Rail Accident Investigation Branch

Rail Accident Report

Fatal accident involving a train passenger near Balham
7 August 2016

Report 09/2017
May 2017

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

Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where the RAIB has described a factor as being linked to cause and the term is unqualified, this means that the RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident. However, where the RAIB is less confident about the existence of a factor, or its role in the causation of the accident, the RAIB will qualify its findings by use of the words 'probable' or 'possible', as appropriate. Where there is more than one potential explanation the RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, the words 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the event being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of the RAIB, expressed with the sole purpose of improving railway safety.

The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

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Fatal accident involving a train passenger near Balham, 7 August 2016

Contents

Summary

At about 17:24 hrs on Sunday 7 August 2016 a passenger, travelling on a Gatwick Express service from Gatwick Airport to London Victoria, suffered fatal injuries as a result of having his head out of a window and striking it on a signal gantry near Balham in south London. The train was travelling at about 61 mph (98 km/h) at the time of the accident.

The window concerned was on a door opposite a guard's compartment in the train; this door was accessible to passengers but it was not intended for passenger use. The RAIB has found no evidence to explain why the passenger put his head out of the window at that time.

The accident occurred because the passenger's head was out of the window, there was nothing to prevent passengers from opening the window or putting their head out of the opened window, and because there was less than the normal standard clearance between the train and the signal gantry. Although the clearance was compliant with standards for existing structures, it was less than an industry recommended minimum for new structures where there are trains with opening passenger windows.

An underlying cause was that the process for assessing the compatibility of this train on this route did not identify the risk of the combination of reduced structure clearances and opening windows.

The RAIB has made two recommendations and identified one learning point. One recommendation is addressed to Network Rail, and seeks to improve the industry's management of the interacting risks between infrastructure and rolling stock. The second recommendation is addressed to relevant train operators with the intention of reducing the risk from people leaning out of opening train windows.

The learning point reinforces the need for regular monitoring and management of structure clearances when those clearances are reduced from normal.

Introduction

Key definitions

1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.

2 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B. Sources of evidence used in the investigation are listed in appendix C.

The accident

Summary of the accident

3 At about 17:24 hrs on Sunday 7 August 2016, a passenger travelling on the 17:05 hrs Gatwick Express service from Gatwick Airport to London Victoria suffered fatal head injuries as a result of having his head out of a window and striking it on a signal gantry on the *cess* side of the train approaching Balham junction in south London (figure 1). The train was travelling at about 61 mph (98 km/h) at the time of the accident.

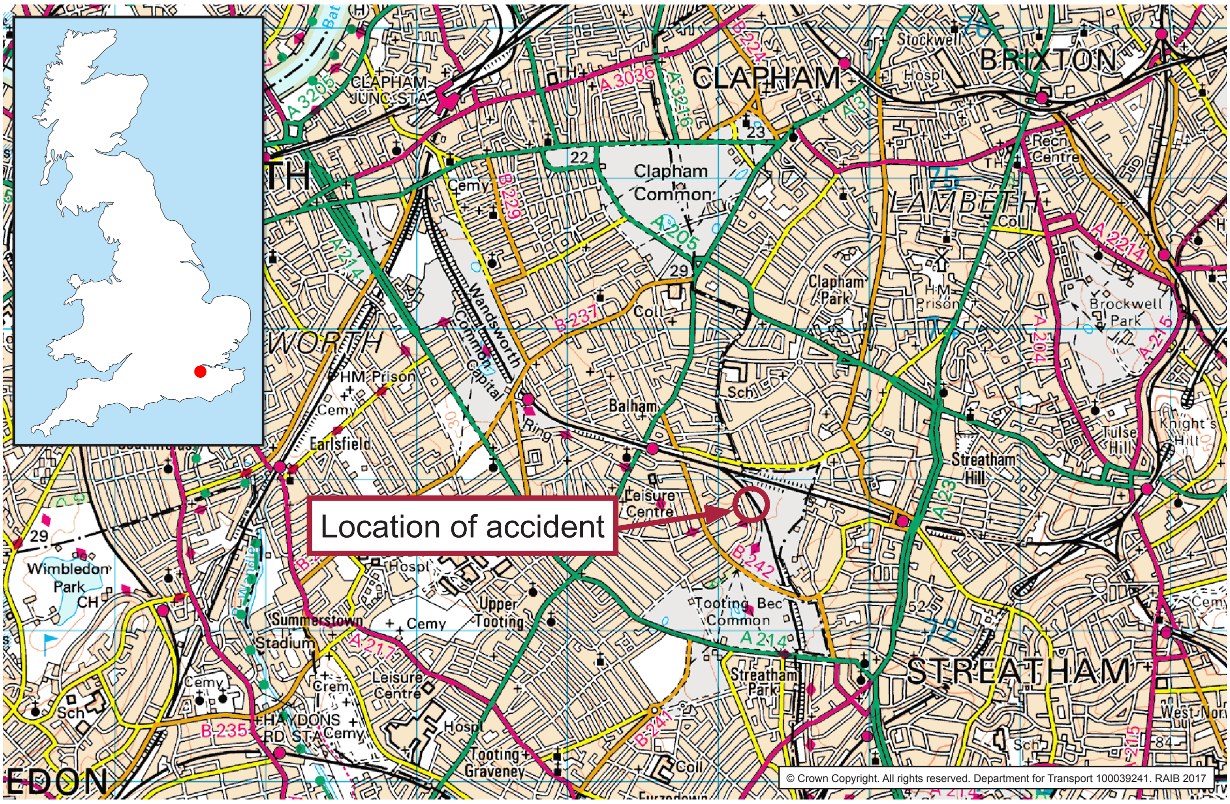

Figure 1: Extract from Ordnance Survey map showing location of accident

Context

Location

4 The signal gantry is located at around 5 miles 12 *chains*[1] on the line from London Victoria to Brighton (*engineer's line reference* at this location is VTB1). The railway at this location comprises four tracks: the *up* and *down* Brighton fast lines, and the up and down Brighton slow lines (figure 2).

5 Signalling in this area is controlled by the Victoria Area Signalling Centre (ASC).

6 The train was travelling on the up Brighton fast line. The maximum permitted speed is 70 mph (113 km/h) at this point, reducing to 60 mph (97 km/h) shortly after the signal gantry.

[1] Measured from a datum at London Victoria.

7 In the direction of travel of the train, the gantry is located on a left-hand curve with a radius of 600 m.

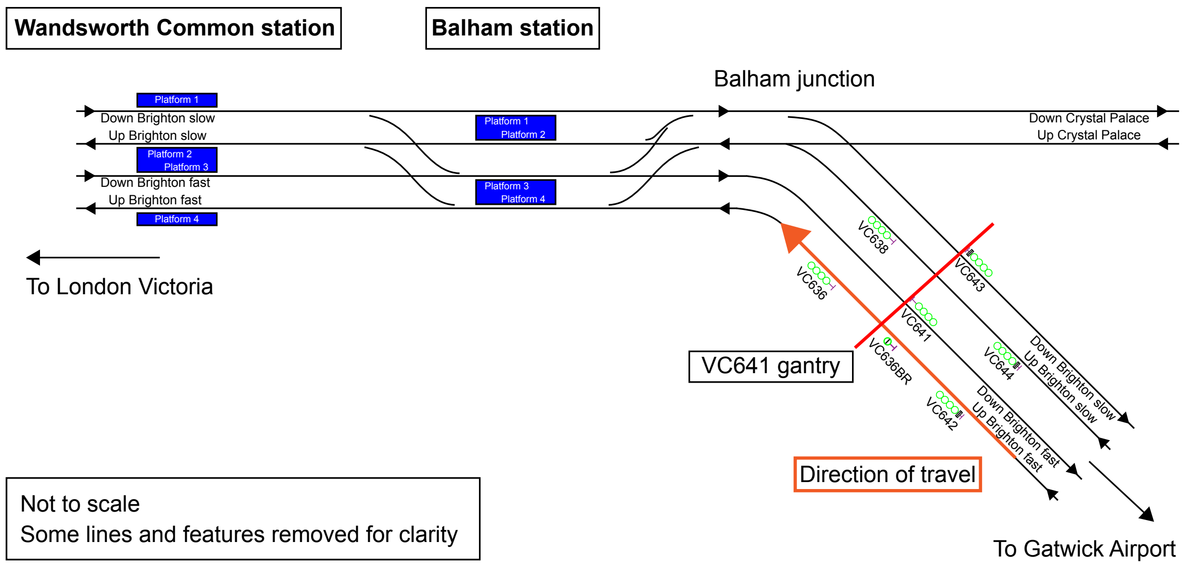

Figure 2: Schematic diagram of the track layout

Organisations involved

8 Gatwick Express is a trading name of Govia Thameslink Railway Limited (GTR), which is a subsidiary of Govia. Govia has operated the Southern franchise since August 2001 (when it was known as SouthCentral). Gatwick Express was incorporated into the Southern franchise in June 2008, and in July 2015 the franchise was merged into the GTR management contract. For consistency and unless otherwise explained, this report will refer to GTR throughout. GTR operated the train and employs the driver of the train involved in the accident.

9 Network Rail is the owner and maintainer of the infrastructure, and employs the signalling staff involved.

10 Both GTR and Network Rail freely co-operated with the investigation.

Train involved

11 The train was a Class 442 *electric multiple unit* (number 442 411) formed of five carriages. These units were used on the Gatwick Express service from December 2008 until December 2016, having replaced the Class 460 units previously used on the service. The class 442 units have now been replaced by Class 387 units (see paragraph 110).

12 Since its introduction on the Gatwick Express, the Class 442 operated as a *driver-only* service from London Victoria to Gatwick Airport (although guards[2] have been provided on other routes travelled by the Class 442 on the Southern network).

[2] This report uses 'guard' as the railway's generic term for a crew member on board a passenger train whose duties include train dispatch (ie, monitoring and closing doors). GTR uses 'conductor' as the job title for the person performing the role of the guard.

13 Each Class 442 unit comprises five carriages, and each carriage is 23 metres long (compared to 20 metres on the Class 460 and Class 387 units). The formation includes a driving cab at each end of the train and a guard's compartment at the centre of the middle carriage. This compartment separates two areas of passenger seating; a corridor running along one side of the carriage adjacent to the guard's compartment allows passengers to move between these areas (figure 3).

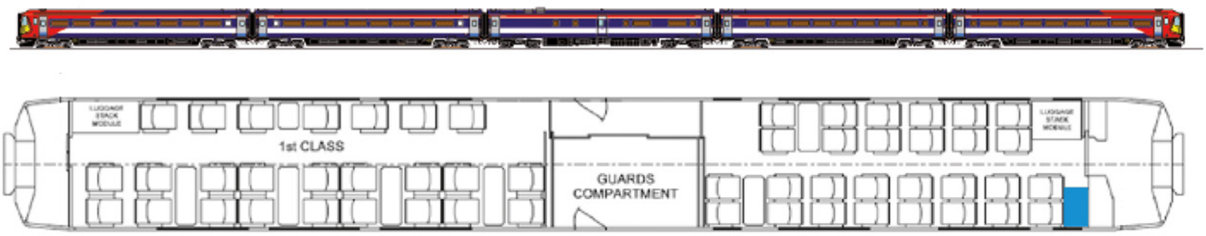

Figure 3: Layout of the Class 442 unit and detail of middle carriage (courtesy of GTR)

14 There are power-operated external doors at each end of every carriage for passengers to use when boarding and alighting the train. In addition, there are manually-operated external doors at the centre of the middle carriage intended for use only by the guard during train dispatch at stations (figure 4). One of these doors is in the guard's compartment, while the other is opposite the compartment in the connecting corridor. When not in use, these doors are locked with a *carriage key*.

Figure 4: Middle carriage of a Class 442 unit showing guard's door (NB: the yellow tape on this door reflects a post-accident modification intended to discourage passenger use of the droplight window; see paragraph 111).

15 Each passenger door has an opening *droplight* window which is usually locked with a carriage key, but can be opened to a limited extent by train crew for emergency ventilation during hot weather. The doors adjacent to the guard's compartment have fully opening droplight windows which are not lockable, so that the guard may use them during train dispatch.

Rail equipment/systems involved

16 The signal gantry is a *portal* structure spanning all four tracks of the railway (figure 5). It carries signals VC641 and VC643, which are for trains running in the down direction. The column on the up (west) side stands on the crest of a low embankment which is about 4 metres high and rises at an angle of approximately 30 degrees.

17 Evidence indicates that the gantry was installed in 1952, but no records relating to its design or installation are available.

Figure 5: Overhead view of the signal gantry (courtesy of Network Rail)

Staff involved

18 The train driver has been a railway employee since March 1980, and has been driving trains on the Southern network since October 1985. He began working the Gatwick Express service in January 2016. He was deemed to be competent in his most recent practical driving assessment before the accident, on 22 April 2016.

19 The signaller on duty at Victoria ASC at the time of the accident had 23 years' experience, and had been based at Victoria since 2002. He passed his most recent annual competence assessment on 26 October 2015.

The passenger

20 The passenger was aged 24. He lived near Three Bridges in West Sussex, and had recently started working as a commissioning engineer for a railway system supplier at North Pole depot, west London.

21 On the day of the accident, the passenger was commuting from home to work, having begun his rail journey at Three Bridges station and connected with the Gatwick Express at Gatwick Airport.

External circumstances

22 The weather was warm at the time; data from a weather station at Gatwick Airport recorded a temperature of 23°C and light cloud.

23 The RAIB found no evidence that the weather contributed to the cause of the accident (paragraph 15).

The sequence of events

24 At about 16:50 hrs, unit 442 411 arrived at Gatwick Airport platform 6, having formed the 16:15 hrs service from London Victoria. It was then due to form a non-stop service back to London, scheduled to depart at 17:05 hrs.

25 On arrival at Gatwick Airport, the droplight window on the door opposite the guard's compartment (ie in the connecting corridor (paragraph 14)) was partly lowered. Soon after the train stopped, someone already on board opened the window fully, and it was still open when the train later departed.

26 At about 16:59 hrs, the passenger boarded the train using the rear door (in the direction of travel towards London) of the third carriage.

27 The train departed for London Victoria on time at 17:05 hrs.

28 At approximately 17:24 hrs, the train passed the gantry carrying signals VC641 and VC643 at a speed of around 61 mph. The passenger's head struck the cess column of the gantry, and he fell to the floor in the connecting corridor of the carriage. Another passenger, travelling with her teenage daughter in the same carriage, became aware of what had happened and went to assist.

29 Around 25 seconds after the train passed the gantry, someone on board the train in the middle carriage operated the emergency alarm[3], which automatically applied the emergency brake on the train. The train stopped 28 seconds later, between Balham and Wandsworth Common stations.

30 When the train stopped, the driver contacted the signaller using the *GSM-R* train radio to inform him of the brake application. During this conversation, the 16-year-old daughter of the assisting passenger (paragraph 28) knocked on the cab door and requested an ambulance. The driver passed on this request for an ambulance and informed the signaller that he would investigate the situation and call him back. The driver then accompanied this passenger through the train to the scene of the accident.

31 At 17:29 hrs, the driver returned to the cab and made an urgent GSM-R call to the signaller requesting an ambulance to meet the train at Wandsworth Common, the next station on the line. The assisting passenger then helped the driver by marshalling passengers away from the scene.

32 The signaller passed the driver's message on to his signalling shift manager (SSM). At 17:30 hrs, the SSM contacted Network Rail's Rail Operating Centre (ROC) at Three Bridges to relay the request for an ambulance. A route controller at the ROC used a dedicated telephone line to call London Ambulance Service (LAS) at 17:32 hrs.

33 During this time, the train moved forward to Wandsworth Common, arriving at 17:32 hrs.

[3] The railway industry's generic term for the emergency alarm on a train is the passenger communication apparatus (PCA). For the reasons explained at paragraph 85, we have adopted the term 'emergency alarm', in line with the label on the equipment on this train.

34 Between 17:37 and 17:40 hrs, the other passengers were led off the train by the driver, station staff at Wandsworth Common and the assisting passenger (paragraph 31). They were directed to other parts of the station to await another train to London.

35 At 17:49 hrs, the first response paramedic arrived at Wandsworth Common station. At 17:58 hrs, an air ambulance landed on the Common and about a minute later, a road ambulance also arrived at the station. The ambulance staff declared the casualty to be deceased at the scene.

Key facts and analysis

Identification of the immediate cause

36 **The passenger's head struck a signal gantry**.

37 Witness marks were found on the gantry for VC641 and VC643 signals, consistent with the nature of the accident. The RAIB's analysis of these marks suggested that the passenger's head overlapped the gantry by just over 60 mm.

Identification of causal factors

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

a. the passenger's head was out of the window (paragraph 39);

b. there was nothing to prevent passengers from opening the window or putting their head out of the opened window (paragraph 42); and

c. there was less than the normal standard clearance between the structure and the train (paragraph 50).

Each of these factors is now considered in turn.

The actions of the passenger

39 **The passenger's head was out of the window**.

40 The RAIB has found no evidence to explain why the passenger put his head out of the window at that time. The train has internal CCTV covering the passenger accommodation, but when the data recording disks were downloaded after the accident, the recordings for the second, third and fourth carriages were found to be faulty[4].

41 The passenger was 1.87 m tall, while the height of the top of the window is approximately 1.63 m above the floor, meaning that he would have had to bend in order for his head to be out of the window. The post mortem report proved negative for the presence of alcohol and drugs, and the evidence suggests that he was not taking photographs.

[4] The internal CCTV is provided for passenger security and there is no requirement for operators to provide or maintain it for safety or investigation purposes. Nevertheless, such images are frequently useful during accident investigations and the RAIB observes that the malfunctioning of the CCTV in this case has prevented a deeper analysis of this causal factor.

The window

42 **There was nothing to prevent passengers from opening the window or putting their head out of the opened window**.

43 The window involved was in the door in the connecting corridor of the third carriage, opposite the guard's compartment (paragraph 14). Although this door is not intended for use by passengers, it is accessible to passengers and the window, unlike the other windows on the train, is not restricted from fully opening (paragraph 15). There was a push-bar at the top of the droplight which was designed to retain the window in the fully 'up' position, but this was faulty and when the window was pushed up, it stayed open about 28 mm. Three features of the window are explained below.

Window locks

44 When class 442 units are operated with a guard on board, the guard may use this door to carry out their train dispatch duties (paragraph 14). In that case, the guard would need to open the window in order to use the external door handle, because there is no handle on the inside of the train. For this reason, GTR did not fit these windows with locks. However, as with all Gatwick Express services, this train was operated without a guard on board (paragraph 12).

45 There is no requirement for passenger droplight windows to be locked. In April 2002, a Railway Group Standard[5] was issued which did mandate that such windows be locked, but the relevant clause was withdrawn in June 2004 after industry parties made the case that the requirement was not reasonably practicable (a significant number of passenger trains in the UK have unlocked droplight windows; see paragraph 115).

Window bars

46 Window bars have been fitted to some older types of train (*Mark 1* and *Mark 2 stock*) with similar droplight windows, on various lines where restricted clearances existed. Window bars and droplights with restricted opening were fitted to trains used on the Uckfield and East Grinstead branches in the 1980s, following track upgrades in Surrey that identified reduced clearance for trains passing through Oxted tunnel.

47 Following two fatalities involving passengers leaning out of train windows in 1999 and 2002 (see paragraphs 99 and 100) the operator of the South Central franchise at the time was required to review its risk assessments and control measures to address this risk. The response from the operator was to fit window bars and droplights with restricted opening to its remaining Mark 1 stock, provide new warning signs and on-train announcements, and ultimately replace all its Mark 1 stock with newer trains by the end of 2004.

48 Window bars were not fitted or modifications made to droplight windows designed to be used by the guard because these windows were used for train dispatch purposes, as described in paragraph 44.

[5] GM/RT2456 issue two (April 2002), 'Structural requirements for windscreens and windows on railway vehicles'.

Warning signs

49 There is a yellow warning sticker on the door above the window stating, 'Emergency ventilation. Do not lean out of window when train is moving' (figure 6). The RAIB observed that the warning about leaning out of the window was secondary to the wording about emergency ventilation; moreover, this sticker exists in a cluttered environment of other warning and information signs. One of these signs, which is more prominent than the warning sticker, provides instructions on opening the door (including lowering the window to access the exterior door handle), despite the fact that this door is not intended for passenger use. Although there is a notice on the outside of the carriage that this door is 'not for passenger use', there is no such notice on the inside. It is not possible to say whether the lack of conspicuity of the warning notice was a factor in the accident at Balham, although the passenger was an experienced railway employee (paragraph 20), who was accustomed to trains with windows of this type.

Figure 6: Warning signage above the window

Clearance to the structure

50 **There was less than the normal standard clearance between the structure and the train.**

Background

51 The fundamental principle used for defining and maintaining clearances between trains and infrastructure is that there should be adequate clearance to ensure safe passage. In other words, the primary objective is to prevent collisions between trains and structures. This principle is reflected in guidance[6] published by the predecessors of the Office of Rail and Road (ORR) as well as the current Railway Group Standard[7] on this issue.

52 Railway Group Standard GI/RT7073 defines additional minimum requirements for clearances at window level, to cater for trains with opening windows. These requirements are for 450 mm *dynamic clearance* if there are opening windows that allow passengers to lean out, or 250 mm where there are opening windows for the use of train crew. These values have been present in standards and guidance dating back to at least 1996[8], but they only apply to new and altered infrastructure, and the current standards do not require these additional clearance values to be maintained (see paragraph 54).

53 At the time that the gantry was installed (paragraph 17), Ministry of Transport requirements[9] specified a minimum *static clearance* of 610 mm to signal posts. However, Network Rail has been unable to supply original design specifications for the gantry to determine whether it was compliant with these requirements at the time of installation.

54 Clearances to existing structures are managed according to the process set out in GI/RT7073. For the upper part of the train (including the window area), the standard categorises ‘normal’ clearances to the *swept envelope* as 100 mm or above; clearances less than 100 mm but greater than 49 mm are defined as ‘reduced’, while a clearance greater than 0 mm up to 49 mm is defined as ‘special reduced’. Reduced and special reduced clearances are permissible but are subject to additional control measures (based on risk assessments). By implication, clearances less than or equal to 0 mm (ie, the structure is potentially *foul* and there is a risk of trains striking the structure) are not compliant with the standard.

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[6] Railway Safety Principles and Guidance part 1 (1996). HSE Books.

[7] GI/RT7073 issue one (December 2015), ‘Requirements for the Position of Infrastructure and for Defining and Maintaining Clearances’.

[8] Railway Safety Principles and Guidance part 2, section A: Guidance on the Infrastructure (HS(G)153/2, 1996). HSE Books.

[9] Ministry of Transport (1950). Requirements for Passenger Lines and Recommendations for Goods Lines of the Minister of Transport in regard to Railway Construction and Operation. London: Her Majesty’s Stationery Office.

55 Network Rail's implementation of this standard is through its own company standards[10], which interpret the additional control measures for reduced and special reduced clearances as an increased frequency of survey monitoring at those structures. Such monitoring may be achieved by using the *structure gauging train* (which the standard states should be carried out every year, or at a maximum every two years) or by taking manual measurements (every 26 weeks or a maximum of every 60 weeks).

56 Clearances are calculated by comparing the results of structure surveys (such as those using the structure gauging train) with a computerised model of a given vehicle's swept envelope, with associated worst case tolerances. Because of these tolerances the vehicle model is defined to a given probability (whereby the swept envelope covers more than 98% of cases) and, as such, the calculations represent a nominal value of clearance. A calculated clearance of less than or equal to 0 mm is outside the scope of Railway Group Standards and indicates an 'unacceptable probability' of a vehicle colliding with the structure[11] (although the actual clearance will probably be greater than this calculated value because of the way the model of the swept envelope is calculated[12]). Network Rail's standard categorises these values as 'anomaly' clearances which should be restored to normal (where practical, otherwise to 'reduced' clearance). The restoration should take place within 12 months unless the anomaly pre-dates January 2009, in which case it should be restored at the next track renewal.

57 When a structure is identified with reduced clearance or less, Network Rail's local *Track Maintenance Engineer* (TME) carries out additional manual monitoring at the structure, in accordance with the processes described in paragraph 55. This involves measuring the lateral distance at rail level, from the *running edge* of the nearest rail to a datum point on the structure. The objective of this monitoring is primarily to ensure that lateral clearance is not reducing further; it takes little account of the type of train running on the line or the effect of *cant* or curvature of the track on clearances at window level. If the measurements reveal that clearance is reducing, then track work may be planned to restore clearance, although there is no objective threshold to trigger such work.

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[10] NR/L2/TRK/3201 issue 3 (4 December 2010), 'Management of Tight Clearances and Track Position'; NR/L2/TRK/3203 issue 1 (3 September 2011), 'Structure gauge recording'.

[11] Network Rail has not been able to provide RAIB with figures for the probability of collision between a vehicle and a structure where the calculated clearance is negative, or information on how the acceptability of this figure has been determined.

[12] Further information on this topic can be found in 'Assessing the impact of risk on gauging practice' by C Davenport, N Barker & C Lewis (IMechE, Proceedings of the Stephenson Conference, London , 2017).

58 Network Rail's current standard for new signalling installations[13] states that the distance from a structure to the nearest running edge of a rail should not normally be less than 1624 mm, with an absolute minimum of 1364 mm. This reflects long-standing railway guidance[14]. The standard also provides data for calculating additional allowances taking account of track cant and *overthrow* on curves. For a 600 m radius curve, the additional allowance is 43 mm. However, the RAIB determined that these data were based on a 20-metre vehicle; for a 23-metre vehicle (such as the Class 442), the allowance should be 55 mm. The equivalent minimum distance would be 1419 mm, while the recommended distance would be 1679 mm.

Clearance to gantry VC641/VC643

(a) clearance at window level

59 Prior to the accident on 7 August 2016, the most recent survey of the gantry by the structure gauging train was on 15 May 2015. Taking into account the full swept envelope of a Class 442 unit, this survey found that the smallest dynamic clearance from the window (measured at the top of the window) was 68 mm, while the static clearance was 209 mm. After the accident, the RAIB measured the static clearance at the impact point (which was about one-third of the way down the window) to be 260 mm (figure 7). Given the differences in measurement points and statistical variation in gauging surveys, these values are broadly consistent with each other.

Figure 7: Static clearance to the gantry from the droplight window

[13] NR/L3/SIG/11303/2G05 issue 5 (3 December 2016), Signalling Installations Module 'Locations: Construction'.

[14] Railway Safety Principles and Guidance part 2, section A: Guidance on the Infrastructure (HS(G)153/2, 1996). HSE Books.

60 The oldest figure that Network Rail has for the dynamic clearance to the gantry at the upper end of train window level was recorded in January 2001, when there was a positive clearance of 160 mm at the top of the window, which is in the ‘normal’ band. Later surveys by the structure gauging train in December 2008, February 2011 and January 2015 found that clearance to the gantry was in the ‘anomaly’ band, with negative values of -38 mm, -90 mm and -55 mm respectively. Despite these negative values, there is no evidence that passenger trains were making contact with the structure. Track work carried out on 3 February 2015 restored the clearance to the positive value reported above (paragraph 59).

61 The RAIB observed that the frequency of surveys carried out by the structure gauging train did not meet the requirements of Network Rail’s standards (paragraph 55). However, during the period Network Rail had authorised a temporary variation against this requirement, dated 20 August 2015, due to problems with availability of the structure gauging train. The variation was authorised until 1 August 2016, by which time Network Rail expected a second structure gauging train to be delivered.

(b) clearance at rail level

62 The most recent manual monitoring before the accident took place on 19 April 2016 and measured the lateral distance between the base of the gantry and the nearest rail at 1232 mm. This is the largest recorded clearance in measurements dating back to 26 January 2012 (although the datum point has changed in that time, so the measurements are not directly comparable), but it is still less than the minimum recommended in Network Rail’s standard for new signalling installations (paragraph 58).

63 Manual monitoring surveys prior to 19 April 2016 are detailed in figure 8. Across these measurements, the minimum recorded distance was 1102 mm on 26 January 2012. *Tamping* work was carried out on three further occasions after this, with the effect of increasing the distance to 1232 mm (paragraph 62).

64 The RAIB observed that, although the frequency of manual monitoring was within the maximum 60-week interval specified by Network Rail’s standard (paragraph 55), it did not meet the nominal 26-week frequency recommended by that standard.

65 As well as lateral distance, the manual measurements also record track *cant*. These data show that, as well as the changes in lateral distance described above (paragraphs 62 and 63), track cant at this location also increases over time[15] (figure 8). The minimum value of cant, recorded on 26 January 2012 following the tamping work, was 100 mm; the maximum value (on 6 June 2014) was 122 mm, which was followed by tamping work (paragraph 63). The tamping work aimed to restore cant to a target value of 105 mm.

[15] This may be due to the track gradually slipping down the embankment (paragraph 16). Although Network Rail reported that there are no known earthworks problems in the area, many of the tamping records refer to problems with retaining the ballast on the track.

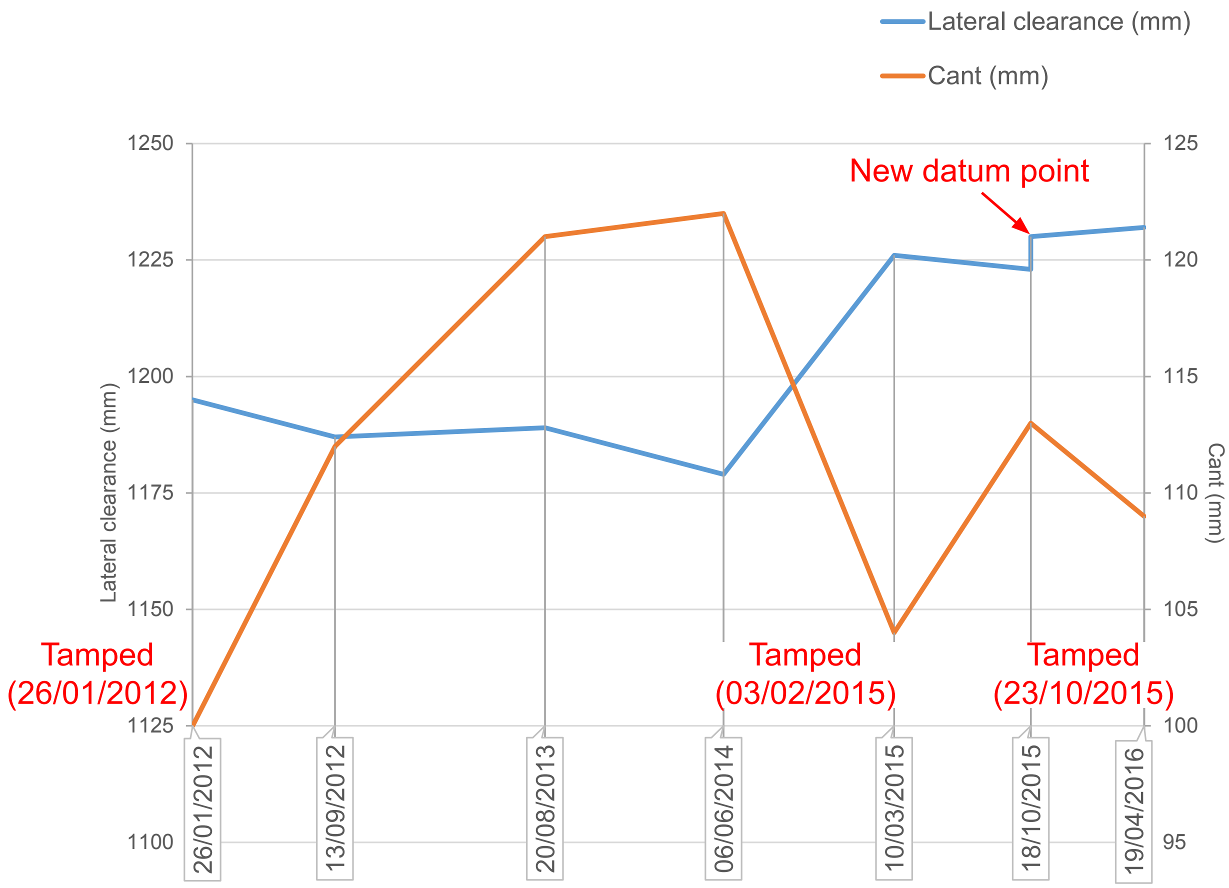

Figure 8: Graph of the lateral clearance and cant measurements since 2012

66 For a stationary train (ie considering static clearance), track cant will have the effect of tilting the top of the train towards the structure. However, when it is moving (considering dynamic clearance) the train will normally tend to sway away from the structure as it traverses the curve at speed. The *equilibrium cant* for a curve of 600 m radius at a speed of 60 mph (97 km/h) is 185 mm. Because the actual applied cant is less than this, a train travelling at 60 mph (97 km/h) will lean further away from the structure than a stationary train.

67 The effects of cant on clearance are not trivial; data in Network Rail's standard (paragraph 58) show that each 10 mm increase in cant requires an additional lateral clearance of approximately 32 mm to cater for slow or stationary trains leaning towards the structure.

68 The RAIB's site inspection found that the gantry column on the up side of the track leans inwards (towards the track) by two degrees. This results in a further reduction in clearance of about 105 mm at the top of the window.

69 Taking all of these data together, the RAIB calculated the theoretical static clearance at window level for a 23-metre vehicle, based on the manual measurements. On 19 April 2016, the last monitoring survey before the accident, the clearance at the top of the window would have been 192 mm. This corresponds reasonably well with the measured static clearance value of 209 mm reported in paragraph 59. The lowest calculated clearance arises from the measurements on 6 June 2014, which results in a clearance value of 111 mm for the top of the window.

70 Since the accident, further manual measurements were taken on 15 September 2016, 15 December 2016 and 23 March 2017 (see paragraph 112). The most recent of these recorded a lateral distance to the nearest rail of 1210 mm and a cant value of 126 mm. Applying the same calculations, these figures would equate to a static clearance of 134 mm at the top of the window.

71 Network Rail stated that its risk management at this gantry was partly based on the assertion that there had been no vehicle impacts with the structure, despite surveys indicating negative clearance values for several years (paragraph 60). However, the RAIB observed witness marks on the structure indicative of a previous impact with the column (figure 9). Photographic records from Network Rail's structure examinations suggest that this impact occurred between April 2011 and April 2013, a period during which the surveyed clearance to the gantry was at its smallest and when track maintenance work took place to restore the clearance (paragraphs 60 and 63). However, there is no record of a vehicle striking the gantry, and so the RAIB cannot be certain about what caused the marks.

Figure 9: Witness marks (highlighted) on the gantry indicative of an earlier vehicle impact

Other structures

72 The signal gantry falls in the Croydon North area for track maintenance, which covers London Victoria to Merstham and includes about 40 miles (64 km) of route. Network Rail's database for structures in this area contains nearly 3000 records, of which 11% (324) are categorised as less than 'normal' in terms of clearance (measured against all trains that use the area), 5.4% (161) are 'reduced' or 'special reduced', while 5.5% (163) are in the 'anomaly' band. Many of these structures are clearly identifiable as being in the lower sector of a train's swept envelope (such as platforms and underline bridges); filtering these out leaves 4% (118) structures with less than 'normal' clearances, with 1.5% (45) categorised as 'anomaly'[16].

73 A research project[17] commissioned by RSSB[18] reviewed structure clearances on the national suburban rail network with the aim of developing a standardised *vehicle gauge* for future use. This study identified 175 structures (excluding platforms and underline bridges) that were foul of the swept envelope. Although most of these could be accounted for by measurement error or other surveying issues, the report found 23 structures (including VC641/VC643 gantry) that could not be ruled out and were therefore deemed to be restrictions to the proposed standard vehicle gauge.

Identification of underlying factors

The route compatibility assessment process

74 **The process for assessing the compatibility of this train onto this route did not manage the risk of the combination of reduced structure clearances and opening windows**.

Background

75 The process for assessing the compatibility of a given train with a particular route is set out in Railway Group Standards. As with the standards for maintaining clearance (paragraph 51), one purpose of these standards is to ensure clearances are sufficient to avoid the risk of collisions between trains and infrastructure.

76 The current standard[19] states that it is the train operator's responsibility to demonstrate compatibility of the train with the route (which includes clearance to infrastructure). The infrastructure manager (Network Rail) then considers the train operator's proposal and, if it is in agreement, produces a certificate of authority[20] to operate. This certificate may include additional controls (such as speed restrictions or monitoring for reduced clearances).

[16] Many permanent railway structures (such as bridges and tunnels) were built in the nineteenth century and hence pre-date modern clearance requirements. This is likely to account for a significant proportion of the 'reduced' and 'anomaly' clearances described in paragraphs 72 and 73.

[17] 'Development of a Suburban vehicle gauge: Concluding report'. Research project T978, published July 2013.

[18] A not-for-profit company owned and funded by major stakeholders in the railway industry, and which provides support and facilitation for a wide range of cross-industry activities. The company is registered as 'Rail Safety and Standards Board', but trades as 'RSSB'.

[19] GE/RT8270 issue three (December 2015), 'Assessment of Route Compatibility of Vehicles and Infrastructure'.

[20] This term has been replaced by 'Statement of Compatibility' in the latest issue of the standard.

77 Meanwhile, Railway Group Standard GI/RT7073 (issue 1) mandates that, for existing infrastructure, Network Rail provides train operators with information on locations with reduced clearances, and the vehicles to which they apply. However, this standard sets out requirements for maintaining gauge clearances; there is no requirement for Network Rail to provide such information during the route compatibility assessment process.

78 The current process is much the same as that described in historical standards which were in force when the Class 442 units were introduced onto the London Victoria to Gatwick route (see paragraph 79). However, one such standard[21] states that the train operator shall obtain from the infrastructure controller appropriate data defining the routes for which acceptance is required, including any specific restrictions due to infrastructure or vehicles. This specific requirement does not appear in the current version[22] of the same standard.

Class 442 compatibility with the London Victoria to Gatwick Airport route

79 Class 442 trains have been running in passenger service on the London Victoria to Gatwick route since 10 November 2008. The current certificate of authority to operate Class 442s covers several other lines served by the Southern franchise, a small number of which have speed or access restrictions as a result of gauge clearance issues (albeit with platforms or other trains, rather than structures). However, there are no such restrictions on the VTB1 line through Balham.

80 Network Rail's certificate of authority states that it will discuss with the train operator any long-term maintenance issues with the potential to affect compatibility, and they shall agree the actions to be taken. GTR stated that it had no knowledge of any issues with clearance at the gantry, nor did it have any information regarding reduced clearances to structures other than a list of bridges and tunnels provided as a result of the Clayton Tunnel accident (see paragraph 100).

81 Network Rail told the RAIB that its survey data on structure gauging is widely available to train operators, but that its clearance data (based on the swept envelopes for specific vehicle types) is not routinely provided, even though Network Rail collates such data for its own purposes.

82 The certificate of authority references a list of emails amongst the principal documentation upon which the compatibility assessment is based. Network Rail has retrieved some of these emails from its archives and, although there is evidence that clearance concerns were considered for other routes operated by Class 442 trains (paragraph 79), there is no evidence of any such discussion for the VTB1 line.

83 In any case, Network Rail's responsibility is only to provide and maintain positive clearances (paragraph 54). A risk assessment for window clearances would not have been carried out unless it had been undertaken by the operator during the route compatibility process.

[21] GM/RT2149 issue three (February 2003), 'Requirements for Defining and Maintaining the Size of Railway Vehicles'. Superseded by GM/RT2173 on 5 March 2016.

[22] GM/RT2173 issue one (December 2015), 'Requirements for the Size of Vehicles and Position of Equipment'.

84 GTR's safety case for Class 442 route compatibility, initially for the London to Gatwick route (but since extended elsewhere; paragraph 79), was based partly on successful trial runs with empty trains, partly on the previous 17-year history of these units running on the Wessex route, and partly on the fact that Class 442s were already listed in the *Sectional Appendix* as being cleared for this route. Structure clearances were considered, but only in respect of vehicle impacts with structures; the risk of passengers leaning out of windows was not recognised or identified in the safety case.

Management of the aftermath

Passenger communication apparatus (PCA)

85 **The train was not fitted with an emergency brake override or two-way voice communication facility as part of the emergency alarm**.

86 The Railway Group Standard for driver only operation[23], which was in force during the route compatibility assessment process for the Class 442, required that operation of the passenger communication apparatus (PCA) on a driver only train shall allow the train to be driven to a suitable place where the emergency can be dealt with, and should also permit two-way voice communication between the train driver and the person at the location of the alarm.

87 The emergency alarm on the Class 442 Gatwick Express units (figure 10) did not have an emergency brake override facility, nor did the alarm system allow voice communication between the driver and the passenger who operated the alarm. This meant that, when a person on board operated the emergency alarm (paragraph 29), the train was unavoidably brought to a standstill (rather than, for instance, being driven directly on to a suitable station). Furthermore, the daughter of the assisting passenger had to walk to the front of the train to communicate directly with the driver (paragraph 30).

88 The railway Rule Book[24] states that, if a PCA is operated, the driver must, if possible, avoid stopping in unsuitable locations such as tunnels or viaducts. However, the driver must stop the train immediately if they believe the train may be in danger, or if the PCA is operated as the train is leaving a station.

89 On 13 February 2007, GTR applied for a *derogation* against the standard requirement for Gatwick Express on the basis that the Class 442 units were needed as contingency against reduced availability of existing Class 460 Gatwick Express units, which were due to undergo a significant maintenance programme (although in fact they never came back into service on Gatwick Express). The justification given for the derogation was that a modification of the PCA system to make it compliant with the standard was not reasonably practicable. GTR told the RAIB that it considered the derogation to be permanent, despite the application implying a temporary situation pending the maintenance of its existing Gatwick Express fleet (the Gatwick Express service has since been provided exclusively by Class 442s; see paragraph 11).

[23] GO/RT3271 issue one (April 1999), 'Driver Only Operation'.

[24] GE/RT8000-TW1 issue 11 (September 2016), 'Preparation and movement of trains'.

Figure 10: Emergency alarm on the Class 442 unit

90 RSSB granted the derogation on 4 April 2007, with the foreknowledge that the requirement was soon to be withdrawn. GO/RT3271 was withdrawn on 5 April 2008 as part of a review of Railway Group Standards, because the requirements were applicable only to single duty holders[25] and therefore out of scope for Railway Group Standards. An equivalent requirement for the PCA facility now exists in EU standards[26], but these are only applicable to new trains.

The emergency response

91 **There were avoidable delays in the arrival of emergency services at the scene**.

92 As soon as the train had been stopped by operation of the PCA, the driver contacted the signaller at Victoria ASC to report what had happened and, after speaking to the daughter of the assisting passenger (paragraph 30), requested an ambulance. As soon as the driver had investigated the situation himself, he made an urgent GSM-R call to the signaller requesting an ambulance to meet the train at Wandsworth Common (paragraph 31).

93 The signaller relayed the request to his SSM, who in turn passed the message on to the ROC at Three Bridges. By this time, the train had arrived at Wandsworth Common station and the driver began guiding passengers off the train with the assistance of a passenger and station staff.

[25] The scope of Railway Group Standards covers areas where there is an interface between duty holders (eg, the infrastructure owner and a train operator). Where an issue applies only to one duty holder, it will be covered in that company's standards.

[26] Commission Regulation (EU) No 1302/2014 of 18 November 2014 concerning a technical specification for interoperability relating to the 'rolling stock – locomotives and passenger rolling stock' subsystem of the rail system in the European Union.

94 The railway Rule Book module[27] covering train accidents states that the signaller must '…arrange for the emergency services to be called if they are needed'. The signaller and SSM complied with this rule, and with standard practice at Area Signalling Centres, by asking the ROC to call for an ambulance.

95 The ROC's telephone system has two dedicated lines to contact London Ambulance Service – one for emergencies, and one for non-emergencies. A route controller at the ROC used the emergency line to request an ambulance to Wandsworth Common station, but this call was routed to a non-emergency call handler's desk at LAS. Investigation after the accident found that the two telephone lines had been incorrectly connected at the ROC, meaning that the emergency line was directed to the non-emergency number, and vice-versa. This problem was found on one route controller's desk only; all other telephone lines were correctly configured.

96 The LAS call handler was not prepared for an emergency call and consequently took seven minutes to classify the call and dispatch a first responder. However, the call was correctly classified as 'immediately life-threatening' and a paramedic was dispatched at 17:39 hrs. The paramedic's navigation system initially took them to the wrong side of Wandsworth Common station, meaning that they arrived on scene at 17:49 hrs, about 25 minutes after the accident occurred.

97 LAS target response times for calls categorised as life-threatening are for 75% of such calls to be responded to within 8 minutes, and 95% within 19 minutes. Statistics for Wandsworth in August 2016 show that 76% of these calls were responded to within 8 minutes. On this occasion, from the time the call was made from the ROC, the response time was 17 minutes.

98 According to the ambulance staff's report, the injuries suffered by the casualty were such that earlier arrival of the ambulance would not have changed the outcome. However, the chain of communication, and in particular the incorrect telephone connection at the ROC, introduced a delay that could have proved critical under different circumstances. From the time of the driver's original request for an ambulance, ten minutes elapsed before a paramedic was dispatched – three minutes for the message to go from driver to signaller, from signaller to SSM, from SSM to ROC and from ROC to LAS, and seven minutes for the non-emergency call handler at LAS to dispatch the paramedic.

Previous occurrences of a similar character

99 On 9 December 1999, a 35-year-old passenger was fatally injured after leaning out of a droplight window and striking his head on scaffolding at Denmark Hill, south-east London. The scaffolding had been erected four days earlier in connection with repair work to a retaining wall by a contractor. The investigation found that the base of the scaffolding was 810mm from the nearest rail, rather than the required 1364 mm, meaning that static clearance to the train was less than 100 mm. Subsequently, the train operator (Connex) risk assessed its routes, after which window bars were fitted to trains using Shakespeare Tunnel near Dover.

[27] GE/RT8000-M1 issue 4 (September 2016), 'Dealing with a train accident or train evacuation'.

100 On 26 October 2002, a passenger died after leaning out of a droplight window and striking his head on the portal of Clayton Tunnel, West Sussex. The subsequent investigation found that clearance to the tunnel was 150 mm, while 94 fixed structures (bridges and tunnels) in the Sussex area had clearances less than 200 mm (none of which were on the VTB1 line).

101 Data from RSSB's *safety management information system* (SMIS) going back to the year 2000 revealed 26 other injury accidents involving passengers being struck while leaning from a moving train. Five of these involved infrastructure (one of which was a major injury and occurred on London Underground), 12 involved vegetation (one major injury), three involved other trains (one major), while the remainder (including one major injury) were grit or other objects. Geographic information was not recorded in the database for many of these incidents, so it was not meaningful to conduct an analysis by location.

Summary of conclusions

Immediate cause

102 The passenger's head struck a signal gantry (paragraph 36).

Causal factors

103 The causal factors were:

a. The passenger's head was out of the window (paragraph 39, no recommendation).

b. There was nothing to prevent passengers from opening the window or putting their head out of the opened window (paragraph 42, **Recommendation 2** and see paragraph 111).

c. There was less than the normal standard clearance between the structure and the train (paragraph 50, see paragraph 117).

Underlying factor

104 The process for assessing the compatibility of this train onto this route did not manage the risk of the combination of reduced structure clearances and opening windows (paragraph 74, **Recommendation 1**).

Management of the aftermath

105 Factors related to the aftermath of the event were as follows:

a. The train was not fitted with an emergency brake override or passenger communication facility (paragraph 85, no recommendation).

b. There were avoidable delays in the arrival of emergency services at the scene (paragraph 91, see paragraph 112).

Previous RAIB recommendations relevant to this investigation

106 The following recommendation, which was made by the RAIB as a result of a previous investigation, has relevance to this investigation.

Accident at Moston, Manchester, 28 January 2015, Recommendation 2

107 Recommendation 2 of this report (RAIB report 17/2015) read as follows:

Recommendation 2

Network Rail should review and improve its process for managing clearances at platforms so that:

- *it provides an effective means for identifying long term adverse movement trends, including an effective means of comparing movement data with any relevant datum information; and*
- *documentation directly related to managing clearances is more clearly presented.*

108 On 6 October 2016, the ORR reported to the RAIB that this recommendation was in the process of being implemented, albeit by alternative means than suggested in the RAIB's recommendation.

109 Recommendation 2 specifically referred to platforms, which are treated as lower sector objects in Network Rail's processes and hence are subject to a slightly different regime from upper sector structures such as signal gantries. Because of the need to maintain clearance while also minimising platform edge gaps at stations, platforms are a greater focus of attention within Network Rail than upper sector structures. Nevertheless, the recommendation addresses long term management and monitoring of clearance, which was a factor in this accident (paragraph 50).

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

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

110 Since the accident, GTR has withdrawn its Class 442 units, in line with a fleet renewal programme that it already had in place. By December 2016, Class 387 trains (which do not have opening passenger windows) replaced the Class 442 on all of the Gatwick Express services. Six Class 442 units remained in service with GTR on routes to Brighton and Eastbourne, until 10 March 2017 when these too were withdrawn. It is likely that, following refurbishment, the class 442 units will be returning to service on the Wessex route. The new operator of these trains will be responsible for carrying out a risk assessment before they enter service. This assessment will need to include the issues of opening windows, the absence of passenger communication equipment and the driver's ability to override a passenger emergency brake application.

111 After the accident, GTR implemented an interim measure of marking the corridor droplight window with yellow hazard tape, in order to deter its use by passengers (figure 11). The company then consulted with its health and safety representatives and, after agreeing that there was no requirement for guards to lean out of the window for train dispatch purposes, fitted window bars to its remaining Class 442 units (figure 12). This was completed by mid-December 2016.

112 Network Rail has reconfigured the emergency and non-emergency telephone lines at Three Bridges ROC so that these lines were correctly connected, and has taken action to check the programming of all other emergency phone lines at its control centres (paragraph 95).

Figure 11: Class 442 unit with hazard tape applied to guard's droplight window

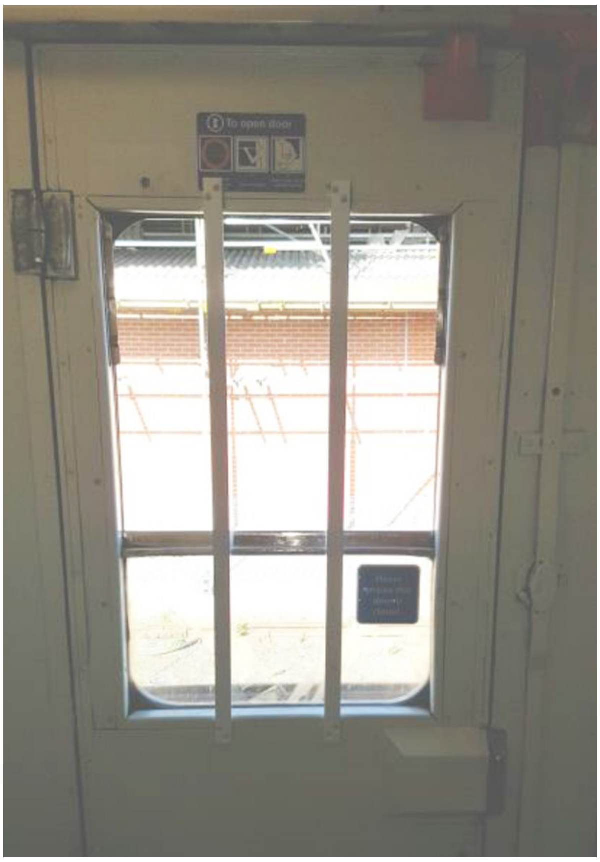

Figure 12: Class 442 corridor droplight window with bars fitted (image courtesy of ORR)

Other reported actions

113 On 15 September 2016, Network Rail's local track maintenance section conducted its first routine manual monitoring of the gantry since the accident. This found that the lateral clearance had reduced by 12 mm; as a result, the TME increased the monitoring frequency from 6-monthly to 3-monthly.

114 Network Rail also fitted a *datum plate* to the gantry during the monitoring work on 15 September 2016, as the structure previously did not have one fitted. Network Rail's standard NR/L2/TRK/3201 states that datum plates shall be provided on all structures with tight (ie reduced) clearances.

Background to the RAIB's recommendations

115 The majority of trains currently running on the British national rail network do not have droplight windows, but there is still a significant number of vehicles with unbarred opening droplight windows. These include the fleet of High Speed Train (HST) sets, running primarily on the Great Western, Midland and East Coast Main Lines, and the *Mark 3* coaches used on the Great Eastern Main Line and the Caledonian Sleeper service. On these trains, passengers must open the droplight window when alighting to enable them to reach out and open the door with an external handle (the doors are centrally locked when the train is moving). Network Rail uses the same regime for management of clearances (paragraph 55) on these routes as it does elsewhere. In addition, there are several heritage and charter train operators who use older types of train with opening windows. These operators make on-train announcements and deploy stewards in vestibules to deter passengers from leaning out of windows. Notwithstanding the risks to passengers, there are occasions when train staff need to lean out of droplight windows. The RAIB is making recommendation 2 to all train operators who still have trains with droplight windows in their fleets.

Recommendations and learning point

Recommendations

116 The following recommendations are made[28]:

1 *The intent of this recommendation is to improve the industry's management of the interacting risks between infrastructure and rolling stock on the route.*

Network Rail, in collaboration with operators of trains, should introduce a process to implement the sharing of data regarding clearances between structures and trains at window height with train operators, so that operators can make more informed decisions about the management of risk associated with opening windows (paragraph 104).

2 *The intent of this recommendation is to reduce the risk of injury at open train windows.*

Operators of trains which include rolling stock with droplight windows should assess the risk arising from reduced clearance outside those windows and implement any reasonably practicable measures to mitigate it. The review should be informed by obtaining from Network Rail the data referred to in recommendation 1, and include consideration of means of preventing people from leaning out of windows and/or improving warning signage. These measures should address the risks to both passengers and staff (paragraph 103b).

[28] Those identified in the recommendations have a general and ongoing obligation to comply with health and safety legislation, and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail and Road to enable it to carry out its duties under regulation 12(2) to:

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

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 200 to 203) can be found on RAIB's website www.gov.uk/raib.

Learning point

117 The RAIB has identified the following key learning point[29]:

1 This accident demonstrates the importance of regular monitoring and management of the structure gauge when clearances are reduced from normal, in accordance with Network Rail's standards. Where these surveys are made at rail level, the clearance in the upper sector should be explicitly considered, taking into account cant and curvature of the track, as well as any overhang of the structure and overthrow of the vehicle.

[29] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

Appendices

Appendix A - Glossary of abbreviations and acronyms

ASC	Area signalling centre
GSM-R	Global System for Mobile Communications – Railway
GTR	Govia Thameslink Railway
LAS	London Ambulance Service
ORR	Office of Rail and Road
PCA	Passenger communication apparatus
ROC	Rail operating centre
SMIS	Safety management information system
SSM	Signalling shift manager
TME	Track maintenance engineer

Appendix B - Glossary of terms

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

Cant	The designed amount by which one rail of a curved track is raised above the other rail.*
Carriage key	A simple key used to operate the secondary locks fitted to coach doors and some other access panels on locomotives and rolling stock.*
Cess	The area along the edge of the outermost railway track(s).
Chain	An imperial unit of length equal to 22 yards. There are 80 chains in a mile.
Datum plate	An approved marker, fixed to a structure, which both provides the datum for, and records, offset data to the adjacent track (from NR/L2/TRK/3201 issue 3).
Derogation	A formal relaxation of a particular requirement for a particular situation. Derogations apply forever, unless superseded.*
Down	In a direction away from London.
Driver-only	Operation of trains by the driver, dispensing with the need for a guard. The driver is assisted in closing the doors by mirrors or CCTV equipment on the platform that allow rearward vision down the train.*
Droplight	A window that opens by sliding downwards, common on doors of older types of train ('slam door' stock).
Dynamic clearance	In this report, the minimum calculated distance between the swept envelope of a vehicle and fixed infrastructure.
Electric multiple unit	An electric train consisting of two or more carriages, with driving cabs at each end, which can be coupled to other units and operated as a single train.
Engineer's line reference	A three or four character identification code used to specify a route or section of a route.*
Equilibrium cant	The value of cant that creates an equal loading on each rail at a particular speed of train.*
Foul	Describing a rail vehicle, object or structure that is infringing the swept envelope of vehicles passing on an adjacent line.*
GSM-R	A national radio system which provides secure voice mobile communications between trains and signallers.
Mark 1 stock / Mark 2 stock / Mark 3 stock	The original British Rail passenger coach models design dating from the 1950s, and its successor designs used from the 1960s and 1970s.

Overthrow	A geometric projection of a vehicle when on curved track (from GI/RT7073 issue one).
Passenger communication apparatus	Equipment provided on trains for use by passengers or others to stop trains in an emergency. EU standards mandate that such equipment shall allow the driver to override the emergency brake application (unless already in a station) and, for driver-only operation, shall allow a communication link between the driver's cab and the place where the alarm was triggered.
Portal	A goalpost shaped structure upon which the signals are mounted.
Running edge	The top corner of the rail surface on which the wheels run.
Safety management information system	A database of incidents occurring on the national railway network, managed on behalf of the railway industry by the RSSB.
Sectional Appendix	A publication produced by Network Rail containing layout and location details for each route, including route clearance for rolling stock.
Static clearance	In this report, the minimum calculated distance between a stationary vehicle and fixed infrastructure.
Structure gauging train	A vehicle-based gauging system using a precise plane of white light or laser-based angle and distance scanning equipment, used to measure the position of lineside structures.*
Swept envelope	A cross-sectional profile, taken at right angles to the track, enclosing all dynamic movements, static deflections and overthrows of all points along the surface of the vehicle that can reasonably be expected to occur under the appropriate range of operating conditions as it sweeps past a theoretical track location (from GI/RT7073 issue one).
Tamping	The operation of lifting the track and simultaneously packing the ballast beneath the sleepers in order to improve the track geometry.
Track maintenance engineer	The Network Rail manager responsible for the delivery of track maintenance within a defined area.
Up	In a direction towards London.
Vehicle gauge	The maximum envelope that a vehicle is permitted to occupy statically and dynamically (from GI/RT7073 issue one).

Appendix C - Investigation details

The RAIB used the following sources of evidence in this investigation:

- information provided by witnesses;
- information taken from the train's on-train data recorder (OTDR);
- closed circuit television (CCTV) recordings taken from the train and stations en route;
- recordings of post-accident voice communications between the railway and the emergency services;
- site photographs and measurements;
- documents and data regarding clearance surveys and maintenance work at the site;
- documents relating to the route compatibility assessment process for this type of train;
- emergency service logs relating to the accident;
- weather reports and observations at the site;
- a review of previous reported accidents;
- a review of railway standards and guidance documents; and
- a review of previous RAIB investigations that had relevance to this accident.

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

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