RAIB

Rail Accident Investigation Branch

Rail Accident Report

Derailment at St Peter's Square, Manchester 29 June 2008

Department for Transport

Report 25/2009
September 2009

This investigation was carried out in accordance with:

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

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Preface

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 Where reference is made to the 'right-hand' or 'left-hand' side of the tram or track it is in accordance with the direction that the tram was travelling at the time of the derailment.

4 Reference is made to both Greater Manchester Passenger Transport Executive (GMPTE) and GMPTE Metrolink. The latter refers to the Metrolink Integrated Delivery Team within GMPTE, which is a separate team dedicated to the Metrolink operation.

5 Reference is made to the bid process; unless qualified this refers to the bid process leading up to the award of the operating and maintenance contract for the Manchester Metrolink tramway to Stagecoach Metrolink (SML) on 25 May 2007.

6 The expression 'city centre renewals agreement' is used throughout the report to reflect the implied agreement that GMPTE would fund renewal of the city centre track outside of the Combined Operations and Maintenance Agreement. The 'city centre renewals agreement' was implied through discussions which started during the tender and continued after SML was awarded the contract. These discussions were supported by tender documentation and 'agreed form documents' prepared by SML, the latter, forming part of the contract.

7 Appendices at the rear of this report contain the following:

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

Summary of the report

Key facts about the accident

8 At 23:10 hrs on 29 June 2008, a Manchester Metrolink tram derailed at St Peter's Square in Manchester City Centre. The tram, forming the trailing half of a *double unit,* had just left St Peter's Square stop and was travelling along Mosley Street towards Piccadilly Gardens.

9 The middle bogie of the tram derailed to the left-hand side. The derailed tram travelled 90 metres, hit the kerb and came to rest partially mounting the pavement.

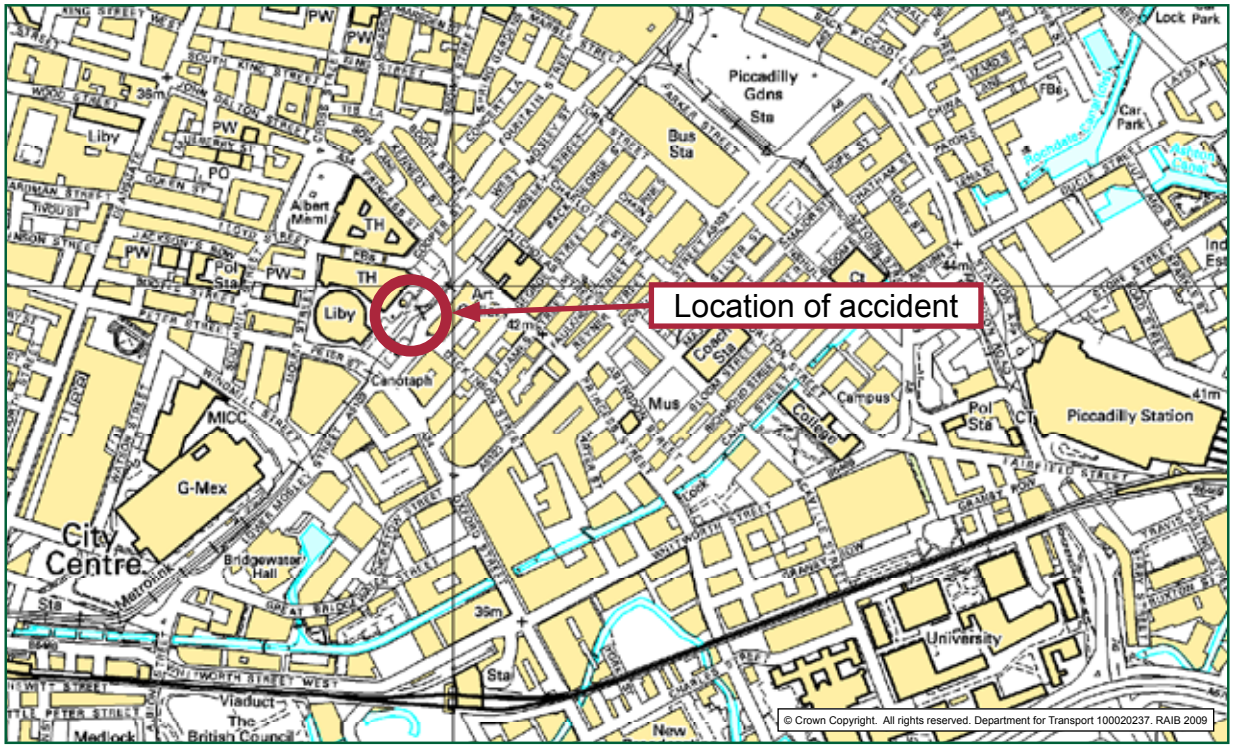

Figure 1: Extract from Ordnance Survey map showing location of accident

Immediate cause, causal and contributory factors, underlying causes

10 The immediate cause of the derailment was failure of the right-hand rail's *keep* allowing the leading right-hand wheel flange to climb the face of the broken keep. The keep of the right-hand rail failed because *sidewear* on the left-hand rail had resulted in the back of right-hand wheel flanges contacting and wearing the keep. The keep is not designed for such contact and track tolerances should be maintained to prevent it. The degree of wear was such that the keep was so thin that it could no longer withstand the force on it from the backs of flanges. The track was outside of maintenance limits.

11 As well as determining the immediate cause of the derailment, the RAIB has investigated how the Metrolink city centre track came to be in a poor condition, why it remained in such a condition and why traffic continued over it.

12 Causal factors have been identified in the following areas:

a. the lack of process, criteria and justification associated with interim measures adopted to address the poor city centre track condition;

b. the track being allowed to continue in a poor condition as a consequence of not implementing the city centre renewals and insufficient maintenance in the interim; and

c. traffic being allowed to continue with the city centre track beyond acceptable maintenance limits.

13 Possible contributory factors have been identified in the following areas:

a. the omission of maintenance limits for the city centre track from the contract between GMPTE and SML and lack of agreement to those proposed by SML; and

b. the organisation structure and resource of SML.

14 Possible underlying factors have been identified in the following areas:

a. the previous contractual arrangements between GMPTE and Serco, the previous operator of the system, in so far as they allowed the city centre track to deteriorate beyond acceptable maintenance limits;

b. the contract between GMPTE and SML;

c. the organisation structure and resource of GMPTE Metrolink; and

d. the health and safety arrangements of both GMPTE Metrolink and SML .

Severity of consequences

15 A number of passengers suffered minor injuries and there was damage to street furniture, a traffic signal, two overhead line stanchions and the kerb and highway, in several locations.

Recommendations

16 Recommendations can be found in paragraph 151. Those addressing the causal and underlying factors relate to the following areas:

- maintaining Metrolink city centre track within defined acceptable limits;
- the health and safety arrangements of GMPTE Metrolink and SML; and
- the Office of the Rail Regulation's (ORR) regulation of duty holders.

The Accident

Summary of the accident

17 A Metrolink tram derailed at St Peter's Square, Manchester at 23:10 hrs on 29 June 2008 (Figure 1).

18 The 22:44 hrs service from Altrincham, consisting of trams 1008 and 1016, had just departed the St Peter's Square stop when the middle bogie of the rear unit (1016) derailed to the left. The tram travelled a further 90 metres before coming to rest across the junction with Princess Street, with the derailed bogie having partially mounted the pavement (Figure 2). No other bogie derailed.

Figure 2: Tram 1016 after the derailment

The parties involved

19 The tram was operated by SML (part of Stagecoach Group PLC), which provides operating and maintenance services of Metrolink, under contract to GMPTE, who own the system. SML commenced its operation and maintenance of Metrolink on 15 July 2007.

Location

20 The tram was negotiating a reverse curve heading along Mosley Street towards Piccadilly Gardens. The location is shown in Figure 1. The radius of the first curve, to the right, is 25 metres and the second, to the left, is 50 metres; both curves have a designed *cant* of 15 mm.

21 The speed limit at the location of the derailment was 12 mph (20 km/h) increasing to 20 mph (32 km/h) just prior to the junction with Princess Street (Figure 1).

External circumstances

22 It was a clear, dry, and mild night at the time of the derailment. The area was well lit by street lighting. Neither the weather nor the lighting played any role in the incident.

23 Metrolink was operating an extended service using double units where possible to cope with the demand arising from a concert at the Old Trafford Cricket Ground.

Trams and track

24 Trams on Metrolink consist of two cars articulated above a common centre-bogie. The outer ends of each car are supported by an individual bogie, giving three bogies supporting the two-car unit. They are 30 metres long and have a maximum speed of 50 mph (80 km/h).

25 The derailed tram, 1016, was the trailing half of a double unit, coupled to tram 1008. Both trams were from the original fleet of type-T68 trams built by Ansaldo in 1991 for phase 1 of the system.

26 In the *city zone* the track construction consists of rail embedded in a polymer block with no specific gauge retention other than that provided by the polymer and the road surface. The track consists of Ri 59 *grooved rail*; the cross section of which is shown in Figure 3. It consists of a main running rail and a keep, between which is the *flange-way*. The keep is provided to maintain a barrier between the flange-way and the road surface; it is not designed to provide rail guidance or be load bearing; there is no intention that the keep should be contacted by wheels.

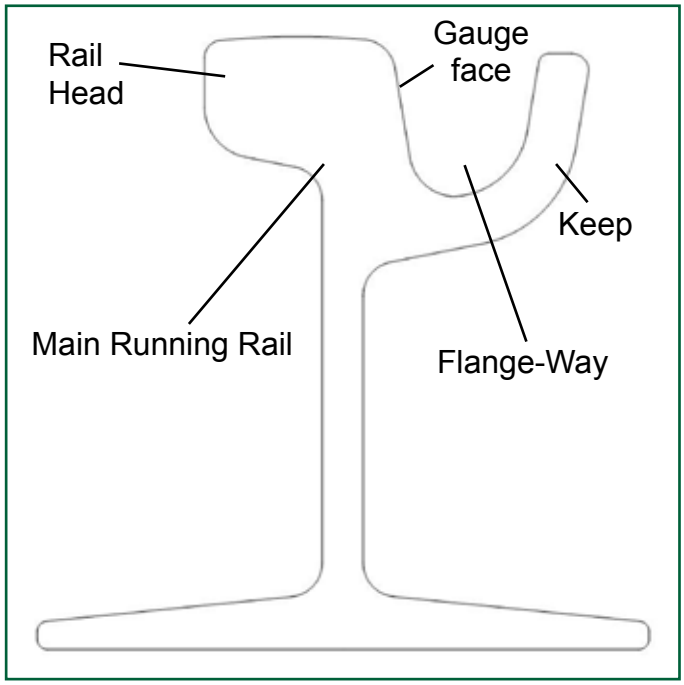

Figure 3: Ri 59 grooved rail cross section

Events preceding the accident

27 On the day of the derailment the driver signed on at 15:34 hrs and completed a scheduled one hour meal break at 19:38 hrs. The tram departed Altrincham at 22:44 hrs and was near to full capacity from the Old Trafford stop; many of the passengers alighted at the St Peter's Square stop.

Events during the accident

28 The tram stopped at St Peter's Square for 40 seconds. It departed and entered the reverse curve, reaching a maximum speed of 16 mph (26 km/h). The centre-bogie of the trailing unit (1016) derailed to the left as it was part-way through the right-hand curve.

29 The leading right-hand wheel on the centre bogie of tram 1016 derailed by its flange riding to the left of the right-hand rail's keep. The wheel flange was allowed to climb behind the keep because a 400 mm section of keep had broken and detached (Figures 4 and 5). It is considered likely that the keep failed due to contact by a previous wheel on the double unit, because other wheelsets of this tram and previous trams had successfully negotiated the curve. The bogie ran for 33 metres with the left-hand wheel riding against the *gauge face* of the left-hand rail and the right-hand wheel running between the back of the right-hand rail's keep and the road surface; the mechanism is shown diagrammatically in Figure 6. The wheels continued on this path due to the *gauge spread* from the sidewear (paragraph 43); when the track gauge narrowed to the design value the left-hand wheel climbed over the left-hand rail, eventually leaving the rail head three metres later. The second wheelset of the middle bogie followed the first wheelset into derailment to the left (Figure 7).

Figure 4: The right-hand rail at the point of derailment where the keep had failed

Figure 5: The failed section of the keep

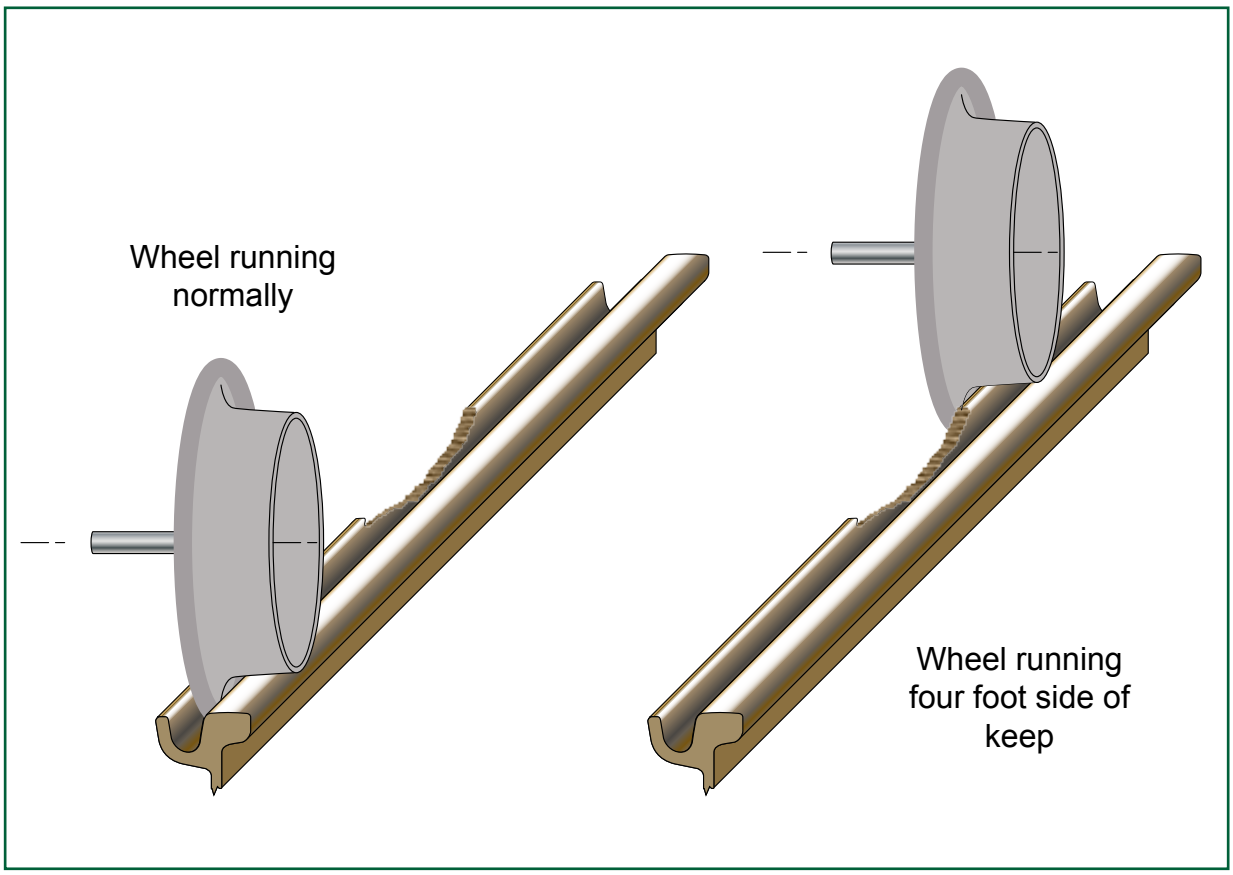

Figure 6: Image showing derailment mechanism

Figure 7: The derailment marks on the road surface

30 The bogie ran derailed for a further 53 metres before the tram was brought to a stop by automatic application of the *air brake*. Evidence from the tram data recorder suggested that an emergency air brake application was initiated on loss of the *door proving circuit*. It is likely that one set of passenger doors was pulled slightly open on collision with the overhead line equipment stanchions causing the door proving circuit to be broken. The *brake raft* ahead of the derailed bogie was severely damaged in the post-derailment collisions; this would also probably have resulted in an emergency air brake application.

31 The bogie remained attached to the tram, but mounted the pavement and came to rest 3 metres to the left of its normal path.

Consequences of the accident

32 A number of passengers sustained minor injuries. No pedestrians were injured as a result of the derailment.

33 The derailed bogie damaged street furniture, a traffic signal, two overhead line stanchions and the kerb and highway in several locations.

34 Tram 1016 incurred damage to the body-side, *solebar*, underframe and deformation to the main bodyshell's structural pillars and *cantrail*.

Events following the accident

35 The driver contacted the *Control Room* and an *Incident Officer* was dispatched to the site. The passengers detrained themselves and were guided out of the area by the emergency services.

36 The overhead line was de-energised and the fire brigade put up *earthing straps* either side of the double unit.

37 Tram 1016 was re-railed at 11:39 hrs on 30 June 2008, checked and moved to Market Street, still coupled to tram 1008. Another tram was brought up and coupled to tram 1016 and the treble unit was taken to Metrolink Queens Road Depot.

38 SML permanent way engineers removed sections of the worn and damaged keep. A test tram was sent through from GMex to Piccadilly and observed to pass the area without problems; service was resumed at 15:45 hrs.

The Investigation

Investigation process and sources of evidence

39 The RAIB investigation determined the derailment mechanism and its immediate physical cause.

40 In addition, the investigation considered how the Metrolink city centre track came to be in a poor condition, why it remained in such a condition and why traffic continued over it.

41 The investigation considered the following sources of evidence:

- a detailed examination of the site, including rail profile measurement;
- a tram survey, including wheel profile measurement;
- tram data recorder download and analysis;
- statements from SML, GMPTE Metrolink and ORR staff;
- track maintenance documentation and survey results;
- procedures and management systems documents;
- contractual documents;
- correspondence;
- minutes of meetings;
- analysis reports; and
- evidence gathered during the RAIB's investigation into the previous derailment at Pomona on 17 January 2007 (paragraph 46).

42 The ORR, SML and GMPTE Metrolink freely co-operated with the investigation.

Key Information

City centre track

43 At the point of derailment the left-hand rail was significantly side worn (Figure 8) by the passage of wheels (Figure 9) and the right-hand rail's keep was worn to a thickness of 2.5 mm, from an original thickness of 15 mm. The right-hand rail's keep had worn because of contact from the backs of passing wheel flanges as a result of wheelsets riding to the left, as allowed by the side worn left-hand rail.

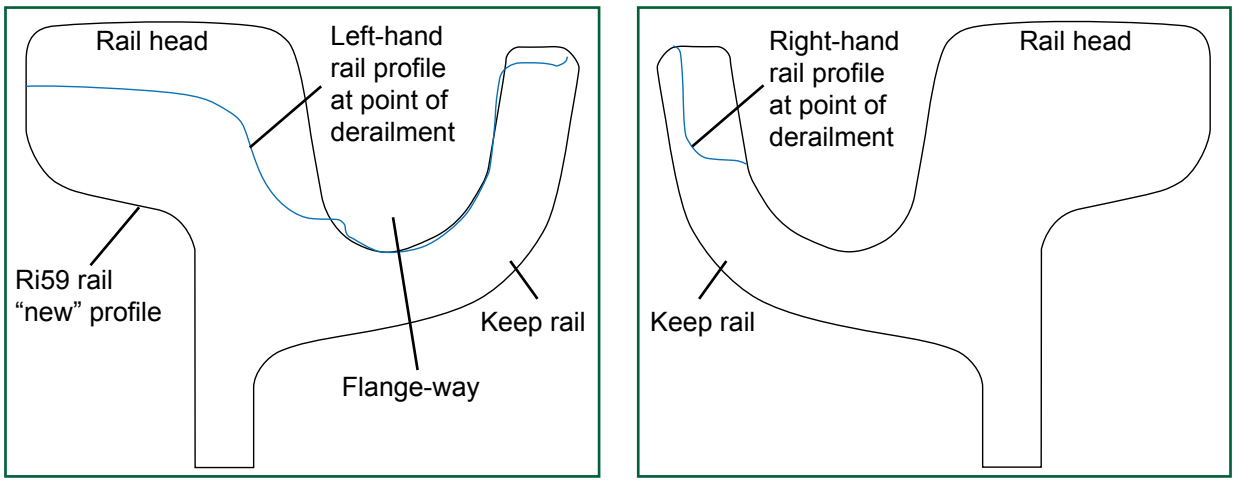

Figure 8: Image showing side wear on left-hand rail and worn keep on right-hand rail (indicative) at the point of derailment

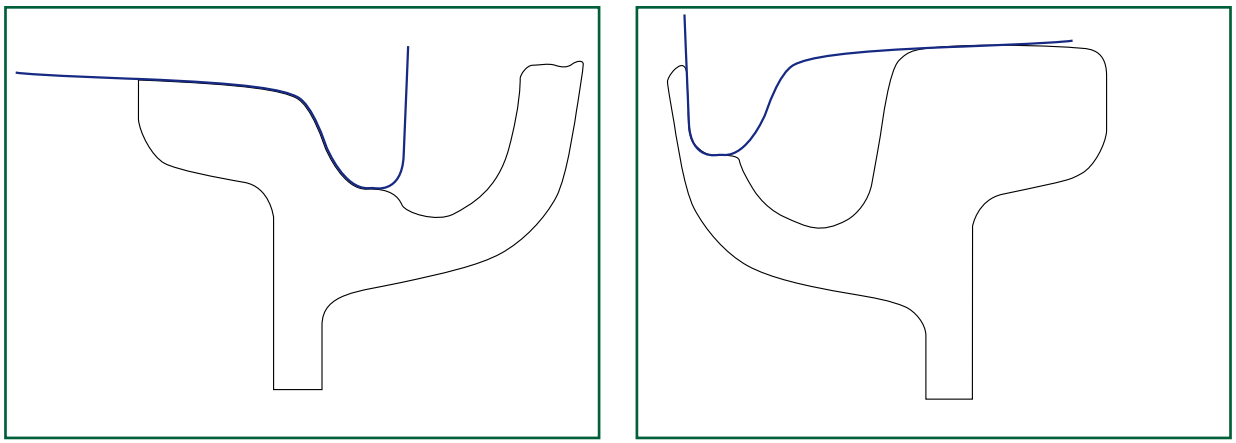

Figure 9: Image showing wheel riding on worn rail and worn keep

Previous derailments

44 This was not the first derailment in Manchester city centre where the immediate cause was the failure of a keep allowing wheel flanges to climb to the *four foot* side of the keep; similar derailments occurred at Shudehill on 31 August 2004 and at London Road on 11 January 2005. At both locations the keep had suffered significant wear due to the extent of sidewear on the head of the opposite rail. In both cases the worn keep had been repaired and subsequently failed. Other actions taken as a consequence of these derailments are discussed in paragraph 52.

45 On 22 March 2006 a derailment occurred at Long Millgate in Manchester city centre due to the failure of a repaired section of track at the transition between *segregated track* and on-street track. The keep had been flared out to provide a wider groove where the wheel flange enters the grooved rail. As the tram passed over it, the flared portion of the low rail broke away from the rest of the rail at the weld and allowed wheels to pass to the four foot side of the keep. The flared keep failed as a result of being struck by the flanges of passing wheels because of the degree of sidewear on the opposite rail head. This derailment was investigated by the RAIB (report 08/2007[1]). The recommendations made as a result of the investigation and relevant to this incident are presented in paragraph 150.

46 On 17 January 2007 a tram derailed approaching Pomona Station on the Eccles line, outside of the city centre. The derailment occurred on segregated track and was due to wide track gauge and a low resistance to gauge spread. The degree of sidewear on the *high rail* contributed to the wide gauge. This derailment was investigated by the RAIB (report 09/2008[1]). The recommendation made as a result of the investigation and relevant to this incident is presented in paragraph 150.

Past events relevant to the investigation

The Manchester Metrolink system

47 The authority to construct phase 1 of Metrolink, Altringham to Bury with a spur to Piccadilly station, was granted in 1988. Phase 1 consisted of a mixture of on-street and segregated track. In 1989 a design, build and operate contract was awarded to the Greater Manchester Metrolink Limited (GMML) consortium, whose shareholders were GEC Alstom, Mowlem and AMEC. Operations started in 1992.

48 In April 1995 GMML received the Manchester Metrolink Track Maintenance Manual that they had commissioned from WS Atkins; this included on-street track and segregated track limits (standards).

49 In 1997 phase 2, an extension to Eccles, was procured under a design, build, operate and maintain contract; it opened in 2000. To facilitate this, GMPTE Metrolink awarded a new concession to the ALTRAM consortium to 2014. The consortium consisted of Laing, Ansaldo Transporti and Serco. After completion of the construction work and delivery of the trams, Laing and Ansaldo left the consortium and Serco became the sole concessionaire to operate and maintain the system from 2003.

[1] Available at www.raib.gov.uk

50 In 2003, in anticipation of the implementation of phase 3 which was expected to start in 2005, the arrangements of the concession between GMPTE and Serco were changed. The original agreement allowed for a 3-month notice period in circumstances where a contract had been let by GMPTE for the extension and for compensation to be paid for lost profits. The 3-month notice period was reduced to 28 days and, the pre-condition that a contract had been let was removed. In addition, compensation for lost profits would no longer be payable, as this had been resolved by a payment from GMPTE to Serco at the time the concession arrangements were changed. The original concession agreement placed a requirement on Serco to 'clean, maintain and renew the system so as to ensure that it remains in good and substantial repair' and that 'there is no impairment of function, no undue wear and no reduction in safety'. There was no further definition of 'good and substantial repair'. It also required that a technical assessment be undertaken on termination of the agreement to 'assess the state and condition of the Metrolink system' and to 'specify the works and estimate the expenditure (if any) required to render the Metrolink system in the state and condition in which it would have been had the concessionaire duly and properly complied with its obligations to maintain, repair and renew the Metrolink system pursuant to the agreement'. The variation to the agreement stated that the 'concessionaire shall pay to the Executive an amount equal to the aggregate amount of such estimated expenditure'. The obligations were not changed by the variation to the agreement.

51 On 15 July 2007 GMPTE Metrolink terminated the concession with Serco, and SML commenced a contract for ten years to provide operation and maintenance services for Metrolink.

City centre track derailment analysis

52 In 2005, following the derailments at Shudehill and London Road (paragraph 44), Serco commissioned Manchester Metropolitan University (MMU) to investigate issues with sidewear and keeps on Metrolink.

53 The study concluded that heavy side and *head wear* was leading to contact between wheels and keeps resulting in keep failures which could result in a derailment due to a wheel flange climbing the face of a broken keep.

54 The analysis suggested that the best approach for the medium to long term was to replace the high rail and restore the gauge. Reinforcement of existing worn keeps could be considered as an interim measure but would require careful monitoring as the repaired keep would be subject to the same high levels of wear as prior to the repair. Replacement of the *low rail* was not considered a good solution.

55 It also concluded that the level of sidewear did not present a high risk from a flange climb derailment perspective, and a tram would be able to negotiate the curves safely without the presence of the keep. However, it did recommend that the structural integrity of the worn rail section should be investigated and a method of keeping the groove clear and restraining the road/paving surface would be needed. Removal of keeps would remove the risk of wheel flanges striking broken keeps and subsequently becoming trapped between the keep and road surface, therefore preventing the build up of lateral forces sufficient to cause the opposite wheel to climb over the rail into derailment.

56 On the basis of the above analysis, Serco adopted the short-term approach of monitoring the keep wear in the city centre. When it became concerned about the keep's continued integrity Serco cut the keep off the rail over the length affected by the sidewear and flared the ends of the remaining keep, thereby removing the risk of keep-climb derailments. SML continued this approach as a short-term measure prior to renewal of the city centre track (paragraph 62).

Contractual arrangements between GMPTE Metrolink and SML

57 The contract between GMPTE and SML is based on GMPTE paying SML a service fee for managing the operations and maintenance on its behalf. SML does not take any fare box revenue risk. Clause 24.1 of the Combined Operations and Maintenance Agreement places the following obligations on SML:

"its procedures for inspecting, maintaining, renewing, repairing and cleaning the Maintained Assets and the implementation of such procedures ensure that:

(a) Passenger Services can be operated in accordance with this Agreement;

(b) the Maintained Assets are kept clean and in good structural and decorative order and condition, with no impairment or loss of function, no undue wear and no reduction in passenger or public safety;

(c) incidents of vandalism and graffiti are minimised; and

(d) on the Termination Date, the Maintained Assets are in a condition complying with the requirements of this Agreement, including by complying with the Handback Requirements where relevant."

58 The contract did not include any allowance for the condition of the system at the time of handover to SML.

59 The contract includes documents defining the requirements placed on SML for operations and maintenance of on-street and segregated track. These documents describe the key activities and frequencies for inspection and maintenance. The segregated track document specifies track maintenance evaluation standards defining acceptable tolerances. For reasons explained in paragraph 97, GMPTE Metrolink thought that there were no maintenance standards for the on-street section. The on-street track document states that SML should develop a set of tolerances and parameters based on recognised practice for the maintenance of on-street running tramways and provide them to GMPTE Metrolink within 6 months of contract commencement. SML submitted a series of developing proposals starting on 20 August 2007. Although not contractually obliged to approve these standards, GMPTE Metrolink entered into dialogue and made comments against them. On 3 February 2009 [after the incident] GMPTE Metrolink wrote to SML to express formal acceptance of the track maintenance values.

60 The contract between GMPTE and SML includes a set of hand-back requirements for the maintained assets. Those covering track include an average remaining life and limits on head wear and sidewear at hand-back. Therefore, the contract generally places asset maintenance and renewals responsibilities on SML. In order to provide itself with a means of monitoring SML's progress towards achieving the hand-back condition, GMPTE Metrolink included a requirement for SML to propose an indicative annual renewals budget. GMPTE and SML are required to use reasonable endeavours to agree the actual work annually. This is subject to a reserve power for GMPTE to require modifications on the basis that the combination of maintenance and renewals will lead to acceptable asset condition at the end of the contract.

61 In addition, GMPTE's invitation to submit best and final offers (issued in November 2006) requested bids for undertaking various improvement and renewal projects, in relation to the Metrolink infrastructure, that would be outside of the service provision contract. These were referred to as special projects. SML submitted proposals against the briefing sheets issued by GMPTE Metrolink, but the parties were unable to agree fixed prices or final terms. As a consequence, the final contract includes an agreement to negotiate outstanding terms in good faith for these special projects. The intent was that each special project, as defined by its briefing sheet, would be carried out by SML as a discrete project once the scope and terms had been agreed by GMPTE Metrolink. However, no date was specified by which agreement had to be reached, only a period after which, if agreement had not been reached, neither party would be under any obligation to continue discussions. However, both parties continued discussion after this period. The contract made no specific provisions should any of the special projects not be implemented.

62 Renewal of the city centre track was covered by special projects 10 and 35. The associated briefing sheets stated that GMPTE Metrolink's strategy was to undertake renewals of identified 'hot-spot' areas as a priority in spring or summer 2008 under special project 10, with all remaining areas to be renewed within the first five years of the contract. During the bid process GMPTE advised SML that, because all funding for these works would be from GMPTE, SML was not required to include renewal of city centre track in its renewals proposals. Special project 10 was to be funded out of a DfT grant and special project 35 out of GMPTE funds.

63 The 'city centre renewals agreement' (paragraph 6) established an effective split of responsibilities between maintenance and renewal of the city centre track.

64 The contract gives GMPTE the right of audit and specifically entitles it to carry out an assessment of the state and condition of the Metrolink system as soon as reasonably practicable after commencement of the SML contract. It also provides for GMPTE to monitor compliance by SML with any of its obligations under the contract, including by inspecting the condition of the maintained asset.

65 The contract does not include arrangements for SML to expedite resolution of safety issues by GMPTE Metrolink. However, provisions are included giving GMPTE the right to step in to undertake service provision where SML is in material breach of contract and GMPTE reasonably believes it needs to act to avoid a serious risk to health and safety.

Knowledge of city centre track condition

66 Witness and documentary evidence indicates that by the end of Serco's concession GMPTE Metrolink, Serco, the bidders and the ORR knew that much of the city centre track was beyond acceptable maintenance limits. GMPTE Metrolink's and SML's knowledge was further evidenced by the inclusion of special projects 10 and 35 in the bid discussions for the new operating and maintenance contract.

67 During the bid negotiations GMPTE Metrolink did not consider it necessary to define the actual track condition because it planned to replace it since it was beyond economic repair. GMPTE Metrolink stated that it was focused on defining a set of requirements for the hand-back condition at the end of the contract.

68 Following release of the RAIB investigation report into the derailment at Long Millgate (paragraph 45) in April 2007, GMPTE Metrolink placed an action on Serco to document the current track condition and associated practices prior to its handover to the new operator. However, the RAIB has been unable to find any evidence that this had been completed by the time of the derailment.

69 GMPTE Metrolink did not undertake a track condition survey before or during the bid process. Sheffield Supertram engineers undertook a qualitative inspection of the track during the bid process on SML's behalf, but this was limited to a visual inspection because they were not granted any special access.

70 In July 2007, the month that it took over the operation, SML received results from a detailed track survey of the city centre that it had commissioned from Corus. The survey consisted of visual inspection and rail head profiling giving a measure of the degree of head and sidewear. Recommendations were made, against a set of predefined criteria, as to whether each section of rail required replacing, weld repairing or could continue in service. This indicated that the *cess* rail on the inbound track at St Peter's Square required immediate replacement. The head and sidewear were reported as 14.919 mm and 10.867 mm, respectively.

71 On 27 November 2007 SML wrote to GMPTE to bring to its attention concerns that it had with respect to the city centre track renewals; it outlined concerns over the lack of progress. It went on to suggest that unless there was a clear plan for the work in the 'next couple of months' there was a serious risk that it would be threatened with either an *Improvement* or *Prohibition Notice*, due to ORR's concerns over track wear and fitness issues. It confirmed that SML deliberately had not programmed any significant maintenance or renewals on the city centre track because they would be addressed by GMPTE Metrolink as part of special projects 10 and 35 and that SML had been led to believe that this work would commence early in 2008. At a meeting on 10 December 2007 between SML and GMPTE an action was placed on SML to 'undertake short-term weld repairs to prolong rail life where possible'. However there was no minuted information on the scope or criteria for the work and the RAIB has not been able to establish either during its investigation.

72 In April 2008 GMPTE Metrolink received the results of a survey that it had commissioned in January 2008 from Corus to determine which sections of the city centre track were in acceptable condition, which could have their life extended by weld deposition on the gauge face and which required immediate replacement. This was part of their ongoing deliberations to determine the best approach for renewing the city centre track. This indicated that the cess rail on the inbound track at St Peter's Square required immediate replacement. The head and sidewear were reported as 16.518 mm and 13.193 mm, respectively.

73 In April 2008 SML received the results from a study it had commissioned from Corus to record the track gauge throughout the whole system. This indicated that the track was consistently wide to gauge between St Peter's Square and Mosley Street, against the emerging criteria proposed by SML (paragraph 59).

74 The results of the track surveys were shared between GMPTE Metrolink and SML; they were used to inform the discussions on track renewals. It would appear that neither SML nor GMPTE Metrolink considered the safety implications of these results for the intervening period before implementation of the track renewals (paragraph 62).

Organisation

GMPTE Metrolink

75 GMPTE Metrolink is the only organisation that has been involved continuously in the Metrolink system since its conception. Historically it was a very small organisation. During the bid process, and at the time of the accident, it was mostly resourced by consultants. Up to February 2008 GMPTE Metrolink did not employ any engineers with responsibility for the existing system.

76 GMPTE Metrolink did not have a Safety Management System (SMS) or similar health and safety arrangements, or a Safety Manager, although the corporate Safety Manager responsible for GMPTE's non-Metrolink interests did provide some advice.

77 The RAIB report into the derailment at Pomona (paragraph 46) highlighted that GMPTE Metrolink may not have been exercising its responsibilities under section 3 of the Health and Safety at Work Act (1974) to ensure, so far as is reasonably practicable, that persons not in its employment who may be affected by its undertaking are not thereby exposed to risk. The RAIB identified this issue and made specific recommendations to address the shortcomings. GMPTE report that the means by which it now undertakes these responsibilities is by attending meetings with SML, GMPTE, ORR and other involved third parties; insisting that SML presents its safety case to GMPTE; and initiating safety audits. The RAIB observes that the meetings attended generally are reviews of past incidents and accidents and only put GMPTE in a reactive position. In addition, no audit was completed from handover up to the accident. Witness evidence indicates that under the new contract, GMPTE Metrolink continued to have insufficient evidence to form an opinion as to whether, so far as is reasonably practicable, sufficient was being done to prevent people being put at risk by the Metrolink system. GMPTE Metrolink have reported that statements such as the following from its contract with SML (Metrolink Combined Operations and Maintenance Agreement, Appendix 1 Operating Specification, Section 2.2) had transferred responsibility for both operational and infrastructure safety to SML, with no need for GMPTE to confirm how or whether it was being managed.

> *"Opco[2] shall be responsible overall for the safety of the Metrolink System and, subject to the terms of this Agreement, control access to the Metrolink System for maintenance and other purposes."*

78 Just prior to the accident, GMPTE Metrolink commissioned an independent safety audit of the Metrolink organisation, including both SML's and GMPTE's roles within it. The audit compared actual performance and arrangements against the Railway and Other Guided Transport Systems (Safety) Regulations (ROGS) and other health and safety legislation; it was completed after the derailment, in July 2008. The audit identified GMPTE Metrolink's lack of a SMS and recommended that it considers the requirements for an SMS in a list of specific areas, including the decision making with respect of all renewals.

79 It also recommended that GMPTE Metrolink and SML should work together to improve their joint understanding of technical issues relating to improving maintenance performance; it recommended that both parties should come to a clear understanding of the work needed for renewals and maintenance of the permanent way and should have a joint strategy in place to secure its ongoing integrity.

SML

80 The organisational structure and personnel in SML remained fundamentally the same as they had been under Serco, with the exception of the senior management.

81 The SML civil engineer was responsible for track maintenance, he reported directly to the head of engineering. Vacancies had existed in the engineering department for all of SML's tenure; significantly there had been no vehicle engineer.

[2] OpCo is the term used in the contract between GMPTE Metrolink and SML to refer to the organisation responsible for managing operations and maintenance on behalf of GMPTE Metrolink

82 SML had an SMS which was significantly based on that produced by Serco; SML had revised it twice prior to the derailment, most recently in February 2008. The Serco SMS was derived from its previous safety case which had become redundant following the change in legislation.

83 The Serco and SML SMSs both referenced the Manchester Metrolink Track Maintenance Manual (paragraph 48) as the standard against which the track should be maintained.

84 The SML SMS specified audit requirements. An audit plan was issued in April 2008, but none of the scheduled audits had taken place up to the time of the derailment.

85 The SMS established the Stagecoach Metrolink Executive Safety Committee (SMESC) as the body with responsibility for the management of safety within SML and it was the means by which issues beyond SML's control should be raised. It was attended by representatives from GMPTE Metrolink and senior level SML staff and chaired by a person independent of both organisations. The ORR attended on occasion as an observer.

ORR approach to safety regulation of Metrolink

86 The ORR is responsible for enforcing health and safety law in so far as it applies to railway and tramway operations and it does this by assessing compliance with relevant legislation, including whether the identified risks are controlled so far as is reasonably practicable. This is primarily achieved by inspecting compliance of the duty holder with its SMS. The approach adopted is to sample elements of the SMS, focussing in particular on the higher risk elements, on the basis of the ORR's strategy for railway and tramway operators, and the individual inspector's experience of the particular operator. The ORR has stated that the depth of inspection for tramways is dependent on the confidence that the ORR inspector has with each duty holder's compliance.

87 The ORR's enforcement powers apply only to bodies that are responsible for the 'operation of a railway (or tramway)' as defined in the Health and Safety (Enforcing Authority for Railways) Regulations 2006 (as amended). The ORR does not currently consider GMPTE to be such a body. Under the RAIR Regulations, the ORR is required to ensure that RAIB's recommendations are duly taken into consideration and where appropriate acted upon by the duty holders. However, it has no role in monitoring actions taken in respect of any recommendations that the RAIB addresses to public bodies, such as GMPTE, although it has previously reported to the RAIB on the state of such recommendations.

Analysis

Identification of the immediate cause[3]

88 The immediate cause of Tram 1016 derailing was failure of the right-hand rail's keep allowing the leading right-hand wheel flange to climb the face of the broken keep.

89 The keep of the right-hand rail failed because the excessive sidewear on the left-hand rail had resulted in the back of right-hand wheel flanges contacting and wearing the keep. The keep became worn so thin that it could no longer withstand the force on it from the flanges pressed against it. Rails on the outside of curves are subject to sidewear due to the curving forces exerted at the wheel-rail interface during the normal passage of trams.

Identification of causal[4], contributory[5] and underlying[6] factors

Deterioration of the city centre track prior to award of contract to SML

90 Evidence indicates that there had been no long-term track maintenance and renewal strategy for the Metrolink city centre track prior to the current contract, ie there had been no consideration of how long the track would last before it required maintenance to extend its life, nor planning of how often this could be done before the track would need replacing. There was no consideration of the balance between maintenance and renewals. The new arrangement agreed between GMPTE and Serco in 2003 (paragraph 50) allowed for a termination period of 28 days with no provision for payment of lost profits. Although Serco still had the responsibility to maintain, repair and renew the Metrolink System in good and substantial repair, witness evidence from GMPTE indicated that GMPTE recognised that altering the termination period of the concession may have resulted in Serco not having financial incentive to replace assets if the time to recoup the cost was greater than 28 days. Further witness evidence indicated that there was a lack of clarity as to the extent of Serco's responsibilities with respect to renewals which may have arisen from GMPTE subsidising some expensive work that would outlast the contract. This and the degree to which "good and substantial repair" would have been open to interpretation may have further reduced the incentive for Serco to fund the replacement of assets.

91 Serco reported that this situation was exacerbated by the lack of engineering resource within GMPTE Metrolink which made it difficult for Serco to engage GMPTE Metrolink in meaningful discussion about the track condition and the need for renewal.

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

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

[5] 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.

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

92 The contractual arrangements between GMPTE and Serco from 2003 onwards are a possible underlying factor to the derailment. The RAIB identified the same possible factor for the derailment at Pomona in January 2007 (paragraph 46).

93 The city centre track was outside any reasonable maintenance limits when SML took over the operation of Metrolink.

City centre track allowed to continue outside of maintenance limits

GMPTE-SML arrangements

94 Both GMPTE Metrolink and SML were aware that the city centre track was beyond economic repair (paragraph 66) and had agreed to work together to renew the track (paragraph 61). However, issues associated with the contractual structure between the two organisations inhibited them working together to identify risks and ensure that they were resolved, as discussed in the following paragraphs.

95 The 'city centre renewals agreement' established an effective split of responsibilities for maintenance and renewals of the city centre track (paragraph 63). Furthermore, because the city centre track was beyond maintenance limits at contract handover there was ambiguity over which improvements should be classed as maintenance and which as renewals. Therefore, the 'city centre renewals agreement' introduced conflicting incentives; it established an environment where it was financially beneficial for SML to delay city centre track maintenance until after the renewals were implemented, and there was no financial incentive for GMPTE Metrolink to expedite the renewals.

96 The audit commissioned by GMPTE Metrolink that was underway at the time of, but published after, the accident (paragraph 78) also highlighted deficiencies in the working arrangements between GMPTE Metrolink and SML. Recommendations were made that GMPTE Metrolink and SML should work together to develop a joint strategy to secure the ongoing integrity of the track.

97 Although the GMPTE contract specified minimum track hand-back requirements (paragraph 60), it did not include a complete specification of acceptable minimum track conditions (paragraph 59). The contract did not make any reference to the Metrolink Maintenance Manual, produced by GMML with the knowledge of GMPTE, in 1995 (paragraph 48). This document contained maintenance limits for the on-street track and was referenced from the Serco Metrolink SMS up to the end of its tenure; it had never been revoked by either GMPTE Metrolink or Serco. The criteria were not included in the contract between GMPTE and SML probably due to the GMPTE Metrolink personnel involved in the contract discussions not being aware of them; this in turn was likely a result of the lack of engineering resource and a relatively fast turnover of consultants within GMPTE Metrolink (paragraph 75). The lack of clearly agreed pass/fail criteria for the city centre track in combination with the track condition at handover introduced further ambiguity as to what action should have been taken and whether the short-term arrangements of keep removal were sufficient (paragraph 56), although it is recognised that SML's SMS included reference to criteria (paragraph 83). The omission of maintenance limits from the contract is considered a possible contributory factor to the derailment.

98 Prior to the accident GMPTE Metrolink acted as though it did not have responsibility to confirm that, so far as is reasonably practicable, sufficient was being done to prevent people being put at risk by their Metrolink system (paragraph 77). This is also likely to have resulted in GMPTE Metrolink's lack of both a SMS, or similar health and safety arrangements, and a Safety Manager (paragraph 76). This issue and GMPTE's responsibilities under the Health and Safety at Work Act (1974) were highlighted in the RAIB report into the derailment at Pomona (paragraph 77). Witness evidence indicated that GMPTE Metrolink believed that there was no need for it to check how SML was ensuring safety because it had transferred all of the safety responsibility to SML through the contract. Although it knew of the condition of the city centre track, the degree to which GMPTE Metrolink checked what SML was doing to ensure safe operation prior to implementation of the renewals projects was very limited and did not include any inspection of physical implementation.

99 GMPTE Metrolink stated that because it believed that SML was responsible for safety it would not specify standards or procedures that assumed any of the responsibility. However, the contract specifies maintenance limits for segregated track (paragraph 59), which is in contradiction to this stance. A GMPTE Metrolink senior manager also stated that if he was concerned about the safety of operation he could not take the decision to stop traffic, because this would have made the safety arrangements very ambiguous; however, he reported that he personally would have informed SML.

100 GMPTE's response to the letters from SML expressing its concerns over city centre track wear and fitness to operate further exhibited this behaviour (paragraph 71); witness evidence indicated that GMPTE did not feel the need to investigate these concerns further because the safety responsibility was with SML. However, subsequent to the letters, an action was placed on SML to 'undertake short term weld repairs to prolong rail life where possible', but no further information included on the scope or criteria for the work. GMPTE did not follow up on the implementation of this action.

101 In summary, the contract structure and the 'city centre renewals agreement' limited the degree to which SML felt 'ownership' of the infrastructure, introduced conflicting incentives for GMPTE Metrolink and SML, and left ambiguity as to acceptable maintenance limits for the city centre track. Also the contract did not make any provision to allow SML to expedite resolution of safety issues by GMPTE Metrolink, specifically with respect to the track renewals (paragraph 108). These are considered to be possible underlying factors resulting in the ongoing poor condition of the city centre track and therefore the derailment. GMPTE Metrolink's view that it was not responsible for safety underpins the above situation.

City centre track condition – removal of the keep

102 SML's approach to city centre track inspection was for track patrollers to inspect it visually on a weekly basis. If they identified a defect which was not already in the *job-bank*, they alerted their supervisors who visited the site and decided whether it should be added to the job-bank. Enhanced daily inspections were undertaken by the supervisors (of approximately 30 key sites of concern in the city centre); these included sites where they were concerned by the amount of wear to the keep. Although on a few occasions SML replaced rails and implemented short weld deposition repair of the high rail, generally it adopted Serco's short term approach of removing the keep when it considered that the degree of wear may lead to a failure (paragraph 56). However, neither Serco nor SML had developed a formal procedure to govern the process or established objective criteria for defining when the keep should be removed or for how long the track could continue to be used without a keep. Furthermore, they had not demonstrated that they could detect a deteriorating keep before it came adrift and posed an immediate risk of derailment. These factors are considered causal to the derailment.

103 Although SML was monitoring the track around St Peter's Square on a daily basis, because of a broken rail and crack in the keep of the outbound cess rail, there is no evidence that the location of the derailment was being specifically monitored, and certainly the keep had been allowed to progress to catastrophic failure before any action was taken. This situation was allowed to arise because of the lack of formal process and criteria for keep removal; these deficiencies are therefore causal to the derailment. The omission of the site of the derailment from daily inspection may have been influenced by the fact that the low rail had been replaced in January 2005 contrary to advice from MMU (paragraph 54) and the keep had worn from a full thickness of 15 mm to that found post derailment in the intervening three and half years, or because the condition of the keep was not as bad as elsewhere on the system. Metallurgical investigation of the failed keep indicated that the crack may have been growing from the outside of the keep towards the flange-way; this would not have been detectable by visual inspection and therefore a different approach was necessary to assure safety.

104 Following the accident SML undertook a programme in the city centre to restore the gauge by building up the rail head profile by weld deposition, instead of continuing the short-term approach of removal of the keep. Restoring the gauge eliminates flange-back contact with the keep and therefore removes the load on it. SML undertook this because of its lack of confidence in identifying all failing keeps, and its reluctance to remove large sections of keep because of concerns on the effect on preservation of the road/pavement surface and preventing debris entering the flange-way. SML adopted this approach even though much of the track where it invested in weld deposition would be removed for scrap as part of the 'imminent' renewals programme.

City centre track condition – delay in renewals

105 Indications of timescales for the renewals programme were given in GMPTE Metrolink's special project briefing sheets (paragraph 62); also GMPTE indicated to the ORR, in its June 2007 response to a previous RAIB recommendation (paragraph 150), that the details of its plan to invest in the city centre would be agreed within 6 months and implemented before the end of 2008. SML continued the approach of short-term keep removal on the basis of the imminent implementation of the city centre renewals programme.

106 The track at St Peter's Square was not included in the 'hot-spot' list identified by GMPTE Metrolink as a priority (paragraph 62). However, following contract handover GMPTE Metrolink started a process of determining the best approach for renewing the city centre track; it was concerned to avoid a 'patchwork' approach. One element of this involved GMPTE Metrolink commissioning a track survey (paragraph 72) which identified that the rail at the site of the derailment needed replacing. These deliberations caused delays to the implementation programme. Witness evidence indicated that the delay was built up from many incremental small delays; GMPTE Metrolink continued to infer that resolution was imminent and that implementation would happen soon.

107 The effective split of maintenance and renewals responsibilities for the city centre track meant that there was no financial incentive for GMPTE Metrolink to expedite implementation of a renewals plan; GMPTE Metrolink believed that SML would maintain the city centre for as long as it took it to decide how and when to proceed with the renewals. Furthermore, GMPTE did not have the arrangements in place to access all of the finance required to fund the full scope of renewal; after the accident GMPTE approached SML to use its annual renewals budget (paragraph 60) to help finance the city centre renewals activities. The effective split of the responsibility for maintenance and renewal and the lack of access to the finance for the renewals are both considered underlying factors to the derailment.

108 The contract did not provide any means for SML to expedite resolution of safety issues by GMPTE Metrolink (paragraph 65). The arrangement within SML for escalating safety issues beyond its control was the SMESC (paragraph 85). The city centre track condition was not raised at this meeting before the derailment, most likely because it was the subject of separate meetings.

109 At the time of the derailment the scope, costs and terms for special projects 10 and 35 had not been agreed, nor had the responsibility for their implementation been passed to SML. The delay to implementing renewals activities and consequentially the track remaining outside of [the unrecognised] maintenance limits (paragraph 83) up to the time of the derailment is considered causal, because if there had been an implementation plan then either the rail at St Peter's Square would have been replaced, or there would have been clarity that the track required maintenance to ensure sufficient life until renewals were implemented.

City centre track condition – insufficient maintenance

110 In the period between contract handover and the accident, SML undertook minimal maintenance in the city centre. It had the option to address the sidewear and improve gauge either by replacing rails and/or undertaking gauge restoration by weld deposition. However, it only undertook a minimal amount of such maintenance (paragraph 102) and this is causal to the derailment.

111 Following contract handover from Serco to SML there was much confusion as to what the acceptable maintenance limits were for the city centre track. Their omission from the contract with SML (paragraph 59), but the inclusion of similar for segregated track, and the various proposals for limits circulating between SML and GMPTE Metrolink without any acceptance from GMPTE Metrolink contributed to this confusion. This lack of agreed criteria introduced ambiguity as to the limits to which the track should be maintained and is further considered a possible contributory factor to the derailment.

112 SML's SMS referenced the Metrolink Maintenance Manual which included criteria for the city centre track (paragraph 83), and yet SML staff did not apply it. Evidence showed that the SMS was not well briefed within SML, the Metrolink Maintenance Manual had not been reinforced by briefing, and there was no implementation of the audit programme (paragraph 84) that may have uncovered the lack of compliance. Generally, there was little awareness of its own SMS within SML. SML's poor implementation, briefing and compliance auditing of its SMS is considered an underlying factor of the maintenance not being undertaken, and therefore of the derailment.

113 A further factor causing the Metrolink Maintenance Manual to be overlooked within SML was the removal of the 'technical engineer' post during the Serco regime. The technical engineer was responsible for undertaking track measurements and ensuring track quality; he was the owner of the Metrolink Maintenance Manual. When the post was removed these responsibilities fell to the civil engineer. The civil engineer in post at, and leading up to, the derailment had very limited experience of grooved rail prior to joining SML. The removal of the technical engineer's post is considered a possible contributory factor to the derailment.

114 SML staff may have become conditioned by their familiarity with the track being in poor condition, particularly during Serco's 28 day notice period, and may have become less interested in understanding the required maintenance limits. This is considered a possible underlying factor to the derailment.

115 Had SML identified the need for maintenance of the city centre track the effective split between maintenance and renewals of the city centre track (paragraph 63) may have acted to deter them from undertaking it. This was particularly relevant considering the costs associated with the maintenance options. Any investment would effectively have been wasted when GMPTE renewed the track; it was financially beneficial for SML to delay any maintenance until after the renewals plan was implemented if it considered it could do so. The effective split between maintenance and renewals is further considered a possible underlying factor to the derailment.

116 Statements in the special project briefing sheets explaining that there was no need for the bidders to include a programme of renewal of the city centre track in their annual renewal proposals (on the basis of existence of special projects 10 and 35 - paragraph 62) also brought into question the value of SML undertaking expensive maintenance activities in the short term.

117 The RAIB identified problems with the management of SML's civil engineering department. Authorities and plans were not briefed down, the management was not well informed about day-to-day activities, and there was no closed-loop feedback of track problems. Since contract handover, the vehicle engineer post, reporting directly to the head of engineering, had been vacant (paragraph 81). The head of engineering had an additional workload in fulfilling that role; this resulted in minimal time being spent with the civil engineering department with a consequential lack of guidance and leadership of it. With better management, the risks associated with the condition of the city centre track may have been alerted to the SML management team and appropriate actions taken to manage them. These issues are considered possible contributory factors to the derailment.

118 There was a distinct difference between the manner in which the city centre and segregated track were managed. This was principally driven by the logistics of working in the city centre. The cost and time for replacement of grooved rail in the city centre were much greater than for segregated track. Contract support was required to replace city centre rail, whereas SML could replace segregated rail itself. Pressure to keep city centre traffic running and minimise the disturbance caused made scheduling work more difficult. These are normal factors in a light rail operation that have to be dealt with, and are not specific to Metrolink or this derailment.

Traffic allowed to continue with the city centre track outside of maintenance limits

119 GMPTE Metrolink and SML were both aware that the city centre track was beyond any acceptable maintenance limits. However, neither party felt they were able to suspend traffic.

SML did not suspend traffic

120 There was evidence that SML management was reluctant to suspend traffic over the city centre track and this was a causal factor to the derailment; SML was concerned that suspending traffic would tarnish its reputation and relationship with its new client early in the contract and this is considered a possible underlying factor to the derailment.

GMPTE Metrolink did not suspend traffic

121 GMPTE Metrolink did not suspend traffic over the city centre track because it did not appreciate the risks from the Metrolink operation (paragraphs 98 and 99). Specifically it was not auditing SML's compliance with its SMS, nor had it undertaken an assessment of the state and condition of the Metrolink system since commencement of the SML contract as specifically allowed for in the contract (paragraph 64). Had GMPTE Metrolink undertaken such a review it may have become aware that the track condition was continuing to be outside of the limits referenced from SML's SMS and that there was no controlled process for keep removal. GMPTE Metrolink not suspending traffic was a causal factor to the derailment, and it not auditing SML's compliance with its SMS was an underlying factor.

122 It is observed that had GMPTE Metrolink suspended traffic it would have highlighted the need to expedite the city centre renewals programme (paragraph 109).

ORR did not take any enforcement action

123 The ORR is responsible for enforcing health and safety law for most railways and tramways in Great Britain by ensuring compliance with relevant legislation (paragraph 86).

124 When SML started operating Metrolink, the ORR took the decision not to undertake any inspections of SML until it had settled in. The ORR considered that Stagecoach was a reputable operator with many years experience operating Sheffield Supertram successfully. The ORR therefore saw no need for it to confirm SML's compliance with the legislation, or to inspect Metrolink operations for compliance with the SML SMS. Additionally, the ORR was aware of the city centre track renewal plans (paragraph 62), and this was a consideration in its decision.

125 The ORR had a meeting with SML and GMPTE Metrolink on 19 May 2008 at which it discussed the poor condition of the city centre track with them. Witness evidence indicated that the ORR had decided not to take any intervention on the basis of the assurances given by the experienced permanent way engineer from Sheffield Supertram (bought in to assist at Metrolink by SML) that SML was monitoring the condition of the track and that it was confident that the track would last until it was replaced.

126 The ORR is required to ensure that RAIB's recommendations are duly taken into consideration and where appropriate acted upon (paragraph 87). It had accepted the submissions made by the duty holders following recommendations made in the Long Millgate report (paragraphs 45) and as such it considered that there was no need to take further actions on the Metrolink system pursuant to these recommendations.

127 The RAIB wrote to the ORR on 17 September 2007 ahead of publishing the Pomona report (paragraph 46) to advise that Serco had not been following all of the track maintenance procedures called up from its SMS, so that the ORR could assure itself that the issues were being properly addressed by the new operator, SML. The ORR confirmed to the RAIB (7 December 2007) that the issues relating to inspection and maintenance procedures had been adequately addressed by SML.

128 The ORR accepted SML's and Stagecoach's assurances and submissions without physically checking implementation of, and compliance to, the various submissions. This meant that the ORR was not aware of the risks associated with the then current condition of the city centre track and this may have prevented it from taking any enforcement action. In the light of the known poor state of the track, and the repeated derailments on the system, the RAIB considers it reasonable that the ORR would have undertaken physical checks to verify that the associated risks were being managed. The ORR not carrying out any physical checks on the implementation and compliance of the submissions received is considered a possible underlying factor to the derailment.

Other factors for consideration

Tram speed

129 The tram was travelling at 16 mph (26 km/h), slightly in excess of the 12 mph (20 km/h) speed limit. Analysis undertaken as part of the MMU study (paragraph 52) indicates that load experienced by the keep increases very slightly between 10 and 12 mph, but with an increase in speed from 12 to 15 mph the load actually reduces. It is therefore concluded that this over speed is unlikely to have contributed to the derailment.

130 On Metrolink the speed of the route ahead is signed to the driver at the location where the speed changes. The Metrolink Drivers Manual specifies that the entire tram (single or multiple) must have passed the termination of the restriction before accelerating. It is likely that the reason for the over-speed was due to the driver's uncertainty as to where the back of the tram was, particularly considering that he was driving a double unit.

For cause screening of the driver

131 The driver passed a police breath test at the site of the derailment. However he was not '*for cause*' screened by SML for either alcohol or drugs. Although 'for cause' screening is standard practice on mainline operations and most tramways and metros in the UK, SML did not have a policy of 'for cause' screening at the time of the derailment; the approach adopted was to test staff involved in accidents for alcohol if the police had not done so, and only to test staff for drugs if SML had a suspicion of drug use.

Severity of consequences

132 The risk of pedestrian injury was limited by the derailment happening in the late evening. If the derailment had happened during the working day, the likelihood of such injuries would have been considerably higher. The over-speed of the tram increased its momentum and could have made the consequences worse.

Conclusions

Immediate cause

133 The immediate cause of the derailment was failure of the right-hand rail's keep allowing the leading right-hand wheel flange to climb the face of the broken keep. The keep of the right-hand rail failed because sidewear on the left-hand rail had resulted in the back of right-hand flanges contacting and wearing the keep. The keep became worn so thin that it could no longer withstand the force on it from the flanges pressed against it. Rails on the outside of curves are subject to sidewear due to the curving forces exerted at the wheel-rail interface during the normal passage of trams (paragraphs 88 and 89).

Causal factors

134 The following were causal to the derailment:

a. the lack of process associated with the keep monitoring and removal arrangements adopted by SML along with no objective criteria defining when the keep should be removed and an omission of any proof that the arrangements would ensure that a degrading keep would be identified and removed before catastrophic failure occurred (paragraph 102 and Recommendation 3);

b. the track being allowed to continue in a poor condition as a consequence of (Recommendation 1):

    a. GMPTE Metrolink's delay in implementing the city centre renewals special projects (paragraph 109); and

    b. insufficient city centre track maintenance by SML (paragraph 110);

c. GMPTE Metrolink allowing traffic to continue with the city centre track in such poor condition (paragraph 121), possibly as a consequence of its attitude towards its safety responsibilities (Recommendation 2); and

d. SML allowing traffic to continue with the city centre track in such poor condition (paragraph 120 and Recommendation 4).

Contributory factors

135 The following are possible contributory factors to the derailment:

- the omission of maintenance limits for the city centre track from the contract (paragraph 97, 111);
- the lack of GMPTE Metrolink agreement to the city centre maintenance limits proposed by SML (paragraphs 111);
- removal of the technical engineer's post by Serco (paragraph 113); and
- SML engineering resource, especially the vehicle engineer vacancy, in so far as it affected the guidance and leadership of the civil engineering department (paragraph 117).

Underlying factors

136 The following are the possible underlying factors to the derailment:

- the contractual arrangements between GMPTE and Serco from 2003 onwards in so far as they allowed the city centre track to deteriorate beyond acceptable maintenance limits (paragraph 92);
- the structure of the contract between GMPTE and SML and the 'city centre renewals agreement', in particular:
  - the effective split between maintenance and renewals of the city centre track (paragraphs 95, 107 and 115);
- GMPTE Metrolink's attitude towards its responsibility for ensuring safe operation so far as is reasonably practicable (paragraphs 101), which in turn is likely to have led to:
  - the lack of engineering resource in GMPTE Metrolink and associated lack of continuity of consultants (paragraphs 91 and 97);
  - GMPTE Metrolink's lack of both a SMS, or similar health and safety arrangements, and a Safety Manager (paragraphs 98);
  - GMPTE Metrolink's lack of audit to monitor compliance by the Opco with any of its obligations under the contract, as allowed for in the contract (paragraph 121);
- GMPTE Metrolink not having the arrangements in place to access all of the finance required to fund the full scope of city centre replacement (paragraph 107);
- SML's non implementation, briefing and compliance audit of its SMS (paragraph 112);
- the possible conditioning of SML staff by their familiarity with the track being in a poor condition (paragraph 114);
- SML's concerns over its commercial reputation with its new client (paragraph 120); and
- the ORR's acceptance of SML's submissions with no check of implementation and compliance (paragraph 128).

Additional observations[7]

137 The driver allowed the tram to accelerate to a higher speed before the whole of the tram had passed the end of the previous speed restriction. This action was contrary to the SML Drivers Manual (paragraph 130).

138 SML did not have a policy of 'for cause' screening of staff following accidents and incidents (paragraph 131).

139 If keep contact occurs on grooved rail, replacement of the low rail and not resetting the gauge is likely to result in continued and accelerated wear of the keep.

[7] An element discovered as part of the investigation that did not have a direct or indirect effect on the outcome of the accident but does deserve scrutiny.

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

City centre track

140 SML has undertaken extensive work on the city centre track prior to its renewal. This has included:

- repairing broken rails;
- extensive gauge restoration by deposition welding;
- securing rails that were *voiding*; and
- restoring the gauge where rails had been incorrectly installed.

141 The whole of the city centre track is being replaced. The section from Piccadilly Gardens to Piccadilly Undercroft was renewed between September and November 2008. The remainder of the city centre track is being replaced between April and November 2009.

142 SML has appointed a new civil engineer. Following an independent review of documentation and processes, it has implemented new city centre track maintenance processes; these have been audited by GMPTE Metrolink. Where SML find track that does not to comply with the standards the matter is required to be elevated to the civil engineer who is responsible for implementing a process that will control the risk (paragraph 134a).

GMPTE Organisation

143 GMPTE Metrolink has developed its own SMS which will be compatible with and complementary to the SML SMS (paragraph 134b, 134c and 136).

144 GMPTE Metrolink is in the process of recruiting both a safety professional and a permanent track engineer; job descriptions and grades have been established (paragraph 136).

Completed actions relating to issues which otherwise would have resulted in RAIB issuing a recommendation

Track standards

145 GMPTE Metrolink and SML have agreed and implemented track maintenance tolerances for the city centre track based on those adopted by other UK tramway operators (paragraphs 133 and 135).

Long-term track condition management

146 SML has introduced a new computerised asset management system that documents and monitors maintenance activities and defects. The system provides full visibility to both SML and GMPTE Metrolink of all maintenance, including track condition, wear monitoring and trend analysis, thereby ensuring that the condition of the track is understood by both parties.

147 GMPTE Metrolink and SML state that the above information and the agreed track standards (paragraph 145) will allow for early warning of the need for track renewals (paragraph 137).

Extent of speed restrictions

148 SML have issued notices to drivers reinforcing that speed restrictions apply to the full extent of a tram. A programme of speed restriction monitoring has been implemented (paragraph 137).

For cause screening

149 SML has formalised and issued its procedure relating to drugs and alcohol testing; following any safety critical incident that either results in an injury to a passenger or member of staff or following a derailment on the main line, the relevant members of staff will be tested for drugs and alcohol (paragraph 138).

Recommendations made as a consequence of other RAIB investigation not complete at time of the incident

150 The safety recommendations listed below were made as a consequence of the RAIB's investigations into the derailments at Long Millgate (paragraph 45) and Pomona (paragraph 46). It is considered that these recommendations had not been fully implemented at the time of the derailment; their implementation would have led to the condition of the city centre track being addressed and therefore the derailment would have been less likely.

- GMPTE should ensure that a standard for Metrolink grooved rail track, including tolerances and limits for wear and gauge, is developed and implemented, and that there is guidance to inspection staff on appropriate levels and types of intervention corresponding to measured values and observations - Long Millgate recommendation 1 (paragraph 133). This has now been addressed (paragraph 145).
- The infrastructure maintainer of Manchester Metrolink and GMPTE should jointly introduce a system for initiating, planning and implementing track renewals on the Metrolink system - Long Millgate recommendation 3 (paragraph 133). This is in the process of being implemented (paragraph 141 and Recommendation 1).

- GMPTE should review, and if found necessary amend, their contractual arrangements for the Metrolink concession to ensure that essential repairs are not deferred for contractual reasons - Pomona recommendation 2 (paragraph 136). This would be addressed by the fuller new Recommendation 2 (paragraph 144).

Recommendations

151 The following safety recommendations are made[8]:

Recommendations to address causal and underlying factors

1. GMPTE should work with SML to put in place processes to identify, manage and rectify any section of operational track that becomes non-compliant to the agreed standards. It should put in place arrangements to ensure compliance with the processes. The processes should require time bound plans to renew or repair, as appropriate, and implementation of suitable mitigation measures to manage the derailment risk until the track is brought back within the standards (paragraphs 133 and 134b) .

2. GMPTE should review its Metrolink organisational structure, policy and procedures to confirm that they are sufficient for it to exercise its responsibilities under the Health and Safety at Work Act. Its consideration should include the need for an identified head of safety, documentation describing the arrangements for management of safety (including, but not limited to, identification and management of risk, and audit arrangements to confirm implementation and compliance) and provision of sufficient competent resource (paragraphs 134c and 136).

3. SML shall review its arrangements for managing safety when assets are outside of normal maintenance tolerances. If these require implementation of interim measures, for example removal of the keep, the arrangements should require demonstration that the interim measures are practical and will achieve the required risk mitigation. Additionally, the arrangements should require procedures to be developed to cover the activities, taking consideration of the associated risks. SML should implement any changes identified as necessary (paragraph 134a).

continued

[8] 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 and Greater Manchester Passenger Transport Executive 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 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 web site at www.raib.gov.uk.

4. SML should carry out a review to check whether its SMS is suitable and sufficient to manage the risks from its operations and make any necessary changes. Following this, it should ensure that all staff are aware of the SMS arrangements that apply to them, and that the arrangements are complied with (paragraphs 134d and 136).

5. The ORR should review its processes, in light of the findings of this investigation, to satisfy itself that there is sufficient guidance as to the circumstances under which its inspectors should verify the implementation of, and compliance with, a duty holder's submissions (paragraph 136).

Appendices

Appendix A - Glossary of abbreviations and acronyms

GMML	Greater Manchester Metrolink Limited
GMPTE	Greater Manchester Passenger Transport Executive
MMU	Manchester Metropolitan University
ORR	Office of Rail Regulation
RAIB	Rail Accident Investigation Branch
ROGS	Railway and Other Guided Transport System (Safety) Regulations
SMESC	Stagecoach Metrolink Executive Safety Committee
SML	Stagecoach Metrolink
SMS	Safety Management System

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

Air brake	An automatic brake where the brakes are operated by air pressure.*
Brake raft	Collection of brake gear mounted on a single frame underneath a tram.
Cant	The design amount by which one rail of a track is raised above the other rail, measured over the rail centres. Cant is applied to negate lateral forces caused by curved track.*
Cantrail	The point on a rail vehicle at which the side of the vehicle body meets the roof profile.*
Cess	The space to the side of a railway or tramway track.
City Zone	The Manchester Metrolink lines between Victoria and G-Mex stops, including the spur to Piccadilly.
Control Room	The central point for Metrolink communications, CCTV monitoring and signal control situated at Metrolink Queens Road Depot.
Door proving circuit	An electrical system that prevents the brakes from being released unless all doors are proved closed, similarly a door opening initiates a brake application.
Double Unit	Two articulated trams coupled together to operate as a single unit.
Earthing strap	A cable provided to transfer electricity from the overhead line equipment to earth, used to isolate a section of overhead line.
Flange-way	The gap between the head of rail and the keep.
For cause screening	Testing of those involved in accidents and incidents for the presence of alcohol or controlled drugs.
Four foot	The space between the rails on which the tram runs.
Gauge face	The side of the rail head facing towards the opposite running rail.*
Gauge spread	The tendency of the gauge to become greater, ie the rails to move apart from each other.
Grooved rail	Rail designed for use in streets, with a cross-section which incorporates a trough (or groove) in which the wheel flanges run.
Head wear	The vertical reduction in rail depth caused by normal wear on the rail head.*
High rail	The outer running rail of a curved portion of a track.*

Improvement Notice	Where an ORR Inspector is of the opinion that a railway undertaking is contravening or has contravened and is likely to continue to contravene a relevant statutory provision, then he may issue an improvement notice to them under Section 21 of the Health and Safety at Work etc Act 1974. An improvement notice will detail the nature of the contravention and the date by which it must be remedied. An improvement notice may or may not require specific remedial measures to be undertaken.
Incident officer	The SML employee appointed by the Metrolink Duty Officer to oversee and manage the aftermath of an incident.
Job-bank	A list of maintenance and repair activities required to be undertaken.
Keep	In grooved rail, the wall of the groove opposite the rail head.
Low rail	The inner running rail of a curved portion of track.*
Prohibition Notice	Where an ORR Inspector is of the opinion that a railway undertaking is contravening or has contravened and is likely to continue to contravene a relevant statutory provision, then he may issue an prohibition notice to them under Section 21 of the Health and Safety at Work etc Act 1974. A prohibition notice will detail the nature of the contravention and will require work to be stopped until the deficiency is remedied.
Segregated Track	Tram track where the route is not shared with road vehicles or pedestrians. The track is normally mounted on sleepers sitting in a bed of ballast.
Sidewear	The reduction in rail head width due to wear caused by flange contact with the rail as trams round a curve.
Solebar	The longitudinal structural members forming the spine of a rail vehicle, located below the carbody. The solebar is supported by bogies.*
Voiding	A condition where support is lost from under the track due to inadequate support.

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