RAIB

Rail Accident Investigation Branch

Rail Accident Report

Derailment of an engineering train between Gloucester Road and Earl's Court stations on London Underground
12 May 2010

Department for Transport

Report 05/2011
March 2011

This investigation was carried out in accordance with:

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

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Contents

Summary

On the morning of 12 May 2010, the leading wheelset of a locomotive that was hauling an engineering train derailed when it was travelling westbound between Gloucester Road and Earl's Court stations on the Piccadilly Line of the London Underground system.

As a result of the derailment, the locomotive and infrastructure were damaged and the driver of the engineering train reported suffering from trauma. The westbound Piccadilly Line was closed between Gloucester Road and Earl's Court stations until the start of the passenger service the following day while the locomotive was re-railed and infrastructure repairs were undertaken.

The derailment occurred because the track was not able to maintain gauge within safe limits as the train passed over it. A combination of factors led to this situation occurring, including:

- the non-identification and misclassification of track faults which led to those faults not being rectified;
- no action being taken in response to the identification of dynamic wide gauge at the location of the derailment in the previous months;
- there were insufficient staff to maintain the track in good condition; and
- the Piccadilly Line team within Tube Lines was mainly focused on managing safety faults and had not identified the safety risks from combined groups of less serious faults.

The RAIB has made nine recommendations. The recommendations include changes to how data from asset inspection equipment is presented, an analysis of the tasks involved in track patrolling and inspecting, changes relating to the training and assessment of track patrollers and inspectors, improvements to assurance processes and consideration of the use of available technologies that can assist track patrollers and inspectors in recording and classifying track faults.

Preface

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

Key Definitions

3 The term westbound refers to trains travelling on the Piccadilly Line between Gloucester Road and Earl's Court stations. The terms left and right are relative to the direction of travel.

4 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B.

The Accident

5 On 12 May 2010, at approximately 05:30 hrs, the leading wheelset of a locomotive hauling a train consisting of engineering wagons and a *ballast* machine derailed as it was travelling between Gloucester Road and Earl's Court stations in a tunnel section of the London Underground (LU) network. The train was travelling westbound on the Piccadilly Line (figure 1).

6 At the time it derailed, the train was travelling at around 26 mph (42 km/h). The train ran with the leading wheelset derailed for approximately 78 metres and came to a stand 230 metres from Earl's Court station. The driver of the engineering train reported suffering trauma as a result of the derailment.

7 The locomotive and infrastructure were damaged during the derailment. The westbound Piccadilly Line was closed between Gloucester Road and Earl's Court stations until the start of passenger service the following day while the locomotive was re-railed and infrastructure repairs were undertaken.

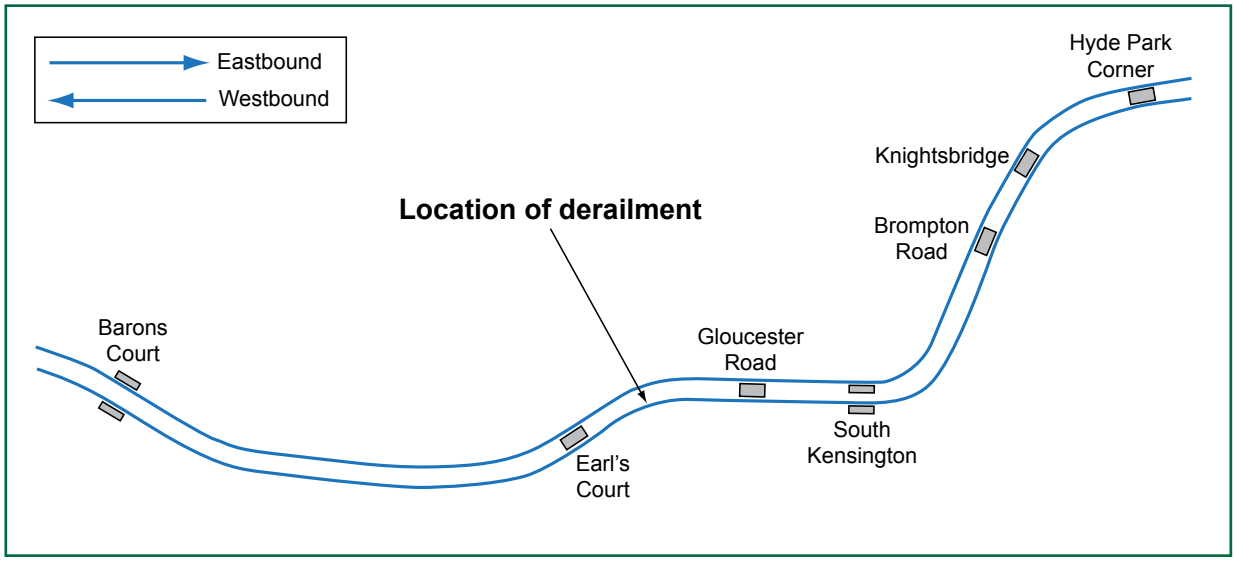

Figure 1: Section of Piccadilly Line showing location of derailment

Organisations involved

8 In December 2002, LU entered a Public Private Partnership (PPP) agreement with Tube Lines. The agreement applied to the Jubilee, Northern and Piccadilly lines and was for 30 years' duration. Tube Lines was required to maintain, renew and upgrade the three lines. LU remained the infrastructure manager and as such continued to be responsible for operating the whole underground network.

9 In June 2010, Tube Lines became a wholly owned subsidiary of Transport for London (TfL).

10 The train involved in the derailment, and the staff on it, worked for the Trans Plant division of Tube Lines. Trans Plant provided specialist engineering trains that operated on the LU network.

Location

11 The railway between Gloucester Road and Earl's Court consists of two parallel *single-bore* tube tunnels, one for the westbound line and one for the eastbound line. The distance between the station *headwalls* at Gloucester Road and Earl's Court is 705 metres (figure 2).

12 The *track geometry* at the location of the derailment consists of a left-hand curve of 305 metres radius. The *cant* on the approach to the point of derailment is 86 mm. The maximum permitted line speed is 45 mph (72 km/h).

13 The point of derailment was 397 metres from the headwall of Gloucester Road station.

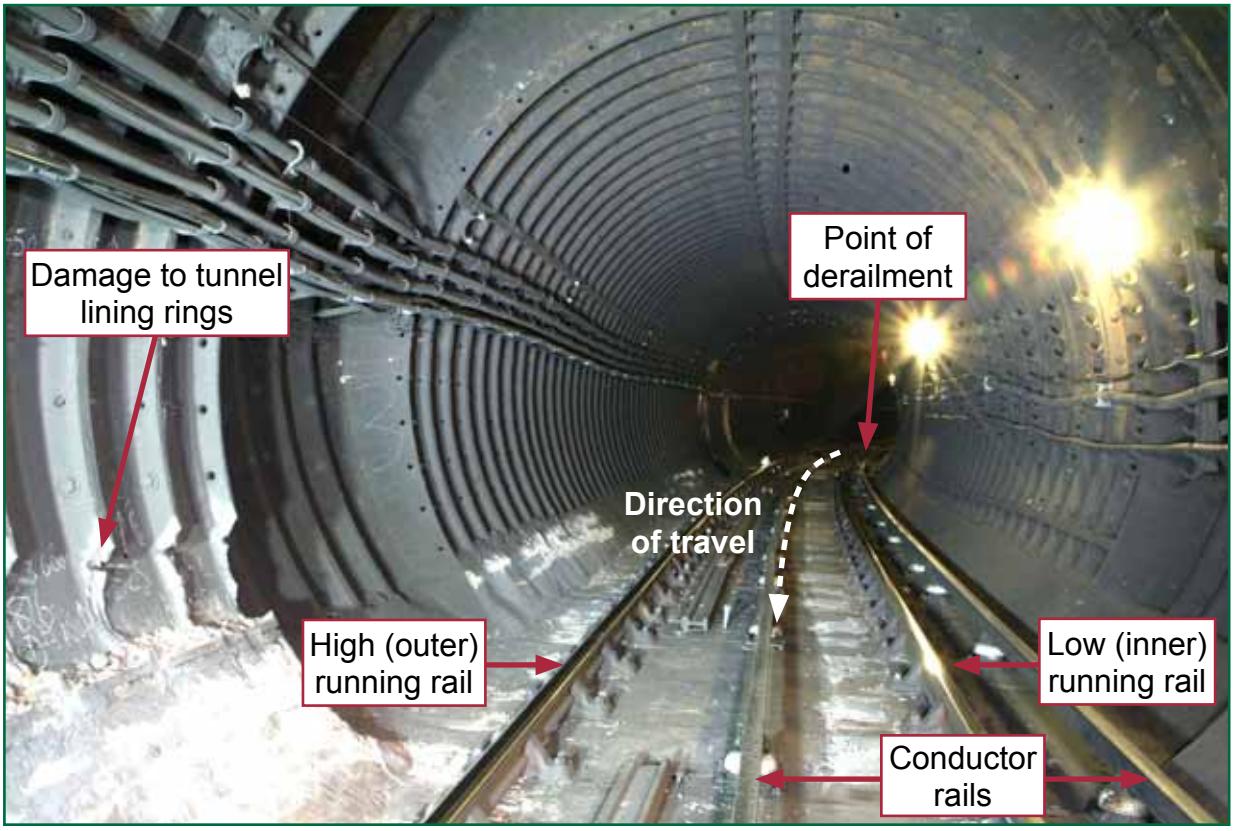

Figure 2: The westbound Piccadilly Line in the vicinity of point of derailment

Train involved

14 The train was an engineering train and consisted of two wagons and a ballast machine hauled by a battery locomotive. There was another battery locomotive coupled to the rear of the train. The total weight of the train, including both locomotives, was 270 tonnes.

15 Battery locomotives such as the one involved in the derailment were built between 1964 and 1965. They weigh approximately 66 tonnes and have two, two-axle bogies giving an approximate axle weight of 16.5 tonnes (figure 3). Battery locomotives are able to run off an internal battery supply if needed but normally use the current in the *fourth rail system* when hauling trains on London's underground system.

16 The RAIB has found no evidence that the condition of the locomotive hauling the train, or the way in which it was driven contributed to the derailment.

Figure 3: Battery locomotive involved in the derailment

The infrastructure

17 At the derailment site the infrastructure consisted of *95 lb bull head rail* secured in cast iron *chairs* by metal *keys*. The chairs were fixed to wooden sleepers using screws. The sleepers were grouted into a concrete track bed forming the track support.

18 The sleepers and concrete sub formation at the site of the derailment have been in place since 1952. The running rails were last replaced in 1994.

Staff involved

Tube Lines

19 The section of line where the derailment occurred was maintained by a local track team based at Ealing Common. The track team was led by the Area Track Manager-West, who was responsible for the maintenance of the Piccadilly Line track between Russell Square and Heathrow terminal 5 and to the boundary with the Metropolitan Line at Rayners Lane. The Area Track Manager-West had worked at the Ealing Common track office since 2006 and for LU since 1999.

20 The track team at Ealing Common comprised 17 track workers, including 3 contracted staff, who undertook *track patrolling* and track maintenance activities and an administrator who was responsible for managing Tube Lines' track maintenance database, Maximo. They reported directly to the Area Track Manager-West.

21 The Area Track Manager-West reported to the Piccadilly Line Track Manager who was responsible for the track over the entire Piccadilly Line. The Track Manager had been in post for five years and had previously also been a Track Manager on another LU line for 3 years. Overall the Track Manager had around 15 years' track management experience.

22 The Piccadilly Line Track Manager reported directly to the Piccadilly Line Infrastructure Manager. The Piccadilly Line Infrastructure Manager was responsible for the maintenance, renewal and upgrade of Piccadilly Line assets which included the train fleet of 1973 tube stock, the signals and track, Tube Lines Trans Plant division and the emergency response unit. In December 2009 a new person was appointed to this role. The previous Piccadilly Line Infrastructure Manager had been in post since 2005 and had worked for Tube Lines since 2003. The Piccadilly Line Infrastructure Manager in place at the time of the derailment had worked on the underground system since 1982. The Piccadilly Line Infrastructure Manager reported to the Tube Lines Director of Operations. A simplified organisational structure is shown at figure 4a.

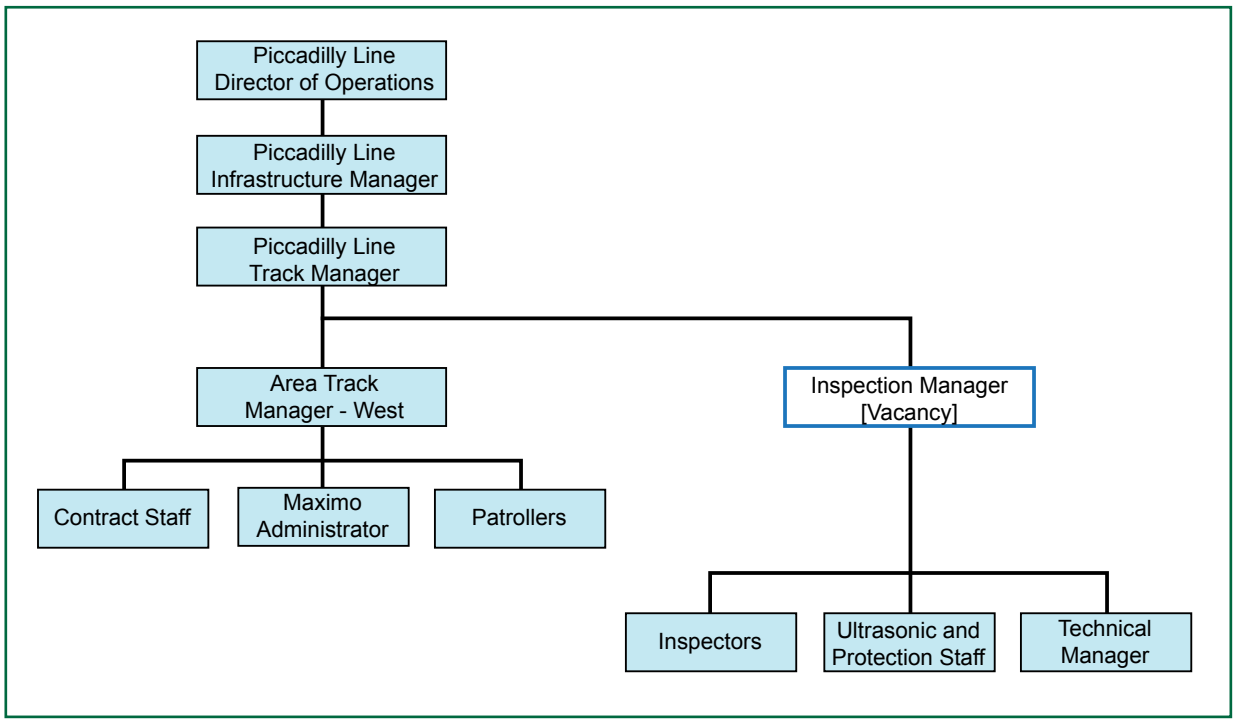

Figure 4a: Simplified Piccadilly Line organisational chart for the Tube Lines track function

23 At the time of the derailment, there was a vacancy for a Track Inspection Manager. As a result of this, the 12 members of staff who normally reported to the Track Inspection Manager were reporting to the Area Track Manager-West at Ealing Common, and to an Area Track Manager-East who managed a team working in a track office at Arnos Grove. A technical team led by a Track Technical Manager and an ultrasonic team reported directly to the Track Manager as a result of the Track Inspection Manager vacancy. A simplified diagram of the organisational arrangements in place at the time of the derailment is shown at figure 4b.

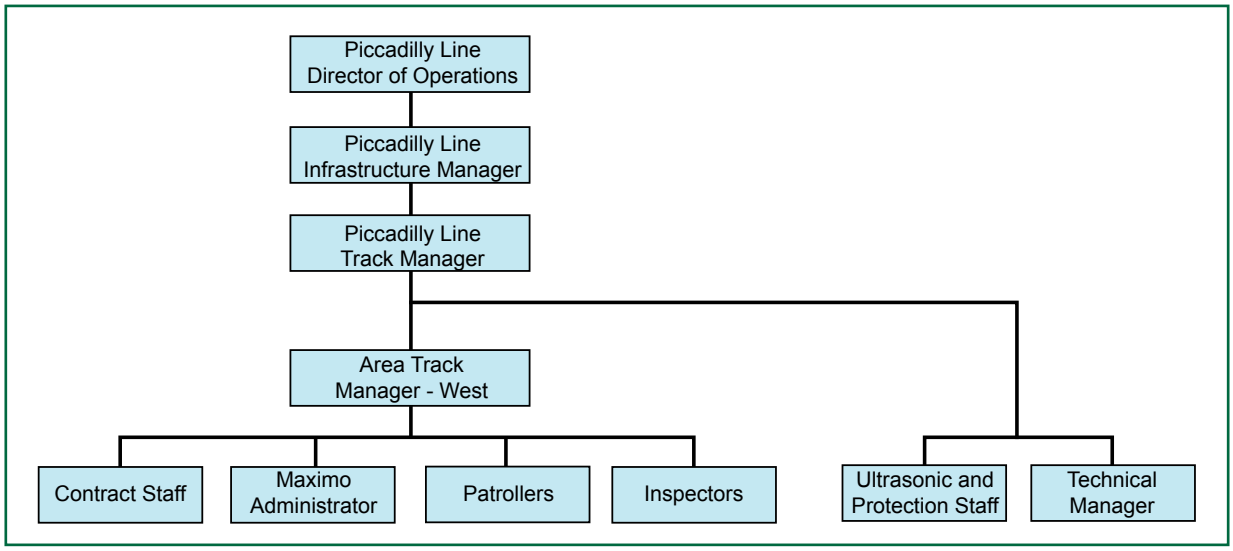

Figure 4b: Simplified Piccadilly Line organisational chart for the Tube Lines track function that applied at the time of the derailment

24 Within Tube Lines there were audit and asset management departments. The audit department was managed by an audit Team Leader who reported to the Head of Risk Management and Audit. The Head of Risk Management and Audit reported to the Director of Health, Safety and Environment. The asset department was managed by the Head of Asset Management and Assurance who reported to the Commercial Director. A simplified diagram of the audit and asset departments is shown at figure 4c.

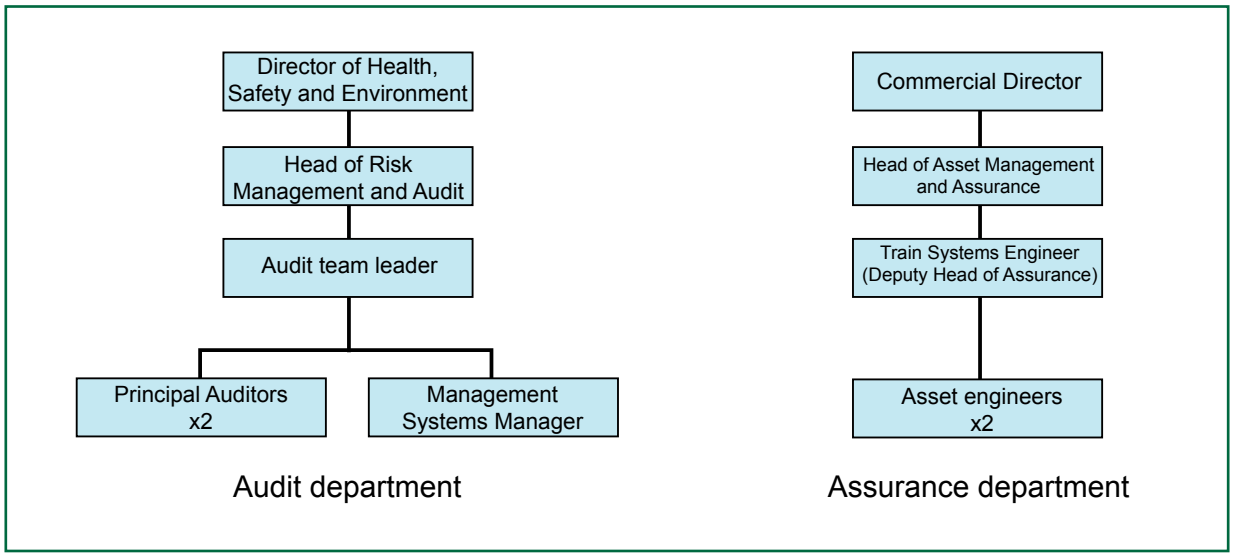

Figure 4c: Simplified Piccadilly Line organisational chart for the Tube Lines audit and asset management departments that applied at the time of the derailment

Events preceding the accident

25 On the day of the derailment, between 02:30 hrs and 03:30 hrs, a planned patrol of a section of the westbound Piccadilly Line took place, including the site where the derailment was later to occur. No relevant faults or concerns were reported by the patroller.

26 At approximately 04:45 hrs an engineering train departed from an engineering worksite at Cockfosters to return to its depot at West Ruislip.

Events during the accident

27 As the train proceeded around a left-hand curve between Gloucester Road and Earl's Court stations at a speed of 26 mph (42 km/h), the track *gauge* widened allowing the leading left-hand wheel to drop off the *low rail* towards the *four-foot* (figure 5). Around 10 metres further on, the leading wheelset suffered a second derailment when the leading right-hand wheel *flange climbed* over the right-hand rail in a section of track which was able to maintain its normal gauge.

28 While the train was running with the leading wheelset derailed, the top right-hand edge of the locomotive body came into contact with the tunnel lining rings. With the leading bogie rotated to the right, the left-hand wheel of the trailing wheelset also derailed when its flange climbed onto the left-hand rail head. This wheelset re-railed itself just before the train stopped.

29 On becoming aware of the derailment the driver applied the train's emergency brake. The train stopped approximately 78 metres beyond the point of the initial derailment.

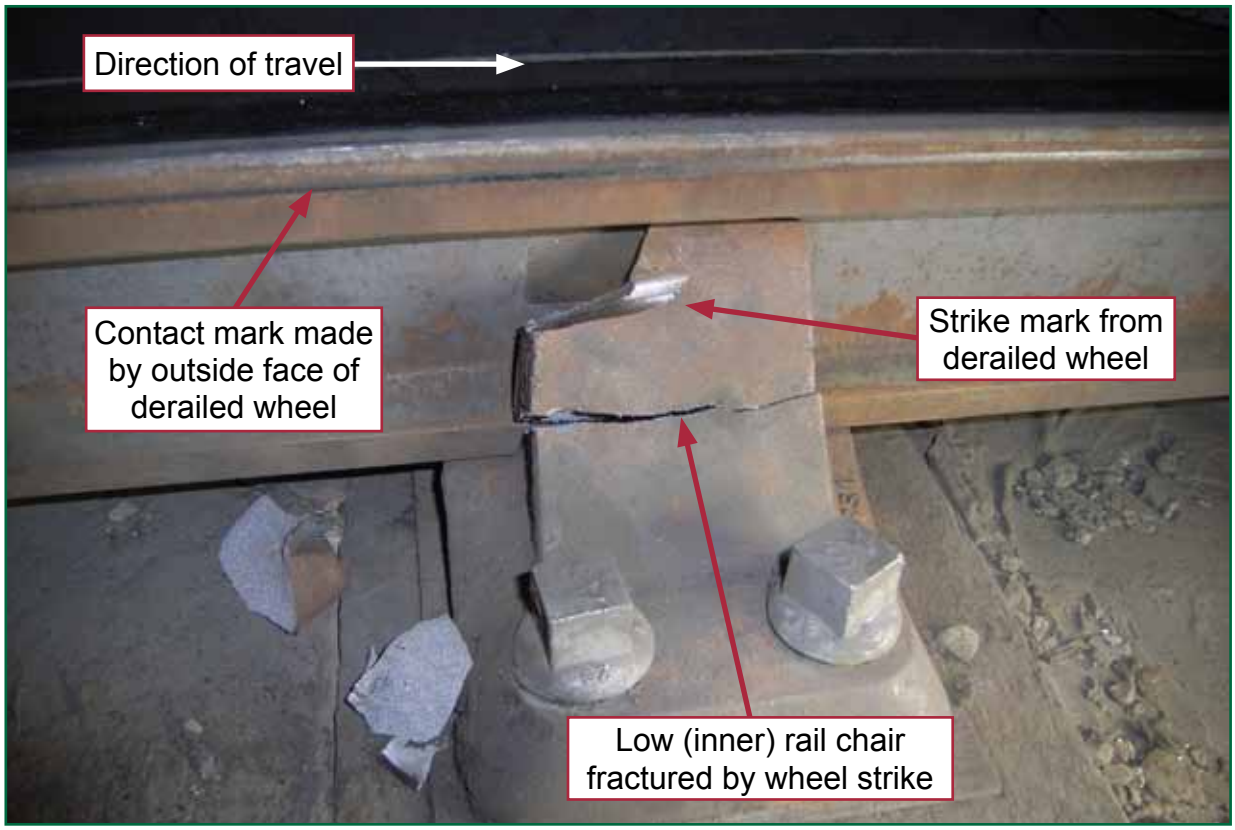

Figure 5: Left-hand wheel tread corner strike mark on low rail chair

Events following the accident

30 The driver of the train made an emergency call to the control room from the driving cab to report the derailment. The London Fire Brigade was called because the large amount of dust created by the derailment was mistaken for smoke from a possible fire. The London Fire Brigade established that no fire had occurred.

31 The RAIB was notified of the derailment by LU and immediately deployed to the site.

The Investigation

Sources of evidence

32 The following sources of evidence were used:

- witness interviews and meetings with LU and Tube Lines management;
- the data recorder fitted to the leading battery locomotive;
- site photographs and measurements;
- train maintenance records;
- track maintenance records;
- relevant LU and Tube Lines standards for track maintenance;
- LU and Tube Lines training, competence and assurance records;
- statistical data on track performance relating to the Piccadilly Line;
- track condition data from the Track Recording Vehicle (TRV);
- a review of previous reported occurrences of wide gauge main line derailments and;
- a review of previous RAIB investigations that had relevance to this accident.

Key facts and analysis

Identification of the immediate cause[1]

33 The track was not able to maintain the correct gauge as the engineering train passed over it.

34 Gauge spread derailments occur when the distance between the rails is sufficient to allow at least one *tread corner* of the wheelset to drop into the gap between the rails (figure 6). When a wheelset is traversing a curve a large lateral force can be generated at the tread of the wheel on the inner rail which is reacted by the wheel's flange against the outer rail (*high rail*). Where the track fixings are not effectively securing the rails, sufficient force can be exerted to cause the rail to roll outwards or move out laterally increasing the track gauge beyond safe limits.

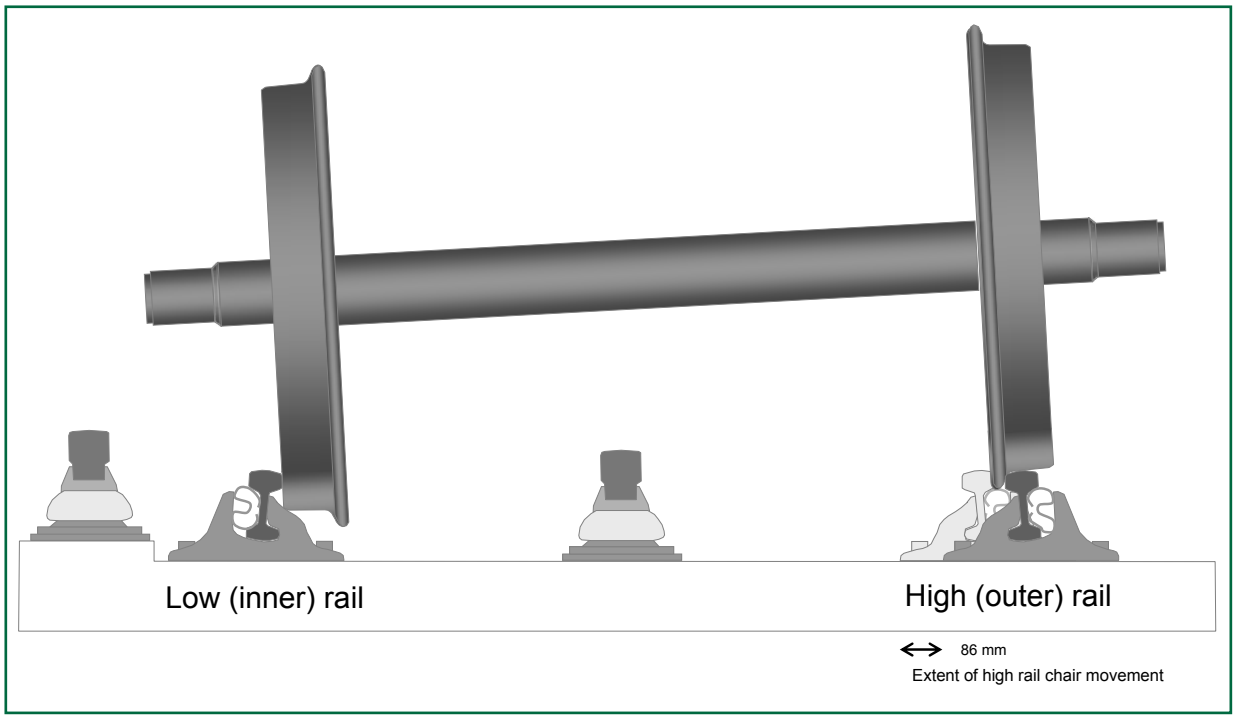

Figure 6: High (outer) rail movement, showing normal chair position and subsequent position of an unsecured chair allowing gauge to widen dynamically.

35 There was evidence of tread corner strike marks on the low rail chairs at the point of derailment clearly indicating a wide gauge derailment had occurred. The strike marks continued to the point where a second derailment occurred when the leading right-hand wheel flange climbed up and over the high rail. The leading right-hand wheel had been forced to climb over the high rail when the leading wheelset encountered track that was fixed more securely to the sleepers. A sideways force towards the high rail was produced when the derailed low rail wheel encountered track of the correct gauge value with secure track fastenings.

[1] The condition, event or behaviour that directly resulted in the occurrence.

36 At the point of derailment the RAIB observed five consecutive chairs on the high rail that were not secured to the wooden sleepers (figure 7). The screws used to secure the chairs to the sleepers had all fractured. A metallurgical analysis of a sample of screws from the derailment site identified that the screws had failed through fatigue as a result of reverse bending. This caused cracks to form on both sides of the screw. The cracks continued until the majority of the cross-section had been compromised, leading to the failure of the remaining material (figure 8). For fatigue failure to occur, the screws must have been subject to repeated bending cycles. Once the screws had failed, the track was no longer securely fastened to the sleepers.

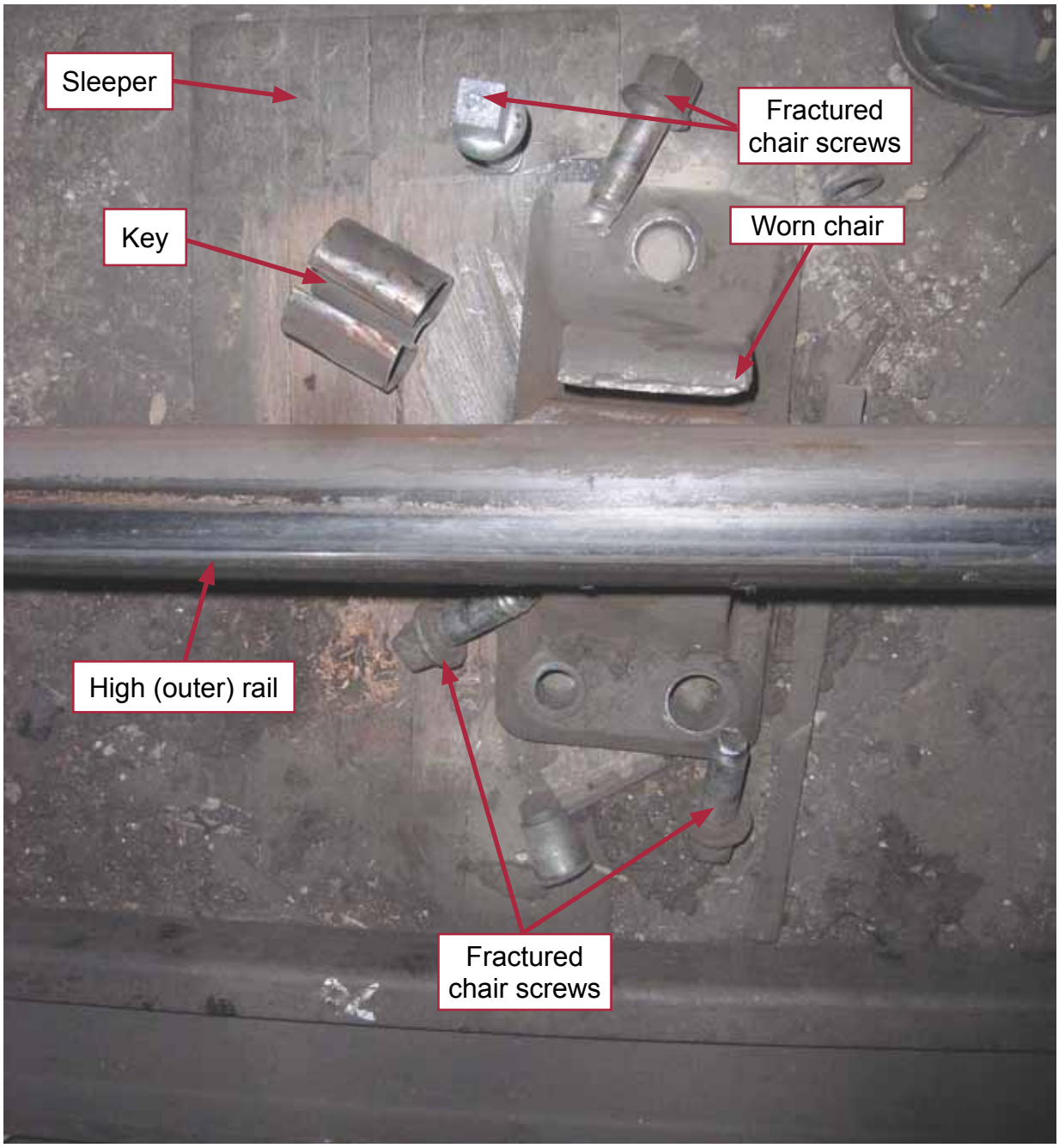

Figure 7: Unsecured chairs at the derailment site

Figure 8: Fractured screws showing signs of fatigue failure

37 The majority of the fractured screws analysed showed evidence of polishing to the screw shank. The polishing was most likely to have been caused by repeated movement between the screw and chair due to loose screw fastenings in sleepers of poor condition. The RAIB observed that several of the wooden sleepers were in poor condition, and that several chairs had been repositioned to enable them to be more securely screwed into the sleeper. There was visible evidence that chairs had been moving on the sleepers causing *chair shuffle* (figure 9) as trains passed. *Side-wear* was also present on the high rail at the derailment site which widened the gauge, but was within the safety limit defined by LU standard 1-159 'Track- dimensions and tolerances'.

38 The TRV had identified wide gauge at the site of the derailment on most recording runs since February 2007. This included the last two recording runs in February 2010 and April 2010 (paragraph 78).

39 The battery locomotive hauling the engineering train had an average axle weight of 16.5 tonnes. This is heavier than a fully loaded tube train[2] that has an approximate laden axle weight of 9.5 tonnes. Although the heavier axle weight of the battery locomotive made it more likely that it would derail than a normal passenger train, the track was designed to support its weight. The same locomotive had, on the previous evening, passed over the same section of track without incident.

[2] Passenger services on the Piccadilly Line are formed of 1973 tube stock.

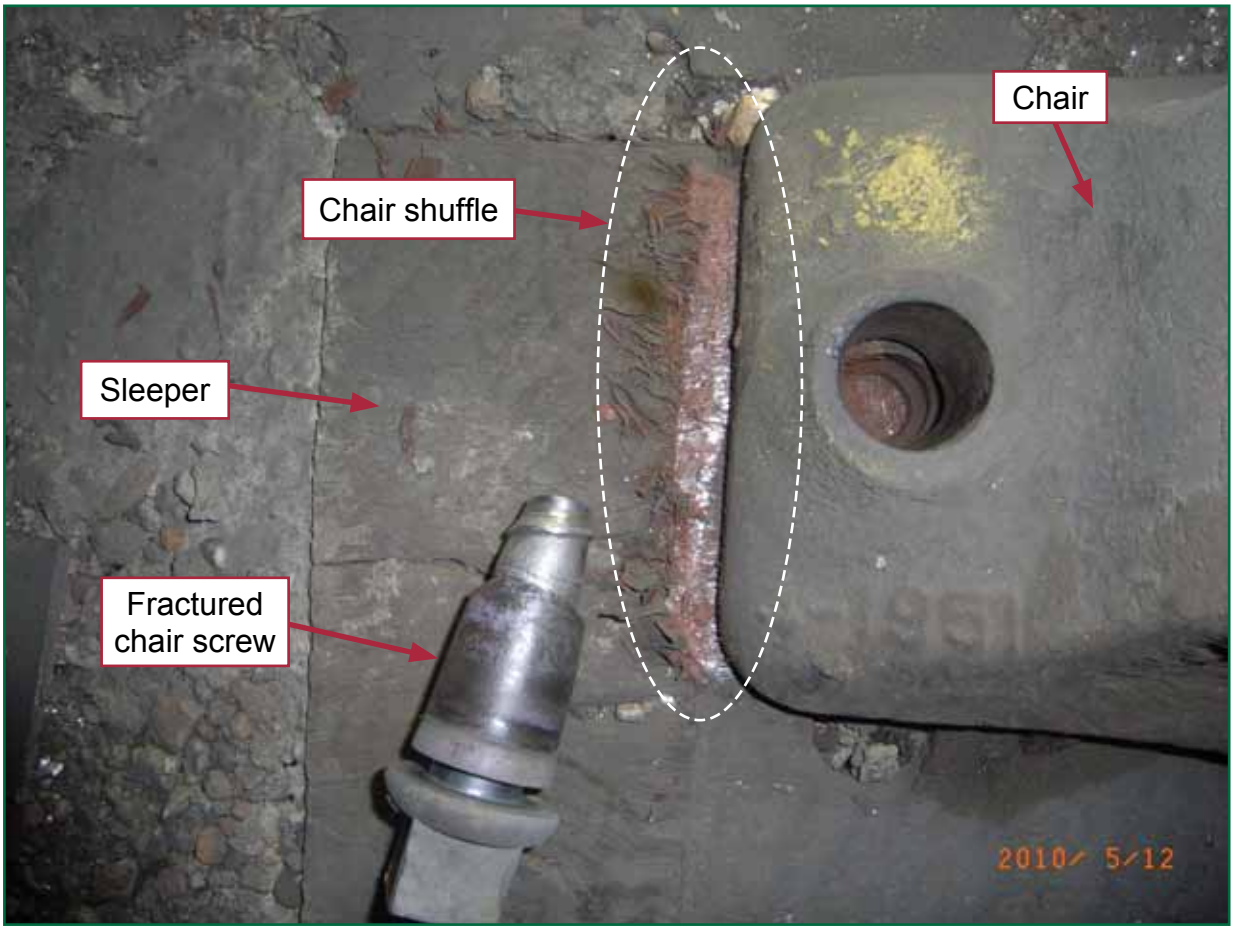

Figure 9: Chair shuffle at derailment site

Identification of causal[3], contributory[4] and underlying factors[5]

Fault identification and classification

40 **Many track safety faults had not been identified, or had been misclassified during planned patrols and inspections leading up to the day of the derailment. The non-identification and misclassification of track faults resulted in the track faults not being rectified which ultimately caused the derailment. This was a causal factor.**

[3] Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

[4] Any condition, event or behaviour that affected or sustained the occurrence, or exacerbated the outcome. Eliminating one or more of these factors would not have prevented the occurrence but their presence made it more likely, or changed the outcome.

[5] Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

The classification of track faults

41 Track faults are classified in LU standard 1-159. There are three main levels of fault described in the standard:

- Safety Standard (SS). It is a requirement that the track system is maintained in a condition such that the SS limits are not exceeded;
- Maintenance Limit (ML). Where a measurement of a track parameter is beyond the ML limits corrective maintenance should be considered; and
- Maintenance Target (MT). The MT limits should be achieved or bettered on not less than 90% of the length of the track where normal conditions apply.

42 LU standard 1-159 also provides information on the different types of track fault to be identified. Each fault is categorised by LU depending on the track category and the degree of safety risk of the relevant fault. The minimum action that must be taken by track maintainers is based on these factors.

The track maintenance database (Maximo)

43 Maximo is an asset management system used by Tube Lines. It was introduced in 2004. Maximo is used to:

- record infrastructure faults;
- assign timescales for fault rectification work;
- record rectification work that has been completed;
- plan and record track patrols and inspections; and
- store the track asset register.

44 Before carrying out a track patrol or inspection, a walk-out report is generated by the Maximo system and handed to the patroller or inspector. The walk-out report can be up to 30 pages long and lists existing faults on the patrol route. When faults are found during patrols and inspections the details are entered onto the walk-out report for recording on Maximo.

Patrolling and inspection regime

45 The track between Gloucester Road and Earl's Court is subject to a regime of track inspections. This includes:

- track safety inspections every 72 hours;
- supervisory inspections every four weeks; and
- track recording vehicle (TRV) runs every eight weeks.

46 The track safety inspections are undertaken by patrollers. The 72-hour track safety inspection frequency is based on the output of a patrolling needs risk assessment that is mandated by a Tube Lines procedure. The risk assessments were undertaken by the Ealing Common technical team and reviewed annually by the Track Manager. The purpose of the track safety inspection is to identify any conditions which are unsafe, potentially unsafe or likely to cause a delay to trains. Patrollers are not required to take measurements during a track safety inspection, but can undertake minor maintenance such as tightening of track securing bolts.

47 The patrollers must hold a safety critical licence in order to undertake track safety inspections (paragraph 61).

48 Supervisory inspections are undertaken every four weeks by inspectors. The purpose of the supervisory inspection is to ensure that track faults are identified at an early stage and that any sub-standard conditions are reported and correctly rectified. The inspectors are required to carry relevant gauges and profiles with them when carrying out supervisory inspections to measure parameters such as track gauge and side-wear.

49 The inspectors were also required to hold a safety critical licence in order to carry out supervisory inspections (paragraphs 61 and 69).

50 The RAIB reviewed the inspection records for the westbound track between Gloucester Road and Earl's Court stations and found that the track safety inspections and supervisory inspections had been recorded as being completed at the required frequency. A track safety inspection had been undertaken no more than three hours before the derailment occurred; no new faults were found that were relevant to the derailment. The last supervisory inspection had been undertaken on 7 May 2010; five days before the derailment. No new faults were raised by the inspector. It is unlikely that the fractured chair screws would have been found during either inspection unless the screws had been physically removed to check them. However, the chair shuffle and poor sleeper condition would have visible during both inspections.

Review of track condition following the derailment

51 Following the derailment Tube Lines carried out an exercise to check the quality of the data held on Maximo. This involved an inspection of the track by an inspector independent from the regular maintenance team who checked the faults registered in Maximo against those found during the review. The review took 4.5 weeks to complete and covered the whole of the Piccadilly Line. Table 1 shows a comparison between the average number of faults found per week in the six weeks before the derailment occurred and the equivalent in the data checking period.

Data	SS faults reported	ML faults reported	MT faults reported	Total faults reported
Weekly average in 6 weeks leading up to the derailment	21.0	38.7	17.2	76.9
Weekly average during 4.5 week checking exercise	92.8	216.6	108.1	417.5
Increase in faults reported	441%	559%	628%	542%

Table 1: Comparison of average number of faults found in the six weeks leading up to the derailment and in the subsequent data cleansing exercise

52 During the checking exercise it was identified that, in addition to previously unreported faults (which included some at SS level), a significant number of existing faults had been incorrectly classified as ML instead of SS, or as MT instead of ML.

Reasons for the misclassification and non-identification of faults

53 The RAIB has considered the possible reasons why a significant number of misclassified and unidentified faults were found when the Maximo data was checked. They are:

- morale of staff (paragraph 54);
- time available for patrols and inspections (paragraph 55);
- competence and training (paragraph 60); and
- difficulty in applying LU standard 1-159 (paragraph 72).

Morale of staff

54 Witness evidence suggests that the morale among many of the staff at the Ealing Common track office was low. The reasons for this included frustration that little progress was being made in improving the quality of the track and faults not being fixed that had been identified. Over the years staff numbers had steadily reduced, increasing the workload for the remaining staff. These may have been factors in the non-identification and misclassification of track faults.

Time available for patrols and inspections

55 **There was insufficient time available to complete thorough and detailed patrols and inspections. This made it more likely that faults would be missed or incorrectly categorised. This was a possible causal factor in the derailment.**

56 For the derailment location, both the patrollers and the inspectors followed the same patrol route, known as patrol route PN12. This covered the westbound line between Hyde Park Corner and Baron's Court, a distance of 2.67 miles (4.3 km). The time available to carry out inspections was normally around 4 hours 15 minutes.

57 The track safety inspections for the section of track in which the derailment occurred took place in a single shift. This allowed a patroller an average of one minute for each 17 metres of track. A major factor affecting the time taken to patrol is the need to replace keys that have worked loose from worn chairs. In the case of the derailment site it was sometimes the case that over 30 keys had to be replaced during a track patrol. The time taken to complete such work meant that the time available for the remainder of the patrol was reduced, thus possibly affecting the quality of the patroller's work.

58 The supervisory inspections were undertaken on route PN12 over two consecutive shifts, allowing an inspector an average of one minute for each 8.5 metres of track. The supervisory inspection involves taking measurements, such as track gauge, cant, side-wear and *track twist*. The purpose of a supervisory inspection includes:

- monitoring the effectiveness of the track safety inspections;
- determining scope, priority and resource requirements for future works; and
- determining degradation rates in terms of wear and condition.

59 Following the derailment Tube Lines undertook a review of the patrol routes. As a result, patrol route PN12 has been changed. The length of the patrol route covering the derailment site has been reduced from 2.67 miles (4.3 km) to 1.67 miles (2.7 km) and now allows the patroller one minute to cover an average of 10.5 metres (instead of 17 metres). The supervisory inspection has been correspondingly shortened. These reductions will provide more opportunity for thorough inspections to be undertaken.

Training and competence of patrollers and inspectors

60 **The patrollers and inspectors did not receive regular re-assessments of their practical and theoretical knowledge and some inspectors had not been formally trained. The training and competence regime was possibly a causal factor in the derailment.**

Patrollers

61 The competence of patrollers (and inspectors) was managed through Tube Lines competence management system. New patrollers attended a five-day training course, after which they received a period of mentoring followed by an assessment. A portfolio was completed that included details of the mentored inspections undertaken by the trainee and assessment results. The portfolio was reviewed by the patroller's line manager and an assessor. When competence was proven, the patroller was issued with a safety critical licence that was valid for a period of three years.

62 The RAIB reviewed the safety critical licence records of the patrollers and inspectors involved in the derailment. The records were up to date and indicated that the patrollers and inspectors had been deemed competent to undertake their duties.

63 Patrollers were briefed on LU standard 1-159 (paragraph 41) and to recognise signs of static and dynamic wide gauge, such as chair shuffle and leaning or missing screws. The length of the patrol routes and the time available meant that a patroller would not be expected to check every screw or to identify chair shuffle unless it was obvious.

64 Once a patroller had a three-year licence, they were joined on a track safety inspection by an inspector every six months. This process was known as a joint inspection and its main purpose was to ensure that the patroller was still competent in performing their duties. There was also the opportunity to discuss any training needs and local issues relevant to the track section being patrolled.

65 The RAIB reviewed a sample of joint inspection forms relating to the track team at Ealing Common depot. On several of them there was little detail about the scope of the joint inspection, or what areas of competence were assessed. This issue was also identified by LU during an audit in 2009 (see paragraph 129). Tube Lines also noted after the derailment that the joint inspection process had been adding little value as a means of monitoring the ongoing competence of patrollers.

66 For a patroller's licence to be renewed a one-to-one meeting was held between the patroller and the Area Track Manager near the end of the three-year period. The Area Track Manager reviewed the competence file of the patroller and discussed any issues arising. If there were no concerns with the patroller's competence, the line manager completed an extension form and sent it to Tube Lines competence assurance manager. If all was in order with the paperwork, a new licence was issued, valid for a further three years.

Supervisory inspections by inspectors

67 Before the derailment not all of the Piccadilly Line inspectors had received formal training. Historically, inspectors had learned the job through hands-on experience working alongside other experienced inspectors. For a brief period in 2007, an inspectors' training course was started but it was suspended. This was because Tube Lines had introduced a new grade of inspector (known as PM4 points and crossings inspector) following a derailment at Archway (paragraph 142) and had given priority to training the PM4 inspectors. At the time of the derailment, the formal inspectors' training course had not been restarted.

68 Inspectors need to be aware of the requirements of standard 1-159. However, the RAIB has evidence that not all of the inspectors on the Piccadilly Line were aware that standard 1-159 was in use and were still using the previous standard, E8404. This had no direct effect on the derailment as the key track tolerances relevant to the derailment were the same in both standards. However, it is evidence that the competence management system was not effective at identifying such issues.

69 The ongoing competence of inspectors was managed through a self assessment process. The inspector was required to complete a competence book over a three-year period. The book should have been reviewed by the Track Inspection Manager at the end of the three-year period and forwarded, along with a recommendation to re-issue the inspector's safety critical licence, to the Tube Lines competence assurance manager who reviewed the books. Any competency issues were fed back to the Track Inspection Manager to resolve. If there were no major issues identified, a three-year extension of the safety critical licence was granted. A formal reassessment of underpinning knowledge and practical application was not required.

70 It was a requirement of the role that the Track Inspection Manager carried out regular assessments of the inspectors to ensure they were still competent to carry out supervisory inspections, and to identify any training or coaching needs. As the Track Inspection Manager's post was vacant on the Piccadilly Line this important activity had not taken place since mid 2007 (see paragraph 110).

71 Had all the inspectors been formally trained and assessed as competent there would have been a more uniform approach to the identification of track faults. A thorough re-assessment process would have verified that patrollers and inspectors remained competent to the required standard.

LU standard 1-159 'Track- dimensions and tolerances'

72 **The track asset is assessed against LU standard 1-159 'Track- dimensions and tolerances'. The requirements of the standard were almost impossible for patrollers and inspectors to apply in the time available because it was difficult to classify faults and to group multiple faults when carrying out track inspections. The weaknesses in LU standard 1-159 were an underlying factor in the derailment.**

73 Standard 1-159 'Track- dimensions and tolerances' was issued by LU in October 2007 replacing standard E8404. Tube Lines staff are required to work to the instructions in standard 1-159. Standard 1-159 includes tables that detail the tolerances that are to be applied for track faults and the minimum action that is to be taken to deal with the identified faults. The key track tolerance parameters in standard 1-159 are also uploaded into Maximo to allow the system to assess the level of fault and assign target dates for rectification work.

74 The factors relevant to the derailment that were assessed during patrols and inspections included sleeper condition, screw fastenings, chair condition and security, keys, side-wear and static track gauge. For the majority of these factors standard 1-159 required them to be assessed over 100 metre and 5 metre cells and the classification of the seriousness of the fault (SS, ML or MT) was sometimes dependent on the number of such faults found within each cell. For example, the assessment of loose and missing screws over a 100 metre cell for an inspector, or a five metre cell for a patroller, was difficult to apply because the boundaries of the cell are constantly moving as the inspection progresses. This made it difficult to establish what level of fault, if any, was present and to identify the safety risk that multiple faults might have on the overall condition of the track.

75 Inspectors were required to monitor the track for static wide gauge. This was carried out using a track gauge to take measurements at locations where the inspector believed there may be a gauge issue, such as curves or where there is visible evidence of chair shuffle. There was no requirement for gauge readings to be taken at regular distances. At the location of the derailment the nominal track gauge should be 1435 mm. The tolerances for gauge in LU standard 1-159 are:

- SS limit: 1462 mm [obligatory requirement: correct within 1 week];
- ML limit: 1457 mm [the standard provides guidance that ML faults should be monitored and corrected within 6 months]; and
- MT limit: 1446 mm [the standard provides guidance that MT faults should be monitored].

76 The tolerances in LU standard 1-159 do not differentiate between *static gauge* and *dynamic gauge*. Although table 3.1 stated that allowance should be made for dynamic movement when taking measurements, inspectors had no means of measuring dynamic wide gauge. It was therefore unlikely that they would have identified an SS exceedence fault when measuring gauge statically. However, the presence of chair shuffle, poor sleeper condition and regular missing keys should have provided sufficient clues to the inspectors that dynamic wide gauge was present at the location of the derailment.

77 LU standard 1-159 did not provide a reliable basis for the identification of those sections of track in which multiple, but less serious, faults combined to create an area of substandard track.

Identification of dynamic wide gauge

78 **The TRV had identified dynamic wide gauge, exceeding the SS limit, through the site of the derailment in February 2010 and April 2010. No corrective action was taken by Tube Lines because the information on dynamic wide gauge had not been included in the level 3 Safety Standard Exceedence reports. This was a causal factor in the derailment.**

79 The TRV was operated by the Trans Plant division of Tube Lines. It was converted by British Rail Engineering Ltd from an unused 1973 tube stock passenger vehicle and entered service in 1987. The TRV is fitted with recording equipment that was broadly the same as that which was fitted to the then-current British Rail track recording train on which it was based. It weighs around 24 tonnes and has two, two-axle bogies with a nominal axle weight of around 6 tonnes.

80 The TRV reports track faults and measures track quality. It runs over most of the London Underground network on a planned cycle of eight-weekly recording runs. The parameters measured by the TRV include:

- cant;
- *curvature*;
- track twist;
- *alignment*;
- *wheel unloading*; and
- dynamic track gauge.

81 Following a TRV run the data is processed by the Trans Plant services team. Three reports are generated:

- Level 1 report. Reports on track quality over 100 metre cells. This report contains a large quantity of data (all MT, ML and SS faults) and is normally sent out to the technical teams within three working days of the run.
- Level 2 report. Reports on individual faults that are at the ML level. Normally sent out via email and fax to the technical teams within three working days of the run.
- Level 3 reports. Two level 3 reports are produced: a report listing localised SS exceedences and a 'standard deviation report' listing average SS exceedences over 100 metre cells. The level 3 reports were introduced in 1996 following the inclusion of the SS value in LU standard E8404, the predecessor to LU standard 1-159. The level 3 reports are sent out via email and fax to the technical teams on the day of the run.

82 An analogue trace is also produced during each TRV run. The parameters detailed on the trace include vertical and horizontal alignment, cant, curvature, twist and gauge. The trace is sent out to the technical teams within three working days of the run.

83 The main purpose of the level 1 and 2 reports and the analogue trace is to provide an opportunity for engineers to understand the general condition of the track asset, with a view to planning maintenance activities which will prevent the development of SS level faults. The level 3 reports are used to identify locations where a SS limit has been exceeded, indicating that there may be a fault. This allows inspection and rectification work to be undertaken in accordance with LU standard 1-159.

84 The TRV had identified wide gauge SS exceedences through the 100 metre cell that included the area of the derailment on the majority of the recording runs since February 2007. In particular, the site of the derailment was measured as a wide gauge SS exceedence on the runs of 15 February 2010 and 12 April 2010, and was at ML level in December 2009.

85 The site of the derailment was not inspected nor was any track maintenance work undertaken in response to the TRV runs in February 2010 or April 2010 because the wide gauge information was not shown on the level 3 SS exceedence report. The information was available in the level 3 standard deviation report and the level 1 track quality report but these were not reviewed by the Piccadilly Line staff for wide gauge exceedences because of a belief that any SS wide gauge locations would be shown on the level 3 SS exceedence report. Tube Lines was focused primarily on the rectification of SS faults. This is discussed further in paragraphs 94-103.

86 The TRV was introduced onto the LU network from around 1987. At that time only level 1 and level 2 reports were produced following a recording run. From 1996 the SS level fault was introduced by LU. The TRV was reconfigured from that point to produce a level 3 SS exceedence report using the data from the existing level 1 and 2 reports. Neither LU nor Tube Lines were able to establish why the TRV was not configured to report wide gauge locations on the level 2 report from 1987 and the level 3 SS exceedence report from 1996.

87 The absence of wide gauge data in the TRV level 3 SS exceedence report was identified by the Tube Lines assurance department in 2008 and the issue was included in the Tube Lines document '2009 Annual Assurance Report- Track Asset' (September 2008 to August 2009). This document was sent to the LU track assurance department but was not circulated within Tube Lines. This meant that knowledge of the issue was limited to the assurance departments in the two organisations.

88 The Tube Lines assurance department identified two mitigations to manage the risk of the absence of wide gauge data in the TRV level 3 SS exceedence report. The mitigations were included in the 2009 Annual Assurance Report- Track Asset:

- review of the analogue trace following each TRV run to identify wide gauge exceedences; and
- carry out manual inspections to verify required rectification works.

89 London Underground's assurance department thought that these risk control measures had been adopted by Tube Lines and that the risk was therefore being addressed. However, neither the issue nor the identified control measures were promulgated within Tube Lines organisation and the Ealing Common technical team were unaware of them. Therefore the TRV analogue traces were not reviewed by the technical team to identify wide gauge locations.

90 There was a commonly held belief among many of the people directly involved with the management of track maintenance on the Piccadilly Line that, if there was a wide gauge fault, it would be identified on the TRV level 3 SS exceedence report. Generally, it was also a common belief that the TRV data for wide gauge was not accurate because it used a white light measuring system that was prone to misidentifying wide gauge locations. Although the Tube Lines assurance department had identified that wide gauge was not being reported in the TRV level 3 SS exceedence report there was a reluctance to promulgate the issue because Tube Lines believed that if wide gauge was reported on the level 3 SS exceedence report, large numbers of false SS exceedences, such as wide gauge through points and crossings, would be incorrectly identified and would overload the level 3 SS exceedence report. Following the derailment Tube Lines configured the level 3 SS exceedence report to include wide gauge SS exceedences and found that the expected high numbers of false exceedences do not occur.

91 The loss of horizontal track geometry, beyond the safety threshold due to the failure of fastenings, including wide gauge, was the third highest risk[6] identified in the 2009-2010 Track Asset Group Strategy document. The mitigations identified for that risk included improved compliance with E8404 (although at that time 1-159 had replaced E8404) and monitoring of track geometry with the TRV. The means of achieving these mitigations was not included in the document.

92 Overall, the Piccadilly Line team within Tube Lines placed a low emphasis on the risk of wide gauge derailments through the failure of fixings because:

- historically, there were very few running line derailments due to wide gauge with only one wide gauge derailment occurring on the passenger network in the previous 10 years;
- its belief that manual track inspections would identify locations with wide gauge;
- a confidence among some Tube Lines staff that the absence of wide gauge being identified by the TRV on the level 3 reports meant wide gauge was not a problem; and
- its belief that the current *surveillance* and competence processes were robust.

Tube Lines approach to the management of the track asset

93 **Tube Lines focused mainly on SS faults. It made no attempt to analyse the risk posed by clusters of ML faults on the Piccadilly Line. Tube Lines' focus on SS faults was an underlying factor in the derailment.**

94 When Tube Lines took over the maintenance of the Jubilee, Northern and Piccadilly lines under the PPP contract, a number of 'vital signs' performance measures were jointly agreed between Tube Lines and LU. The vital signs were reported to LU each period through an asset performance review report. The vital signs were:

- Safety issues – broken rails, fires and TRV SS exceedences; and
- Availability issues – the number of incidents, failures and delays greater than 15 minutes and the numbers of emergency and temporary speed restrictions.

[6] The top risk was derailment through points and crossings. The number two risk was an object being left on the line by maintenance staff. Tube Lines also gave a high focus to the risk of derailment from broken rails based on a trend that had been identified on the Piccadilly Line.

95 In early 2003 Her Majesty's Railway Inspectorate, then within the Health & Safety Executive but now part of the Office of Rail Regulation (ORR) (paragraph 141), served an Improvement Notice on LU on the grounds that it was not addressing known non-compliances with its own track standards, contrary to the requirements of its approved *safety case.* The Improvement Notice required LU to prepare a plan describing how and when a return to full compliance would be achieved. LU worked with the infrastructure maintainers, including Tube Lines, to produce a compliance recovery plan. The compliance recovery plan was split into three phases:

- phase A: regularisation of all SS exceedence non-compliances by 31 May 2005;
- phase B: reduction in the number of SS exceedences regularised by *concession* or by *temporary approved non-compliance*, to an acceptable level by 31 May 2010; and
- phase C: further improvement in the condition of assets in accordance with the requirements of the PPP contract (up to 31 May 2025).

At the time of the derailment LU and Tube Lines had achieved the requirements of phases A and B of the compliance recovery plan.

96 SS exceedences, those found by the TRV and through manual inspection, were likely to feature as vital signs (paragraph 94). However, it is the RAIB's view that individual ML faults were unlikely to lead directly to any safety incidents or to cause train delays and did not therefore feature as vital signs.

97 LU standard 1-159 formed the basis of the contractual arrangements between LU and Tube Lines with regard to the maintenance of the track asset. It was an obligatory requirement that the track asset was maintained in a condition which ensured that safety standards were not breached. MT and ML fault values were advisory and Tube Lines was required to consider corrective maintenance when the measurement of a track value was beyond the ML value. In addition, standard 1-159 stated that two or more track geometry parameters just under the safety standard at one location, may together present a greater safety risk than a single parameter that is at or beyond the SS level.

98 There were significant numbers of ML faults at the site of the derailment that were recorded as open on 12 May 2010. These are shown in table 2:

Fault	Location (derailment site - 397m)	Classification and relevance to wide gauge	Date reported	Due date for rectification	Days overdue rectification
Voids, bouncing sleeper ends, broken grout around sleepers	300 m to 600 m	ML[7] but not relevant to wide gauge	13 December 2006	7 February 2007	1190
Worn chairs	320 m to 440 m	ML[8] and relevant to wide gauge	13 February 2007	13 March 2007	1156
Insecure and missing screws	80 m to 420 m	ML[9] and relevant to wide gauge	17 March 2010	12 May 2010	0 (due on day of derailment)

Table 2: Overdue significant ML faults in Maximo at time of derailment on 12 May 2010

[7] ML level for voiding at the location of the derailment was a twist gradient of 1 in 300.

[8] ML level for worn chairs at the location of the derailment was 15 over 100 metres of track or 3 per group of 5 sleepers in one rail.

[9] ML level for insecure or missing screws at the location of the derailment was 30 over 100 metres of track or 4 per 5 adjacent sleepers on one rail.

99 Neither the Track Manager, nor the Piccadilly Line Infrastructure Managers (before and after the change of personnel in December 2009) had any concerns about the condition of the track in the derailment area because:

- they considered overdue ML faults in Maximo were not a safety risk (they could be addressed when they became SS faults);
- they were not concerned about the general level of SS faults for that section of line when compared with other similar sections of the Piccadilly Line; and
- there were ongoing routine track *fettling* activities undertaken by the Ealing Common track team which periodically improved the general condition of the track and removed ML faults.

100 Following an increase in the number of broken rails on the Piccadilly Line, a working group analysed broken rail data which showed the vast majority of breaks had occurred in tube tunnel sections, on bullhead track: either at bolted joints; previously bolted rail joints that had been welded together; or in the high (outer) rail of curves where rail fastenings were known to be poor. Around June and July 2009, an exercise was undertaken to visit the top ten locations identified by the broken rail working group. The area of the derailment was one of the top ten locations visited.

101 The person undertaking the broken rail review recorded the general condition of the track between Gloucester Road and Earl's Court stations following their visit between June and July 2009. This included the site of the derailment. A number of faults were identified. The observations were recorded on a document that was given to the Area Track Manager-West and the Track Manager. The person undertaking the review also arranged for a member of their team to enter the details of the observations onto Maximo as 'information faults'. In the opinion of the person undertaking the broken rail review, none of the faults identified were SS faults, but they did relate to the condition of the track fastenings, chairs and sleepers at the site of the derailment. Not all of the faults were followed up by the Area Track Manager-West or the Track Manager, and many of the information faults were recorded as open on Maximo at the time of the derailment.

102 The open ML faults in Maximo, and the information faults found during the broken rail review, indicated to all those with access to the Maximo data, and with a responsibility for maintaining the track in the location of the derailment, that there was a long-term problem with track condition. While the problems identified were below the SS level individually, the ML faults were likely to present a safety risk collectively. For example, worn chairs, loose screws and poor sleeper condition may present a low risk to safety at individual ML level, but are likely to present a more significant risk to safety when they are grouped together in the same geographical location.

103 Witness evidence supports the conclusion that within Tube Lines there was a wide-spread focus on the management and rectification of SS faults and broken rails, as these were key performance indicators (KPIs), and a requirement of the PPP contract. Management of ML faults did not feature in KPIs and as such were seen to be a lower priority. In addition, there was no requirement for Tube Lines to address ML faults individually. However, had the ML faults in table 2 been identified as a collective safety risk, and been rectified, the derailment would not have occurred. The fact that not all SS faults were being identified (paragraphs 51-53) compounded the impact of an approach to maintenance that was primarily focused on the rectification of SS faults.

Staffing levels and workload

104 **There were insufficient staff at the Ealing Common track office to maintain the track in good condition while also reacting to safety faults. The Track Inspection Manager's post had been vacant since mid-2007, increasing the workload on other members of the management team and the Maximo Administrator's post had also been vacant for a long time. The lack of resources in key posts was an underlying factor in the derailment**.

Track patrollers and maintainers

105 At the time of the derailment there were 17 members of staff assigned to carry out track patrols and undertake track maintenance work at the Ealing Common track office. This number comprised 14 Tube Lines permanent staff and three contracted staff. Allowing for the nightly patrols, around six persons could be available to carry out track maintenance work, but that number could be depleted by leave, training or sickness. The Area Track Manager-West estimated that a team of six persons would be able to change four sleepers in an open (non-tube section) or one sleeper in a tube section during the night-time maintenance hours, or carry out fettling activities. Typically, less than five hours were available to carry out overnight track maintenance.

106 Additionally, two teams of track maintenance personnel had been working on the Piccadilly Line since 2009. They were known as Capex-Ops. They had undertaken several medium-sized corrective maintenance activities but had not undertaken any work in the area of the derailment because they had been assigned to other tasks that the Track Manager considered a higher priority.

107 The Area Track Manager-West attempted to plan track maintenance activities on a weekly basis. However, on most occasions the plans were not implemented because tasks with a higher priority arose from matters found during track patrols and inspections. As a result, he was not able carry out effective maintenance other than to deal with SS faults.

108 The Area Track Manager-West had raised his concerns to the Track Manager and to the Piccadilly Line Infrastructure Manager's assistant about the team's inability to complete track maintenance work. However, no additional staff were recruited because:

- the Track Manager believed there were sufficient staff to cope with the workload, particularly as the Capex-Ops team were undertaking work on the Piccadilly Line generally;
- the Track Manager believed that contractors were an effective way of providing support to the team because they were a consistently available source;
- the Track Manager believed that the general reduction in staff numbers over the years was mainly as a result of certain aspects of track maintenance being undertaken by other departments, such as litter picking and lubrication and that there was a lower workload for the remaining staff; and
- the Piccadilly Line Infrastructure Manager's assistant believed that no recruitment would be authorised because the organisational structure was going to be changed in 2010.

Track Inspection Manager

109 The Track Inspection Manager was a key post within the track maintenance function. The responsibilities of the Track Inspection Manager included:

- managing and directing the production activities of the inspection staff to ensure that all mandatory inspection works were correctly carried out;
- coaching and supporting the track inspection team members in order that they effectively delivered the requirements of their roles;
- identifying and prioritising all corrective work required and ensuring that it was loaded into Maximo in a timely and accurate fashion; and
- managing technical competence and training requirements.

110 From mid-2007 the position of Track Inspection Manager had been vacant on the Piccadilly Line. No comprehensive arrangements had been made by Tube Lines to ensure that the responsibilities of the vacant Track Inspection Manager role were being satisfactorily completed. Some of the responsibilities of the role were being shared between the Track Manager and Area Track Managers, such as ensuring the supervisory inspections were being completed. However, the interim arrangements did not fully cover some critical tasks of the Track Inspection Manager's role. In particular the following tasks were not being fully discharged:

- the identification and prioritisation of corrective work required;
- ensuring work orders were loaded onto Maximo accurately; and
- coaching and development of the inspectors.

111 There were inaccuracies and a lack of detail in many of the reports completed by patrollers and inspectors following track inspections. In particular, the location of faults was often described in an imprecise manner (eg 'loose fastenings between 200 metres and 300 metres'), which meant that accurate location, and critically, grouping of faults was not possible. Faults were occasionally missed because of a belief they had already been reported in Maximo. These sub-optimal inspection reports should have been reviewed by the Track Inspection Manager.

112 The Track Manager stated that he had approached the Piccadilly Line Infrastructure Manager with a request to fill the Track Inspection Manager vacancy in 2008 but the request had been refused. The Piccadilly Line Infrastructure Manager could not recall refusing that request. The Piccadilly Line Infrastructure Manager stated that he was not aware of the Track Inspection Manager vacancy as he was only monitoring his direct reports; he would expect the Track Manager or the assurance department to raise any concerns with long-term vacancies in key posts. The Piccadilly Line Infrastructure Manager was not aware of the Track Inspection Manager's role, the responsibilities of the post or how those responsibilities were being managed.

113 The Track Inspection Manager vacancy was further discussed in January 2010 when the new Piccadilly Line Infrastructure Manager was in place. However, the Track Manager did not request that the vacancy be advertised as he believed the impending Piccadilly line re-organisation would resolve the situation.

Maximo Administrator

114 From the summer of 2008 until February 2009 there had been no Maximo administrator at the Ealing Common track office. This was due to a delay in recruiting an appropriate person into the role following the departure of the previous administrator. During this time not all of the reported faults were being entered onto Maximo and the Area Track Manager-West asked the patrollers and inspectors to raise any serious issues directly with him. However, this approach meant that Maximo did not contain accurate information on the condition of the track asset.

115 The data stored in Maximo was one of a number of data sources input into the model used by Tube Lines to assess asset condition as part of its long-term maintenance planning and renewal strategies. For effective assessments to be made of the asset condition the data in Maximo must be accurate. At the time of the derailment the data stored in Maximo did not present an accurate picture of the condition of the track.

Audit and surveillance

Tube Lines audit and surveillance regime

116 **The Tube Lines audit and surveillance regime for the track maintenance activity was ineffective in identifying concerns over the adequacy of patrols and inspections and the risk arising from long-term vacancies. This was an underlying factor in the derailment.**

Tube Lines audits

117 Under the PPP arrangements, Tube Lines was required to submit a safety case to LU for approval. The safety case included a description of the arrangements for carrying out audits. Tube Lines carried out internal audits in accordance with an annual audit plan managed by the Tube Lines audit department. The plan was based on a risk assessment undertaken by Tube Lines using information received from various Tube Lines departments (including the Tube Lines assurance department), the Tube Lines safety risk register and the results of previous audits. Where necessary the audit plan was amended if additional issues were identified during the life of the audit plan. The audit process was managed by the audit team leader and all audit reports, both internal and external, were reviewed by the risk review group chaired by the Tube Lines Director of Health, Safety and Environment. All corrective actions arising from audits were monitored by the risk review group. The closure of a corrective action features as a Tube Lines KPI.

118 No specific audits of track maintenance had been undertaken by Tube Lines in the period before the derailment because:

- no requests for an audit, or concerns with track maintenance, had been raised with the audit department from within Tube Lines; and
- LU had undertaken an audit on that topic in 2009 and the corrective actions from it were being monitored by Tube Lines.

Tube Lines surveillance findings

119 Tube Lines surveillance activities were undertaken by two asset engineers with the assistance of people from other departments when specialist knowledge was required. The Tube Lines asset engineers reported to the Tube Lines Head of Assurance. The Tube Lines Head of Assurance reported directly to the Tube Lines Commercial Director.

120 Tube Lines annual surveillance activities were detailed in document TLF 245. The document was prepared by the asset engineers and reviewed by the head of assurance. Section 1 of the TLF 245 document concerned data collection and included evidence from the previous year's performance, the findings of internal and external incident reports and risk assessments. Section 2 detailed the high-level actions that Tube Lines would undertake to mitigate the risk that had been identified following the data collection exercise. Document TLF 245, for the year 2009-2010, did not identify any issues with regard to:

- the long-term vacancy for the Track Inspection Manager on the Piccadilly Line although it effectively changed the structure and responsibilities of that part of the organisation;
- the resourcing issues at the Ealing Common track office and the effect this had on work planning and fault rectification;
- inadequate identification and reporting of track faults;
- the number of outstanding ML faults on the Piccadilly Line; and
- recurring concerns from LU following the 2009 audit report and various concerns raised by LU field agents in 2008 and 2009.

121 Tube Lines used a process of end-checks to verify compliance with LU and Tube Lines standards and procedures. End-checks consisted of office based activities, such as reviewing documents and records and practical activities, such as observing a track safety inspection and reviewing the actual condition of the track asset against that recorded in Maximo. Table 3 lists the various practical surveillance activities conducted on patrollers on the three lines within Tube Lines' scope by the Tube Lines assurance department between October 2007 and May 2010. No concerns of relevance to the derailment were identified during those surveillance activities.

Surveillance details	Line	Number of checks	Comment
Track safety inspection	Piccadilly	5	4 checks undertaken between 29 and 30 October 2007 and 1 check on 15 January 2009.
	Northern	3	3 checks between 23 January 2009 and 10 March 2009.
	Jubilee	3	3 checks undertaken 16 January 2009 and 5 March 2009.

Table 3: record of patrol surveillance activities completed by Tube Lines assurance department between October 2007 and May 2010.

122 No formal patroller and inspector surveillance plan was in place before the derailment. The patroller surveillance checks undertaken did not identify any serious concerns with the quality of track safety inspections. No inspector surveillance checks were undertaken between October 2007 and May 2010 by the assurance department. With the Track Inspection Manager post vacant, the assessment of the quality of the supervisory inspections was not being comprehensively reviewed by Tube Lines.

Action following London Underground's audit and surveillance findings

123 **London Underground had raised concerns with Tube Lines regarding the quality of track inspections and fault reporting during 2009 and 2010. Neither the action taken by Tube Lines in addressing those issues, nor the actions of London Underground in following-up their concerns, was effective. This was a contributory factor in the derailment.**

London Underground audit findings

124 LU audits generally focused on the testing of Tube Lines health, safety and environmental management systems to assess whether Tube Lines had processes in place to manage the risk in those areas. In addition, LU carried out audits on topics that were identified by means of risk assessment. LU recognised that the track asset contributed a significant portion of the overall safety risk arising from the operation of the railway, and normally focused some form of audit activity in that area.

125 In November 2009, LU completed an audit of Tube Lines *permanent way* fault management processes. The scope of the audit was:

- inspection and fault reporting regimes;
- fault prioritisation and scoping;
- fault rectification and planning; and
- fault repair and close out.

126 The audit was conducted at various offices on the Jubilee, Northern and Piccadilly lines and involved interviews with track maintenance staff and reviewing inspection records and documentation. The audit identified 2 corrective actions and a total of 15 observations. The conclusion of the audit report was that further improvement to Tube Lines fault management processes was required.

127 A closing meeting to discuss the audit report was held between LU and Tube Lines on 18 November 2009. During this meeting the audit findings were accepted by the Tube Lines assurance department. The actionees and milestones for completion of the corrective actions required were also agreed. LU and Tube Lines agreed a milestone completion date of December 2010.

128 The LU auditors raised an action to rectify the incorrect identification and classification of some faults on the Maximo walkout reports. The review of track walkout reports used during the track patrol activities showed that several faults on the walkout reports had been incorrectly identified, located or classified. LU believed that these faults should have been identified during the supervisory inspections and suggested that the supervisory inspections were not being carried out as thoroughly as required. At the time of the derailment Tube Lines had not closed out this audit finding. The Tube Lines assurance department had planned to cover this issue with the introduction of a new standard; however the introduction of this standard was delayed by Tube Lines internal review processes. As an interim measure, one of the Tube Lines asset engineers (paragraph 119) proposed issuing a briefing notice to the patrollers and inspectors. However, the notice was not issued because it was believed that the new standard would be ready for issue around the time the briefing notice would be available. At the time of the derailment the new standard had not been issued.

129 LU observed that the joint inspection forms (paragraph 64) did not always provide a detailed assessment of the quality of work carried out by patrol staff. No effective action to address this issue on the Piccadilly Line had been taken by Tube Lines prior to the derailment on 12 May 2010.

130 LU also observed that some ML and MT faults were not being input into Maximo for several weeks. Tube Lines stated that similar problems with the inputting of fault data in Maximo had been identified during patrol route surveillance activities, and that there was a plan to conduct surveillance activities to monitor the inputting of fault data in Maximo. The delay in inputting Maximo data was a result of the Maximo planner vacancy (paragraph 114). No additional surveillance had been undertaken by Tube Lines before the derailment, and no additional surveillance was documented to be undertaken during 2009-2010.

London Underground surveillance findings

131 In addition to audits, the LU track assurance department conducted planned verification of Tube Lines maintenance activities. Surveillance was undertaken by LU field agents who reported to the LU safety assurance engineer. The LU safety assurance engineer reported to the LU head of track engineering. LU surveillance was based on a risk-based plan known as the verification activity plan (VAP). The VAP was prepared annually by the LU safety assurance engineer. A key input into the VAP was the Tube Lines asset specific assurance plan, known as the TLF 245. The TLF 245 document detailed the assurance activities Tube Lines planned to undertake, for example: the management of point and crossing condition, review of competence assessments, review of temporary approved non-compliances and the review of the prevention of buckling standard.

132 LU field agents conducted surveillance activities on the Jubilee, Northern and Piccadilly Lines. Each patrol route was visited at least once in a twelve month period. The safety assurance engineer, within the LU track assurance department collated the results of the field agents' surveillance activities and produced a periodic report which was sent to the relevant Tube Lines Track Managers and Area Track Managers and also to the Tube Lines assurance department. Any urgent issues were additionally communicated via telephone call and email following their identification.

133 LU field agents had raised concerns with Tube Lines following surveillance activities in 2008, 2009 and 2010 with regard to the quality of track safety inspections and supervisory inspections. The action taken by Tube Lines in response to LU's concerns was not effective at improving the quality of the patrols and inspections. Additionally, Tube Lines did not use the findings from LU's surveillance activities when planning its own surveillance activities, nor were LU's findings passed on to the Tube Lines audit department for them to consider as part of their audit planning process.

134 On the night of 23/24 February 2010, an LU field agent completed a surveillance check that included the track through the derailment location. The check was undertaken alongside a Tube Lines inspector. The LU field agent observed that between Gloucester Road and Earl's Court stations at between 120 metres and 460 metres there were:

- 20 to 25 defective sleepers per 100 metre cell;
- 50 to 60 defective screws per 100 metre cell; and
- 5 broken chairs and a significant number that were worn.

135 As a result of the surveillance check, the field agent highlighted four SS faults that needed urgent attention. They included defective sleepers, defective screws and defective chairs. The LU field agent also noted that in the previous three month period several faults had not been entered into the Maximo system. This included SS faults. A general concern was raised regarding the quality of inspections that were being carried out by Tube Lines staff.

136 The Tube Lines Track Manager and Area Track Manager-West were contacted by the LU surveillance team by telephone and email on the 24 February 2010 to inform them of their concerns. The concerns were also discussed during a routine monthly assurance meeting between LU and Tube Lines in March 2010. Minutes of the meetings were not always made; issues were generally communicated by email and telephone conversations.

137 On receipt of the information through email and telephone calls from the LU surveillance team on 24 February 2010, the Area Track Manager-West arranged to undertake corrective maintenance through the affected area on the night of 24/25 February 2010 and to brief the patrollers and inspectors with regard to the identification and reporting of faults. The briefing was in the form of an informal 'toolbox talk'. No records of this briefing were made by the Area Track Manager-West and the RAIB has witness evidence that not all the patrollers and inspectors received the briefing. The SS faults identified by the LU field agent were not entered into Maximo and there was no record of any corrective maintenance that was undertaken to rectify the faults. However, on the night of 13/14 April 2010 the LU field agent conducted a follow-up track inspection through the area where he had raised concerns in February. He was satisfied that improvements had been made, but commented in his report (paragraph 131) that further work was still needed to improve the track condition and data in the Maximo workbank.

138 A monthly permanent way asset performance review meeting (known as APRM) was held between LU and Tube Lines. The meeting was used to discuss issues related to the track asset including life extension works, operational incidents, the compliance recovery plan and audit plans. However, up to the day of the derailment, LU surveillance findings were not discussed. Regular one-to-one assurance meetings were also being conducted between LU and Tube Lines. No minutes were made of these meetings; therefore the issues discussed were normally not systematically communicated outside of those attending the meeting.

139 LU experienced difficulty in closing out the concerns it was identifying because it often could not measure how effective Tube Lines was in dealing with the underlying issues. With LU's concerns not being discussed at the APRMs, responsibility for resolution of the underlying issues was split between the asset engineers, the Track Manager and the Area Track Manager-West. There was no clear ownership and nobody took responsibility to close out the issues and concerns raised.

140 The Piccadilly Line Infrastructure Manager in post from 2010 was not aware of the concerns raised by LU because:

- the findings were not discussed at the APRMs and so were not on the APRM minutes he received;
- no minutes were being produced and distributed following the one-to-one assurance meetings; and
- the Track Manager did not raise the issue directly with him.

The role of the Office of Rail Regulation

141 The Office of Rail Regulation (ORR) is the independent safety and economic regulator for Britain's railways, including the London Underground system. The ORR carried out inspections on LU's systems and procedures in accordance with a *delivery plan*. For 2009/2010 the delivery plan included inspection topics related to the continued monitoring of the compliance recovery plan (paragraph 95) and the management of points and crossings. The ORR also monitored LU with regard to the management of broken rails. During 2009 the management of ML level faults and the identification and recording of track faults were not routinely monitored by the ORR because those topics were not part of the ORR's delivery plan.

Previous occurrences of a similar character

142 A train, which was not in passenger service, derailed while entering a siding near Archway on the Northern Line in June 2006. The derailment was caused by a broken switch rail in a set of facing points. Tube Lines carried out an internal investigation into the derailment. The RAIB carried out an independent investigation and made three recommendations: two to LU and one to Tube Lines. The recommendation to Tube Lines was:

'Tube Lines should carry out a review of their track inspection system to ensure that faults are being consistently detected and correctly identified, and the appropriate level of remedial action is being programmed'.

143 Tube Lines considered that the RAIB recommendation was broadly similar to one that had been made in its own internal investigation. Tube Lines formed a working group to manage the recommendations arising from the Archway derailment investigations towards the end of 2006. This group identified several actions that it believed would satisfy the requirements of its own, and the RAIB's recommendation. The ORR accepted the RAIB recommendation as closed because it was sufficiently confident that the actions Tube Lines intended to take would satisfy the intent of the recommendation. At some point after January 2007, the document that was being used by Tube Lines to capture and monitor the actions ceased to be updated. Tube Lines was unable to provide a close-out document detailing how all the actions had been dealt with. Nevertheless, a review meeting held by Tube Lines on 12 October 2010 to identify how the actions had been managed concluded that all of the actions had been completed or addressed by other actions.

144 A derailment occurred on the Hammersmith and City Line near Paddington station on 27 May 2000[10]. The cause of the derailment was wide track gauge as a result of the loss of seven consecutive keys from the high rail. Additionally, there was excessive side-wear and loose chairs present.

145 Causal factors identified in the investigation report that were relevant to the derailment between Gloucester Road and Earl's Court included:

- the performance of track patrols and track inspections; and
- insufficient maintenance staff.

146 The Paddington derailment investigation resulted in 23 recommendations. The RAIB has not been able to establish how the recommendations were managed because in the meantime, LU changed its recommendation tracking system. When the data was transferred to it from the previous system the detail of the close out of recommendations was not entered into the new system.

[10] The derailment near Paddington on the Hammersmith and City Line in May 2000 occurred before the existence of the RAIB. The RAIB became operational in October 2005.

Summary of Conclusions

Immediate cause

147 The track was not able to maintain the correct gauge as the engineering train passed over it (paragraph 33).

Causal factors

148 The causal factors were:

a. the non-identification and misclassification of track faults resulted in the non-rectification of those faults which ultimately caused the derailment (paragraph 40, **Recommendations 4 and 9**); and

b. Tube Lines was unaware that dynamic wide gauge had been identified by the track recording vehicle in February 2010 and April 2010 because the information had not been included in the level 3 Safety Standard Exceedence reports (paragraph 78, **Recommendation 1)**.

149 It is possible that the following factors were causal:

a. there was insufficient time available to complete thorough and detailed patrols and inspections (paragraph 55, **Recommendation 3**); and

b. not all of the inspectors had received formal training and the ongoing reassessment of competence for patrollers and inspectors was not effective (paragraph 60, **Recommendation 4**).

Contributory factors

150 A contributory factor was:

a. neither the action taken by Tube Lines in addressing concerns raised by London Underground following audit and surveillance activities, nor the actions of London Underground in following-up their concerns, was effective. (paragraph 123, **Recommendations 6 and 7**).

Underlying factors

151 The underlying factors were:

a. It was difficult to apply London Underground standard 1-159 'Track-dimensions and tolerances' (paragraph 72, **Recommendation 2**)

b. The Piccadilly Line track team within Tube Lines was mainly focused on managing the level of SS faults and had not identified the risk from groups of ML faults (paragraph 93, **Recommendation 8**)

c. there were insufficient staff to maintain the track in good condition (paragraph 104, **Recommendation 5**); and

d. Tube Lines audit and surveillance regime for the track maintenance activity was ineffective in identifying concerns over the competence of patrollers and inspectors and the risk arising from long-term vacancies (paragraph 116, **Recommendation 6**).

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

152 Following the derailment a Track Inspection Manager was recruited on the Piccadilly Line. Tube Lines has also reorganised the Piccadilly Line track maintenance organisation, to include a new position of Engineering Manager who will be responsible for focussing on engineering analysis and work prioritisation.

153 LU and Tube Lines agreed a 36 point action plan following the derailment. The plan included review of, and improvements to many track maintenance processes. It also included a review of the data stored on Maximo relating to asset condition that was recorded during the post-derailment Maximo data quality inspections (paragraph 51). Tube Lines have reported that additional maintenance resources were deployed to complete rectification work identified during these inspections and that the actions arising from the action plan are being monitored at the monthly APRM (paragraph 138).

154 Tube Lines has issued two new standards. One standard details the roles, responsibilities and actions required in response to reports produced following TRV recording runs. The other new standard defines the requirements for management and supervisory track inspections. Tube Lines has also reported that it has:

- revised its approach to surveillance checks;
- implemented a database to record surveillance findings and monitor the close out of issues raised;
- changed the way asset engineers record their activities;
- configured the TRV level 3 SS exceedence report to include wide gauge data; and
- completed a joint inspection patrolling review on a sample of patrol routes to verify the competence of track patrol and inspection staff.

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

155 Tube Lines has reported that it has made changes to the way it manages the tracking and close out of recommendations. The reported changes include:

- documenting evidence on how recommendations have been closed out;
- documented review meetings with the people responsible for actions arising from recommendations; and
- the tracking of open recommendations at Tube Lines safety review group meetings.

Recommendations

156 The following recommendations are made:[11]

Recommendations to address causal, contributory, and underlying factors

1 *The purpose of this recommendation is for data from any equipment used to assess the track asset to show clearly what safety faults have been identified and where they are located. This will help to promote a situation where those track faults that are more reliably detected by asset inspection equipment are acted upon.*

London Underground, in consultation with Tube Lines, should arrange for all data on track faults identified by asset inspection equipment, such as the asset inspection train, to be presented clearly. The procedures for managing the data should indicate how required remedial actions are planned, prioritised and executed by those in receipt of the data (paragraph 148b).

2 *The purpose of this recommendation is for London Underground to make improvements to the way in which track faults are identified and classified during track inspections, thus reducing the risk that faults will be overlooked*.

London Underground, in consultation with Tube Lines, should review standard 1-159 'Track- dimension and tolerances' with a view to making changes to the standard or take other appropriate steps to make it easier for patrollers and inspectors to identify and record issues of concern (paragraph 151a).

continued

[11] 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 Regulation 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 167 to 171) can be found on RAIB's website www.raib.gov.uk.

3 *The purpose of this recommendation is to allow sufficient time for track patrols and inspections. This will enable staff to meet the requirements of the relevant standards for these activities, so that track faults are not missed.*

Tube Lines should review and revise its patrol route risk assessments, and inspection routes, taking account of human factors issues, to ensure there is sufficient time available to complete thorough and detailed patrolling and inspection activities in accordance with relevant standards (paragraph 149a).

4 *The purpose of this recommendation is for patrollers and inspectors to be adequately trained and undertake regular assessments to ensure their ongoing competence.*

Tube Lines should review its training and competence management processes for patrollers and inspectors. The review should aim to establish a comprehensive training programme for each grade of staff and a regular cycle of rigorous competence assessments (paragraphs 148a and 149b).

5 *The purpose of this recommendation is for Tube Lines to modify its processes to make sure it assesses the effect of vacancies in safety-critical positions within Tube Lines asset maintenance organisation immediately. This should enable appropriate steps to be taken so that there is no detrimental effect on safety-critical activity.*

Tube Lines should modify its processes to include the requirement to actively monitor and assess safety critical vacancies within its asset maintenance organisation. Where key vacancies are identified the reasons for not filling the post should be explored and assessments undertaken to understand and control the risk arising. The review of key vacancies should not be limited to management grades but should include key personnel, such as those involved in asset inspections and asset condition recording (paragraph 151d).

6 *The purpose of this recommendation is for Tube Lines to ensure that systematic and regular reviews are undertaken of the quality of track patrols and inspections, including the recording of faults found and their rectification. This should achieve a more rapid identification of lapses in the quality of track patrols and inspections which could result in safety-critical faults not being identified and rectified.*

Tube Lines should improve its assurance processes to ensure a robust system of assurance activities is undertaken, with particular emphasis on practical activities. The activities should target the quality of track patrols and inspections, and the identification and prioritisation of faults. The improvements should include a process for following-up and rectifying issues identified (paragraphs 150a, and 151d).

continued

7 *The purpose of this recommendation is for London Underground to make improvements to its processes for following-up issues found during its audit and surveillance of Tube Lines track maintenance activities.*

London Underground should improve its assurance processes to ensure that issues identified during audit and surveillance of Tube Lines track maintenance activities are actively monitored and addressed by Tube Lines in a timely manner (paragraph 150a).

8 *The purpose of this recommendation is for London Underground to consider how the level of risk from ML faults should be evaluated after patrols and inspections have taken place in order to clarify the action required where there are multiple faults.*

London Underground, in partnership with its track maintainers, should review standard 1-159 'Track- dimension and tolerances' with the aim of providing guidance on the assessment of risk from ML faults. The guidance should address how the effect of other ML or SS faults in the same location or immediate vicinity should be evaluated so that impending problems at particular locations can be identified (paragraph 151b).

9 *The purpose of this recommendation is for Tube Lines to consider the use of technology to assist patrollers and inspectors in recording and classifying track faults, thereby reducing the risk that faults will be overlooked.*

Tube Lines should review current technologies and, following production of an action plan, implement any that can assist patrollers and inspectors. This should include the consideration of the use of hand-held computer devices to record and classify faults and geometry recording equipment that can be moved along the track to record parameters such as track gauge and twist (paragraph 148a).

Appendices

Appendix A - Glossary of abbreviations and acronyms

APRM	Asset Performance Review Meeting
KPI	Key Performance Indicator
LU	London Underground
ML	Maintenance Limit
MT	Maintenance Target
ORR	Office of Rail Regulation
PPP	Public Private Partnership
RAIB	Rail Accident Investigation Branch
SS	Safety Standard
TRV	Track Recording Vehicle

Appendix B - Glossary of terms

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

95 lb bull head rail	A rail weighing 95 lbs per yard that has a rail head and rail foot that are similarly shaped.
Alignment	The longitudinal vertical and lateral direction of a section of track.
Ballast	Crushed stone that is normally used to support railway sleepers both vertically and laterally.
Cant	The design amount by which one rail of a track is raised above the other rail, measured over the rail centres.*
Chairs	A cast or fabricated support for bull head rail.*
Chair Shuffle	The tendency of inadequately maintained chairs on wood sleepers to move laterally under traffic, so wearing the wood away from under them.*
Concession	Authorisation not to comply with the requirements of an applicable standard.
Curvature	The radius of the curve of track.
Delivery Pan	An ORR document outlining specific aims and objectives that are to be achieved during a defined time period.
Dynamic gauge	The gauge of the track, measured as a train passes over it. It can be estimated by applying a realistic spreading force to the rails and measuring the resulting displacement.*
Fettling	To make small manual adjustments to the track, such as tightening fastenings and replacing keys.
Flange climb	A condition in which the lateral force exerted on a rail wheel is sufficient to force the rotating wheel up the gauge face of the rail and onto the rail head.
Four-foot	The space between the running rails of a track.
Fourth rail system	A traction power supply system using two conductor rails.
Gauge	The distance between two rails of the same track. The measurement is taken at a point 13 mm below the running surface of the rails.
Headwall	The flat wall where the tunnel enclosing a platform reduces to the narrower diameter running tunnel between stations.*
High rail	The outer running rail of a curved length of track.
Keys	A shaped wedge of spring steel used to secure bull head rail in a Chair.*

Low rail	The inner running rail of a curved length of track.
Permanent way	The track including, rails, fastenings, sleepers, ballast and track bed.
Safety Case	A document setting out the arrangements which a railway company has put in place to control the risks created by its operations.
Side-wear	The progressive removal of rail metal generally afflicting the high rail on curves, due to the high lateral forces produced when a train negotiates a curve. Eventually the rail head assumes a profile complimentary to the passing wheelsets, increasing the likelihood that wheelsets will climb the rail. Sidewear is measured using a side-wear gauge.*
Single bore	In railway usage, a narrow tunnel built to carry one single track only.*
Static gauge	The gauge of the track, measured when no trains are present.*
Surveillance	Monitoring and observational activities.
Temporary approved non-compliance	An assessment that the risk introduced by non-compliance with a standard is acceptable for a defined period of time.
Track geometry	The horizontal and vertical alignment of the track, including cant.*
Track patrolling	Visual inspections of the track carried out on foot by a trained person on a regular basis.
Tread corner	The approximately 45° chamfer applied to the outer edge of the outer tread of a rail wheel.*
Track twist	A rapid change in cant. Twist is calculated by measuring two points a short distance apart, and then expressing the difference as a 1 in x gradient over the distance measured.
Wheel unloading	The reduction of the force applied to the rail by one or more wheels.

Appendix C - Key standards current at the time

London Underground standard 1-159 issue A1 October 2007	Track- dimensions and tolerances.

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