Rail Accident Investigation Branch

Rail Accident Report

Derailment of a tram at Pomona, Manchester
17 January 2007

Department for Transport

Report 09/2008
April 2008

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.

Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Email: enquiries@raib.gov.uk
Telephone: 01332 253300
Fax: 01332 253301
Website: www.raib.gov.uk

This report is published by the Rail Accident Investigation Branch, Department for Transport.

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Contents

Introduction

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.

3 Access was freely given by Serco Metrolink and Greater Manchester Passenger Transport Executive (GMPTE) to their staff, data and records in connection with the investigation.

4 Appendices at the rear of this report contain glossaries;

- acronyms and abbreviations are explained in Appendix A; and
- certain technical terms (shown in *italics* the first time they appear in the report) are explained in Appendix B.

Summary of the report

Key facts about the accident

5 At 17:14 hrs on 17 January 2007 Metrolink tram no. 1005, forming the 16:35 hrs service from Eccles to Piccadilly, derailed as it approached Pomona station (Figure 1).

6 There were over 120 passengers on the tram at the time. No one was injured in the derailment. The passengers were evacuated onto the viaduct walkway and from there onto the station platform. The position of the emergency equipment and the method of door control of the tram made this evacuation difficult.

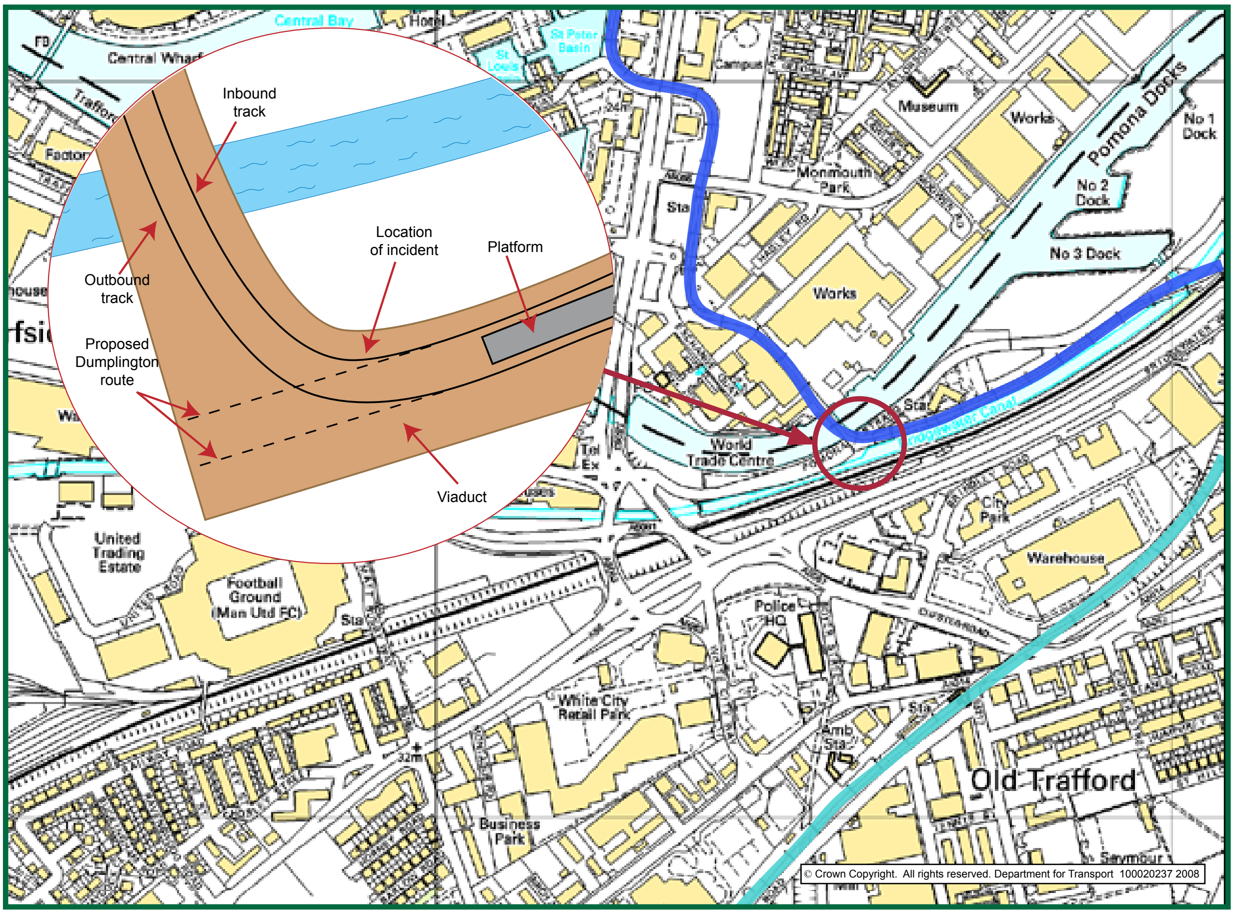

Figure 1: Extract from Ordnance Survey map showing location of incident

Identification of immediate cause, causal and contributory factors and underlying causes

7 The immediate cause of the derailment was out of tolerance track gauge which widened further as the tram ran over it.

8 The design of the track system at the Pomona curve contributed to the derailment.

9 The underlying causes of the derailment were that track inspection and maintenance procedures specified in the Metrolink Maintenance Manual were not followed.

10 The contractual arrangements between GMPTE and Serco may have been causal to the derailment as they gave rise to a situation where Serco had no financial incentive to carry out repairs to the track at Pomona.

11 The lack of effective audit of Serco Metrolink's maintenance and inspection procedures contributed to the derailment.

Recommendations

12 Recommendations can be found in paragraph 111. They relate to the following issues;

- supervision of the Manchester Metrolink operation by GMPTE;
- contract arrangements between GMPTE and the operator;
- accessibility of the emergency equipment on the tram; and
- the system of operation of the tram doors.

13 Responsibility for maintenance and inspection has changed since the time of the incident and no recommendations are made regarding the maintenance and inspection of the track as these would have applied to the old concessionaire. The new contractual arrangements are different from the previous ones as they involve the appointment of an operating contractor. The operating contractor has introduced a new inspection and maintenance regime to ensure that the track is safe for traffic. Office of Rail Regulation (ORR), the safety authority, are satisfied that the new inspection and maintenance procedures represent best industry practice.

The Accident

Summary of the accident

14 At 17:14 hrs on Wednesday 17 January 2007 tram 1005, forming the 16:35 hrs service from Eccles to Piccadilly, was approaching Pomona station. The station and its approach tracks are situated on a viaduct and the approach to the station from the Eccles direction involves a 90 degree left-hand curve of 40 m radius (Figure 2). As the tram was negotiating this curve the left-hand leading wheel of the first bogie derailed by dropping into the *four-foot*. The speed of the tram at the time of derailment was 6.3 mph (10 km/h).

Figure 2: The track on which the tram derailed, looking towards Pomona station

15 The *wheelset* was able to drop into the four-foot as the track gauge was wider than allowed in the specification and the rails were able to be forced further apart relatively easily. The wheelset ran with the left wheel in the four-foot and the right wheel on the rail for 17 m, forcing the rails apart, until it encountered an *expansion joint* in the rails. The rails here were more securely held to gauge than in the curve and the right-hand side wheel was forced over the rail head and into derailment by the narrowing gauge of the more securely fixed rails (Figure 3).

Figure 3: Derailed wheel at front left-hand side of tram

16 At this point the wheel and bogie structure contacted the concrete *derailment containment upstand*, which prevented further sideways movement. The tram came to rest in contact with the station platform (Figure 3).

17 The driver felt the tram jolt and made a full service brake application. A Metrolink supervisor was riding with the driver and assisted with the detrainment of the passengers. No one was injured in the derailment or the evacuation process.

The parties involved

18 The tram was operated by Serco Metrolink, who, at the time of the incident, held the concession for the operation and maintenance of the Manchester Metrolink tram system, under contract to the Greater Manchester Passenger Transport Executive (GMPTE). GMPTE terminated the concession on 15 July 2007 and a new company, Stagecoach Metrolink, was appointed as operating contractor from that date. The change of operator was planned as part of the phase 3 extension work of the Metrolink system and was not in response to the derailment at Pomona.

Location

19 Pomona station is situated on a viaduct adjacent to the Manchester Ship Canal in the City of Manchester. The station is on the Eccles line, which was built as phase 2 of the Manchester Metrolink system, and opened in 1999 through Pomona and throughout in 2000. A junction was planned at Pomona where a possible future extension to Dumplington was to leave the Eccles line. The viaduct was designed to accommodate this junction and concrete track plinths for both diverging routes were provided. Only the Eccles route had the rails and *baseplates* installed on the plinths, the proposed Dumplington route being left with just the concrete plinths.

20 The line between Eccles and Pomona crosses the Manchester Ship Canal as it approaches Pomona station and ascends a ramp from ground level before crossing the waterway. The line then curves sharply left into Pomona station. The tram involved in the derailment was on an inbound journey from Eccles to Piccadilly and therefore ascended this ramp before encountering the curve into Pomona station.

21 The speed limit on the curve into Pomona station is 10 mph (16 km/h).

22 The track at Pomona consists of BS80A flat bottom rails held on cast iron baseplates by *Pandrol clips*. The baseplates are bolted to reinforced concrete plinths which were constructed as part of the bridge deck. Figure 2 shows a general view of the track at this location. The concrete plinths for the proposed Dumplington extension can be seen leading off to the right of this picture.

23 The rails in the curve at Pomona were continuously welded with an expansion joint at the end of the curve corresponding with an expansion joint in the bridge deck.

The tram

24 The tram, number 1005, was one of the original fleet of type T68 trams built by Ansaldo for phase 1 of the system in 1991. It has since been modified to operate on the phase 2 extension line to Eccles. These modifications did not affect the behaviour of the tram in the derailment.

25 The Manchester Metrolink system has stations with platforms at the same height as conventional railway platforms and so the trams have high floors.

Events during the accident

26 The tram was heavily loaded with passengers as it formed an evening peak service through the commercial area around Salford Quays.

27 The tram driver was joined in the cab by his supervisor at Harbour City tram stop. This was a routine observation of the driver by his supervisor.

28 As the tram approached Pomona station the driver allowed the gradient to slow the tram for the curve. Whilst the tram was negotiating the curve the driver and his supervisor felt the tram jolt then they heard an unusual sound from beneath the tram. The driver applied full service brake and the tram stopped 17 m from the point of derailment.

29 The supervisor asked the driver to contact the Metrolink control room by radio to report the incident and got down to examine the tram. He found that the leading wheelset had derailed.

Events following the accident

30 The supervisor contacted the control room by mobile phone and agreed that the tram should be detrained.

31 The trams carry emergency equipment, including a ladder for detraining passengers, but this equipment is located in the centre section of the vehicle and the driver and supervisor could not get to it due to the crowded condition of the tram.

32 The front of the tram was adjacent to the platform at Pomona station but this is an island platform and so was on the right-hand side of the tram. The door control system does not allow the driver to release the front right-hand side set of doors without also releasing all the other doors on that side. The driver and supervisor considered this but decided that this could lead to the risk of passengers falling out from doors not adjacent to the platform. They decided instead to unload the front half of the tram via the front left side doors using the crew access facility which allows these doors only to be released. The driver and supervisor assisted the passengers in climbing down from the tram onto the viaduct walkway.

33 Once the standing passengers were clear of the front section of the tram, the driver planned to get to the detrainment ladder to assist with detraining the remainder. When the passengers started to detrain however, the driver and supervisor found it impossible to stop them and almost all of the passengers were detrained via this door, climbing down onto the viaduct walkway. They then had to be walked along the viaduct to the far end of the station platform before crossing the track and ascending the platform ramp.

34 There were two disabled passengers who were unable to be detrained via this route and they waited until Metrolink technical staff arrived and released the right-hand side doors. They were then able to leave directly onto the platform.

35 The Eccles line tram service was suspended for the remainder of the day and for all of the following day while the tram was recovered and the track repaired.

The Investigation

Sources of evidence

36 The investigation was carried out using evidence obtained from the following sources;

- statements by GMPTE and Serco Metrolink staff;
- evidence gathered on site and at Queens Road depot;
- photographs taken by Serco Metrolink with the RAIB's permission immediately after the derailment;
- documents supplied by Serco Metrolink;
- documents supplied by Stagecoach Metrolink;
- documents supplied by GMPTE; and
- the tram's onboard data recorder.

37 The driver was tested for the presence of drugs and alcohol following the incident as is normal in accordance with industry practice and the tests showed that none was present.

Previous occurrences of a similar character

38 There have been no previous derailments reported on Metrolink caused by gauge spread. However, there have been derailments caused by other track defects.

39 Trams were derailed by failure of the *keep rail* on *grooved rail* curves at Shudehill on 31 August 2004 and London Road on 11 January 2005.

40 A tram was derailed by a failed transition joining grooved rail and normal rail at Long Millgate on 22 March 2006. This derailment was investigated by the RAIB (report 08/2007, available at www.raib.gov.uk) and the cause found to be that a repair to the *transition rail* was undertaken without the use of a formal design change control process or quality control of the work done. The recommendations made by the RAIB included one that asked GMPTE and the infrastructure maintainer to introduce a system for initiating and implementing track renewals, and one that asked GMPTE to review the infrastructure design change procedures to ensure proper control of alterations made during maintenance.

Analysis

Identification of immediate cause

41 The initial derailment occurred when the left side leading wheel dropped into the four-foot at a location directly opposite a *fishplated joint* in the *six-foot* rail. Figure 4 shows the resulting mark on the rail. The fishplated joint was one of two in the six-foot rail where a section of rail had been replaced.

Figure 4: (left) side rail, showing wheel drop-in mark (arrowed)

42 No gauge widening was specified for this curve, so the gauge should have been 1435 mm. The wheel was able to drop in because the *static gauge* at this point was wider than specified and the resistance of the track to gauge spread was low. The gauge was measured by the RAIB the day after the derailment and was found to be 1463 mm. It is possible that some of this gauge widening could have been caused by the derailment, but this is not likely.

43 At the time of the RAIB measurement there was a gauge *tie bar* installed at the rail joint at this location. The Metrolink permanent way staff informed the RAIB that this tie bar was present at the time of the derailment and so the gauge measurement, and subsequent gauge spread test, was performed with this bar present. However, when the photographs of the site taken by Metrolink staff at the time of the derailment were made available to the RAIB, it was apparent that the tie bar had not been present.

This meant that the static gauge and gauge spread measurements made by the RAIB at the derailment point were underestimates of the actual gauge and gauge spread at the time of the derailment. Discussions with Serco Metrolink showed that the RAIB permission to commence recovery had been misinterpreted as permission to commence track repairs.

44 The Railways (Accident Investigation and Reporting) Regulations 2005 require that evidence at the site of a railway accident is preserved until the RAIB has concluded its investigation or no longer requires the evidence. The installation of the tie bar was thus contrary to these regulations.

45 The derailed wheelset ran with the left wheel rubbing on the *cess* rail leaving a mark on the side (Figure 5) and the right wheel running normally on the six-foot rail, but pressing hard against it, forcing the rail outwards and widening the gauge.

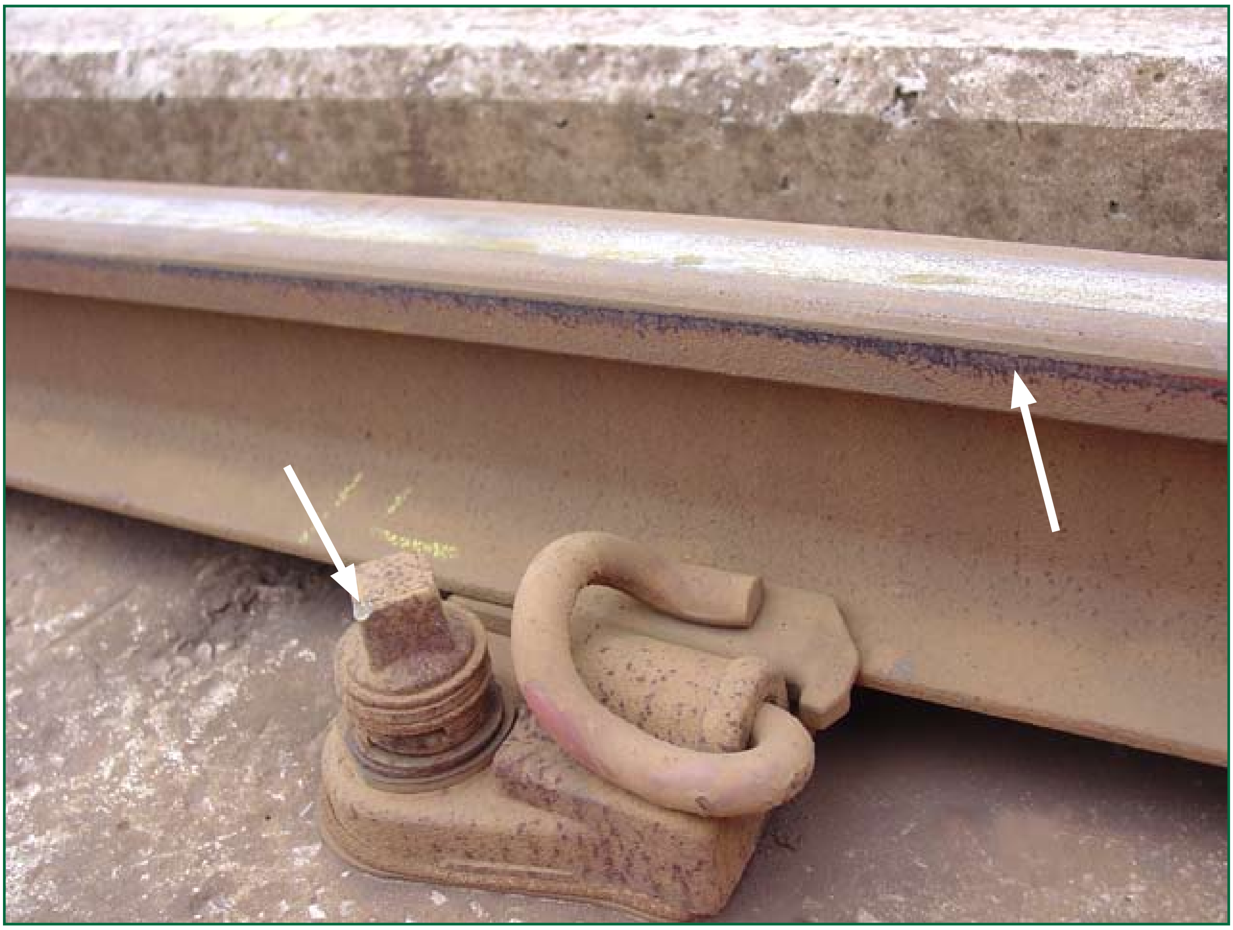

Figure 5: Cess side rail showing marks left by wheel (arrowed)

46 The wheelset ran in this position until it encountered the expansion joint at the end of the curve where the rails were securely fixed to the concrete track plinths. Here the left wheel tread corner started to dig into the *running edge* of the rail and started to climb back towards its correct position. However, the lateral force involved caused the right side wheel to climb over the head of the six-foot rail and derail to the six-foot.

47 The immediate cause of the derailment was wide gauge and the lack of effective gauge restraint within the curve, allowing the already wide gauge to spread further.

Identification of causal and contributory factors

The driving of the tram

48 The onboard data recorder fitted to the tram showed that the tram was being driven correctly on the approach to Pomona. The tram approached the ramp onto the bridge over the Ship Canal at 12 mph (19 km/h) and slowed for the 10 mph (16 km/h) speed limit at the start of the Pomona curve. The driver applied power to keep the tram moving as the speed fell on the gradient. The tram was rounding the curve at 6.3 mph (10 km/h) with power applied when the derailment occurred.

49 The driver immediately removed power and applied the brake bringing the tram to a stand within two seconds of the brake being applied.

50 The driving of the tram did not contribute to the derailment.

The tram

51 The tram was rerailed and taken to Queens Road depot where the bogie which derailed was removed. The RAIB examined the tram at Queens Road and measured the tyre profiles of all of the wheels on the derailed bogie. The wheelset *back to back* measurements were also taken. All of the profiles were found to conform closely to the Metrolink reference profile. The back to back measurement of the wheelset which derailed was taken at four locations around the wheel and three of these measurements were found to be below tolerance by 1 mm (the designed back to back measurement is 1362 mm +0/-2 mm). This may have been caused by the derailment. The wheels are of a resilient design with the tyre and centre separated by rubber blocks. The back to back measurements of the other wheelset were all within the design tolerance.

52 The condition of the tram is not considered to have contributed to the derailment.

Factors relating to the track

Contractual arrangements between GMPTE and Serco

53 The phase 2 (Eccles) extension to the Metrolink system was procured under a 'design build operate maintain' (DBOM) contract in 1997. This contract was between GMPTE, as client, and the ALTRAM consortium, which included Laing, a civil engineering construction company, Ansaldo Transporti, the tram manufacturer, and Serco Metrolink, as operator. The operating concession was to run to 2014.

54 The specification of what was required under the contract consisted of a four-page high level functional specification. This required that the concessionaire design the extension to be compatible with the existing system and in accordance with all relevant statutes and orders. The specific requirements listed covered the accessibility of the extension to disabled people, the passenger flows to be catered for and some requirements for information presentation to passengers. The specification referred bidders to the scheme drawings showing the route of the extension and to the various statutory authorities that needed to be satisfied by the design. It is inherent in this type of contract that the detailed design is done by the bidder.

55 ALTRAM submitted their detailed proposals to GMPTE and these were accepted as the basis of the contract. These proposals included details of the trackforms to be used and the parameters that would govern its design. ALTRAM proposed to conduct a wheel/rail interface assessment '...to set all relevant parameters for the design and also to produce recommendations for limits of wear for both wheels and rails...'. The RAIB have been unable to locate a copy of the results of this assessment or determine whether it was actually done.

56 The ALTRAM proposals included a statement that 'the track gauge may be adjusted on sharp curves as required by the design of the rolling stock.' No gauge widening was specified for the curve at Pomona nor, so far as the RAIB can establish, for anywhere else on the system.

57 After completion of the construction work and delivery of the trams, Ansaldo and Laing left the ALTRAM consortium, leaving Serco as sole member from 2003. At this time, and in anticipation of work starting on the phase 3 extension to Metrolink, GMPTE and Serco agreed a shortening of the operating concession from its original 2014 completion date. The new arrangement allowed for the concession to be terminated at one month's notice at any time from 2003 onwards. It was anticipated that this would probably happen in 2005. In fact, the arrangement lasted until 15 July 2007.

58 This arrangement may have made it difficult for Serco to justify investment in repairs to the system since they potentially had only one month to recoup the cost of their investment. The contractual responsibility for renewals was unclear and Serco were unable to clarify whether they were actually responsible for renewals. When the worn rail at Pomona was discovered in 2004, no plans were made for its replacement apart from a note that it would require replacement by January 2007. The contractual arrangements between GMPTE and Serco from 2003 onwards are considered a possible causal factor in the derailment.

Track standards

59 Phase 1 of the Metrolink system involved the conversion of existing heavy rail lines to light rail use. Only the city centre section involved street running. Heavy rail maintenance standards were applied to the heavy rail track. The Metrolink Maintenance Manual therefore refers to existing heavy rail standards.

60 The construction of phase 2 of Metrolink was within the scope of the Construction (Design and Management) Regulations, 1994, and so a project Health and Safety File was produced which included a maintenance manual for the track on the Eccles line. The track maintenance requirements in this manual are based on the Metrolink Maintenance Manual, but mention *trackforms* found only on the Eccles line, such as grass track. Track on concrete plinths, as at Pomona, is specified to be maintained to 1435 mm gauge with a tolerance of +10/-6 mm.

61 Serco Metrolink prepared a Permanent Way Maintenance Strategy and Annual Plan document which set out how they aimed to maintain the system. This referred to the Metrolink Maintenance Manual, the phase 2 maintenance manual and then-current heavy rail standards from Railtrack and British Rail.

62 The Metrolink system was operated under a Railway Safety Case (RSC) until April 2006 when the Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGTS) came into force. The existing Metrolink Railway Safety Case (issue 8, May 2005) was then adopted as a Safety Management System, as required by the ROGTS regulations. The Metrolink Railway Safety Case document was not re-titled and is referred to here as the Metrolink RSC.

63 The Metrolink RSC states that the track will be maintained to relevant Network Rail standards and the Metrolink Maintenance Manual. It cites specific Railway Group Standards and Network Rail Company Standards, but states that these are for guidance as they may not be applicable to light rail conditions. It also mentions a Metrolink Technical Instruction, TI/002 'Prioritisation of Defects', but does not specify when or how it should be used. Technical Instruction TI/002 is not referred to in the Permanent Way Maintenance Strategy and Annual Plan.

64 The track standards available to Serco Metrolink would, if they had been followed, have led to the replacement of the worn rail at Pomona before the derailment occurred; the track inspection and maintenance standards are not regarded as contributory to the derailment.

Track construction

65 The rail baseplates were bolted to the reinforced concrete upstands on the bridge deck by means of two holding down bolts per baseplate. These holding down bolts had been found to be prone to failure in shear and Serco Metrolink had been replacing them with a revised design. The revised design involves a larger diameter bolt with a spring bearing down on the baseplate. One of these bolts can be seen in Figure 6, but appears not to be tightened down fully.

66 The track slab on the bridge deck includes concrete upstands for derailment protection purposes. One of these upstands limited the movement of the derailed bogie and was damaged in the process. These upstands are situated just outside the running rails and have been used to provide additional lateral restraint to the six-foot rail in at least one location by means of timber wedged between them (Figure 7).

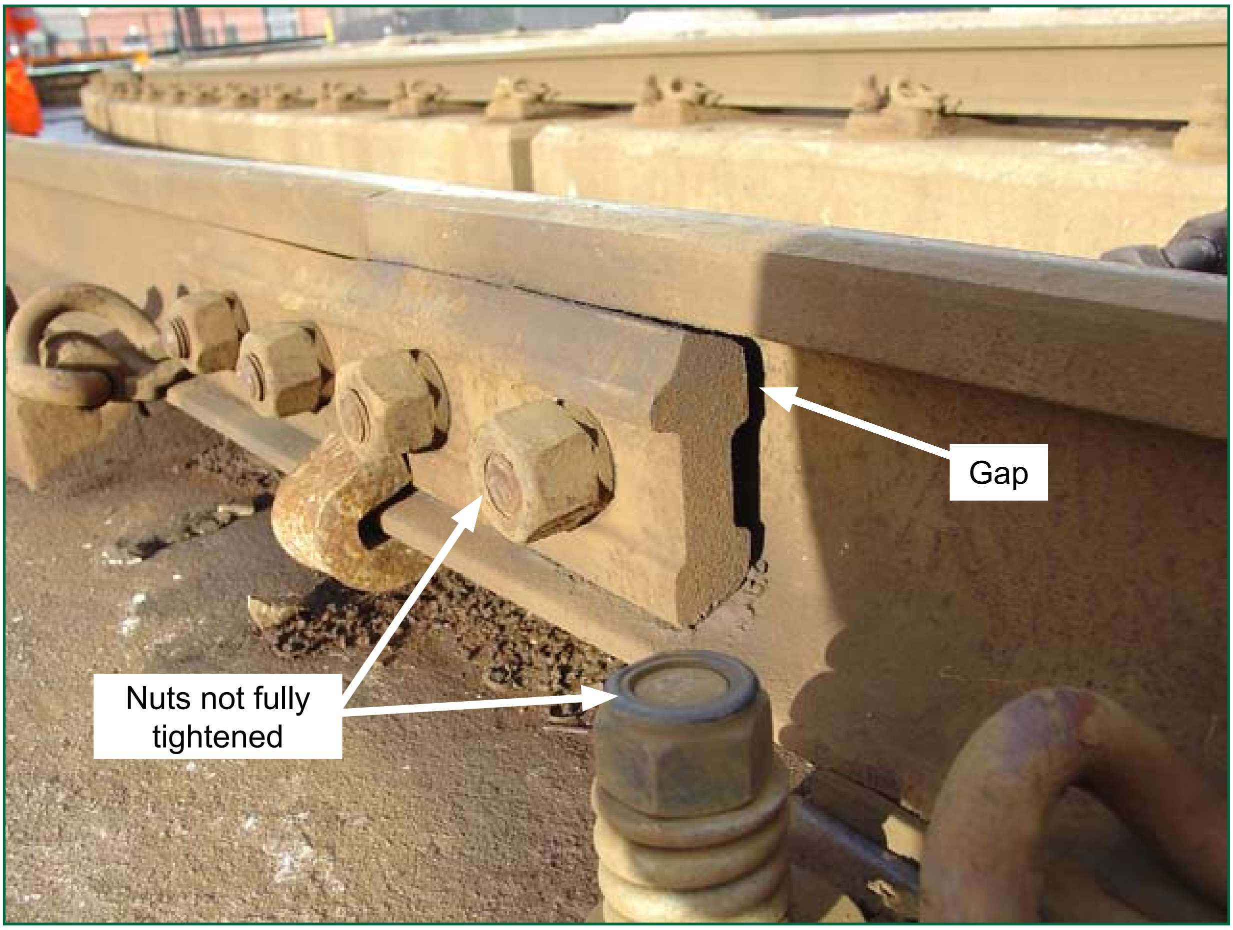

Figure 6: Rail joint in six-foot rail at point of derailment

67 The bolt failures, gauge tie bars and use of timber props are evidence that the track is unable to sustain the gauge spreading forces at this location. It is concluded that the holding down arrangements of the baseplates did not provide sufficient restraint to maintain track gauge on the curve.

Figure 7: Timber propping six-foot rail against concrete upstand

<u>Track maintenance</u>

68 Maintenance of the Metrolink system is governed by the Metrolink Maintenance Manual. This was prepared in 1995 as a guide to how the system was to be maintained.

69 Within three years of tram services starting on the Eccles line, in May 2002, *corrugation* was noticed in the rails at Pomona curve. This was rectified by rail grinding.

70 In July 2004 the six-foot rail at Pomona curve broke at a welded joint. The break was clamped using emergency fishplates and the broken section propped from the derailment upstand using pieces of timber.

71 At about the same time as the rail break, a *sidewear* survey found that the six-foot rail had reached a sidewear reading of zero, its fully worn state. Technical Instruction TI/002 'Prioritisation of Defects' states that this condition should be remedied by replacement of the rail with a priority of one. The priority of one means that the action should be carried out within one month or the defect should be reprioritised within the same timescale. The reprioritisation process involves inspecting the defect to ensure that it has not deteriorated further and is safe to be left for another period. The rail replacement was not carried out and no further sidewear measurements were made.

72 The broken rail was repaired by bolting in a replacement section using fishplated joints at each end. As the existing rail was heavily sideworn, the replacement rail had to also be made from heavily sideworn rail so as not to provide a step in the running edge at the transition to the existing rail. The installation of the replacement rail was done by Grant Rail under contract to Serco Metrolink. No Metrolink procedure existed for this type of repair and so it was left to the contractor to determine how to carry out the repair. This work was completed on 3 October 2004 and a member of Serco Metrolink staff noted on the work ticket that 'the (fishplate) bolts might be wrong' and needed checking by the Serco Metrolink permanent way supervisor.

73 The track was inspected by the Serco Metrolink permanent way supervisor on 19 October 2004 and he noted 'bad sidewear on joint' and recorded an action to replace the rail by 1 January 2007. The rail to be replaced included the section that had just been installed. No gauge or sidewear measurements were taken to back up the decision to defer replacement for over two years. Technical Instruction TI/002 required that this defect should have been repaired within one month.

74 The joints at each end of the replacement rail were made with straight fishplates and normal fishplate bolts. The tight curvature meant that it was not possible for the outer bolts to be tightened sufficiently to bring the outer ends of the fishplates into contact with the rails (Figure 6). The effectiveness of the joint was therefore compromised and this provided a weak spot in the six-foot rail where the gauge could widen further under the lateral load from tram wheels.

75 The initial 'drop in' derailment of the left side wheel occurred opposite one of these joints. At this point the concrete upstand was not present and the rail was only restrained by its *fastenings*. The fishplated joint at the other end of the replacement rail was propped from the adjacent upstand by a piece of timber (Figure 7). The design of the track at this location called for continuous welded rail (CWR) and there should not have been any fishplated joints here.

76 That Serco Metrolink did not follow their Technical Instruction and the Metrolink Maintenance Manual is one of the causal factors of this derailment.

77 The lack of a suitable procedure to govern the replacement of a section of rail in CWR is noted as an observation.

<u>*Track inspection*</u>

78 The basic visual inspection of the track was done by patrolling at the frequencies specified in the Metrolink Maintenance Manual which, for the Eccles line, was weekly. These patrols were carried out, the most recent one before the derailment being on 14 January 2007 which recorded no new defects.

79 In addition to the regular weekly patrols, each section of track must also be inspected by the permanent way supervisor, at intervals no longer than six monthly, and the track engineer, at intervals no longer than two yearly. The most recent inspection of the Pomona curve before the derailment by the permanent way supervisor was made on 8 November 2006 and by the track engineer on 28 February 2006. The requirement for inspections by these staff was therefore met.

80 The Metrolink Maintenance Manual listed other inspections that were required. One such inspection was a manual inspection at three monthly intervals, its purpose being 'to check the general condition of all of the track and to provide information for programming and initiating routine maintenance work'. The dates of these inspections are not known but the checking of rail sidewear could be deemed to constitute a manual inspection. The permanent way maintenance strategy document cites Network Rail company procedure RT/CE/S/103 for guidance. This procedure assesses sidewear on a scale of 0 (fully worn) to 17 (new rail) and calls for a sidewear survey every 24 months except for sites where the wear is below four, which should be surveyed every six months.

81 A sidewear survey was carried out on the Pomona curve between May and July 2004 (the exact date is not recorded) and a reading of zero was obtained. This should have triggered further surveys at six monthly intervals but no further surveys were recorded. The track engineer recalled a survey being conducted in 2005, but no records could be found.

82 The Metrolink Maintenance Manual also called for track geometry recording on an annual basis. The manual listed the inspection as 'track recording vehicle' but no suitable vehicle was available to Serco Metrolink so they used a small recording trolley pushed by hand. This covered the Altrincham and Bury lines on an annual basis but was not used on the Eccles line. The track geometry on the Eccles line was not measured.

83 Track gauge is measured by most track geometry recording systems but the permanent way maintenance strategy document also calls for gauge to be checked by manual inspection to RT/CE/S/103 section 4.4. The section referred to in the standard described how the measurements were to be taken but did not specify how often they were to be done. Serco Metrolink did not measure the gauge on the Eccles line at any time.

84 The Serco Metrolink RSC required that annual independent audits be carried out on the whole safety management system. The most recent audit of the permanent way department at the time of the incident was an internal audit carried out on 24 August 2005. This did not identify any shortcomings in the way in which the permanent way department was following the Serco Metrolink standards and procedures. This audit was mainly a paper based exercise and the only sampling of actual work records was a spot check on a patrol record. The lack of effective audit of the permanent way department is regarded as contributory to the derailment.

85 The fact that Serco Metrolink did not follow their inspection and audit procedures is one of the causes of the derailment.

Track Gauge

86 The static track gauge was measured by the RAIB after the derailment and after Serco Metrolink had commenced track repairs. The repairs already undertaken consisted of replacement of worn *nylon insulators* and broken Pandrol clips and the insertion of gauge tie bars. The RAIB requested Serco Metrolink to restore the track to the condition it was in at the time of the incident. This was done by removing the new Pandrol clips, replacing the new nylon insulators with the old ones and slackening off the gauge tie bars. It was not recorded where each insulator had been at the time of the derailment, but the wear on the insulators was fairly consistent, so the effects of variation caused by this would have been small. Serco Metrolink informed the RAIB that a tie bar was in place at the time of the derailment at one of the rail joints. This bar was left. However, as discussed in paragraph 42, this bar was not present at this location at the time of the derailment. The gauge and gauge spread measurements at this joint are therefore an underestimate of the likely values at the time of the derailment.

87 The static track gauge at the initial point of derailment was 1463 mm and the dynamic gauge would have been more than this. The gauge had to spread to 1510 mm as the tram passed over in order to allow the wheelset to drop in. The gauge through the rest of the curve varied from 1451 mm to 1470 mm but was 1437 mm at the end of the curve by the expansion joint.

88 The Metrolink Maintenance Manual stated that the target gauge range for this type of track was 1433 mm to 1438 mm and the acceptable range was 1429 mm to 1445 mm. The Network Rail track inspection standard RT/CE/S/103, referred to by Serco Metrolink as guidance, required that if static gauge of 1465 mm or over is found, the *dynamic gauge* should be measured within 24 hours if practicable. If the dynamic gauge was found to be 1481 mm or over the line should be closed to traffic immediately. Since Serco Metrolink did not measure the gauge on the Eccles line, they were not aware that these limits were exceeded at Pomona.

89 The ability of the track to resist gauge spreading forces was measured by means of gauge spread tests conducted by the RAIB the day after the derailment. These tests consisted of forcing the rails apart using a calibrated hydraulic jack and measuring the resulting track gauge. The tests were carried out at the point of the initial derailment of the left wheel, the point of the final derailment of the right wheel, the location of a second fishplated joint in the six-foot rail and at a section of good track clear of the derailment area. The last location was included as a control. The results of the gauge spread bar tests are shown in Figure 8 as load/deflection curves.

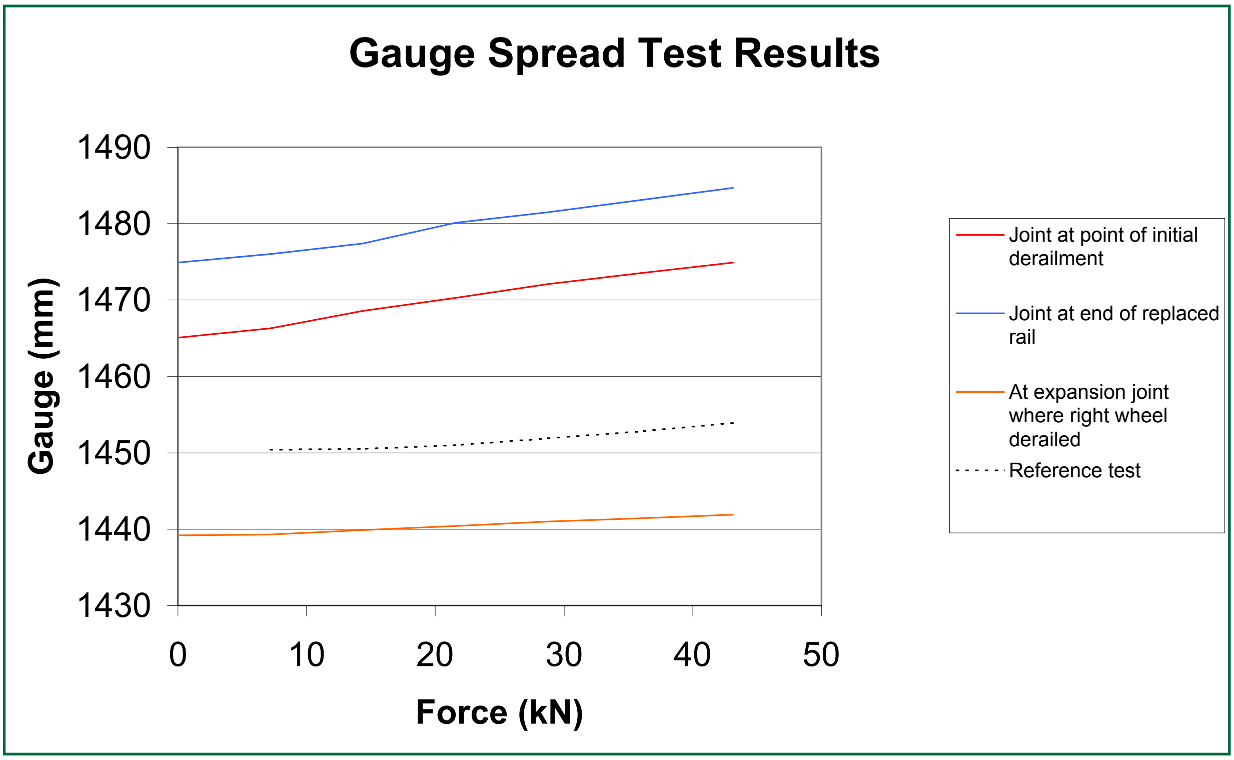

Figure 8: Gauge spread bar tests

90 The gauge spread test carried out at the initial point of derailment of the left wheel (Figure 8) shows that the gauge could be spread to 1475 mm by a 44 kN force. The gauge spread test carried out on the joint at the other end of the replaced rail, where there was no tie bar, showed that the gauge could be spread to 1485 mm by the same 44 kN force. By comparison, the control test on track away from the site of the derailment only spread to 1454 mm with the 44 kN force.

91 The combination of wider than specified gauge and low resistance to spreading force allowed the rails to move apart sufficiently for the leading left side wheel to drop in.

92 The right side wheel climbed out at the expansion joint where the rails were securely fixed. The gauge spread test at this point is the lower curve in Figure 5 and shows that the 44 kN spreading force only pushed the gauge to 1442 mm.

93 Serco Metrolink had commissioned the Rail Technology Unit (RTU) of Manchester Metropolitan University in 2005 to investigate the curving behaviour of the trams on sharp curves. This work was in connection with an investigation of *rail keep* wear but gives an estimate of the force on the high rail of a sharp curve. The dynamic simulation was done for a 25 m radius curve and showed a peak force on the high rail of 39 kN at 10 mph (16 km/h). The radius of the Pomona curve was 40 m, so the results are a conservative estimate of the force on the rail. The results do, however, show that the 44 kN maximum force used in the gauge spread tests is of the right order to represent the real force from the tram.

94 The wide track gauge and relatively low resistance to gauge spread caused the derailment.

Compliance with safety management system

95 GMPTE have a general duty under section 3 of the Health and Safety at Work Act 1974 to ensure the safety of persons not in their employment who may be affected by their undertaking, and consequently that such persons are not exposed to risks involving their health and safety. This general duty extends to GMPTE tram operations on Metrolink. GMPTE had a contract with Serco Metrolink but did not carry out any checks to see if they were delivering their safety management system. In particular, GMPTE did not check that Serco Metrolink had commissioned external audits, as required by the Serco Metrolink safety management system.

96 The lack of checks on compliance with the safety management system is a contributory factor to this derailment.

Conclusions

Immediate cause

97 The derailment was caused by wide track gauge in the curve and a low resistance to gauge spread (paragraph 94).

Causal factors

98 Serco Metrolink did not follow their procedures for inspecting the track at Pomona (paragraphs 81 and 83).

99 Serco Metrolink did not follow their procedures for maintaining the track at Pomona (paragraph 76).

100 The contractual arrangements under which Serco operated and maintained the system for GMPTE may not have provided a robust framework for repairs to be carried out under (paragraph 58).

Contributory factors

101 The lack of effective audit of the permanent way department allowed the lack of inspection and maintenance to go unnoticed (paragraph 84).

102 The lack of checks by GMPTE that Serco Metrolink were conducting external audits also allowed the lack of inspection and maintenance to go unnoticed (paragraph 96).

Additional observations

103 The lack of a suitable procedure to cover the replacement of a section of rail in CWR led to an inappropriate repair being made (paragraph 77).

104 The position of the emergency ladder in the centre of the tram made it difficult to gain access to while the tram was crowded with passengers (paragraph 31).

105 The inability to open only the front set of doors on the right-hand side of the tram meant that the passengers had to be evacuated onto the track, rather than onto the platform (paragraph 32).

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

106 Serco Metrolink replaced the worn rail at Pomona and also replaced rails at other locations where excessive rail wear was identified.

107 GMPTE terminated the concession with Serco Metrolink on 15 July 2007 and appointed a new operating company, Stagecoach Metrolink, on a different contractual basis. This was done as part of the work to develop phase 3 of the Metrolink system and not in response to the derailment at Pomona.

108 Stagecoach Metrolink have undertaken a review of track inspection and maintenance procedures throughout the Metrolink network.

109 GMPTE have stated that the contractual arrangements with the new operating contractor allow GMPTE to monitor asset condition more closely than was previously the case.

110 The RAIB wrote to Stagecoach Metrolink and ORR to advise them of the maintenance shortcomings on the Eccles line on 17 September 2007. Stagecoach Metrolink have put in place procedures to address these shortcomings to the satisfaction of ORR.

Recommendations

111 The following safety recommendations are made[1].

Recommendations to address causal and contributory factors

1. GMPTE should put in place procedures to enable them to review the audits carried out by their operating contractor, to satisfy themselves that their contractor's internal audit regime and safety management system are being complied with (paragraph 101).

2. GMPTE should review, and if found necessary amend, their contractual arrangements for the Metrolink operation to ensure that essential repairs cannot be deferred for contractual reasons (paragraph 100).

3. Stagecoach Metrolink should review, and if necessary amend, their Safety Management System so as to require formal approval by a professional head of any derogation to a safety critical standard (paragraph 98 and 99).

Recommendations to address other matters observed during the investigation

4. GMPTE, jointly with Stagecoach Metrolink, should investigate alternative locations for the safety equipment in Metrolink trams such that it is more accessible when the tram is fully loaded. If it is reasonably practicable, the emergency equipment should be relocated (paragraph 104).

5. GMPTE, jointly with Stagecoach Metrolink, should investigate, and if reasonably practicable implement, changes to the door operating system to allow the driver to open the front set of doors on either side of the tram (paragraph 105).

[1] Duty holders, 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 ORR and GMPTE to enable them to carry out their duties under regulation 12(2) to:

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

(b) report back to the 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 can be found on RAIB's web site at www.raib.gov.uk.

Appendices

Appendix A - Glossary of abbreviations and acronyms

CWR	Continuous Welded Rail
GMPTE	Greater Manchester Passenger Transport Executive
ORR	Office of Rail Regulations
ROGTS	Railways and Other Guided Transport Systems (Safety) Regulations 2006
RSC	Railway Safety Case

Appendix B - Glossary of terms

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

Back to back	The distance between the inner faces of a pair of wheels on an axle.
Baseplate	Metal casting which supports and holds a flat bottomed rail on a sleeper or concrete base.
Cess	The space to the side of a railway or tramway track.
Corrugation	A type of deterioration in the rail running surface which leaves the surface uneven with regularly spaced indentations.
Derailment containment upstand	Low walls provided alongside the rails on bridges to prevent containment upstands derailed vehicles from moving very far away from the track.
Dynamic gauge	The distance between the rails when loaded by a tram passing over them.
Expansion joint	A sliding joint in the rails to allow thermal expansion and contraction to take place.
Fastening	The means by which a rail is held to the baseplates or sleepers.
Fishplated joint	A rail joint made by means of a pair of shaped steel plates and bolts.
Four-foot	The space between the rails on which the tram runs.
Grooved rail	Rail designed for use in streets, with a cross-section which incorporates a trough (or groove) in which the wheel flanges run.
Keep rail	in grooved rail, the wall of the groove opposite the rail head.
Nylon insulators	Moulded plastic inserts which are inserted between the rail and fastening to provide electrical insulation.
Pandrol	A type of proprietary rail fastening.
Rail keep	(see 'keep rail').
Running edge	The top corner of the rail surface on which the wheels run.
Sidewear	The reduction in rail head width due to wear caused by flange contact with the rail as trams round a curve.
Six-foot	The space between a pair of railway or tramway tracks.
Static gauge	The distance between the rails measured with no rail vehicles present.
Tie bar	An adjustable metal bar fixed between rails to restore and maintain gauge.*
Trackform	A generic name for a type of railway track.
Transitional rail	A piece of rail shaped so as to provide a smooth transition between two rails of differing cross section.
Wheelset	A pair of wheels mounted on a rigid axle.

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This report is published by the Rail Accident Investigation Branch,
Department for Transport.

Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Telephone: 01332 253300
Fax: 01332 253301
Email: enquiries@raib.gov.uk
Website: www.raib.gov.uk