RAIB
Rail Accident Investigation Branch

Rail Accident Report

Derailment at Birmingham Snow Hill, Midland Metro
29 January 2007

Department for Transport

Report 38/2007
October 2007

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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Derailment at Birmingham Snow Hill, Midland Metro, 29 January 2007

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 Travel Midland Metro (TMM), Carillion Rail (Carillion) and Centro to their staff, data and records in connection with the investigation.

4 Appendices at the rear of this report contain the following glossaries:

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

The Incident

Summary of the incident

5 At 14:25 hrs on Monday 29 January 2007, the centre *bogie* of tram 06 became derailed at the *switch and crossing* (S&C) on the approach to Birmingham Snow Hill terminus. Tram 06 was operating the 13:50 hrs service from Wolverhampton to Birmingham at the time of the derailment. See Figure 1.

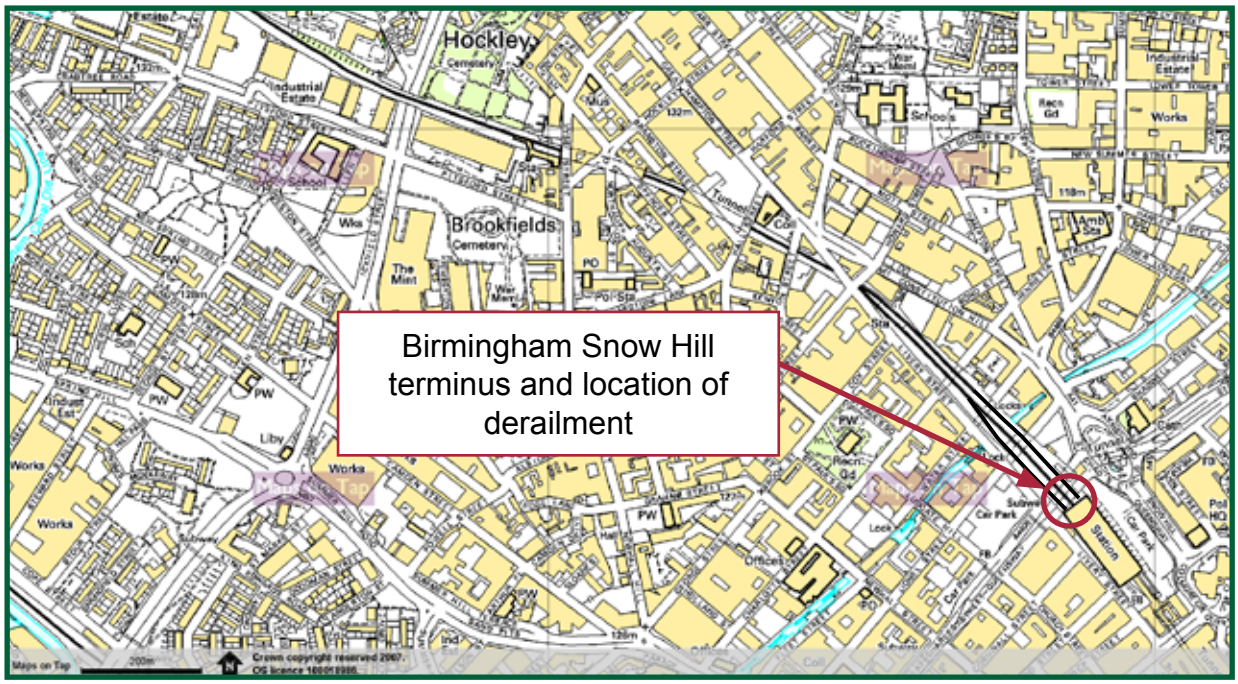

Figure 1: Extract from Ordnance Survey map showing the Midland Metro route into Birmingham Snow Hill terminus and the derailment location

The parties involved

6 Centro, the West Midlands Passenger Transport Executive, owns the Midland Metro and works under the policy and financial guidance of the West Midlands Passenger Transport Authority.

7 TMM operates the Midland Metro. TMM is part of Travel West Midlands which in turn is part of the National Express Group.

8 Carillion Rail inspects, maintains and repairs the Midland Metro *infrastructure* under contract to TMM. Carillion Rail is part of Carillion Construction.

9 SkyBlue is the labour supply subsidiary of Carillion Rail.

Midland Metro

10 The Midland Metro was designed and built by Altram, a consortium of Ansaldo Trasporti and John Laing. Ansaldo was responsible for the supply of trams, signalling, communications, overhead line and power supply equipment. John Laing was responsible for construction of the track, tram stops and buildings. The off-street S&C was designed and supplied by Grant Lyon Eagre, at that time a part of the British Steel Group, now named Corus Cogifer.

11 The tramway is 20 km in length, running on-street for 2 km from Wolverhampton to Priestfield and off street for 18 km from Priestfield to Birmingham. The tramway is double track with a short section of single track on the approach to Birmingham Snow Hill terminus. The tramway has 23 tram stops including the Wolverhampton and Birmingham termini. See Figure 2 for a diagram of the route and the tram stops.

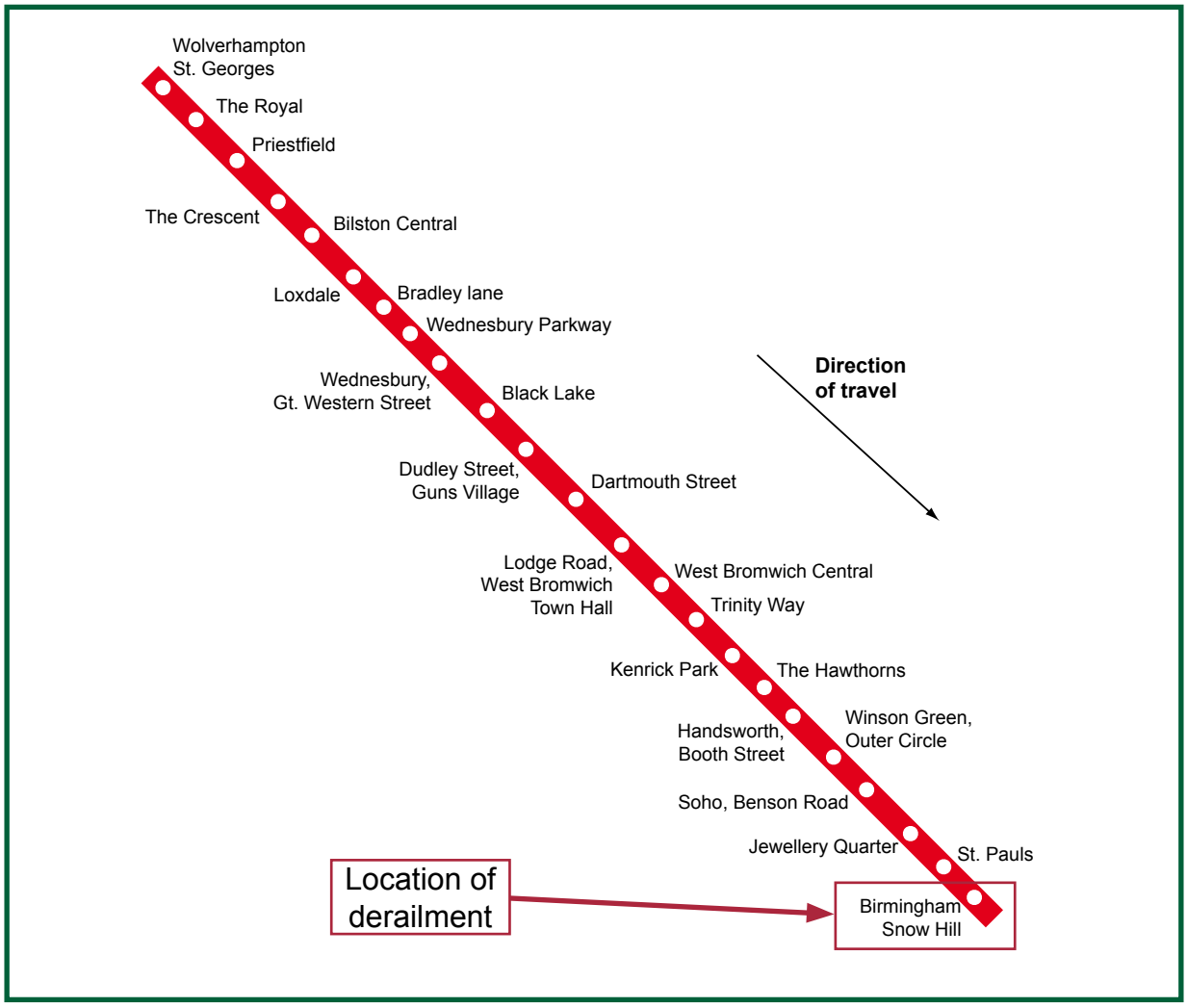

Figure 2: The route and its tram stops

12 The Midland Metro commenced operation on 30 May 1999. At this time GT Railway Maintenance (GTRM), a joint venture between GEC Alsthom (later Alstom) and Tarmac (later Carillion), was responsible for the inspection and maintenance of Midland Metro infrastructure. Carillion acquired Alstom's shares in GTRM and, in 2002, combined GTRM with two other divisions to create Carillion Rail.

Location

13 The derailment occurred at the S&C on the approach to Birmingham Snow Hill terminus where the single track becomes double track. Travelling into Birmingham Snow Hill, the left and right hand tracks go to platforms five and four respectively. See Figure 3.

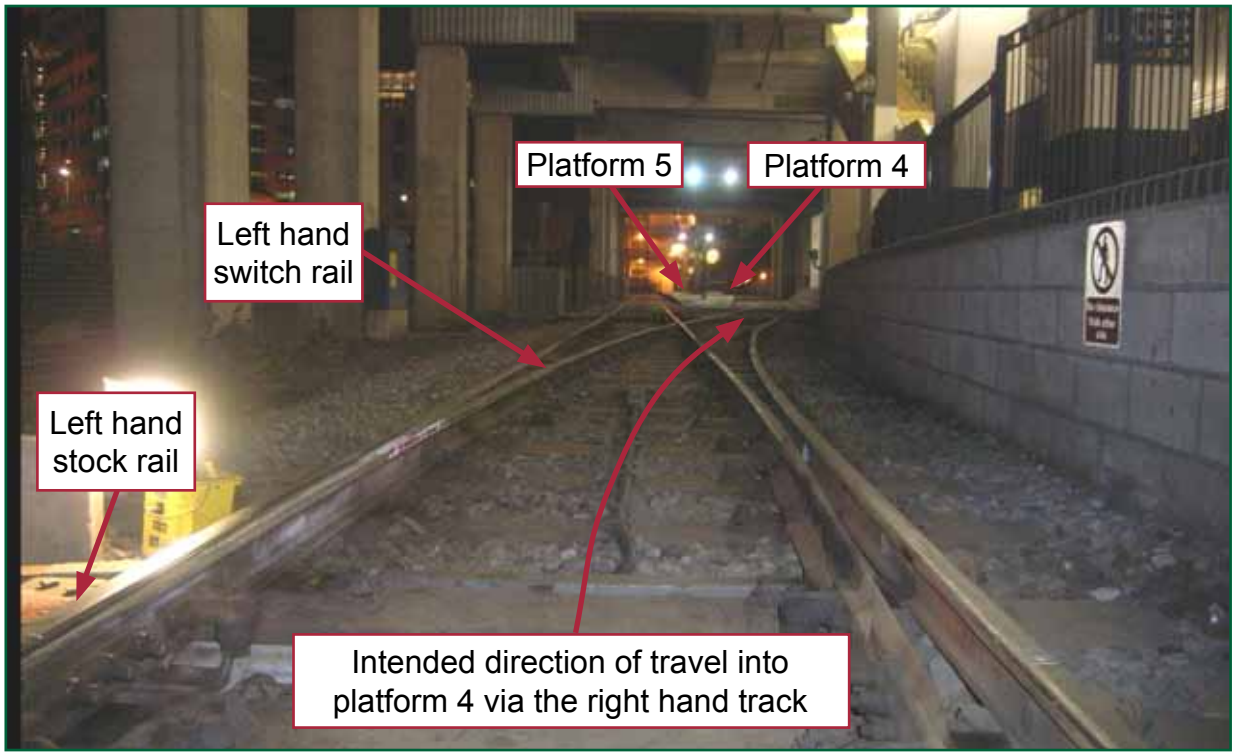

Figure 3: The approach to Snow Hill terminus

Trams

14 Each tram consists of two saloon units joined by a centre articulation unit. Each saloon unit has a driving cab and a raised seating area immediately above a powered bogie with conventional *wheelsets*. The tram's low floor height is achieved by mounting the articulation unit on a non-powered bogie with stub axles and independently rotating wheels (IRWs). See Figure 4.

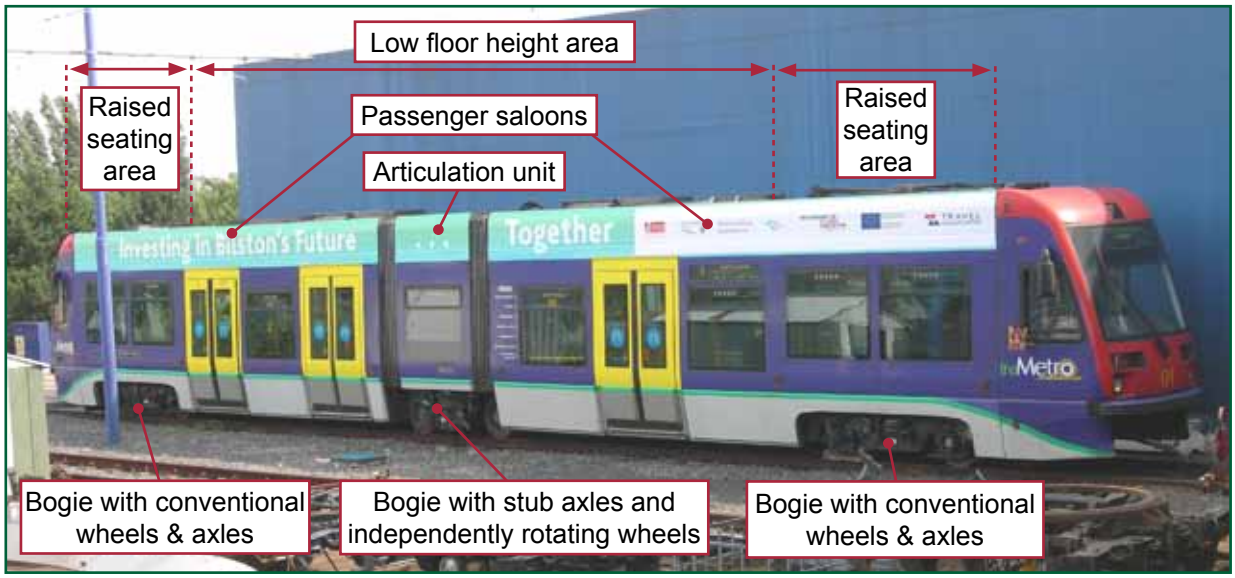

Figure 4: The layout of the tram

Events preceding the incident

15 S&C *sidewear* is caused by interaction between the rail and wheel *flanges* and is most pronounced on the *switch rail* that causes a tram to change from the straight to the diverging track. A sideworn switch rail can usually be repaired, with lost material built up by welding and its as-designed geometry restored by grinding.

16 Travelling into Birmingham Snow Hill, the S&C diverging track is formed by the left hand switch and right hand *stock rails*. See Figure 5 for its layout. Between the Midland Metro commencing operation in May 1999 and December 2006, the left hand switch rail had been weld repaired on at least three known occasions. The dates of these repairs were November 1999, July 2001 and March 2004.

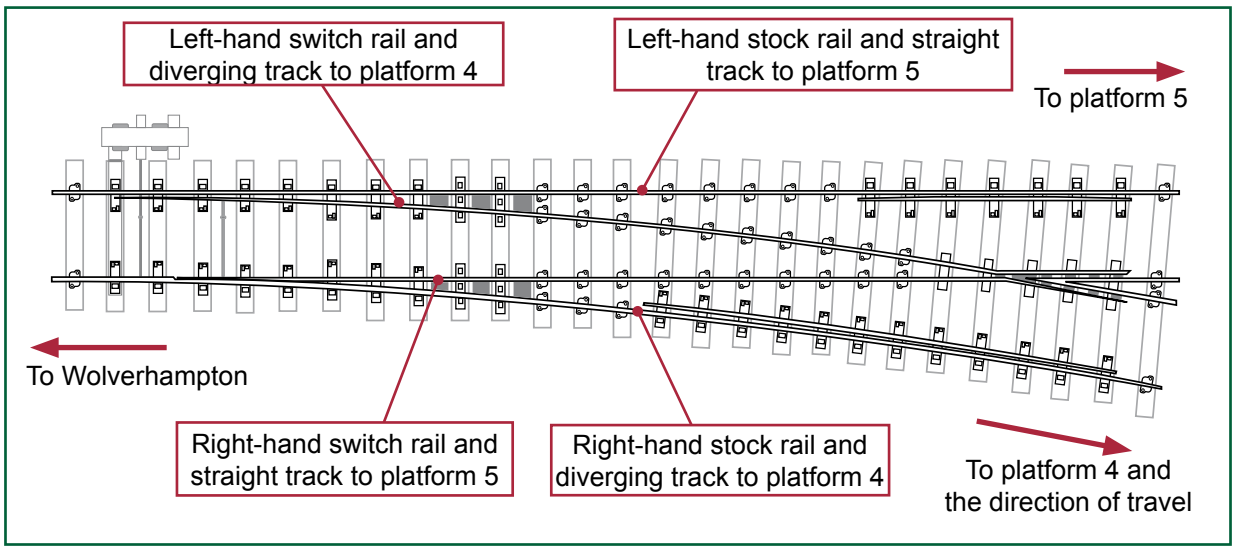

Figure 5: The S&C layout at Birmingham Snow Hill

17 In summer 2006, Carillion informed TMM that the left hand switch rail of the Birmingham Snow Hill S&C had failed its sidewear inspection; it was then *clipped and scotched* to take the diverging track, and thus Birmingham Snow Hill platform four, out of use. Soon afterwards, a TMM manager decided to reinstate the S&C without rectification, increased inspection or any other measure put in place to take account of its condition.

18 On 21 December 2006 a Carillion track worker again found that the left hand switch rail failed its sidewear inspection, clipped and scotched it out of use and advised Midland Metro in writing of this course of action. See Figure 6.

Figure 6: The S&C clipped and scotched out of use

19 A Carillion welding work supervisor inspected the S&C on 19 January 2007 and advised TMM that a routine, in situ repair was required. TMM verbally instructed Carillion to proceed with the repair.

20 Staff from Carillion's Doncaster Welding Depot were involved in the switch rail repair carried out on night shifts on 22, 23 and 24 January 2007. The work group on each night comprised a welding work supervisor, a welder and a welding assistant. A local SkyBlue track worker acted as the *controller of site safety* on all occasions.

21 Carillion clipped and scotched the diverging track out of use between night shifts; it remained clipped and scotched out of use after the repair had been completed.

Events during the incident

22 The Carillion contract manager and two SkyBlue track workers arrived at Birmingham Snow Hill on the morning of 29 January 2007 to test the S&C, the control centre permitting its release and testing between trams. The Carillion staff liaised with the control centre and confirmed to the controller that the straight and diverging tracks could be selected satisfactorily. The contract manager then had the diverging track clipped and scotched out of use until the track workers could return to clean the S&C slide mechanism to eliminate judder under operation, after which all three left site.

23 The two track workers returned to site during the afternoon and cleaned the S&C, the control centre again permitting its release and testing between trams. The two track workers contacted the contract manager and stated that the S&C had been cleaned, re-tested and that judder under operation had been eliminated.

24 The contract manager concluded, without any further inspection, that the repair was complete and contacted the control centre to advise that the S&C could be reinstated. The S&C and platform four were put back into use following this conversation, the control centre requesting that the track workers observe the passage of tram 02 and then tram 12 over the diverging track, into and out of platform four. The track workers observed that both trams successfully traversed the diverging track and then left site at 14:20 hrs.

25 Tram 06 was the next tram to arrive into Birmingham Snow Hill; its journey had been uneventful up until that point. At 14:25 hrs, as it traversed the S&C at 10 km/h, the driver heard a loud bang and stopped the tram. After liaising with the control centre the driver detrained and found that the tram's centre bogie had derailed to the left in the direction of travel.

26 When the site was examined it was found that the tram had derailed 2.6 metres from the *switch tip* and had stopped 7.7 metres beyond the point of derailment.

Consequences of the incident

27 There were neither injuries nor significant damage to tram or infrastructure as a consequence of the derailment. After the incident trams commenced and terminated their services from St. Pauls, the next tram stop towards Wolverhampton from Birmingham Snow Hill, until the line resumed normal operation at 23:51 hrs that night.

Events following the incident

28 Tram 06's driver and conductor enquired into the wellbeing of the passengers and determined that no injuries had been sustained. They then obtained the permission of the control centre to detrain all passengers who then walked the short distance along the *cess* into Birmingham Snow Hill terminus.

Analysis

Identification of the immediate cause

29 As tram 06 traversed the S&C, the centre bogie's leading left hand wheel struck and climbed the left hand switch tip and ran along the switch rail. Figures 7 and 8 show wheel flange contact marks on the switch tip and switch rail top respectively.

30 The wheel flange travelled 2.6 metres along the switch rail top then dropped into the widening gap between switch and stock rails. The centre bogie trailing wheel derailed in the same manner, resulting in the derailment of all wheels. See Figure 9.

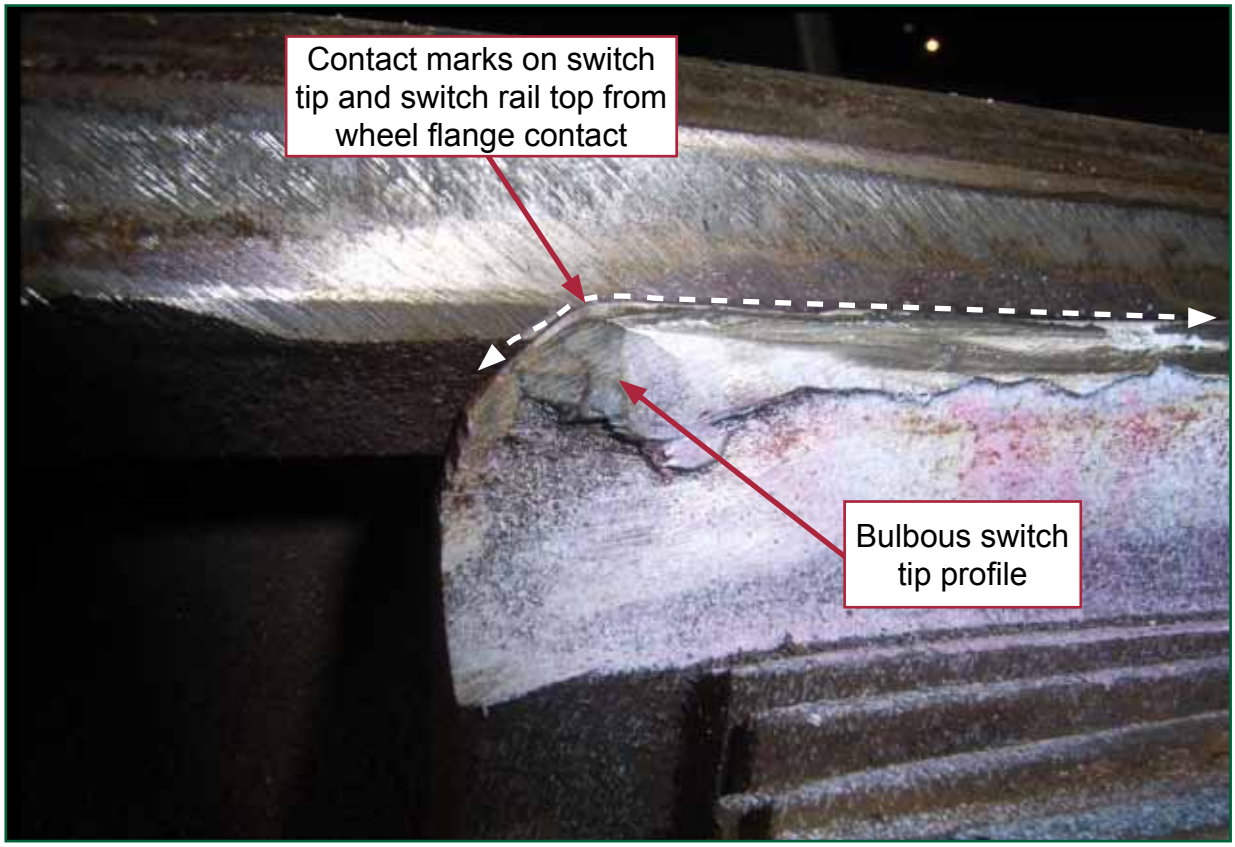

Figure 7: Left hand switch tip

31 The immediate cause of the derailment was the interaction between the wheel and the switch tip, causing the wheel to climb onto the top of the switch rail.

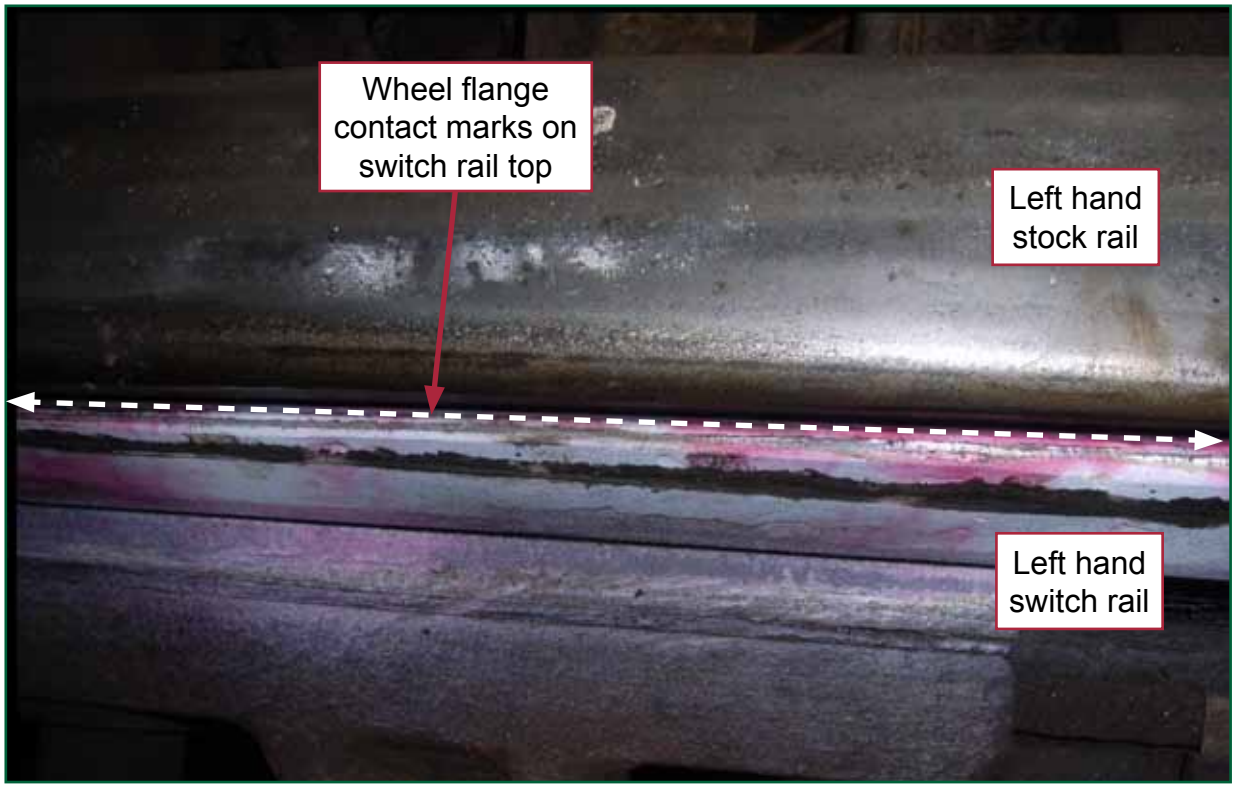

Figure 8: Left hand switch rail

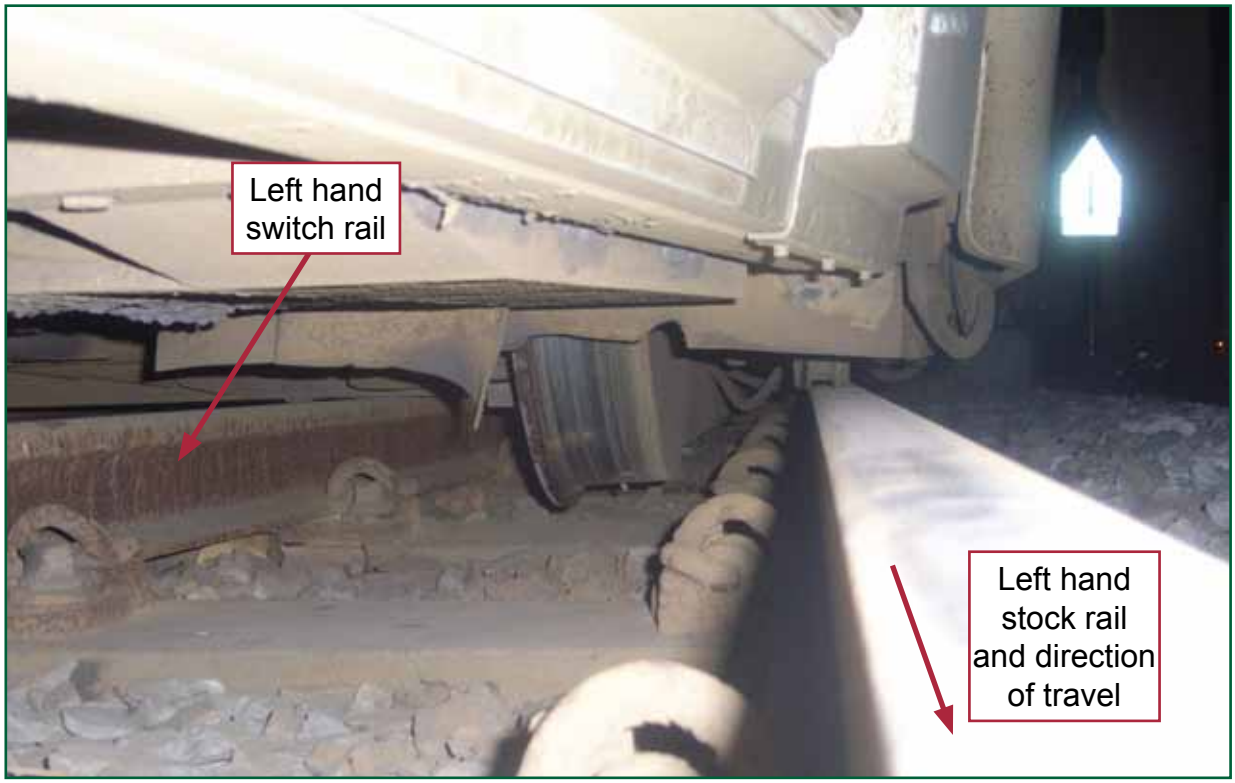

Figure 9: Articulation unit centre bogie derailed all wheels

Discounted factors

The performance of the tram driver

32 The speed limit over the S&C was 15 km/h. After the Birmingham Snow Hill S&C was reinstated, it was successfully traversed by trams 02 and 12 travelling into and out of platform four at 5 km/h and 15 km/h respectively. Tram 06 was coasting over the S&C into platform four at 10 km/h when its centre bogie derailed. The speed was confimed by analysis of the tram data recorder.

33 Tram 06 had performed satisfactorily in all respects before the derailment; afterwards it was the subject of post-incident testing with no faults found in its control or braking systems. The tram data recorder confirmed that within three seconds of the derailment the brakes had applied and the tram had stopped.

34 The performance of the tram driver was neither causal nor contributory to the incident.

Identification of causal factors

35 There is an increased risk of derailment when traversing S&C compared with *plain line* track; the combination of wheel/rail friction and lateral force from track curvature may cause a wheel to climb a switch rail. The risk is greatest for a wheel in flange contact with a stock rail on the approach to S&C that is worn, damaged or otherwise at variance with its as-designed geometry.

36 The TMM tram wheel has a square *flange tip* designed to run in contact with the groove in the on-street crossing at Wolverhampton St Georges. Flange tip running permits the use of narrow groove track and reduces wheel/rail noise because the wheel is continuously supported as it traverses the crossing. However, a square flange profile is more susceptible than a conventional, rounded flange to digging into the side of a switch rail or striking and riding up a switch tip.

The left hand switch rail geometry

37 The as-designed switch rail is chamfered to a 'knife edge' and undercuts the stock rail at its tapered end to ensure that wheel contact occurs away from the switch tip. See Figure 10.

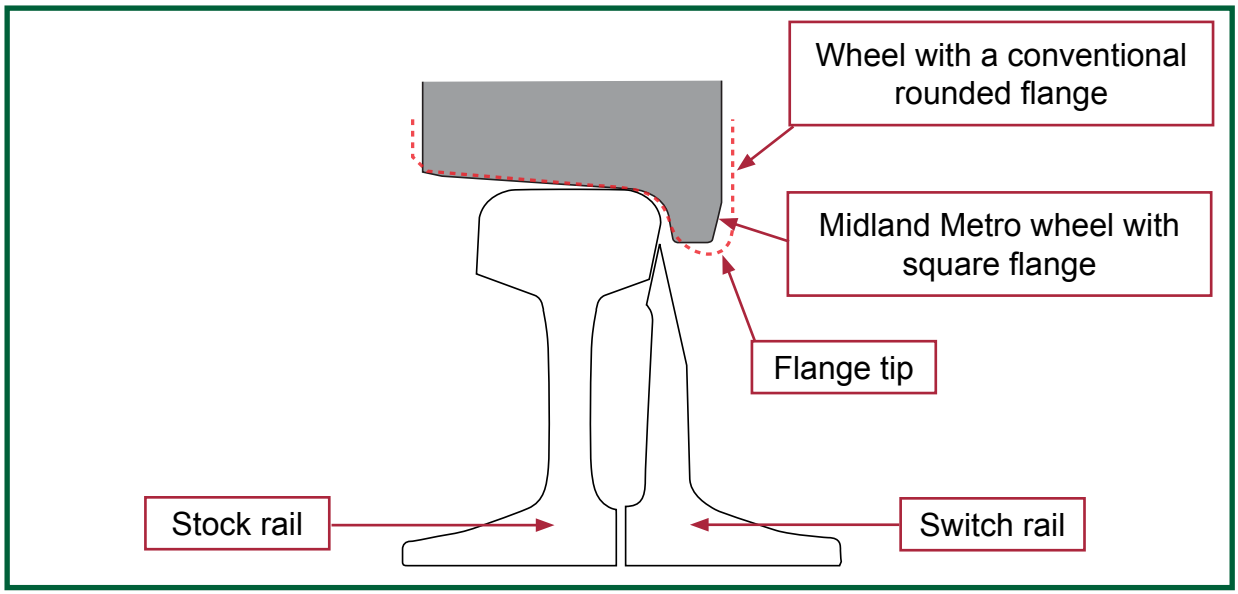

Figure 10: As-designed tram wheel and switch tip geometry

38 The repaired switch tip had a rounded and bulbous profile, was not chamfered to a 'knife edge' and did not undercut the stock rail. It was a derailment hazard as its profile was flatter than that of the stock rail and had an angle of less than 60° where indicated. See Figures 7 and 11. Contact marks from the passage of a number of wheels from trams 02, 12 and 06 can be seen in the *dye penetrant testing* material left from the welding repair. See Figure 12.

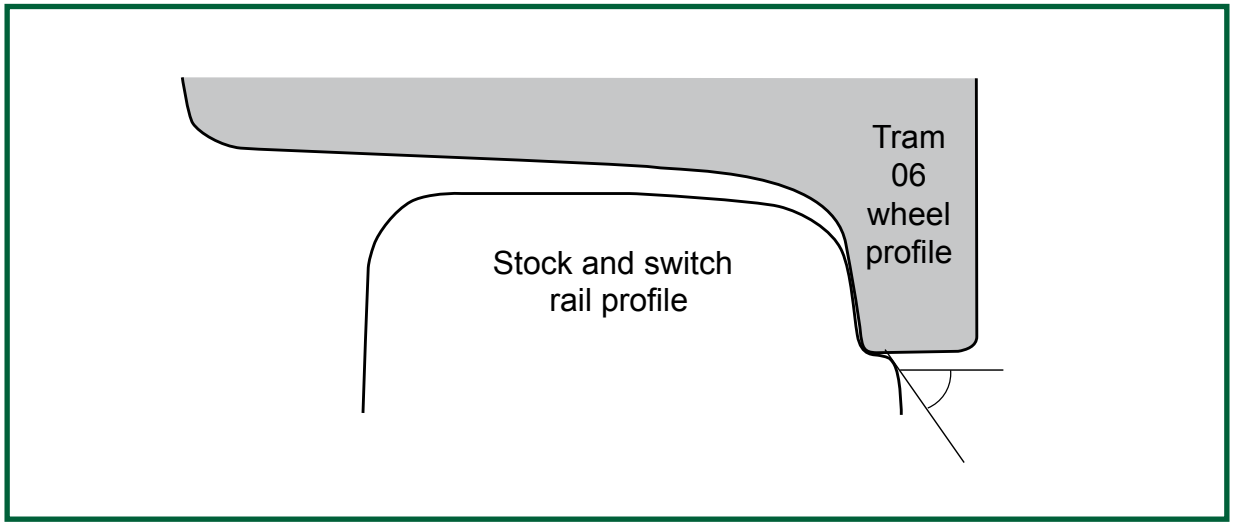

Figure 11: As repaired switch tip and tram 06 centre bogie leading left hand wheel

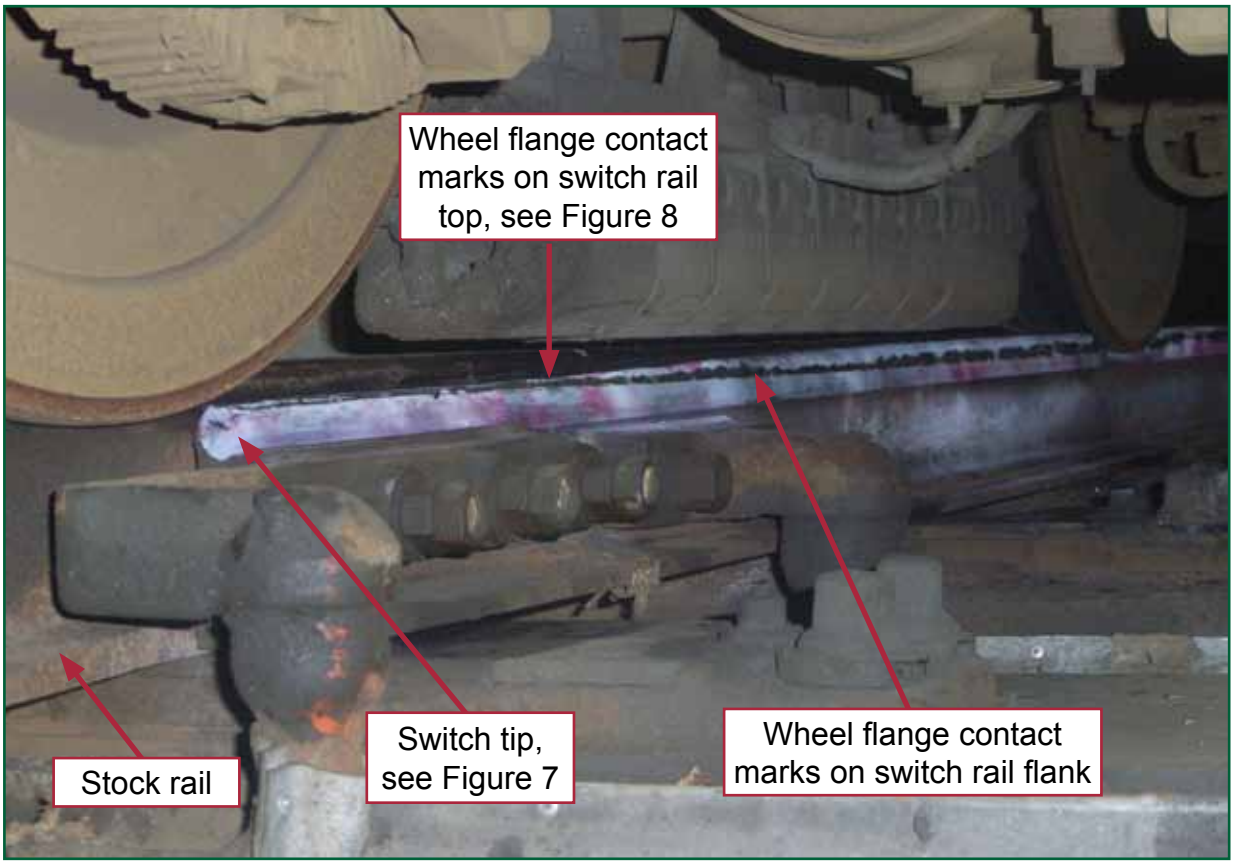

Figure 12: Wheel contact marks in residual dye penetrant material

39 Impact forces from a number of wheels from trams 02, 12 and 06 were sufficient to crack the switch rail 0.38 metres from the switch tip. The crack was not present before or during the weld repair as it contains no dye. See Figure 13.

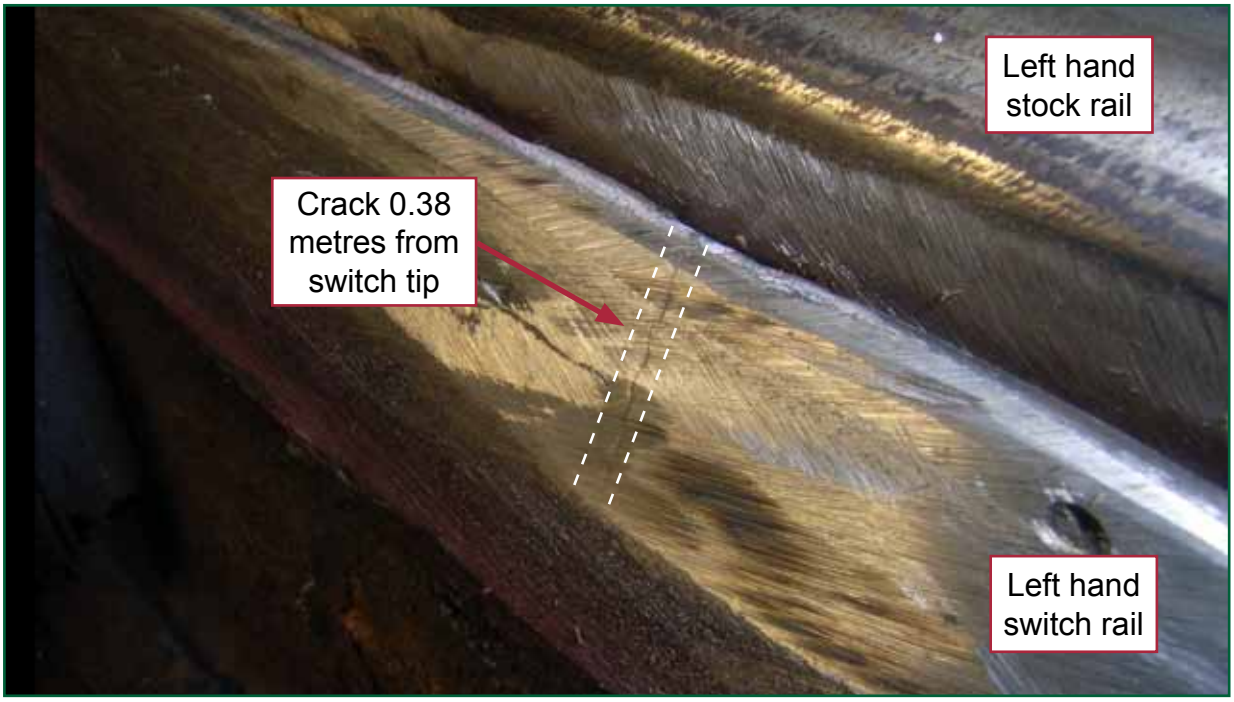

Figure 13: Left hand switch rail fracture

40 A causal factor was that the left hand switch rail had not been restored to its as-designed geometry following weld repair.

Centre bogie bias

41 While a conventional wheelset steers itself during *curving*, an IRW (paragraph 14) cannot as its wheels are not joined by a common axle. Therefore IRWs may run in flange contact, may be more prone to wear and may run misaligned on the approach to S&C.

42 In addition to this common IRW limitation, some TMM tram centre bogies have a bias to one side that manifests itself as heavy wear to the flanges of the leading and trailing wheels on that side of the bogie. While the cause of bias is not fully understood it is known that:

a. Paragraph 6.6 of a Health and Safety Laboratory (HSL) report[1] identified TMM wheel wear as an operating challenge, stating that 'uneven wear to the flanges of wheels on the [centre bogies], when compared side-to-side, has been observed'.

b. Studies undertaken for TMM by Manchester Metropolitan University's Rail Technology Unit (RTU)[2 3] found that when four of the fleet's fifteen operational trams were examined, all had heavy wear to the flanges of the leading and trailing wheels on one side of the centre bogie. In both studies, a number of wheels had worn to less than the minimum flange thickness.

[1] A survey of UK tram and light railway systems relating to the wheel/rail interface. HSL report reference FE/04/14 dated 14 March 2006. Prepared for Her Majesty's Railway Inspectorate.

[2] Midland Metro wheel/rail interface study. RTU report reference 140/2 dated 22 December 2004.

[3] Midland Metro wheel profile wear study. RTU report reference 140/4 dated 8 August 2005.

43 The centre bogie wheel flanges of trams 02, 12 and 06 were examined after the incident. Trams 02 and 12 had wheel flanges that had recently been re-profiled and so could not indicate directional bias. The centre bogie left hand wheel flanges of tram 06 exhibited heavy wear, indicating a left hand bias in the direction of travel on the approach to the reinstated S&C. This bias would lead to the left hand wheel flanges bearing hard on the left hand switch rail, increasing the risk of derailment as explained in paragraph 35.

44 A causal factor was that the centre bogie left hand wheels were biased toward the left hand switch rail as the tram approached the S&C.

Identification of contributory factors

45 *Heavy rail* investigations identified a number of S&C conditions that increased the risk of derailment and Network Rail and its predecessors incorporated these findings into a set of procedures[4]. These procedures require thorough S&C inspection and repair to defined standards by qualified personnel using specified gauges. The application of these procedures has helped to reduce the number of S&C derailments on Network Rail infrastructure.

46 For the reasons explained in paragraph 36, the S&C on Midland Metro should be maintained to an appropriate standard to reduce the risk of derailment. However, neither TMM nor Carillion had procedures that were prescriptive with respect to repair and inspection (refer to paragraph 55). For this reason the repaired S&C was not thoroughly assessed and its non-compliant geometry went undiscovered.

47 A contributory factor was that the switch blade was not subjected to an appropriate post-repair inspection.

Identification of underlying causes

TMM and Carillion staff competence to inspect and maintain Midland Metro S&C

48 Under the contract between Carillion and TMM, two SkyBlue track workers carried out basic Midland Metro *permanent way* inspection and maintenance tasks (eg lubrication and cleaning). Carillion carried out all other work arising on an ad hoc basis at additional cost, using staff drawn from elsewhere in the Carillion organisation.

49 The two track workers spent two to three days per week on the Midland Metro permanent way; the remainder of their time was spent working away on other Carillion contracts. Both held valid certificates for S&C inspection and maintenance to Network Rail standards and correctly identified the need to remove the Snowhill S&C from service. The track workers reported to the Carillion contract manager, an experienced permanent way engineer, who in turn reported to the TMM infrastructure manager.

50 The TMM infrastructure manager, appointed in December 2006, was neither qualified nor experienced in permanent way matters and expected Carillion to carry out work to a standard sufficient to ensure the safe operation of the tramway.

[4] NR specification NR/SP/TRK/053 issue 03 dated Oct 2002. Inspection and repair procedures to reduce the risk of derailment at switches.

51 Welders repairing Network Rail S&C must have valid *MMA 5*[5] competence. The welders from Carillion's Doncaster Welding Depot who repaired the Birmingham Snow Hill S&C neither had current MMA 5 competence nor were familiar with the Midland Metro permanent way. Carillion, however, agreed to undertake the repair because TMM were not prescriptive on the matter of S&C competence and applied no requirement similar to MMA 5.

52 Although TMM remained responsible for the operational safety of the Midland Metro irrespective of who was undertaking work on its behalf, it was wholly reliant on Carillion carrying out work to an adequate standard due to insufficient permanent way competence in its day to day operations. Carillion, however, had insufficient competence with respect to Midland Metro S&C repairs; the competence of the Midland Metro track workers and the staff drawn from elsewhere in its organisation was with renewals on Network Rail infrastructure.

TMM and Carillion S&C inspection, maintenance and repair procedures

53 At the time the system commenced operation, the information handed over to TMM by Altram (who designed and built the Midland Metro) was inadequate; insufficient information was given on the system's design, its construction and its maintenance requirements. The information that is now available has been obtained piecemeal as needs have arisen.

54 The TMM permanent way maintenance instructions and procedures, both at handover and now, provided fixed frequencies for S&C inspections, an aide memoire of conditions to be looked for and brief statements of actions to be taken. At the time of this investigation the TMM documents were at issue 1 revision 0 dated July 2005. Carillion had paper copies of these documents at draft issue revision A dated April 2001, issued by TMM to GTRM in 1999 and not updated by subsequent re-issues. However, the Carillion and TMM documents were comparable in content and format.

55 TMM did not have prescriptive documents for the assessment, repair and subsequent inspection of S&C, nor were the standards and procedures of other parties (such as Network Rail) invoked. This absence of prescriptive standards and procedures led to Carillion's ad hoc use of local procedures and inspection techniques: on previous occasions Carillion had inspected and repaired the S&C using standard Network Rail gauges, a gauge developed specifically for TMM or a combination of the two, recording the work undertaken on Carillion 'switchwear inspection assessment' and 'crossing repair and maintenance' forms, both developed for use on the Midland Metro system.

56 The switchwear inspection assessment form makes reference to Network Rail S&C inspection gauges and records whether switch rail geometry passed or failed inspection. The crossing repair and maintenance form requires brief details on the location of the S&C and the repair undertaken; it does not require any information on S&C geometry.

57 For the S&C repair undertaken prior to the derailment, Carillion completed crossing repair and maintenance forms on 24 and 25 January 2007 but no switchwear inspection assessment form. Therefore, although the left hand switch rail had not been restored to its as-designed geometry, this was neither inspected for nor detected. Had Carillion thoroughly examined the S&C it would have failed inspection by the switch blade angle gauge (see Figure 11), the TMM wheel profile gauge and the switch blade radius gauge.

[5] NR specification NR/SP/TRK/0132 issue 04 dated Feb 2007. Maintenance arc welding of rails, switches and crossings.

58 The underlying causes were that:

a. neither TMM nor Carillion staff had sufficient competence to adequately inspect and maintain the Midland Metro S&C;

b. the TMM standards and procedures that support staff competence were not sufficiently prescriptive with respect to S&C inspection, maintenance and repair.

Additional observations

Control of the work undertaken on the S&C at Birmingham Snow Hill

59 Carillion neither requested nor received a *permit to work* on the S&C, although the TMM control centre and the relevant TMM staff were fully aware of the work being carried out. Nevertheless, Carillion did not follow the TMM permit to work procedure[6].

60 Carillion did not follow their routine for work undertaken on Network Rail infrastructure that requires inspection by signal and telecommunications (S&T) staff before S&C reinstatement. However, S&T inspection would have tested only for the satisfactory selection and detection of straight and diverging tracks. It would not have identified that the left hand switch rail had not been restored to its as-designed geometry and would not have prevented the derailment.

61 The TMM infrastructure manager expected Carillion to provide a letter of completion before the S&C was reinstated; however on this occasion the TMM control centre reinstated the S&C following a conversation with the Carillion contract manager. A letter of completion would have confirmed more formally that the S&C could be reinstated. It would not have identified that the left hand switch rail had not been restored to its as-designed geometry and would not have prevented the derailment.

62 TMM agreed to the S&C repair being carried out, although Carillion had not defined the repair in terms of scope of work or cost. Without a scope of work, standards for weld repair, grinding, inspection and reinstatement were not specified. Carillion were therefore not required to assure that the work had been satisfactorily executed to specified standards.

63 TMM did not carry out verification, audit or review of works undertaken by Carillion to ensure that their contractor's competence existed, was applied and was sufficient to maintain safe operation (**Recommendation 4**).

UK tram and light rail

64 Modern UK tram and light railway systems have been designed and built independently of one another and without the benefits of standardisation or interoperability. While the Office of Rail Regulation (Her Majesty's Railway Inspectorate) and the industry are aware that tram wheels with square flange tips may interact adversely with S&C, TMM and possibly other tram and light rail operators have not developed or adopted standards and procedures for effective S&C inspection, maintenance and repair.

[6] OPS051 Administration of permit to work issue 003 dated 07 October 2004.

Conclusions

Immediate cause

65 The immediate cause of the derailment was the interaction between the wheel and the switch tip, causing the wheel to climb onto the top of the switch rail (paragraph 31).

Causal factors

66 The causal factors were that:

a. The left hand switch rail had not been restored to its as-designed geometry following weld repair (paragraph 40);

b. The centre bogie left hand wheels were biased toward the left hand switch rail as the tram approached the S&C (paragraph 44).

Contributory factors

67 The contributory factor was that the switch blade was not subjected to an appropriate post-repair inspection (paragraph 47).

Underlying causes

68 The underlying causes were that:

a. neither TMM nor Carillion staff had sufficient competence to adequately inspect and maintain the Midland Metro S&C (paragraph 58a and **Recommendations 1** and **3**);

b. the TMM standards and procedures that support staff competence were not sufficiently prescriptive with respect to S&C inspection, maintenance and repair (paragraph 58b and **Recommendation 2**).

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

69 The Office of Rail Regulation (Her Majesty's Railway Inspectorate) is supporting research into UK tram and light rail systems' wheel/rail interfaces. Reference 1 (paragraph 42a) contains the findings from the first phase of this research and includes summary information on all UK tram and light rail systems.

70 The S&C was clipped and scotched after the incident, taking the diverging track and platform 4 out of use. The S&C remains out of use at the time of publication of this report.

71 TMM have started to bring infrastructure inspection and maintenance in-house. Carillion and TMM are working together through the period of transition.

72 TMM carried out an investigation into the incident and made recommendations to:

a. review their engineering standards and the process for dissemination of the same;
b. review contractor arrangements;
c. review the permit to work system;
d. review the formal handover process for equipment and infrastructure.

73 Carillion carried out an investigation into the incident and made recommendations to:

a. carry out no further work on TMM without defined contractual arrangements in place that specify the standards to which the works are to be delivered;
b. carry out no future work on TMM without work plans that cover the entire scope of the job;
c. commission a Carillion Contract Management review to assure that sufficient competent staff are allocated to the contract for the sound planning and delivery of works;
d. publicise the event in future safety briefings.

Recommendations

74 The following safety recommendations are made[7]:

Recommendations to address underlying causes

1 TMM should either employ or provide from elsewhere, personnel competent to specify and approve the inspection, maintenance and repair of switches and crossings (paragraph 68a).

2 TMM should develop or adopt and implement standards and procedures for effective switch and crossing inspection, maintenance and repair (paragraph 68b).

3 Carillion should verify by audit that switch and crossing work its Doncaster Welding Depot undertakes elsewhere is carried out by competent staff (paragraph 68a).

Recommendations to address observations

4 TMM should verify, by monitoring and auditing, that switch and crossing inspection, maintenance and repair is carried out by them or on their behalf to a standard that achieves safe operation (paragraph 63).

[7] Responsibilities in respect of these recommendations are set out in the Railways (Accident Investigation and Reporting) Regulations 2005 and the accompanying guidance notes, which can be found on RAIB's web site at www.raib.gov.uk

Appendices

Glossary of abbreviations and acronyms — Appendix A

S&C	Switch and Crossing.
GTRM	GT Railway Maintenance Limited.
IRW	Independently Rotating Wheel.
HSL	Health and Safety Laboratory.
RTU	Rail Technology Unit.
S&T	Signal and Telecommunications
TMM	Travel Midland Metro

Glossary of terms — Appendix B

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

Bogie	A frame equipped with wheels that is able to rotate freely, used to improve ride quality and distribute forces to the track.*
Cess	The area beside the tramway that provides a safe area for walking.
Clipped and scotched	A term used to describe a set of switches that has been rendered inoperable by use of a switch clamp to secure the closed switch and a scotch to secure the open switch.*
Controller of site safety	Safety critical qualification demonstrating the holder's competency to arrange a safe system of work.*
Curving	In a curve, the outer rail is longer than the inner rail. The wheelset moves laterally as it enters a curve, with the rolling radius of the outer wheel becoming larger and the other smaller. If the difference in rolling circumference matches the difference in length of the rails the wheelset will steer itself around the curve.
Dye penetrant testing	A method of finding cracks in metal by using different colours and viscosities of dye to show them up. Used during the weld repair of rail defects.*
Flange	The extended portion of a rail wheel that provides it with directional guidance.*
Flange tip	The portion of the wheel flange furthest from the axle.*
Heavy rail	A term used to differentiate between tram and light rail systems and the national railway system.*
Infrastructure	The fixed equipment and structures on a tramway, such as bridges, buildings, power supply and overhead line equipment, lineside fencing, signalling equipment, stations, telecommunications equipment and permanent way.*
MMA 5	A competency for repair of switch rails awarded by Network Rail on completion of an approval test. Prerequisites for MMA 5 are that the welder is trained and certificated to MMA 1-4 (lesser approval tests) and that MMA 4 has been held for the prior 12 months minimum. Any welders who do not carry out switch blade welding for a period of six months or more have their MMA 5 approval suspended until successful completion of refresher training and reassessment.
Permanent way	The part of the infrastructure that includes track & S&C, its supporting structures, tramway drainage etc.

Permit to work	Defined in TMM procedure OPS051 as 'A document intended to ensure that a potentially hazardous job is undertaken safely, taking into account all the foreseeable circumstances which could arise during the course of the task concerned'
Plain line	Track without S&C.*
Sidewear	Progressive removal of rail metal generally afflicting the high [outer] rail on curves, due to the high lateral forces produced when a train negotiates a curve. Eventually the rail head assumes a profile complimentary to the passing wheels, increasing the likelihood that a wheel will climb the rail.*
Stock rail	The fixed rail in a switch. The other rail is the switch rail.*
Switch and crossing	An installation with two moveable switch rails that permits a tram to travel in one of two directions.
Switch rail	The thinner movable machined rail section that registers with the stock rail and forms part of a switch assembly.
Switch tip	The top corner of the switch rail at its end.*
Wheelset	Two wheels mounted on the same axle.

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