This recommendation reads as follows:

> *UK tram operators, owners and infrastructure managers should jointly conduct a systematic review of operational risks and control measures associated with the design, maintenance and operation of tramways. The review should include:*
>
> *i. examination of the differing risk profiles of on-street, segregated and off-street running*
>
> *ii. safety issues associated with driving at relatively high speeds in accordance with the line-of-sight principle in segregated and off-street areas, particularly during darkness and when visibility is poor*
>
> *iii. current practice world-wide and the potential of recent technological advances to help manage residual risk*
>
> *iv. safety learning from bus and train sectors that may be applicable to the design and operation of tramways*
>
> *v. consideration of the factors that affect driver attention and alertness across all tram driving scenarios in comparison to driving buses and trains*
>
> *vi. guidance on timescales for implementing new control measures (eg whether retrospective or only for new equipment).*
>
> *Using the output of this review UK tram operators, owners and infrastructure managers should then, in consultation with ORR, publish updated guidance on ways of mitigating the risk associated with design, maintenance and operation of UK tramways.*

108 The Light Rail Safety and Standards Board (LRSSB) was established following the accident at Sandilands. LRSSB has developed an industry risk model based on feedback from all tram networks in the UK. The outputs from this model were used to develop and issue industry guidance in various subject areas, including driver attention and speed control.

109 In March 2023, the safety authority for tramways in Great Britain, the Office of Rail and Road (ORR) reported to RAIB that it considered this recommendation to be implemented.

Recommendation 4

110 This recommendation reads as follows:

> *UK tram operators, owners and infrastructure managers should work together to research and evaluate systems capable of reliably detecting driver attention state and initiating appropriate automatic responses if a low level of alertness is identified. Such responses might include an alarm to alert the tram driver and/or the application of the tram brakes. The research and evaluation should include considering use of in-cab CCTV to facilitate the investigation of incidents.*
>
> *If found to be effective, a time-bound plan should be developed for such devices to be introduced onto UK tramways.*

111 LRSSB commissioned independent research into the engineered systems available to monitor the attentive state of tram drivers. This concluded that a well-adjusted driver's vigilance device system with multiple regular inputs linked to the tram braking system is the most reliable way of addressing the risk of driver inattentiveness on a line-of-sight system, when taking into account other risk management systems also present. NTL reported that it planned to install a vigilance system in response to this recommendation. This system was in the process of being fitted to the NTL tram fleet when the Bulwell derailment occurred (paragraph 12).

112 ORR have reported that, based on the vigilance system having been successfully trialled on a single tram, and given the plan for it to be installed on the rest of the fleet by January 2024, it considered that this recommendation was closed for NTL.

Recommendations that are currently being implemented

Pushchair trapped in tram doors and dragged at Radford Road, Nottingham, 15 December 2017, RAIB report 15/2018, Recommendation 2

113 This recommendation reads as follows:

> *Nottingham Trams Limited should review its risk assessment process with a view to:*
>
> - *improving the means by which it considers learning from other parts of the tramway and railway industries*
> - *giving explicit and detailed consideration of the ways in which identified mitigation measures can fail, and the consequences when this happens*
> - *effectively evaluating the safety impact of changes to design and/or operational procedures.*
>
> *Nottingham Trams should then implement the identified changes and update its existing tram operation risk assessments in accordance with the enhanced procedures.*

114 In August 2019, ORR reported to RAIB that NTL was planning to change its risk assessment and 'request for change' procedures to address this recommendation, so it considered this work as progressing. This is consistent with the findings of this investigation that NTL did not assess the risk of a driver incorrectly passing an FPI (paragraph 88) and that NTL's process for assessing the effects of a proposed engineering change did not consider the human factors affecting drivers when introducing the new vigilance system (paragraph 93).

115 As such, RAIB has made further recommendations in these areas.

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

116 NTL advised RAIB that it has started a project to undertake route risk assessments, with the aim of strengthening its understanding of its risk profile and supporting the development of more robust safe systems of work. NTL also plans to further develop its managers in the undertaking of risk assessments by delivering specific health and safety training.

117 NTL also reported that it is exploring the feasibility of introducing a beacon to selected FPIs to highlight out of correspondence faults. The beacons provide a flashing warning light to drivers approaching a set of points that are out of correspondence.

Recommendations and learning point

Recommendations

118 The following recommendations are made:[1]

1 *The intent of this recommendation is to improve the communication between control room staff and tram drivers when dealing with engineering faults.*

Nottingham Trams Limited should review its operating rules and control room policies and procedures, with the intention that control room staff are given clear and complete guidance on how to respond to engineering faults. This should specifically consider when it would be appropriate for control room staff to warn tram drivers of arising issues, associated with such faults.

Nottingham Trams Limited should develop a timebound programme to make any appropriate changes identified to operating rules, policies and procedures.

Nottingham Trams Limited should ensure that control room staff and tram drivers are trained and briefed appropriately on any revised operating rules, policies and processes which result from these changes and should ensure that their staff have ongoing and ready access to the relevant documents (paragraphs 103b and 104a).

2 *The intent of this recommendation is to improve Nottingham Trams Limited's understanding and control of the operational risks relevant to this accident.*

Nottingham Trams Limited should review and update its risk assessments to ensure that the risks highlighted by this accident are effectively assessed and that appropriate measures are implemented to control them.

The review should take into account any work already completed in response to recommendation 2 of RAIB report 15/2018 and should specifically consider:

- the risk of trams approaching points which are in an unsafe condition

[1] 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 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.

- the limits of relying on the line-of-sight principle and the correct action of tram drivers as risk controls
- the role of control room staff
- risk modelling and risk profiling data, such as that provided by the Light Rail Safety and Standards Board
- relevant industry guidance and good practice.

Nottingham Trams Limited should develop a timebound programme to review and update its risk assessments and to identify appropriate risk controls.

(paragraphs 103a, 103b and and 104b).

3 *The intent of this recommendation is that Nottingham Trams Limited ensures that its management of change includes appropriate consideration of human factors.*

Nottingham Trams Limited should review its 'request for change' process to ensure that it includes appropriate consideration of environmental, organisational and job factors, and human and individual characteristics, which influence behaviour in a way which can affect safety (paragraph 105).

Learning point

119 RAIB has identified the following important learning point:[2]

1 Tram drivers should not make assumptions about the status of signals and indicators based on their previous experience (paragraph 103b).

[2] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where 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

Abbreviation / acronym	Full term
CCTV	Closed-circuit television
FFCCTV	Forward-facing closed-circuit television
FPI	Facing point indicator
NET	Nottingham Express Transit
NTL	Nottingham Trams Limited
ORR	Office of Rail and Road
OTDR	On-tram data recorder
RAIB	Rail Accident Investigation Branch
SCADA	Supervisory control and data acquisition

Appendix B - Investigation details

RAIB used the following sources of evidence in this investigation:

- information provided by witnesses
- information taken from the tram's OTDR
- CCTV recordings taken from the tram and tram stop
- site photographs and measurements
- weather reports and observations at the site
- data from NTL's SCADA system and Agility asset management system
- recordings of voice communications between the control room and trams
- copies of NTL policies and procedures
- a review of previous RAIB investigations that had relevance to this accident.

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