Rail Accident Investigation Branch

Rail Accident Report

Freight train derailment at Sheffield station
11 November 2020

Report 07/2021
October 2021

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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Freight train derailment at Sheffield station, 11 November 2020

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Summary

At 02:44 hrs on Wednesday 11 November 2020, 16 wagons of a freight train that was conveying cement powder from Hope, Derbyshire, to Dewsbury, West Yorkshire, derailed at the north end of Sheffield station. A number of wagons were damaged and there was significant damage to the track, resulting in a partial closure of the station. No one was injured.

The train was coasting through the station at a constant speed of around 12 mph (19 km/h) when the leading right-hand wheel of the twelfth wagon dropped into the space between the two running rails, because the rails were too far apart: a problem known as gauge widening. The train stopped when the signaller observed a number of signalling equipment failures indicated on a display screen, and alerted the driver to a problem.

The track gauge had widened because a number of track screws, that secured the rails and baseplates to the wooden bearers, had broken, allowing the rails to spread apart under the loads from passing trains. The track screws had failed several weeks, or perhaps months, before the derailment, but the failures had not been identified by Network Rail's maintenance inspection activities.

Although this was a location with a potentially high risk of derailment, it had not been recognised as such because Network Rail's guidance for identifying such risk had not been applied. Additional mitigation had therefore not been considered.

RAIB has made four recommendations to Network Rail concerning the implementation of processes for identifying high derailment risk locations, the implementation of safety-critical changes to its processes, standards governing fitment of check rails, and track geometry data formats.

RAIB has also identified three learning points for track maintenance staff alerting them to the need for effective management of track gauge in tightly curved track, the limitations of geometry alerts provided by static measuring equipment, and the importance of monitoring track geometry trends for the identification of track deterioration.

Introduction

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. These are explained in Appendix A. Sources of evidence used in the investigation are listed in Appendix B.

The accident

Summary of the accident

3 At 02:44 hrs on Wednesday 11 November 2020, 16 wagons of a freight train conveying cement powder derailed as the train was passing through 4062 points at the north end of Platform 1 at Sheffield station (figures 1 and 2). The train had been travelling at around 12 mph (19 km/h) before coming to a stand with the 16 wagons derailed and with one of them having fallen onto its side (figure 3). No one was injured in the accident, but there was significant damage to the railway infrastructure that resulted in a partial closure of the northbound route from the station.

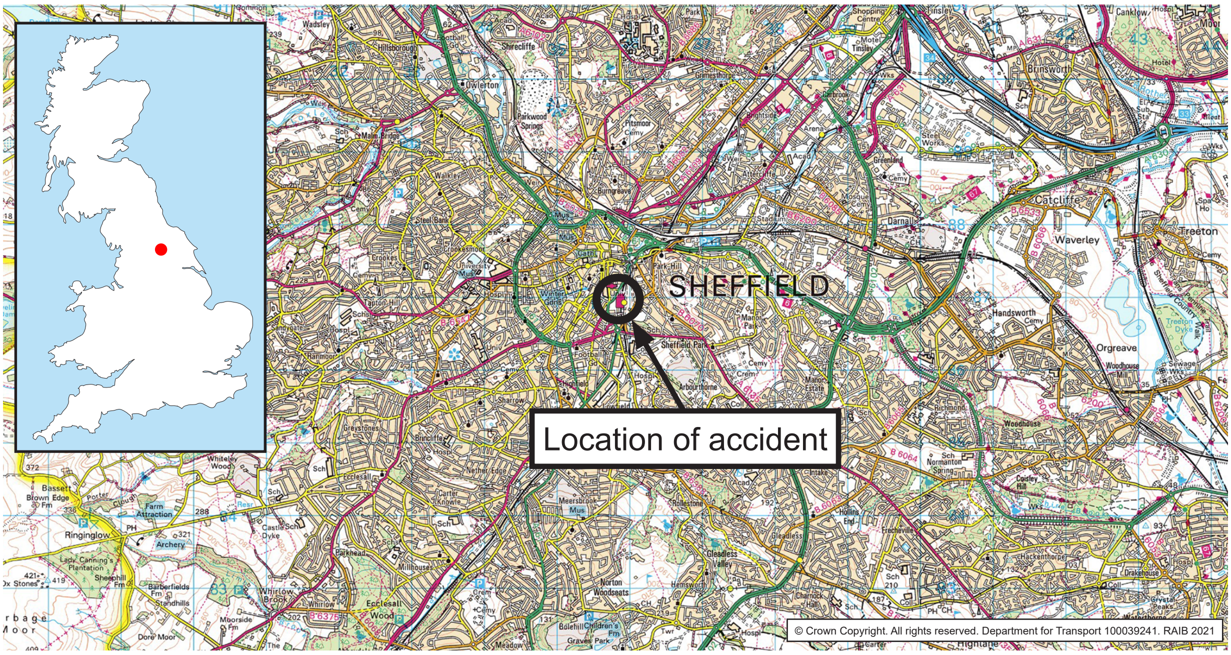

Figure 1: Extract from Ordnance Survey map showing location of accident

Figure 2: Aerial overview of the derailed train (image courtesy of Network Rail Air Operations team)

Figure 3: Wagon BCC10756 toppled on its side

Context

Location

4 The accident occurred within 4062 points at 158 miles 52 chains,[1] at the north end of Platform 1 in Sheffield station. At this location, the Down Through line joins the Platform 1 line (figure 4).

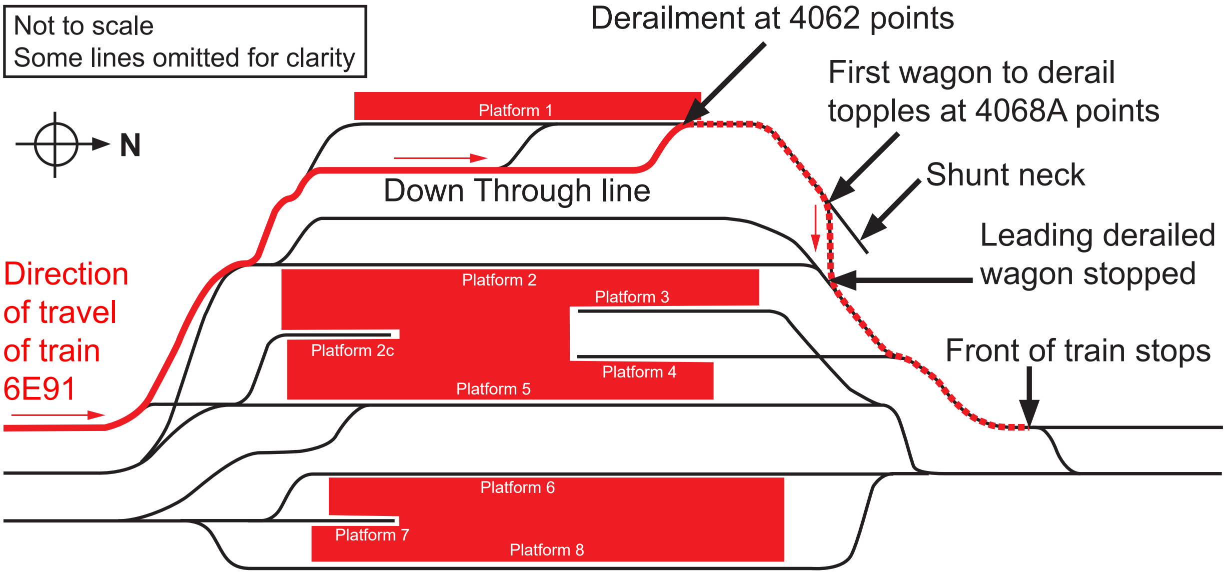

Figure 4: Track layout at Sheffield, showing the route of the derailed train

[1] This mileage is referenced to a zero point at the original buffer stops in London St Pancras station, via the Erewash valley route.

5 The maximum permitted speed on both the Down Through and Platform 1 lines is 15 mph (24 km/h). Both lines are on a gradient of 1 in 330, downhill in the direction of travel of the derailed train.

6 The signalling in the area is controlled from the Sheffield workstation which is located at the York Rail Operating Centre (ROC). None of the tracks through Sheffield station are electrified.

Organisations involved

7 Network Rail owns and maintains the infrastructure through Sheffield station, which is on its 'North and East' route. It also employs the staff responsible for the maintenance of the track.

8 Freightliner operated the train that derailed and employed the driver. Freightliner also owned the wagons that derailed and was the entity in charge of maintenance (ECM) for them, meaning that it was responsible for ensuring that maintenance activities were correctly carried out.

9 Both Network Rail and Freightliner freely co-operated with the investigation.

Train involved

10 The train that derailed was 6E91, the 02:13 hrs service from Hope (Earles Sidings), in Derbyshire, to Dewsbury cement terminal, near Wakefield, West Yorkshire. It consisted of a Class 66 locomotive hauling 34 PCA cement tank wagons (figure 5).

Figure 5: PCA cement tank wagon

11 The PCA wagons in the train were part of a fleet of wagons that were built in the UK between 1981 and 1987. These are two-axle wagons each consisting of a frame that supports a mild steel tank which is used to carry cement powder. These wagons have a gross weight of 51 tonnes when laden and weigh around 13 tonnes when empty. The wheelbase of each wagon is 4.88 metres.

12 RAIB found no evidence of any significant defects in the wagons or their suspensions after the derailment.

Staff involved

13 The driver of the train had been driving trains for 29 years, 19 of them for Freightliner. RAIB found no evidence to suggest that the way the train was driven contributed to the cause of the derailment.

14 Staff based at Network Rail's Sheffield maintenance depot were responsible for maintaining the track where the derailment occurred. The Sheffield track maintenance engineer (TME) had worked on the railway for twelve years, with the last six as assistant TME at Sheffield. He had been appointed as acting TME five months before the derailment, pending a permanent appointment being made.

15 The infrastructure maintenance engineer (IME) at Sheffield, who manages the TME, had a total of 29 years' experience on the railway, with the last six of those being as TME at Sheffield. He had been appointed as acting IME five months before the derailment, also pending a permanent appointment being made.

External circumstances

16 The weather was dry at the time of the derailment, with a temperature of about 7 degrees Celsius. It was dark, although there would have been some illumination from the lights in the station. There is no evidence to suggest that any external circumstances influenced the accident.

The sequence of events

Events preceding the accident

17 Train 6E91 departed from Earles Sidings, at Hope, with a full cargo of cement bound for Dewsbury cement terminal. The journey to Sheffield was uneventful, although there was a temporary 30 mph (48 km/h) speed restriction in Totley Tunnel, on the southern outskirts of Sheffield, that the driver complied with.

18 On the approach to Sheffield station, the driver used the brakes to reduce the train’s speed to 12 mph (19 km/h), which was below the maximum permitted speed of 15mph (24 km/h). The train then coasted through the station at a relatively constant speed with no power applied or brake applications made.

19 Train 6E91 took the Down Through line in the station to bypass the platforms and approached 4062 points, where that line joined the line that passed through platform 1.

Events during the accident

20 As the twelfth wagon in the train passed through 4062 points, its leading wheelset derailed, with the right-hand wheel (in the direction of travel) dropping into the gap between the two rails (known as the ‘four-foot’), due to the distance between the rails (or ‘gauge’) having become too wide (figure 6). This occurred between the crossing and the switch rail of 4062 points (figure 7).

21 The left-hand wheel on the same axle later climbed over the left-hand rail into derailment because the outer face of the right-hand wheel was constrained by the inner rail as the track gauge tightened on the approach to the switch toes of 4062 points. A number of subsequent wheels on wagons 12 to 26 followed similar derailment paths through 4062 points, leading to those wagons becoming derailed.

22 The train continued until wagon 12 reached the next set of facing points (4068A). Here, derailed wagon 12 attempted to follow the straight-ahead route into the shunt neck siding, while those ahead of it took the diverging right-hand route for which the points were set, towards the main line out of Sheffield. This conflict resulted in wagon 12 falling onto its side and wagon 11 becoming derailed because of the relative movement of wagon 12 behind it.

23 The signaller was alerted to a number of track faults caused by the derailed wagons and immediately contacted the driver of the train, using the GSM-R radio system, to check if there was a problem. The train driver responded by applying the train brakes to stop the train. Around the same time, the brake pipe along the train was disrupted by the derailment, resulting in an automatic brake application. The train stopped as wagon 26 was passing through 4062 points.

Events following the accident

24 After the driver of 6E91 advised the signaller that his train had derailed, the signaller applied signalling protection to the station area to prevent other trains from moving.

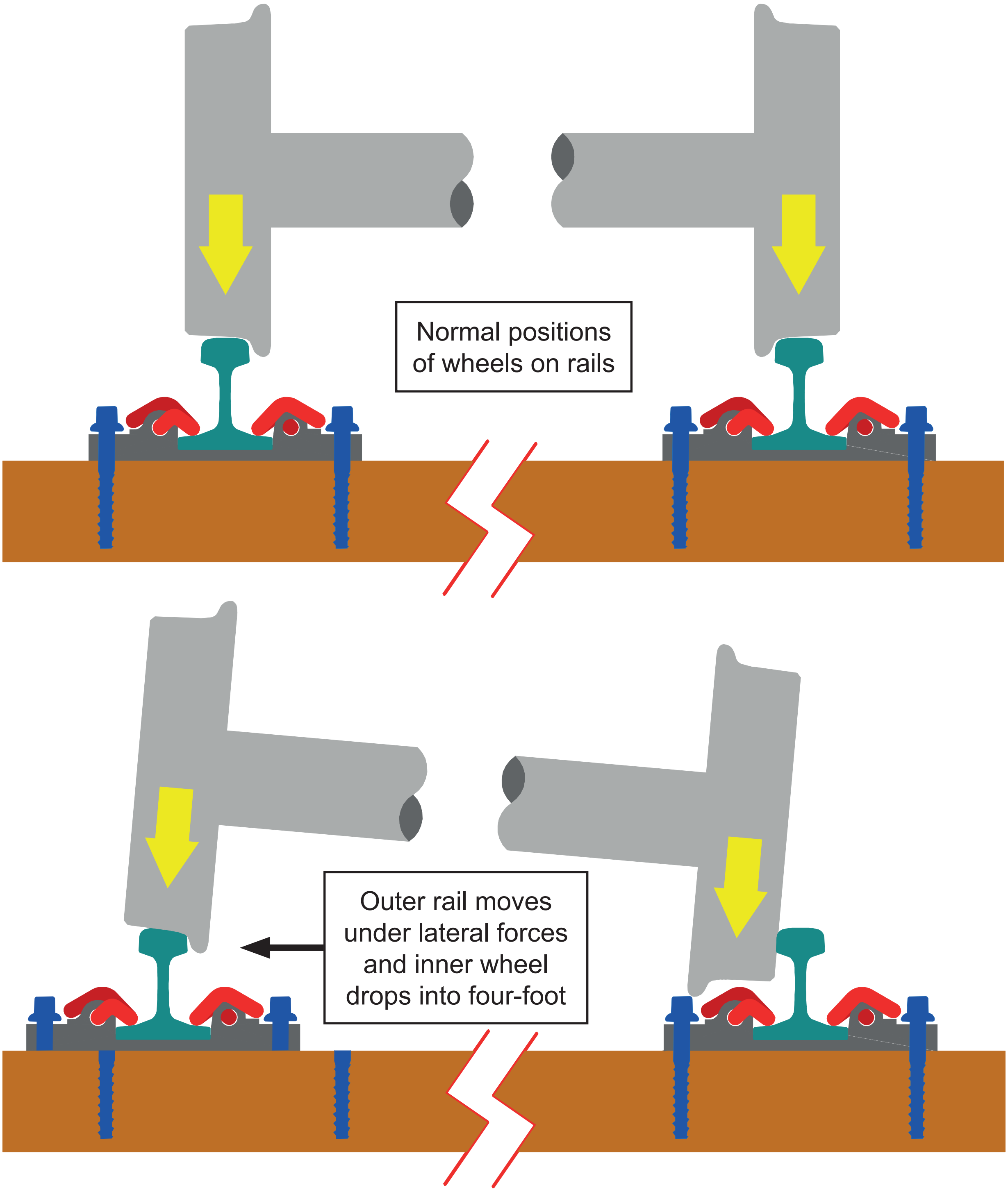

Figure 6: Sketch of the derailment in 4062 points

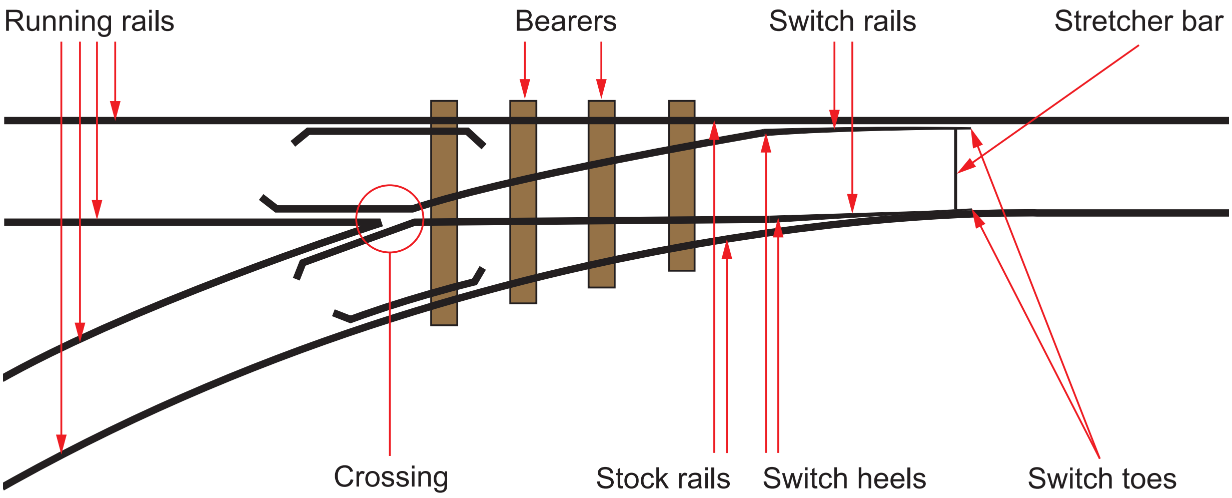

Figure 7: Sketch showing the component parts of a set of points (switch and crossing)

25 There were no injuries as a result of the derailment, although the derailed wagons caused extensive damage to 4068A points, and to the track after 4062 points. The north end of Sheffield station was partially closed for 5 days while the train was recovered, and the track repaired. There was also some damage to the wheels and couplings on wagon 11 and wagons 13 to 26. The suspension on wagon 12 was severely damaged and largely detached. The tank on wagon 12 was also ruptured, leading to a small quantity of cement powder being spilled onto the track.

Analysis

Identification of the immediate cause

26 An undetected failure of the rail fixings meant that the track was unable to maintain gauge as the train passed through 4062 points.

27 Examination of the track after the derailment showed that there were a number of broken track fixings on the left-hand rail in the area between the crossing and the switch blade of 4062 points (see paragraph 43). This meant that the rail was not secured to the bearers at this location and could be moved outwards when subjected to the load of the train's wheels, locally increasing the track gauge.

28 Rail marks showed that the right-hand wheels of several wagons dropped off the head of the right-hand rail, into the four-foot, at this location, referred to as the point of derailment (figure 8). These wheels then ran derailed, with their corresponding left-hand wheels still on the left-hand rail, for several metres until reaching the switch heel. This is the location where the movable switch rail is fixed, via a heel block, to its outer stock rail (figure 7). Rail marks showed that the left-hand wheels on the derailed wheelsets climbed over the left-hand rail into derailment and the right-hand wheels remained derailed.

Figure 8: Wheel mark on the inside edge of the right-hand rail showing the first drop-in at the point of derailment (the red step gauge is only present to indicate the point of derailment)

29 Examination of the derailed wagons showed damage on the outside face of the wheels consistent with several right-hand wheels having dropped into the four-foot (figure 9). The leading right-hand wheel of wagon 12 suffered the worst damage, indicating that it is likely to have been the first to derail into the wide gauge. Subsequent wheels also dropped into the wide gauge, but the damage was less severe. Their derailment was made more likely by the gauge having been further widened by the derailed leading wheelset on wagon 12 dropping in ahead of them.

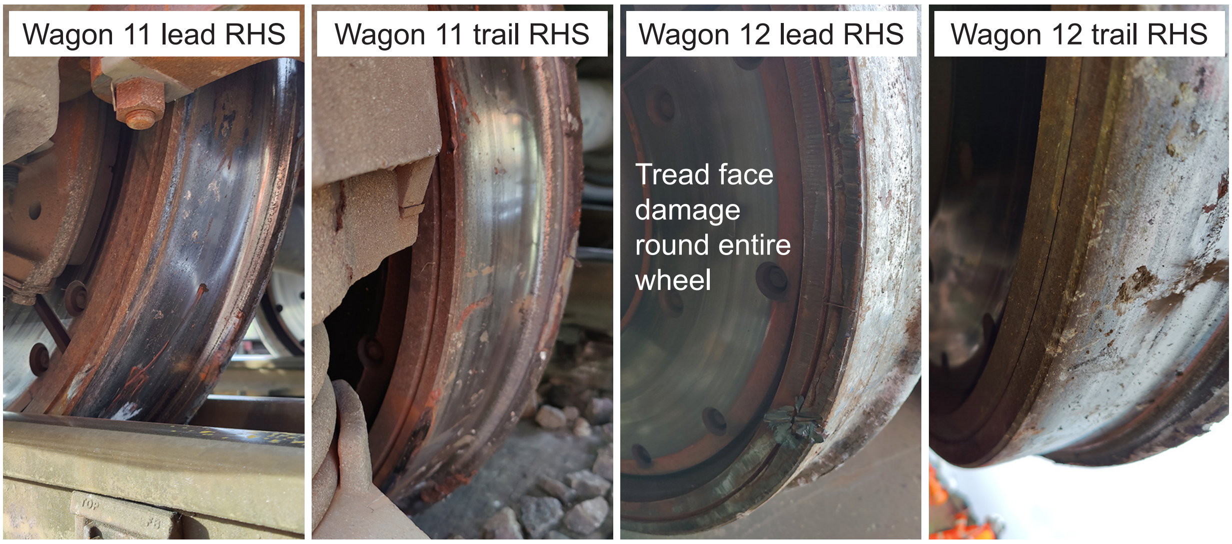

Figure 9: Tread face damage on the right-hand leading wheel of wagon 11 compared to wagon 12

Track forces from wagons negotiating the track curve

30 When a railway vehicle runs over a section of track, its wheels impart forces to the rails, consisting of both vertical and lateral components. These forces tend to push the two rails apart and are affected by a number of factors. These include, amongst others, the vehicle loading, the characteristics of the wagon suspension, the distance between the axles on the vehicle, the track curvature, and the speed. These track spreading forces from the wheels can result in the track gauge widening if the track system is insufficiently robust to withstand them.

31 At the point of derailment the track curves to the right in the direction of travel, with a radius of approximately 165 metres. Passage of a train over such a curve results in relatively high lateral forces on the track, acting on the outer rail (the left-hand rail in the direction of travel).

32 Network Rail undertook computer modelling of the interaction between this type of wagon and the track geometry as recorded at site. This estimated that the outer rail would experience a peak outward force of approximately 95 kN (9.7 tonnes force). RAIB undertook separate indicative modelling and estimated similar forces.

33 Network Rail was unable to identify the levels of force that the track fixings were designed to be able to react. However, Railway Group Standard GC/RT5021 'Track System Requirements' specifies that the track system needs to be able to sustain a 'lateral force generated by a train of 100 kN over a length of 2 metres'. This requirement relates to the entire track formation, and, as such, individual track components, such as the fixings, would need to be able to withstand this lateral force. Therefore, although the lateral forces generated by the train moved the rails apart, those forces were not unusual or in excess of the intended design requirements of the track.

Condition of the wagons

34 RAIB inspected wagon 12, which is believed to be the first to derail. It was badly damaged in the derailment, having fallen onto its side (paragraph 22). Both wheelsets had become separated from the chassis, and the associated suspension assemblies were partially detached. The inspection did not identify any pre-existing defects that could have caused higher than expected lateral forces as it traversed curved track.

35 It was noted that the wheel flanges on the left-hand wheels on both wheelsets were slightly thinner than those on the right-hand wheels (figure 10). However, they were all well within the acceptable maintenance specification limits. It is possible that a thinner left-hand wheel flange could result in the wheelset being positioned slightly further to the outside rail on a right-hand curve, such as at the point of derailment. This means that the associated wheel tread corner on the right-hand wheel would also be positioned slightly closer to the four-foot on the right-hand rail, and so be fractionally more at risk of derailment (figure 11). The estimated difference in position on the twelfth wagon is only about 1-2 mm.

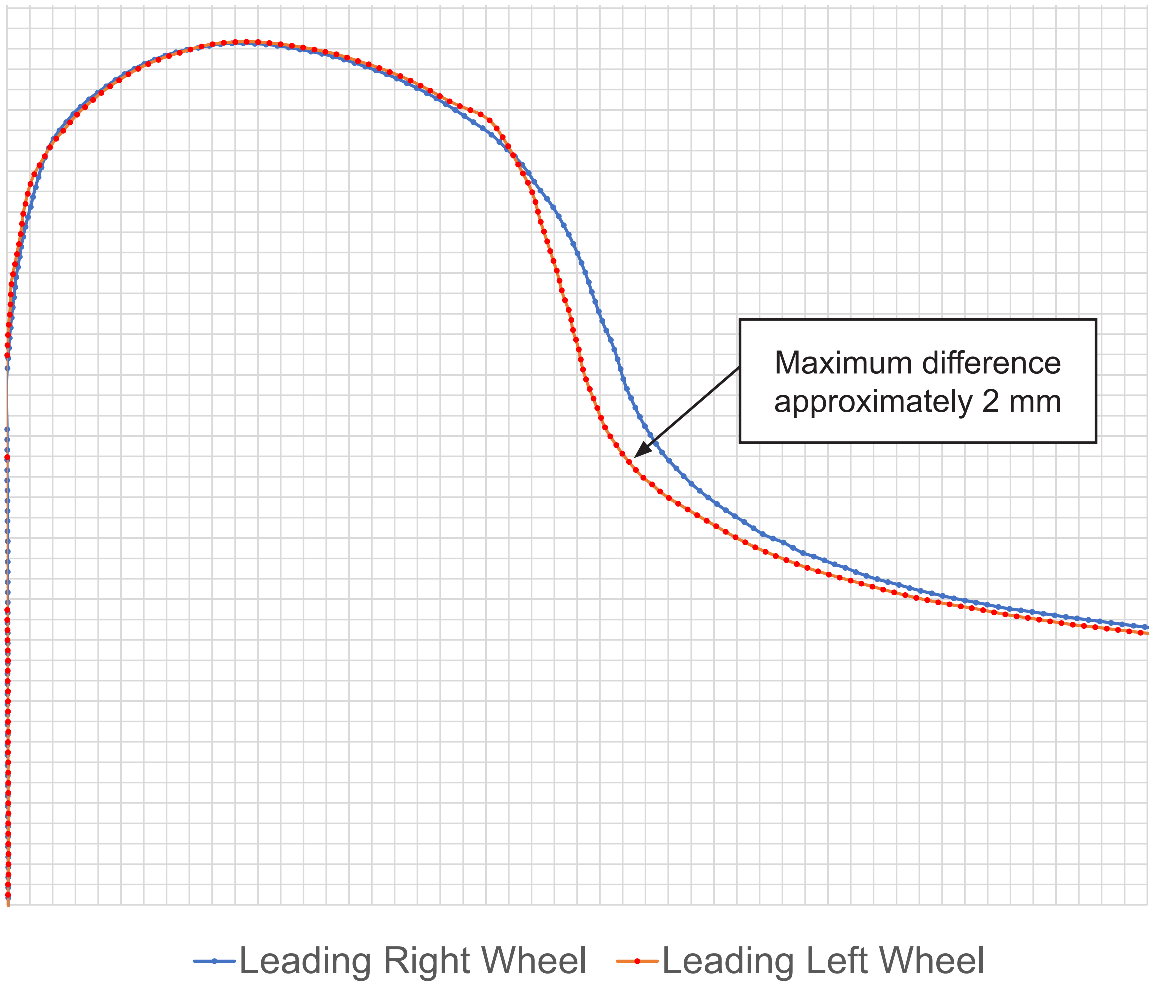

Figure 10: Comparison of wheel flange thicknesses on wagon 12

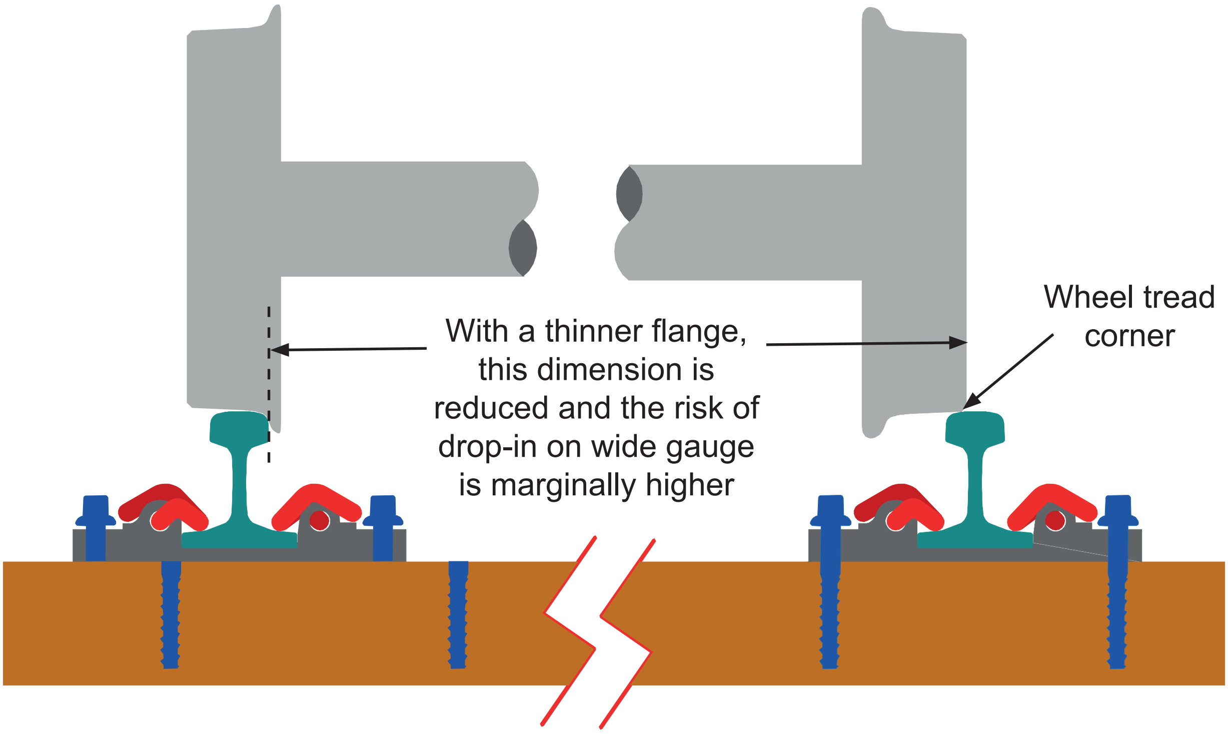

Figure 11: Illustration of the possible effect of a narrower wheel flange

36 Wagon 12 ran in the same train, in the same orientation, and by the same route through Sheffield station, on the two nights prior to the derailment. This suggests that the slightly thinner wheel flanges were unlikely to be a significant factor in the derailment.

37 RAIB also examined wagons 10, 11 and 13 and found no defects. In addition, the maintenance records indicated that maintenance activities for all the wagons inspected had been carried out by their due dates and that there were no outstanding defects.

38 RAIB obtained data from the wheel impact load detector system at Grindleford, that the train had passed over between Hope and Sheffield. This recorded no abnormal weight distribution that would indicate uneven loading or a problem in the wagons' suspensions.

Identification of causal factors

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

a. Multiple track screws securing the rail baseplates to the bearers had failed prior to the derailment (paragraph 40)

b. The failed track screws had not been identified by the routine inspection regime (paragraph 52)

c. There was no additional mitigation in place at 4062 points, because it had not been identified as a location with a high risk of derailment (paragraph 80)

d. The design of 4062 points did not include the fitment of a check rail at the sub-200 metre radius curve between the crossing and the heel of the switch (paragraph 102).

Each of these factors is now considered in turn.

Failure of the track screws

40 Multiple track screws securing the rail baseplates to the bearers had failed prior to the derailment.

41 The track at the derailment location, inside the length of 4062 points, consisted of flat-bottomed rail held on metal baseplates by spring 'Pandrol' type clips (figure 12). Each of the baseplates was secured to timber bearers by three track screws, with most of the baseplates having two track screws on the four-foot side of the rail, and the third on the outside.

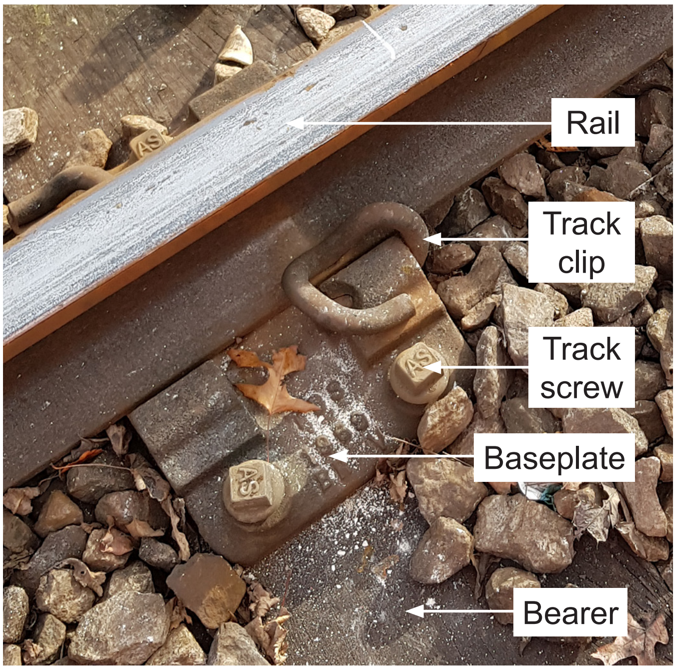

Figure 12: Illustration of rail secured to bearer by baseplates, clips and track screws

42 All the track screws in the vicinity of the derailment were Network Rail approved standard grade AS track screws, to Network Rail drawing RE/PW/43. This drawing specifies the dimensions, materials and markings for such screws (figure 13). All were marked as having been manufactured in 2005 or 2006.

43 Figure 14 shows 4062 points and the direction of travel of the train. The point of the derailment, where the first wheel dropped between the rails, is labelled as bearer 0. The locations of the track screws that were found to be broken are also shown. All the track screws on the outer rail (left-hand in the direction of travel) were broken from bearers -3 to +1, with negative numbers indicating bearers before the point of derailment and positive numbers, bearers after it. Bearer +2 had one broken screw and the baseplate had also fractured. The baseplates on bearers +3 to +5 were also broken, while their screws remained intact. The newness of the baseplate fractures indicates that these almost certainly failed during the derailment, as the derailed wheelsets tried to force the rails apart.

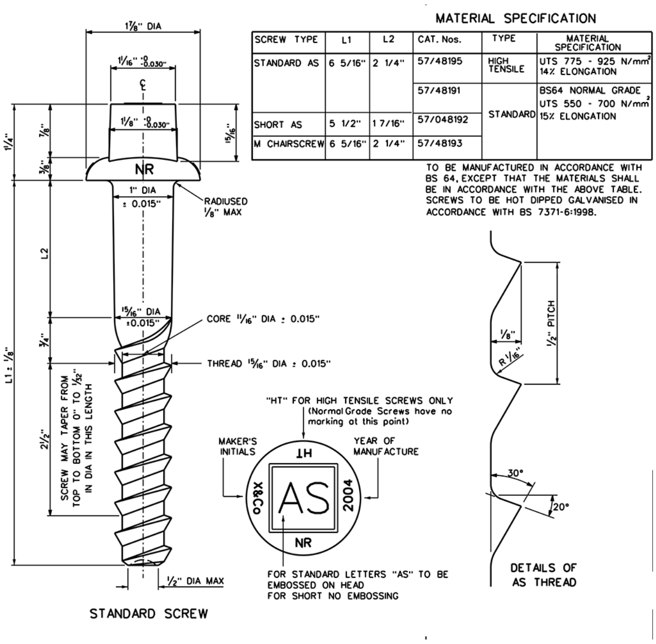

Figure 13: Extract from Network Rail drawing of AS track screws

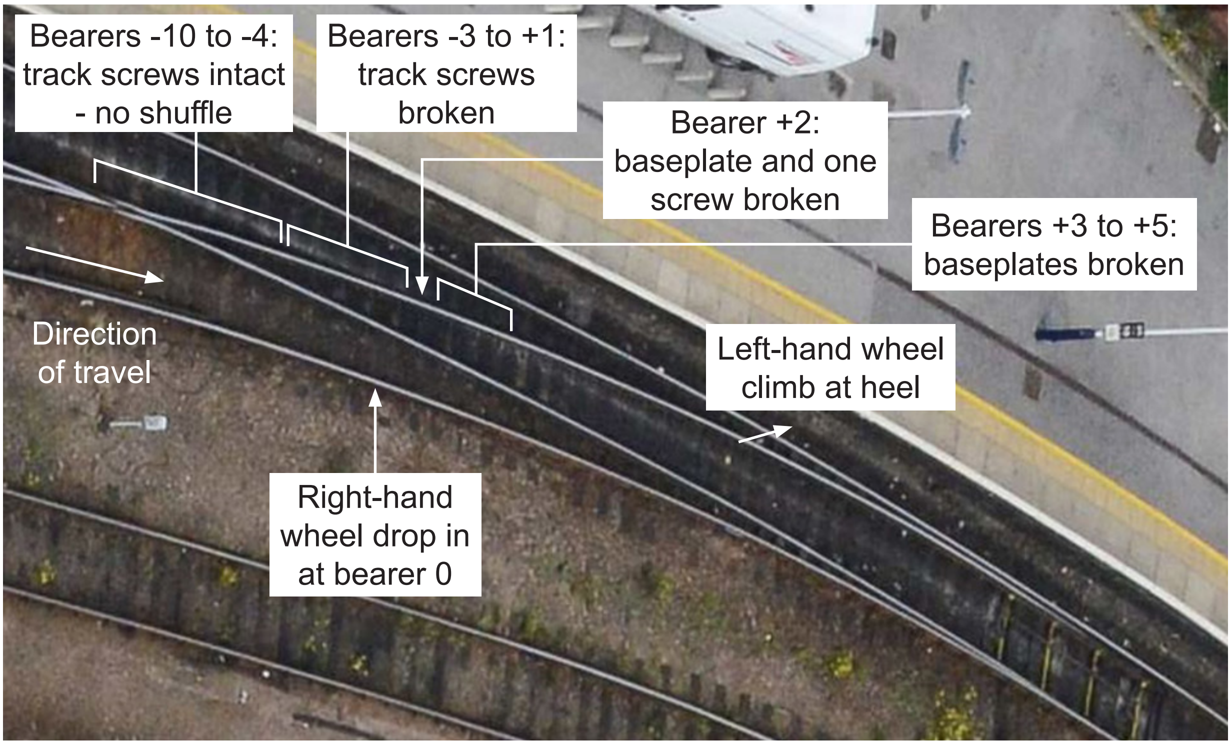

Figure 14: Diagram showing track screws that had failed in 4062 points (background image courtesy of Network Rail)

44 RAIB commissioned an external contractor to undertake a metallurgical examination of the screws that had broken, to determine compliance with the appropriate specification, the mechanism(s) for their failure, and the likely order of failure.

45 This identified that the screws were largely compliant with the specifications in the drawing (figure 13). One screw (from bearer -1) had slightly reduced mechanical properties. However, because this screw was among the last to fail, it is unlikely that its characteristics contributed to the failure of any of the other compliant screws. The study also concluded that all the screws had failed as a result of cyclical unidirectional bending, leading to fatigue cracking, followed by a mechanical overload failure of the residual material thickness.

46 The amount of corrosion on the fracture face surfaces indicated that the breaks had occurred weeks, or perhaps months, before the derailment (figure 15). This was further evidenced by the presence of marks showing repeated relative movement between the two fracture faces on each screw. None of the screws had failed immediately prior to the derailment.

Figure 15: Examples of broken track screws, showing fracture surfaces during examination

47 Although not conclusive, the amounts of corrosion observed on the fracture faces suggested that the first failures started near to the crossing of 4062 points, at bearer -3, with subsequent failures moving sequentially towards the point of derailment at bearer 0.

48 The examination also concluded that all the screws had broken at approximately the same position, below the head near to the expected stress concentration point at the top of the threaded portion. This position would have been a few millimetres below the top of the timber bearers and was consistent with the screws having experienced a cyclical lateral force being transferred from the outer rail, through the supporting baseplates into the screws.

49 The simulation work undertaken by Network Rail indicated that this type of loaded wagon exerted peak lateral forces of the order of 95 kN on the outer rail, in the vicinity of the point of derailment (paragraph 32). The modelling also showed that the leading wheelset of each wagon exerted a large lateral force on the railhead and the trailing wheelset exerted a smaller force. Therefore, every loaded freight train that passes through 4062 points causes a repeated cyclic lateral load on the outer rail. For example, the incident train exerts a series of 74 load cycles (six from the locomotive and two from each of the 34 wagons).

50 The magnitude of these lateral forces is directly related to the curvature of the track. The curvature was at its tightest at the point of derailment, with a radius of approximately 165 metres, having tightened up from an approximate 310 metres radius at the crossing of 4062 points.

51 In summary, the repeated lateral loading of the outer rail under the passage of loaded freight trains led to fatigue cracking of the track screws and subsequent failure over an extended period, despite the track screws being compliant with standards.

Maintenance and inspection of the track

52 The failed track screws had not been identified by the routine inspection regime.

53 The metallurgical examination indicated that the track screw failures had occurred over an extended period, with the last failures occurring a minimum of several weeks before the derailment (paragraph 46). Staff from Network Rail's Sheffield depot had undertaken multiple maintenance and inspection activities throughout the life of the track and its fastenings up to the time of the derailment. The more recent activities are summarised in table 1.

Date	Activity	Notes
2006-2007 (estimated)	Installation of track screws	Based on manufacture date 2005-2006
4 August 2019	Last measurement of dynamic track geometry	Recorded by MPV train
8 September 2019	Static geometry measured	
December 2019	Crossing replaced in 4062 points	Due to crack
6 May 2020	Last 2-yearly 'Engineer inspection'	Routine
6 September 2020	Last measurement of static track geometry	Measured by manual recording trolley
16 September 2020	Last 3-monthly 'Supervisor inspection'	Routine
7 October 2020	Last 'Basic visual inspection' that records 'baseplate shuffle' in 4062 points (see paragraph 59)	Precise shuffle location not identified
4 November 2020	Last weekly 'Basic Visual Inspection'	No record of defects
11 November 2020	Derailment of train 6E91	

Table 1: Timeline, showing recent maintenance and inspection activities undertaken at 4062 points

54 None of these activities identified that any of the track screws in 4062 points were broken, and so no maintenance actions were initiated to replace them.

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

a. The failed track screws were not identified by routine visual inspections (paragraph 56)

b. Static geometry measurements did not identify any issues with the track gauge (paragraph 66)

and probably because:

c. No dynamic geometry measurements had been recorded at 4062 points for 15 months prior to the derailment (paragraph 73)

Each of these factors is now considered in turn.

Visual inspections

56 The failed track screws were not identified by routine visual inspections.

57 The track in Sheffield station was subject to routine 'Basic Visual Inspections' (BVI), as required by Network Rail standard NR/L2/TRK/001 'Inspection and maintenance of permanent way'. At Sheffield station, the BVIs were undertaken weekly, during daylight hours. This involved track patrollers walking a defined route through the station's tracks, visually inspecting them to identify defects, such as broken or loose track components that could affect the safety of the railway. In addition, some minor repairs, such as tightening loose bolts or replacing displaced track components, would be undertaken if identified as being required.

58 Maintenance records showed that all the scheduled BVIs in recent weeks had been carried out as planned, and some of the associated record sheets noted where defects had been identified. On occasions where nothing was found, no notes of defects were recorded. However, where small repairs were undertaken at the time of detecting a defect, such as tightening loose bolts, the defect and repair would not necessarily be recorded.

59 On the last four BVI record sheets, no defects were recorded as having been found at 4062 points. These were undertaken on 4 November and on 28, 21 and 14 October. However, the BVI patroller's record for 7 October noted that there was 'baseplate shuffle at the heel of 4062 points'. Baseplate shuffle is a term used to describe the wear marks on a timber bearer that indicate that a baseplate has been moving relative to the bearer it is fastened to. Witness evidence indicated that the note referred to shuffle located between the heel of the points (at the fixed end of the movable switch rail) and the crossing (figure 16). However, from the evidence available, RAIB has not been able to determine the exact location of the shuffle within this 15 to 20 metre distance, or the amount of shuffle, although this was likely to have been less than 10 mm. It is worth observing that the BVI on 7 October was undertaken by a patroller who does not routinely patrol Sheffield station, and was therefore perhaps more likely to record all defects and not omit any minor defects that were repeatedly present during previous inspections.

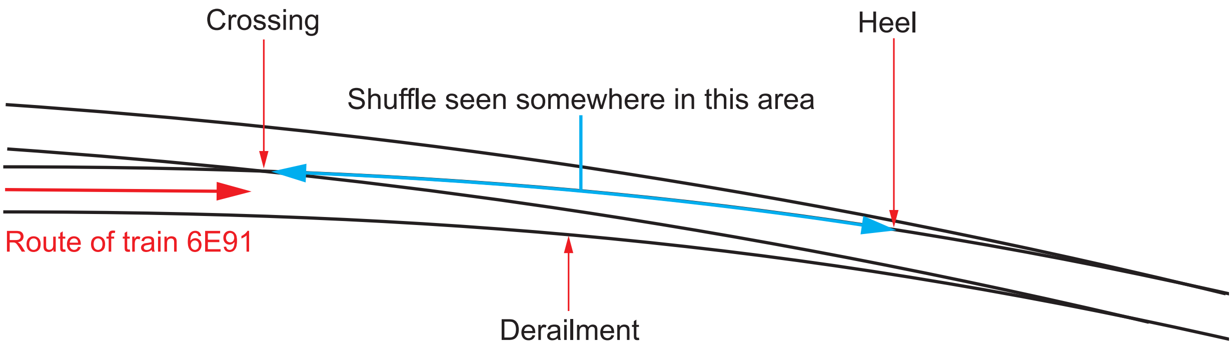

Figure 16: Approximate location of the identified shuffle in 4062 points on 7 October 2020

60 This BVI record was reviewed by a supervisor, and a maintenance intervention to address the observed shuffle was entered into the depot's list of forthcoming work. This intervention was due to be completed within a period of three months from the BVI on 7 October 2020.

61 A review of BVI records prior to 7 October 2020 indicated a similar note relating to baseplate shuffle on 5 June 2019, but nothing between these dates. However, the note from 2019 was less specific and may not have referred to the same location. A supervisor undertook a follow-up inspection and identified that no corrective action was required.

62 The failures of the multiple track screws were not immediately obvious when RAIB attended the derailment. The upper part of each broken screw was held in its associated baseplate by a plastic ferrule that had been compressed around it during installation. These ferrules held the broken screw heads tightly in the baseplates, so that they could not be turned by hand, and felt solid when given a kick. The failed state would similarly have been hidden from visual inspection, and from any test kicks from a patroller's boots, making detection by a BVI difficult.

63 RAIB observed baseplate shuffle between the outer rail baseplates and the associated timber bearers at the derailment location. This appeared to have occurred very recently and was probably a result of the derailment pushing the rails further apart. There was no evidence of any prior baseplate shuffle marks, that could have presented a sign that the outer rail was moving under the passage of trains. However, if any such marks had been present, they would have been destroyed by the shuffle caused during the derailment.

64 In addition to BVIs, NR/L2/TRK/001 requires supervisor inspections to be carried out at three-monthly intervals and engineer inspections to be carried out at two-yearly intervals. During some of these inspections, the track gauge was recorded at the mid-point between the heel and crossing of 4062 points. This is estimated to be at bearer +4, which is shortly after the point of derailment. Table 2 documents the gauge measurements recorded at this location prior to the derailment. All of these are a little wider than the nominal gauge of 1435 mm, but are not at a level that would require corrective action. The first level at which a maintenance alert is triggered is 1455 mm, with corrective action only required when the gauge reaches 1460 mm. There were no notes in these inspection records that identified any gauge issues or signs of baseplate shuffle.

Date	Inspection Type	Measured Gauge
March 2018	Engineer	1440 mm
August 2018	Supervisor	1443 mm
May 2019	Supervisor	1442 mm
August 2019	Supervisor	1444 mm
April 2020	Engineer	1441 mm
August 2020	Supervisor	1446 mm

Table 2: Manual gauge measurements undertaken at 4062 points

65 Sheffield depot staff highlighted to RAIB that there was a long-standing issue with gaining access to some of the lines in Sheffield station to perform routine inspections and maintenance. This was due to trains being stabled in the station area both overnight and during the day. However, this did not contribute to this derailment as the required inspections had been carried out at the derailment location.

Measurement of static geometry

66 Static geometry measurements did not identify any issues with the track gauge.

67 In addition to the sample track geometry measurements taken during the supervisor and engineer inspections, Sheffield depot undertook an annual trolley-based recording of the track geometry in the station. Being trolley-based, this measures the geometry continuously along the length of track and shows the geometry when the track is unladen. This can be different from the dynamic geometry that would be measured under the loading of a train.

68 The last such static geometry measurements were taken in September 2019 and September 2020. This frequency was in line with the maximum permitted interval for the track at Sheffield station. Figure 17 shows the gauge recorded on the route taken by train 6E91 through 4062 points, on these dates.

69 It is notable that there is an apparent calibration difference between the two recordings, with the run in September 2020 recording approximately 3 mm wider gauge, throughout the 300 metre length, than that recorded in September 2019. However, such a discrepancy would not be apparent to the user taking the recording on either date, as it is only evident when the two graphs are compared against each other.

70 There was a slight exceedance of the alert limit (1455 mm) in the vicinity of the point of derailment in September 2020. Alert limit faults are not allocated a timescale by which they need to be repaired, but they are intended to be corrected as part of the planned maintenance activities. Sheffield depot had not undertaken any corrective action in response to this alarm notification prior to the derailment.

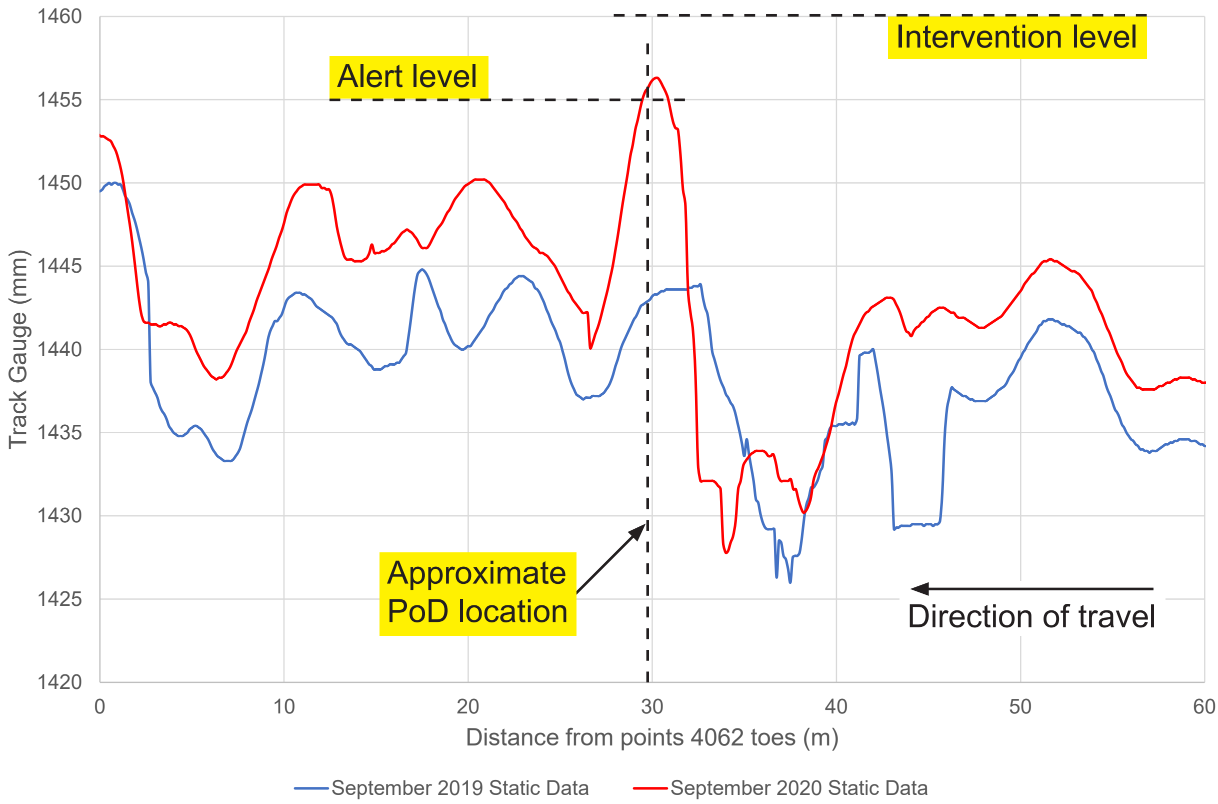

Figure 17: Static geometry measurements at 4062 points

71 The September 2020 gauge at the point of derailment was approximately 13 mm wider than that recorded at the same location in September 2019. However, this would only have been apparent to the TME if he had carried out a detailed comparison of the data from the two dates. The TME only undertook such comparisons to identify trends where he recognised that there was a risk of deterioration, but this was not recognised as being such a location.

72 Had it been undertaken, the task of comparing data to identify deterioration trends would have been hampered by the fact that the two recordings were made in opposite directions. To make such a comparison would have required the TME to import the data into a spreadsheet, or similar, and manipulate the data so that it ran in the same direction and aligned the locations. The TME was not provided with any tools to allow such analysis to be undertaken simply or automatically.

Measurement of dynamic geometry

73 No dynamic geometry measurements had been recorded at 4062 points for 15 months prior to the derailment. This is a probable factor.

74 'Dynamic track geometry' is a term used to describe the geometry of track as trains pass over it, and so includes any changes resulting from the wheel loading from a train. Network Rail uses track measurement trains to measure dynamic track geometry across the network on a routine basis. However, most of these are unable to record some characteristics, for example gauge, at low speed, and they only take a single defined route when passing through stations. As a result, there are many areas in stations and other locations with complex track layouts where dynamic geometry does not get fully recorded by the track measurement trains. Network Rail has a single multi-purpose vehicle (MPV) that is equipped to be used for dynamic geometry measurement in such locations (figure 18).

Figure 18: Network Rail's MPV based track recording vehicle (image courtesy of Brian Creasey)

75 The MPV was scheduled to visit Sheffield station every three months, to record the track geometry for all through lines and terminal platforms. However, no recording runs had been made by the MPV since November 2019, because it had been out of service for overhaul and upgrading.

76 Network Rail stated that compliance with standard NR/L2/TRK/001 does not require the use of the MPV for measurement of dynamic geometry. This is consistent with the wording of the standard which requires the use of track recording vehicles on passenger lines to be planned where this is practicable, but allows alternative approaches, such as inspecting for symptoms of track movement (including baseplate shuffle). The Sheffield TME had implemented a maintenance regime that was compliant with the standard without requiring the information from the MPV. However, information from the MPV, when it was available, augmented his ability to manage dynamic track geometry.

77 The availability of dynamic track geometry data from the MPV was further compromised by issues relating to its reliability and coverage. In total, of the nineteen planned three-monthly MPV runs through Sheffield before the derailment, only five delivered data relating to the Down Through line. This occurred for the reasons below:

- Seven did not happen because the MPV was out of service
- Two were cancelled due to a lack of a driver
- Three runs lost data because it was corrupt or could not be geo-located
- Two runs did not travel via the Down Through line.

78 RAIB analysed the last set of dynamic geometry measurements, recorded on 4 August 2019, for the route through 4062 points. This showed no gauge exceedances, at either the alert or intervention levels (figure 19). The flat portions on the dynamic data line are due to the vehicle stopping recording when its speed falls below its minimum recording threshold.

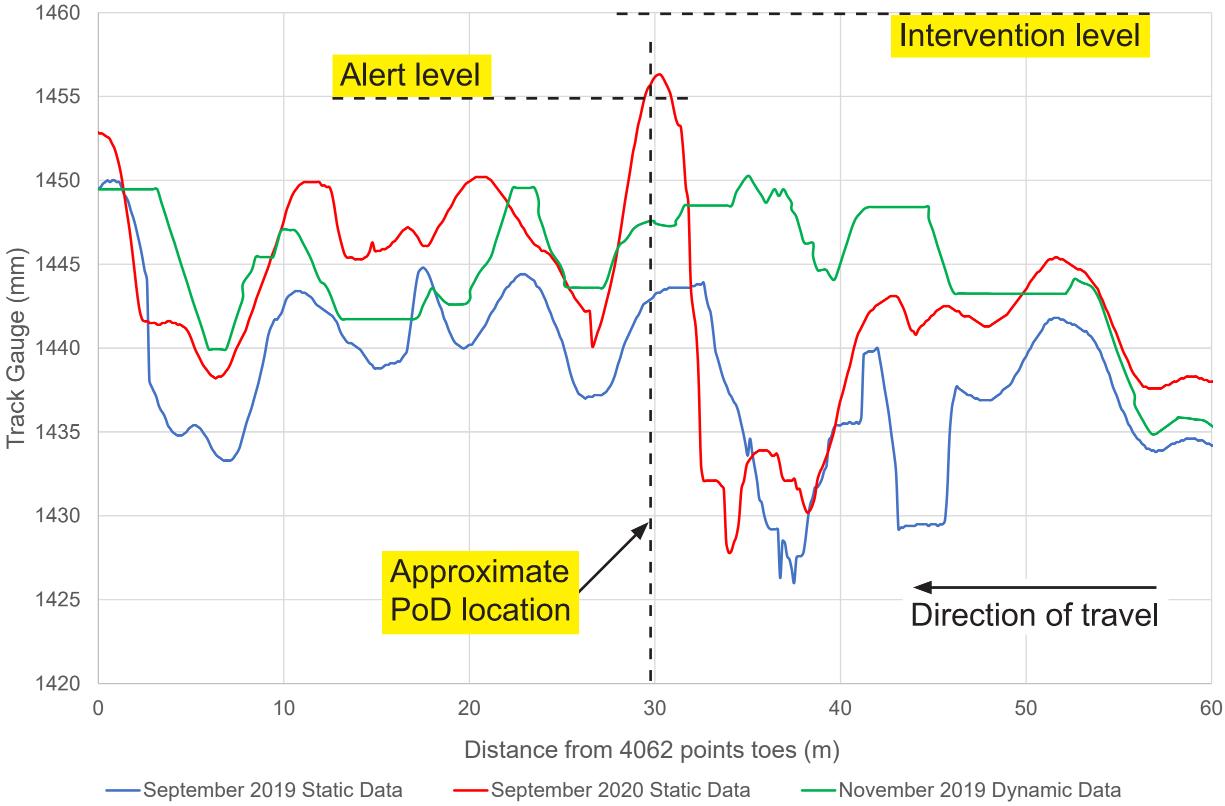

Figure 19: Dynamic geometry compared with static geometry at 4062 points

79 Comparison with the static geometry data from September 2019 and September 2020 (paragraph 68) shows that the deterioration in gauge only becomes visible in the September 2020 static data. There was no dynamic data measured after August 2019 to determine when this trend started to appear and to suggest when the track screws had started to fail, or to indicate the actual gauge experienced by passing trains.

Locations with higher than normal risk of derailment

80 There was no additional mitigation in place at 4062 points, because it had not been identified as a location with a high risk of derailment.

81 Standard NR/L2/TRK/001 defines requirements relating to the assessment and management of risk arising from track assets. These include:

> *'The Track Maintenance Engineer (TME) and Section Manager [Track] (SM[T]) identify risk from the track assets, assess those risks and take action to control them. This is a continuous process…'*
>
> *'Newly appointed TMEs and SM[T]s make themselves familiar with their area and its high risk locations as soon as possible.'*
>
> *'The Infrastructure Maintenance Engineer (IME) arranges transfer of knowledge of high risk locations from previous postholders to newly appointed TMEs and SM[T]s when they take responsibility for an area or route.'*

82 These requirements result in the need to develop and maintain an inspection plan to manage these risks. The acting TME at Sheffield, and his predecessor, had an inspection plan and held records of locations that were known to require additional maintenance focus. These records were based on their knowledge of the history of track faults and the locations that required more maintenance interventions.

83 In response to a recommendation from RAIB's investigation into the derailment at Liverpool Street station, London, in 2013 (see paragraph 143), Network Rail developed a Track Work Information sheet (TWI) to assist TMEs with identifying areas of higher risk of derailment. This was TWI 3G130 'How to determine higher or unusual risk of derailment in track assets', issued in April 2016. This TWI introduced the concept of the 'Track Risk Register', which the TME would create and maintain. This 'register' was intended to record *'locations with higher or unusual risk of derailment'.* TWI 3G130 included a scoring methodology for assessing the risk of derailment at individual assets, a threshold score and suggested mitigations if that was exceeded. This was briefed out to maintenance staff at depots and was refreshed at TME conferences. Both the acting TME and acting IME at Sheffield were aware of this document.

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

a. The maintenance history for 4062 points had not alerted staff that it was a location with a higher risk of derailment (paragraph 85)

b. The risk of derailment at 4062 points had not been assessed using the methodology contained in Network Rail's Track Work Information sheet TWI 3G130 (paragraph 88)

c. Network Rail's assurance regime had not identified that its derailment risk methodology was not being applied (paragraph 94)

Each of these factors is now considered in turn.

Awareness of risk history

85 The maintenance history for 4062 points had not alerted staff that it was a location with a higher risk of derailment.

86 Depot staff were not aware of any history of gauge exceedances at 4062 points, and so did not consider this to be an asset that required additional monitoring. RAIB's review of the inspection records for the previous two years showed that there were no notes of any gauge exceedances. The inspection records did have the occasional note about baseplate shuffle, but the locations for this were not specific to the point of derailment in this incident. Most related to shuffle and slight gauge widening at the toe end of the switch rails. All of these were followed up at the next supervisor or engineer inspection and were actioned for repair if required. There was no record of any corrective action being required at the point of derailment.

87 Most of the recent maintenance history for 4062 points was focused on the crossing, where cracking had been identified. This was corrected by replacement of the crossing in December 2019. It was noted that the radius of the replacement crossing assembly was not in accordance with the design. However, this was an improvement on the crossing's geometry compared with that present before replacement. Since the modelling used to calculate lateral forces on the outer rail undertaken by Network Rail (paragraph 32) included the geometry of the replacement crossing, RAIB does not consider the crossing radius to have significantly contributed to the derailment.

Application of TWI 3G130

88 The risk of derailment at 4062 points had not been assessed using the methodology contained in Network Rail's Track Work Information sheet TWI 3G130.

89 The depot staff at Sheffield were aware of TWI 3G130, having been briefed on its introduction on more than one occasion. However, they did not take immediate, specific action to implement it because they did not consider it to be either urgent or mandatory (see paragraph 115). They considered that they were meeting its intent because they believed they already had a good understanding of the risk locations in their maintenance area. Although this knowledge was not documented in the form of a risk register, they held paper records of what they considered to be higher risk locations. These included details of longitudinal timbers on bridges and areas subject to repeat faults, and thus subject to increased maintenance activity.

90 Had the TWI been implemented by depot staff at Sheffield, this would have resulted in a risk score being developed for every section of track under their management. Had this been done for 4062 points, the score for the Down Through line through the points would have been as follows:

• Curve between 300m and 600m radius	0 pts	
• **Curve tighter than 300 metre radius**	**4 pts**	
• **Wooden sleeper/bearer construction**	**2 pts**	
• **Curve not continuously checked**	**2 pts**	
• Wet/corrosive environment	0 pts	
• **Mixed use**	**1 pt**	
• **No dynamic geometry recording**	**3 pts**	
• Inspection in low light	0 pts	
• Fastenings obscured by ballast/debris	0 pts	
• Additional Factors	0 pts	**Total 12 pts**

91 Although there was a scheduled dynamic geometry recording every three months, the depot staff did not consider this to be a part of their essential maintenance regime. As a result, they have stated that they would not have considered the scheduled operation of the MPV as allowing the related 3 points to be removed. In practice, the unreliability of the MPV meant that dynamic geometry information was not routinely available (paragraph 77).

92 As defined in TWI 3G130, the threshold for inclusion on the risk register and requiring consideration of additional risk mitigation is 10 points. With a score of 12 points, the Down Through line route at 4062 points should have been on the risk register, and additional mitigation measures implemented.

93 TWI 3G130 suggests possible mitigation methods to address the factors leading to the score at 4062 points. These include installation of a check rail, implementation of regular dynamic geometry measurement and an increased or themed inspection regime. The depot staff at Sheffield considered that the most likely of these to be implemented for this location would have been enhanced inspection to look for signs of track deterioration.

Assurance of track maintenance

94 Network Rail's assurance regime had not identified that its derailment risk methodology was not being applied.

95 Network Rail's management assurance processes are set out in company standard NR/L2/ASR/036 and are intended to provide assurance, at every level of the organisation, that risk management systems are operating as intended. Network Rail has three levels of assurance; levels 1 and 2 are relevant to the application of its derailment risk methodology:

- Level 1: 'Local (route) management controls' including compliance monitoring, inspections, management reviews and self-assurance.
- Level 2: 'Corporate oversight' including engineering verification, deep dive reviews, and functional and management system audits, conducted by persons independent from those with the responsibility for implementing the risk controls.
- Level 3: 'Independent challenge and assurance of risk control policies' consisting of audits undertaken by Network Rail's internal audit team with the findings reported to the Network Rail board.

96 At Level 1, Network Rail assures compliance of track maintenance with NR/L2/TRK/001 and other relevant standards primarily by the IME monitoring maintenance frequencies and outputs against the requirements of the relevant standards. In addition, the IME monitors the knowledge and competence of the TME when he first takes up the post, and continuously thereafter.

97 At Sheffield, the IME at the time of the derailment had taken up that post having been the previous TME. He and the TME at the time of the derailment had worked together in the depot for the previous six years. Therefore, the IME had a good understanding of the TME's knowledge and competence.

98 Both the IME and the TME believed that they had records of their high-risk locations based on underlying risk and operational history. Both believed that they were familiar with them and considered that this met the requirements of NR/L2/TRK/001.

99 At Level 2, depots are subject to an external audit every four years. This audit is carried out by a team from another route. At Sheffield, the last external audit was undertaken by a team from London & North Western route in November 2019.

100 This audit carries out a check of maintenance frequencies planned and delivered against the requirements of the standards. The depth of this check depends on the initial findings and goes into more depth if discrepancies are identified. The last external audit at Sheffield identified a few minor non-conformances with standards, but these did not relate to track maintenance frequencies or to activities directly related to the derailment. These non-conformances were addressed, and the audit was signed off.

101 The audit regime is supplemented by sample inspections of infrastructure assets as part of engineering verification. However, both the audit regime and engineering verification only considered the compliance of maintenance processes against the relevant standards. The requirements for numerical quantification of risks against the threshold and maintaining a track risk register only appear in TWI 3G130, which is a guidance document, and not a standard (see paragraph 115). As a result, these processes did not check for their implementation.

Use of check rail

102 The design of 4062 points did not include the fitment of a check rail at the sub-200 metre radius curve between the crossing and the heel of the switch.

103 A check rail is a component provided alongside a running rail to assist guidance to flanged wheels by restricting their lateral movement (figure 20). It is normally used on tight curves to manage derailment risk and is positioned on the four-foot side of the inner rail of a curve.

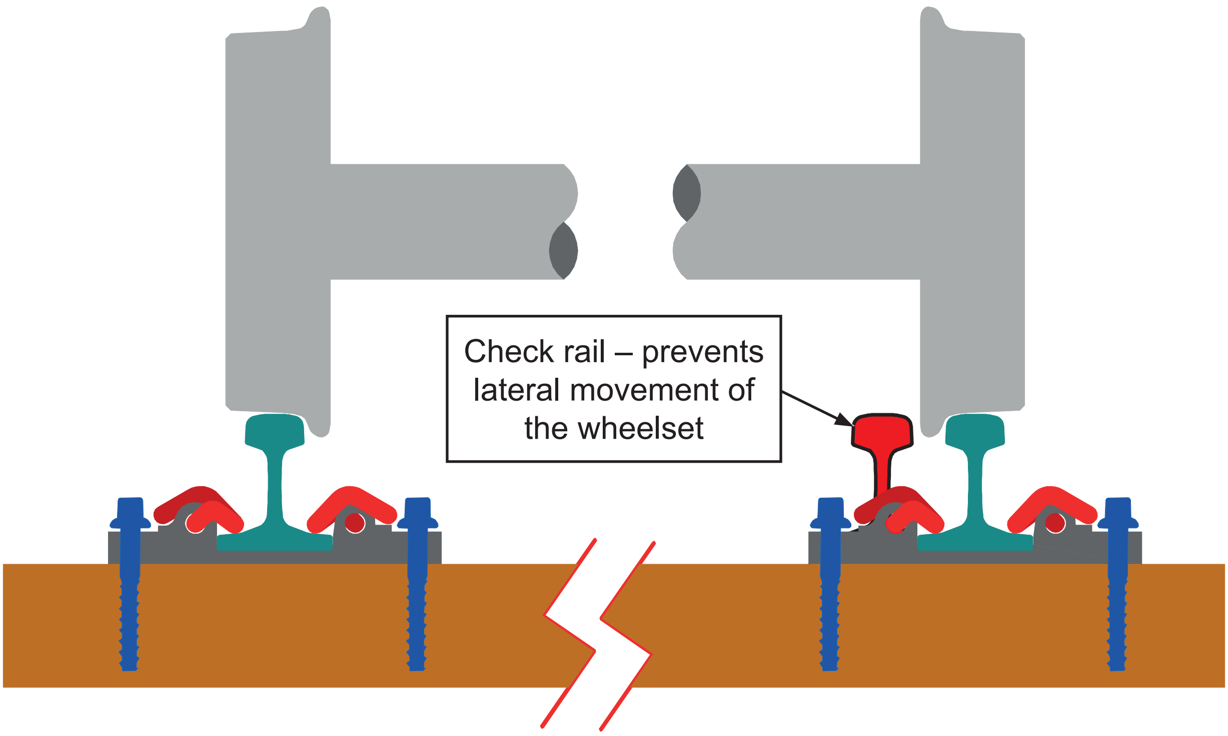

Figure 20: Illustration of a check rail on the inside rail of a curve

104 Railway Group Standard GCRT5021 issue 5 'Track System Requirements', implemented in December 2011, states:

'All passenger lines, and freight only lines adjacent to passenger lines, with a horizontal radius of 200 m or less shall be fitted with a continuous check rail to the inside rail of the curve, except where the design of S&C prevents this from being provided.'

105 A similar requirement is applied in Network Rail standard NR/L2/TRK2102 'Design and Construction of Track', and dates back to at least 2000. This states:

'Check rails shall be fitted on … all passenger lines and passenger diversionary lines with a track radius of 200 m or less … and … running lines with a track radius of 200 m or less at a track interval of less than 3.1m to adjacent passenger lines.'

106 Historic requirements for check rails are also found in the 1950 Ministry of Transport 'Blue Book', titled 'Railway Construction and Operation Requirements for Passenger Lines and Recommendations for Goods Lines'. This states:

'Check rails to be provided on curves where the radius is 10 chains[2] or less'

A similar requirement can also be found in the 1892 'Requirements of the Board of Trade in regard to the Opening of Railways', which states:

'In any curves where the radius is 10 chains or less, a check-rail to be placed inside the rail of the curve'.

107 None of these documents limits the use of check rails to plain line nor do they explicitly exclude curves in switches and crossings. The wording of the later standards specifically requires their consideration for curves in switches and crossings, where the design makes this practicable. Network Rail has reported that the designs for new-build switches and crossings now include a check rail that extends from the crossing to the switch heel where the curve radius is less than 200 metres.

108 The Down Through line route through 4062 points is at its tightest, with a radius of approximately 165 metres, at the point of derailment (paragraph 50). However, despite having a radius less than 200 metres, no check rail had been fitted to the inside rail.

109 A similar lack of check rail was referred to in the RAIB investigation into the derailment that occurred at Liverpool Street station, London, in 2013 (see paragraph 143). No associated recommendation was made at that time because the trackwork involved was more complex and installation of a check rail was not considered to be practicable. However, in 4062 points at Sheffield it would be practicable to have a check rail. This is demonstrated by the presence of such a check rail in similar points (4064 points), 60 metres from 4062 points (figure 21). Fitment of a check rail was part of the original design for 4064 points, which were installed several decades ago.

110 The staff at Sheffield depot stated that they would not routinely consider adding a check rail to points as this would require the design to be amended. They would only make such a proposal if they considered that there was a very high risk of derailment.

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[2] 10 chains is approximately 200 metres.

Figure 21: Check rail fitted within 4064 points

111 Check rails are normally fitted to prevent wheel flanges climbing on to the head of the outer rail, by restraining the lateral movement of the back of the wheel on the inner rail, as vehicles negotiate tight radius curves. This was not the cause of the derailment at Sheffield. However, a check rail would have helped in this scenario because it would have limited the lateral movement of the inner wheel and prevented it dropping into the four-foot if the outer rail and wheel moved outwards. Once the outer rail had started to move, due to the deteriorating fixings, the check rail would also have taken some of the lateral force that was being applied to the outer rail. In addition, the evidence of excessive contact of the inner wheel with the check rail might have alerted track patrollers that the outer rail was moving, and prompted investigation of the cause.

Identification of underlying factors

112 Network Rail issued the methodology for assessment of derailment risk as a Track Work Information sheet (TWI) and did not incorporate it into standards.

113 Network Rail's response to recommendation 2 from the RAIB investigation into the derailment that occurred at Liverpool Street station in 2013 (see paragraph 143) stated that the existing standards, including NR/L2/TRK/001, were adequate to manage the derailment risk. However, it acknowledged that the way the standards were being implemented was not consistent across Network Rail.

114 Network Rail addressed the lack of consistency by developing information sheet TWI 3G130 to set out a methodology for assessing and recording derailment risk and for selecting and implementing appropriate mitigations. This was introduced in April 2016 and briefed out to maintenance staff (paragraph 83).

115 A track work information sheet is not a standard and therefore is not mandatory. It is guidance on how a standard's requirements can be implemented, but alternative methods are allowed, providing that the requirements of the standard are complied with. Although Network Rail expected the methodology in TWI 3G130, and track risk registers, to be adopted by all depots, it did not make it mandatory by including reference to it in the standards. It also did not define a format or template for the track risk register, to allow consistent application across its routes and depots.

116 Network Rail had insufficient track recording capacity capable of recording the dynamic track geometry in station areas to undertake planned measurement runs. This is a probable factor.

117 Network Rail only had one MPV based track recording vehicle capable of recording dynamic track geometry on all lines at stations, and at low speeds (paragraph 74). Had it had greater resource then dynamic geometry data could have been provided to the TME on a regular basis, as planned.

118 The fact that 14 out of 19 MPV runs through the tracks at Sheffield station were not undertaken for various reasons, strongly suggest that there will be many other such shortfalls throughout the network.

Observation

119 The format of the dynamic geometry data output from the MPV track recording vehicle makes it difficult for the data to be analysed by maintenance staff.

120 The MPV track recording vehicle was planned to visit Sheffield every three months (paragraph 75). On each visit it was planned to measure every track by carrying out a series of seventeen runs backwards and forwards through the station. An example of part of the planned route is shown in figure 22.

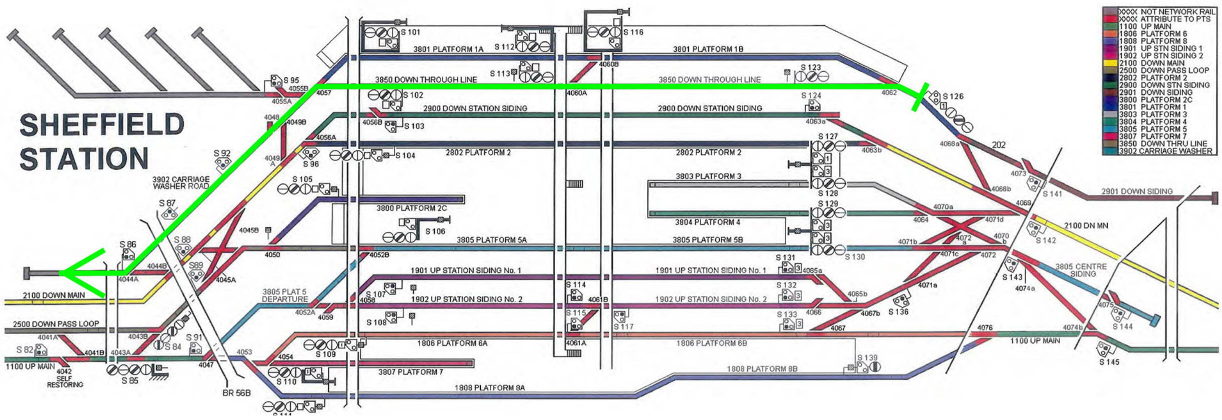

Figure 22: Part of MPV route through Sheffield station

121 The output from this was a single set of data, both in graphical and spreadsheet form, covering all seventeen runs in sequence. Any measured exceedances of standards' requirements were flagged in the data for attention by the TME and maintenance staff.

122 Investigation of deterioration between successive runs is a complex and time-consuming activity. The relevant data needs to be identified and extracted from both data sets. There are no specific tools to facilitate this and it is further complicated by the fact that, on each visit, not all the lines can be recorded due to the presence of stabled trains. This means that the locations of sections of track in the data can vary from set to set. The complexity of the work means that a TME would rarely have the time to undertake trend analysis and would naturally focus on the exceedances highlighted by the MPV.

123 This was not a factor in the derailment, because the MPV had not taken the Down Through route through 4062 points in the 15 months prior to the derailment.

Summary of conclusions

Immediate cause

124 An undetected failure of the rail fixings meant that the track was unable to maintain gauge as the train passed through 4062 points (paragraph 26).

Causal factors

125 The causal factors were:

a. Multiple track screws securing the rail baseplates to the bearers had failed prior to the derailment (paragraph 40, no recommendation).

b. The failed track screws had not been identified by the routine inspection regime (paragraph 52, **Recommendation 4**). This causal factor arose due to a combination of the following:

   i. The failed track screws were not identified by routine visual inspections (paragraph 56, **Learning point 1**).

   ii. Static geometry measurements did not identify any issues with the track gauge (paragraph 66, **Learning point 2**).

   and probably because:

   iii. No dynamic geometry measurements had been recorded at 4062 points for 15 months prior to the derailment (paragraph 73, **Learning point 3**)

c. There was no additional mitigation in place at 4062 points, because it had not been identified as a location with a high risk of derailment (paragraph 80). This causal factor arose due to a combination of the following:

   i. The maintenance history for 4062 points had not alerted staff that it was a location with a higher risk of derailment (paragraph 85, no recommendation).

   ii. The risk of derailment at 4062 points had not been assessed using the methodology contained in Network Rail's Track Work Information sheet TWI 3G130 (paragraph 88, **Recommendation 1**).

   iii. Network Rail's assurance regime had not identified that its derailment risk methodology was not being applied (paragraph 94, **Recommendation 2**).

d. The design of 4062 points did not include the fitment of a check rail at the sub-200 metre radius curve between the crossing and the heel of the switch (paragraph 102, **Recommendation 3**).

Underlying factor

126 The underlying factors were:

a. Network Rail issued the methodology for assessment of derailment risk as a Track Work Information sheet (TWI) and did not incorporate it into standards (paragraph 112, **Recommendation 2**).

and probably:

b. Network Rail had insufficient track recording capacity capable of recording the dynamic track geometry in station areas to undertake planned measurement runs. This is a probable factor (paragraph 116 and Eastleigh investigation **Recommendation 2**, described in paragraph 154).

Additional observation

127 Although not directly linked to the accident on 11 November 2020, RAIB observes that:

a. The format of the dynamic geometry data output from the MPV track recording vehicle makes it difficult for the data to be analysed by maintenance staff (paragraph 119, **Recommendation 4**).

Previous RAIB recommendations relevant to this investigation

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

Derailment at Santon, near Scunthorpe, 25 January 2008

129 RAIB investigated the derailment of a freight train conveying hopper wagons at Santon, near Scunthorpe (RAIB report 10/2009). The train derailed due to a combination of track faults that had developed as a result of water running in the formation underneath the track. The faults had occurred previously and had been rectified, but had reoccurred. The maintenance inspections had not identified this reoccurrence before the derailment.

130 Following the accident, RAIB made the following recommendation:

Recommendation 4

Network Rail should develop appropriate tools to analyse trends in track geometry recording systems in order to identify rapid deterioration in track geometry, with the information output from these tools provided to the local maintenance teams.

131 The Office of Rail and Road (ORR) reported to RAIB that this recommendation had been implemented by Network Rail, with the following comment:

'ORR reports that Network Rail has developed and are now implementing the Linear Asset Decision Support (LADS) tool, which is a track asset information service for decision support:

- *It calculates, consolidates, and geographically aligns key data from source systems*
- *Current and historic track asset data is graphically presented, compared and analysed*
- *Data sources include geographical, condition (track geometry recording, rail breaks/defects) and intervention history and planning*
- *Deployed for desktop PCs and mobile devices.'*

132 The LADS tool was available at Sheffield depot for suitably trained staff to undertake some track geometry trend analysis. However, LADS does not include track geometry data recorded by the MPV used in the station area, nor does it include any geometry data recorded by trolley-based recording systems.

Derailment of a freight train near Stewarton, Ayrshire, 27 January 2009

133 RAIB investigated the derailment of a freight train conveying fuel tank wagons at Stewarton, Ayrshire (RAIB report 02/2010). As the train crossed a bridge, the bridge collapsed resulting in the derailment. The investigation found that the bridge girders had deteriorated leading to its collapse.

134 RAIB also found that the dynamic track geometry data recorded at the location before the collapse showed the early signs of the deterioration, but that the analysis that could have identified this was not being undertaken.

135 Following the accident, RAIB made the following recommendation:

Recommendation 10

Network Rail should evaluate the feasibility of using the track geometry data recorded by its track measurement trains so that trends can be seen that could be used to identify underbridges that may have degraded to an unsafe condition. If reasonably practicable, it should develop and implement appropriate analysis tools and processes and make these available to engineers responsible for the management of structures and track.

136 On 25 February 2011, ORR reported to RAIB that this recommendation had been implemented by alternative means by Network Rail, with the following comment:

'Network Rail have carried out the evaluation in response to this recommendation and concluded that it is not reasonably practicable to use track geometry data recorded by measurement trains in the way envisaged by the recommendation. Network Rail propose no further action.'

137 RAIB expressed concern, in its 2011 Annual Report, that the actions taken in response to the recommendation were inappropriate or insufficient to address the risk and made the following comment:

'The RAIB is concerned that measurement trains provide useful data that could give an early indication of a structural failure. While noting the conclusion of Network Rail's evaluation the RAIB is urging the industry to find ways of making maximum use of data collected by measurement trains.'

Derailment at Windsor and Eton Riverside station, 11 October 2009

138 RAIB investigated the derailment of a charter train at Windsor and Eton Riverside station, Berkshire (RAIB report 11/2010). As the train approached the buffer stops, the rails spread underneath it, allowing the leading wheelset of the leading coach to derail. The investigation found that the poor condition of some of the sleepers allowed the rails to move apart. This fault had been identified four years prior to the derailment, but a discrepancy in the recording of the fault meant that it was not adequately monitored.

139 RAIB also found that the dynamic track gauge at the location was not being recorded, as a track measurement train was not monitoring this section of track. Network Rail had no other systematic method of assessing the change in track gauge under dynamic conditions.

140 Following the accident, RAIB made the following recommendation:

Recommendation 2

Network Rail should develop a proposal for the periodic measurement of dynamic gauge at potentially vulnerable locations not covered by a track recording vehicle, and implement the identified measures, as appropriate.

141 On 17 October 2013, ORR reported to RAIB that this recommendation had been implemented by alternative means by Network Rail, with the following comment:

'ORR has concluded that Network Rail has considered how potentially vulnerable parts of the network that are not covered by track recording vehicles can be subject to dynamic gauge measurement.

Network Rail concluded that: …the underlying issue was non-compliance with company standards and that if action had been taken in accordance with specified minimum actions derailment risk would have been mitigated…and that …the consequential risk posed at these locations is not considered significant as a consequence of their track category assessment.

However, Network Rail has introduced a new Track Geometry Measurement system (TrueTrak) which has been successfully installed on two Track Recording Vehicles, with a lower cut–off speed of 7 mph. These vehicles have just entered into production service and have not yet operated for a sufficient amount of time to demonstrate the delivery of additional gauge data.'

142 RAIB notes that five track recording vehicles were ultimately fitted with the TrueTrak geometry recording system, although the MPV was fitted with an alternative system. Network Rail has reported that the TrueTrak system is being further developed for use on the MPV.

Derailment at Liverpool Street station, London, 23 January 2013

143 The investigation into the derailment of a passenger train at Liverpool Street station, London (RAIB report 27/2014), found that the train derailed on a tight curve with non-standard trackwork. Mitigation measures to manage the enhanced derailment risk at this location were not in place because local maintenance management staff did not have the necessary knowledge to understand these risks or to implement appropriate controls. The investigation found that there were particular issues with maintaining the gauge of the track, due to a degradation in the strength of the rail fastenings. RAIB also found that the manual track measurement methods in use at the location did not report, and possibly did not identify, wider than normal static track gauge or indications of a loss of strength in the fixing between the rail and sleepers.

144 Following the accident, RAIB made the following recommendation:

Recommendation 1

Network Rail should improve its management systems so that both the identification of all non-standard track assets, and the associated inspection regimes intended to manage any enhanced risk of derailment, are recorded and independently checked. The scope of these inspection regimes should include mechanisms for identifying indications of possible gauge widening and, where necessary, assessing dynamic track gauge.

145 On 12 June 2020, ORR reported to RAIB that this recommendation had been implemented by Network Rail, with the following comment:

'Network Rail reviewed its track management system and found it be sufficiently robust. However, shortcomings were identified with different interpretations of standards, so a Track Work Information sheet (TWI) has been produced aimed at standardising the approach to identifying higher or unusual risk assets and suggesting possible suitable mitigations. Network Rail have now confirmed that the TWI has been briefed to TME and RAM (track) in each route.'

146 RAIB also included six learning points. Two were particularly relevant to the derailment at Sheffield. One noted the need for effective management of track gauge where this is not monitored by track recording trains. The other noted that users of trolleys recording static gauge data should be aware that, although pre-programmed to generate alerts related to dynamic gauge intervention limits, the trolley is only recording static gauge and so could mislead the operator, and that they should assess dynamic movement by alternative means and take this into account when assessing whether maintenance intervention is necessary.

Locomotive derailment at Ordsall Lane Junction, Salford, 23 January 2013

147 The investigation into a locomotive that derailed and subsequently caught fire at Ordsall Lane Junction (RAIB report 07/2014) found that the lateral forces involved in curving were sufficient for the wheel flange to climb over the outer rail into derailment. Although a number of factors contributed to the derailment, there was no check rail despite the tightest curve radius being less than 200 metres.

148 Following the accident, RAIB made the following recommendation:

Recommendation 1

Network Rail should identify all curves that are non-compliant with Railway Group standard GC/RT5021 and Network Rail standard NR/L2/TRK/2102 in respect of the need to fit a check rail. For each identified curve, Network Rail should implement measures to adequately mitigate the risk of derailment. These may include one or both of the following methods, although other means of mitigation may also be appropriate:

- *installing a check rail on the curve; and*
- *managing rail lubrication on the curve to a suitable level of availability.*

Implementation of this recommendation may require Network Rail to review curvature information recorded on track geometry measurement train runs.

149 On 16 February 2017, ORR reported to RAIB that this recommendation had been implemented by Network Rail, with the following comment:

'Network Rail report they have identified curves with sub 200m radii that are not fitted with check rails (68% of the 422 curves identified with sub 200m radii), assessed the risk at each curve taking account of local factors and identified appropriate corrective actions. These include measures such as providing or enhancing lubrication, and fitting of check rails as necessary.'

Freight train derailment at Willesden High Level Junction, north-west London, 6 May 2019

150 The investigation into a derailment of a freight train at Willesden High Level Junction (RAIB report 07/2020), found that the train derailed on a curve on top of an embankment that was subject to progressive seasonal movement. The measures that Network Rail had in place for inspection, maintenance and mitigation were not effective in detecting the risk of a track twist developing because of the embankment movements.

151 Following the accident, RAIB made the following recommendation:

Recommendation 1

Taking into account findings from its ongoing research programmes, Network Rail should investigate whether recent advances in computing techniques allow data recorded by its track geometry measurement trains to be analysed in a way that enables the identification of track movement trends that are indicative of underlying problems with the track bed and/or supporting earthworks. If reasonably practicable, it should develop and implement analysis tools and processes and make these available to engineers responsible for the management of such infrastructure assets.

152 Implementation of this recommendation was still in progress at the time of writing this report.

Freight train derailment at Eastleigh, Hampshire, 28 January 2020

153 The investigation into the derailment of a freight train at Eastleigh (RAIB report 02/2021), found that the train derailed on a tight curve with rails fixed to concrete bearers. A number of track fixings, of a different design to those used at Sheffield, had failed prior to the derailment, and these failures had not been identified by the routine maintenance inspections. In addition, track geometry had only been measured statically and, therefore, additional gauge widening under the presence of a train was not identified.

154 Following the accident, RAIB made the following recommendation:

Recommendation 2

Network Rail should review its arrangements for the dynamic measurement of track geometry on the parts of its infrastructure not covered by its track measurement trains. The review should include the identification of high risk locations where additional safeguards are required (such as those subject to high lateral forces, or where there is an increased risk of track geometry faults). Consideration should be given to the number and routing of track measurement trains and alternative ways of measuring track geometry under dynamic conditions. Any additional safeguards identified by this review should be implemented by means of a risk-based programme.

155 Implementation of this recommendation was still in progress at the time of writing this report. Since this addresses the same issue that was subsequently identified at Sheffield, RAIB has decided not to make a further recommendation.

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

156 The TME at Sheffield has implemented additional monitoring of geometry trends in the Sheffield station area. This has been supported by depot staff being briefed to make more detailed records of visually identified faults and their locations. This allows the trend analysis to be focused on the areas perceived to be at highest risk.

157 Network Rail's North and East route has initiated a project to replace standard grade AS track screws with the high-tensile grade AS track screws at locations that have been identified as being at higher risk of derailment. This includes those used on a number of tight radius switches and crossings at Sheffield station.

158 Network Rail has started work to develop a new technical specification for the design of track screws and the associated rail fixing components. This recognises that there was no data on the performance characteristics for existing baseplate and track screw configurations. The work will include an engineering analysis of existing designs to inform the new technical specification.

159 ORR has reported that Network Rail is leading a cross-industry initiative to improve track access for maintenance purposes at Sheffield station.

Recommendations and learning points

Recommendations

160 The following recommendations are made:[3]

1 *The intent of this recommendation is to improve the management of derailment risk at locations where that risk is high.*

Network Rail should review its processes for the application of site-specific derailment risk assessments, such as those implemented by track work instruction TWI 3G130, and make and brief any necessary changes so that they are fully and consistently implemented by track maintenance staff (paragraph 125c.ii).

2 *The intent of this recommendation is to improve the implementation of safety-critical track maintenance activities.*

Network Rail should review its arrangements for how safety-critical changes to the management of track maintenance are incorporated into its processes and procedures, including consideration of management assurance of compliance. In particular, this review should include consideration of how Network Rail determines whether such changes should be implemented as standards or as guidance. Network Rail should make and brief any revisions necessary to facilitate appropriate, consistent and effective implementation of such safety-critical changes (paragraphs 125c.iii and 126a).

3 *The intent of this recommendation is to align standards and practice for the use of check rails.*

Network Rail should review, and update and brief as necessary, its standards and processes relating to the fitment of check rails to clarify their applicability, or otherwise, to tight track radius locations inside switches and crossings as a means of managing derailment risk (paragraph 125d).

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[3] 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.

4 *The intent of this recommendation is to improve the ability of track maintenance staff to detect changes in track geometry.*

Network Rail should review, and change as necessary, the format of the data produced by its MPV track recording unit, geometry recording trolleys and other measurement systems, and analysis tools, so that track maintenance staff can routinely and easily identify fault locations and perform trend analysis of track geometry (paragraphs 125b and 127a). This recommendation reinforces recommendation 1 from RAIB's investigation into the freight train derailment at Willesden High Level junction on 6 May 2019, and could be incorporated into the work resulting from it (paragraph 150).

Learning points

161 RAIB has identified the following learning points:[4]

1 The importance of track maintenance staff implementing effective management of track gauge, particularly in locations of high curvature with no check rail, where this is not monitored by track recording trains (paragraph 125b.i).

2 The importance of track maintenance staff using static geometry measurement equipment, such as recording trolleys, recognising that, although pre-programmed to generate alerts related to dynamic gauge intervention limits, they only record static measurements. Users need to assess dynamic movement by alternative means and take this into account when assessing whether maintenance intervention is necessary (paragraph 125b.ii).

3 The importance of routinely gathering and analysing dynamic geometry data, and its trends, to identify potential deterioration of track and its fixings (paragraph 125b.iii).

[4] '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

BVI	Basic Visual Inspection
ECM	Entity in Charge of Maintenance
GSM-R	Global System for Mobile communications - Railway
IME	Infrastructure Maintenance Engineer
kN	Kilonewtons – a unit of force
MPV	Multi-Purpose Vehicle
ORR	Office of Rail and Road
PCA	A type of 4-wheeled wagon
RAIB	Rail Accident Investigation Branch
ROC	Rail Operating Centre
TME	Track Maintenance Engineer
TWI	Track Work Information sheet

Appendix B - Investigation details

RAIB used the following sources of evidence in this investigation:

- examination of the track and the wagons
- witness interviews
- track maintenance records
- metallurgical examination of track screws
- a review of Network Rail and industry standards and procedures
- the freight train's on-train data recorder
- station closed-circuit television
- a review of previous RAIB investigations that had relevance to this accident.

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