RAIB

Rail Accident Investigation Branch

Rail Accident Report

Occupied wheelchair contacting a passing train at Twyford station
7 April 2016

Report 01/2017
January 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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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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Occupied wheelchair contacting a passing train at Twyford station
7 April 2016

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Summary

At around 10:52 hrs on 7 April 2016, a wheelchair occupied by a teenage girl moved towards the edge of platform 4 at Twyford station and came into multiple glancing contacts with the wagons of a passing freight train. The last contact pushed the wheelchair clear of the platform edge. The girl suffered a minor injury to her foot.

Prior to the accident, the girl and her mother were waiting to catch a train on the platform. The wheelchair was stationary, behind the yellow line painted on the platform, and with the wheels parallel to the railway tracks. It was positioned next to the girl's mother, who had applied the brakes.

The accident occurred because the freight train's slipstream, combined with the ambient wind, generated an aerodynamic force which was able to overcome the brakes on the wheelchair. The mother was unaware that the freight train posed a hazard to the wheelchair, and therefore did not take any additional precautions beyond applying the brakes.

As a result of the investigation, the RAIB has made five recommendations. One recommendation is made to the Rail Delivery Group to inform the public of the potential hazards from train slipstreams and the need to apply brakes and keep a hold of wheelchairs and pushchairs when non-stopping trains pass through stations. Two recommendations are made to RSSB; one to investigate measures to improve the safety of wheelchair and pushchair users at railway stations, and the second to change the Railway Group Standard which specifies when a station operator must carry out a formal assessment of the risks from passing trains. Two recommendations are also made to Great Western Railway, to continue its current work to risk-assess the platforms for which it is responsible, and to ensure that warnings of passing trains provided to station users are timely and effective.

The RAIB has also identified a learning point for members of the public: that trains passing through platforms, particularly freight trains, can generate powerful slipstreams sufficient to move a wheelchair or pushchair against its brakes.

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 around 10:52 hrs on 7 April 2016 a teenage girl seated in a wheelchair and her mother were waiting on platform 4 at Twyford station, Berkshire, (figures 1 and 2) for their train to London. The girl is disabled, and reliant on her wheelchair for mobility. A non-stopping freight train, 7A09[1], passed platform 4 and the slipstream generated by the train caused the wheelchair to move towards the side of the train. The wheelchair contacted the side of the freight train several times on three different wagons. The final contact pushed the wheelchair clear of the platform edge and it came to rest further along the platform, approximately 15 metres from where it had started to move.

4 The teenage girl suffered a minor injury to her foot in the accident. The wheelchair sustained minor damage. Items contained in a bag which had been hung on the wheelchair were also reported as damaged.

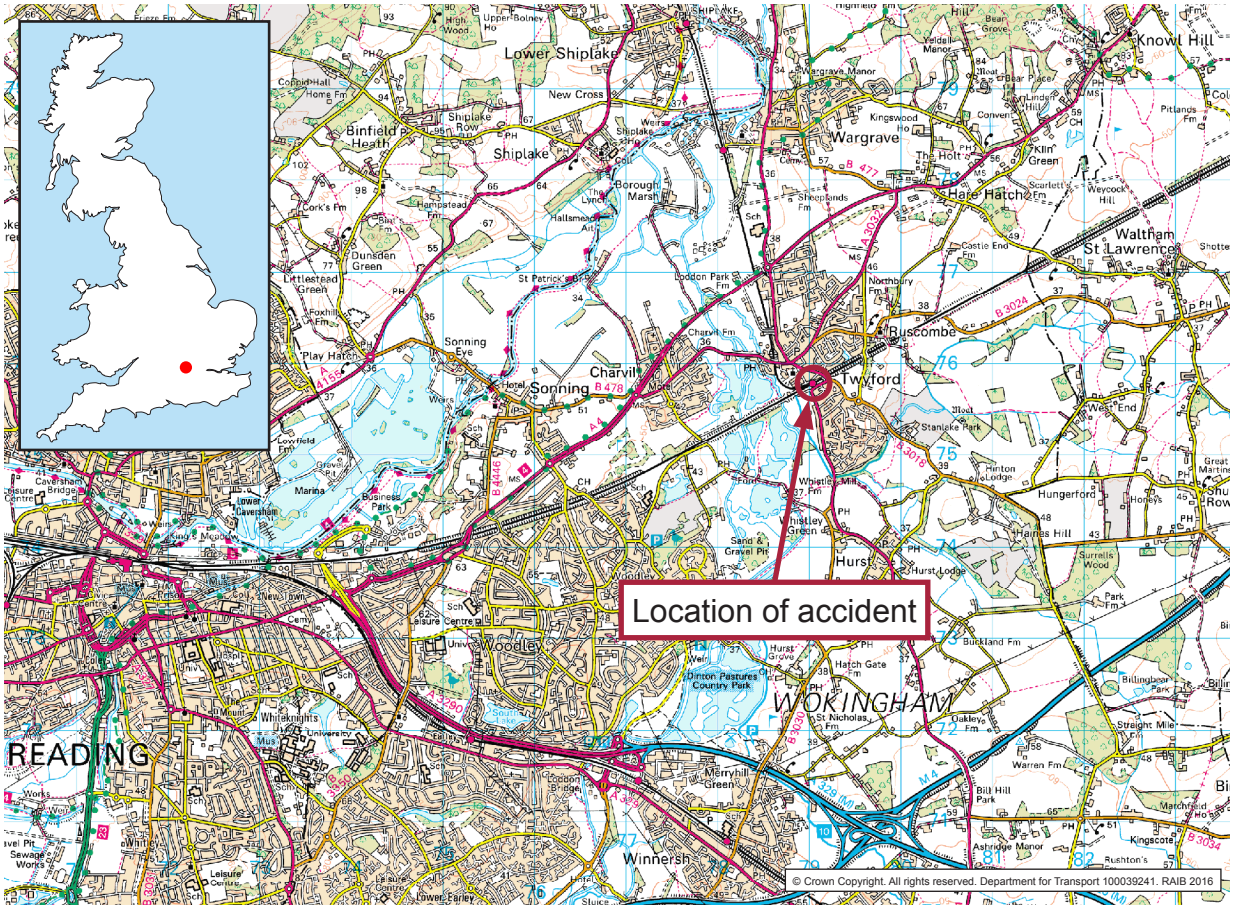

Figure 1: Extract from Ordnance Survey map showing location of accident

[1] An alphanumeric code, known as the 'train reporting number', is allocated to every train operating on Network Rail's infrastructure.

Figure 2: Platform 4 at Twyford station, looking towards Reading

Context

Location

5 Twyford station is located between London Paddington and Reading, 31 miles and 22 yards from London Paddington. The station has five platforms. Platforms 1 and 2 are on the *down* and *up main lines* (figure 3). Platforms 3 and 4 are on the down and up *relief lines*. Platform 5 serves the branch line from Twyford to Henley.

6 Trains running on the main lines are permitted to pass through Twyford station at speeds of up to 125 mph (201 km/h). The main line platforms are normally closed off to the public using barriers[2]. Trains running on the relief lines are permitted to pass through the station at up to 60 mph (97 km/h) for freight trains and 90 mph (145 km/h) mph for passenger *multiple unit trains*.

7 The surface of platform 4 is laid with paving slabs (figure 2) and slopes towards the track at an angle of approximately one degree (1 in 57 or 1.7%)[3]. The platform is level in the direction parallel to the railway. A *tactile strip* is provided approximately 1 metre from the platform edge.

[2] These barriers were provided on platform 1 in 2016 and on platform 2 in 2014. The intent is that the barriers deter individuals intent on self-harm from accessing platforms where fast-moving trains pass through and which are infrequently used by timetabled trains. The barriers are opened during night hours when the station is not staffed.

[3] New and altered platforms are required to slope away from the platform edge at a nominal gradient of 1:50 (within the limits 1:40 and 1:80), in accordance with Railway Group standard GI/RT7016 Issue 5 clause 11.1.3.

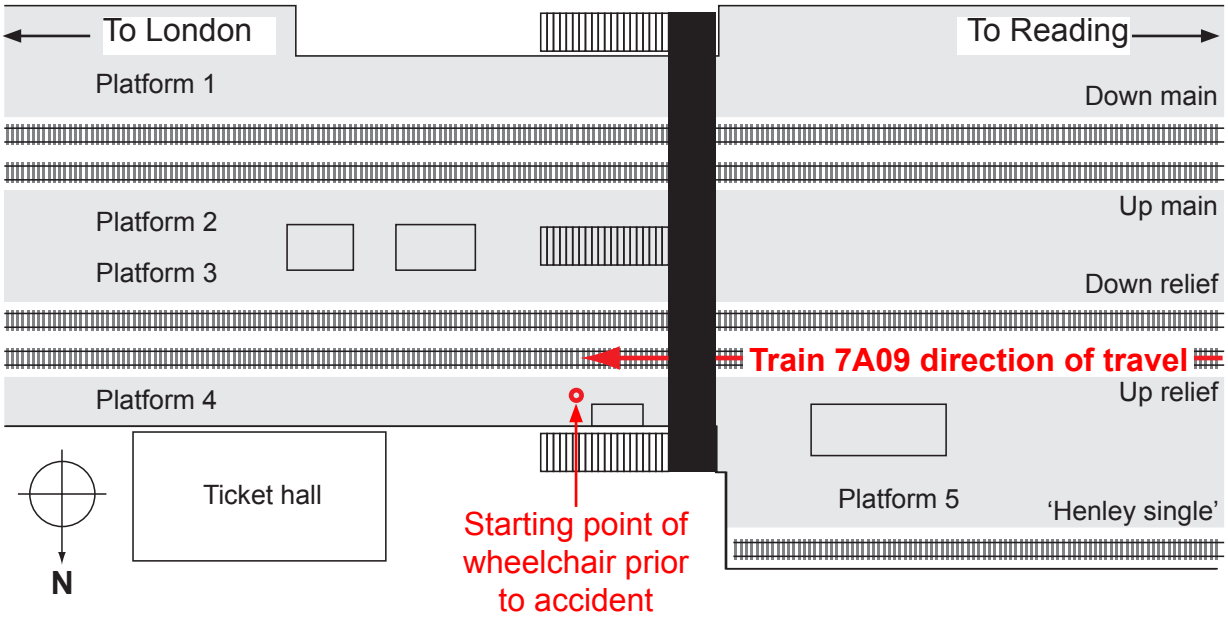

Figure 3: Schematic plan of Twyford Station (not to scale)

Organisations involved

8 Great Western Railway (GWR) manages Twyford station and employs the station staff.

9 DB Cargo (UK) Ltd operated train 7A09 on behalf of Mendip Rail. DB Cargo employs the train driver.

10 Otto Bock Mobility Solutions GmbH manufactured the wheelchair involved in the accident.

11 All parties freely co-operated with the investigation.

Train involved

12 Train 7A09 was the 07:12 hrs service from Merehead in Somerset to Acton Yard in west London. This train conveys stone products from Somerset quarries for use in construction projects. On arrival at Acton Yard, the train is divided into smaller portions of wagons and these portions are forwarded on to various unloading terminals located in London and the south east of England. The loaded train was permitted to operate at a maximum speed of 45 mph (72 km/h), and was therefore described as a class 7 train. Once unloaded, the train of empty wagons returns from London to Somerset as a class 6 train, passing through Twyford, usually through platform 3. Class 6 trains are permitted to operate at up to 60 mph (97 km/h)

13 The *consist* of the train varies from day to day, depending on customer demand and unloading equipment at the various final destinations.

14 On 7 April 2016, train 7A09 comprised:

- a class 59 diesel-electric locomotive; followed by
- 16 loaded *box wagons* of types JNA and JYA (figure 5); followed by
- 28 loaded *hopper wagons* of types IIA and JHA (figure 6).

The total weight of the train was 4274 tonnes.

15 Neither the maintenance of the train, nor the manner in which it was being operated at the time, contributed to the accident.

Figure 4: A train similar to 7A09. The train is formed of a mixture of box wagons (at the front of the train) and hopper wagons (image courtesy of Jonathan Lewis)

Figure 5: A JNA box wagon, similar to the wagons which formed part of train 7A09

Figure 6: JHA hopper wagon, similar to the wagons which formed part of train 7A09

Staff involved

16 The driver of train 7A09 was unaware of the accident[4] and his actions had no bearing on it.

17 A member of GWR ticket office staff at Twyford witnessed the accident and immediately went to assist.

External circumstances

18 The weather at Twyford at the time of the accident was dry and bright. The ambient wind, which is likely to have had a small effect on the accident, is discussed further in paragraph 38.

[4] The accident occurred a considerable distance back from the locomotive. The driver is required to observe the railway ahead of his train. He is not required to, and has no means of, observing occurrences behind the moving locomotive.

The sequence of events

Events preceding the accident

19 On the day of the accident, the girl and her mother arrived at Twyford station at 10:47 hrs. They entered the station by a gate which provides access directly onto platform 4.

20 At 10:50 hrs, the mother moved with the wheelchair to a location adjacent to the kiosk on platform 4. The mother bought a drink, and positioned the wheelchair such that it was parallel to the railway, facing towards London. She reported that she did this with a view to shielding her daughter from the dust generated by passing trains. The centre of the wheelchair was located approximately 2.4 metres from the edge of the platform. The mother stated that she applied the wheelchair's brakes when she positioned the wheelchair.

Events during the accident

21 At 10:51:50 hrs, the locomotive of train 7A09 passed the wheelchair (figure 7). After approximately 13 seconds, the wheelchair began to move slowly, turning to the right and towards the train (figure 8). The initial movement occurred as the transition between the box wagons (wagons 1 to 16) and hopper wagons (wagons 17 to 44) passed the wheelchair.

22 After a further six seconds, the wheelchair's front right foot plate collided with the 27th wagon on the train. This caused the wheelchair to rotate such that it was moving parallel to the train. The wheelchair then struck the 29th wagon, rubbing along the side of that wagon (figure 9) before contacting the leading edge of the hopper on the 30th wagon. This third and final contact caused the wheelchair to be propelled away from the train and along the platform, where it came to rest. Figure 10 illustrates the general path taken by the wheelchair.

Figure 7: CCTV image showing the locomotive of train 7A09 passing the wheelchair (courtesy of GWR)

Figure 8: CCTV image showing the wheelchair moving towards the train (courtesy of GWR)

Figure 9: CCTV image showing the wheelchair in contact with the 29th wagon of train 7A09 (courtesy of GWR)

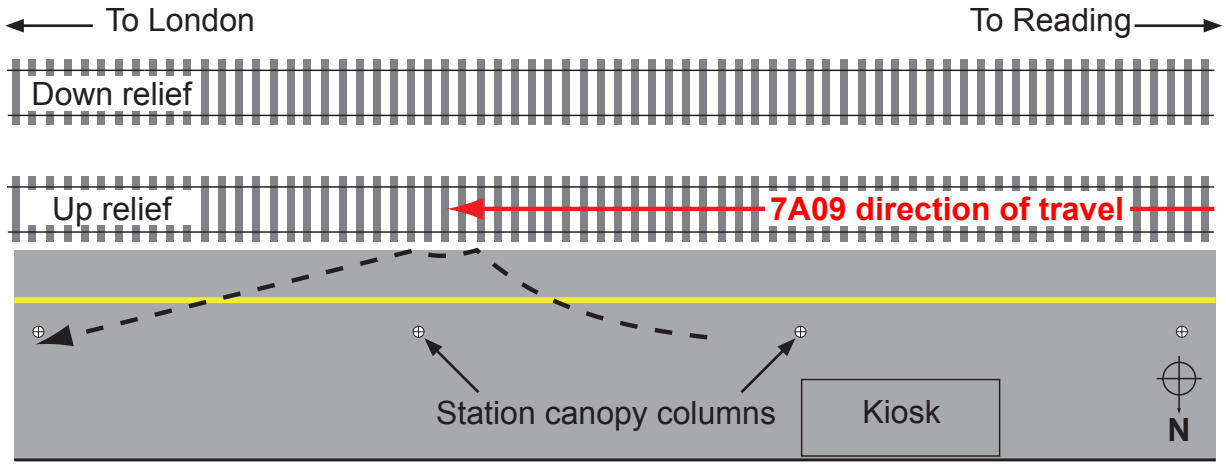

Figure 10: General path of the wheelchair along platform 4 (not to scale)

Events following the accident

23 The accident was witnessed by a member of GWR ticket office staff and a member of the public who both ran to the aid of the teenage girl. Meanwhile the mother, who had been looking in the opposite direction at the time, was unaware of the accident. When she turned round and saw that the wheelchair had moved, she ran to the aid of her daughter. The girl and her mother subsequently boarded the next train to Paddington, which departed from Twyford at 10:56 hrs.

24 On arrival at London Paddington, GWR staff met the girl and her mother. The GWR staff gathered some basic information about the accident and checked on the welfare of the girl and her mother.

Key facts and analysis

Background information

The generation of slipstreams by moving trains

25 A moving train generates a slipstream alongside it and a wake behind it. The air in contact with the surface of the train travels at the speed of the train while the air distant from the train and outside its slipstream travels at the speed of the ambient air. The region between these two extremes is the slipstream. Within the slipstream, the airflow is turbulent and complex but the direction of the airflow is generally aligned with the movement of the train.

26 The velocity of a train's slipstream is dependent on several factors. The most significant are:

- the surface 'roughness' of the train (freight trains are 'rougher' than smooth sided passenger trains);
- the size of the gaps between wagons, or between containers on wagons;
- the speed of the train (for a given type of train, the greater the train speed, the greater is the speed of air movement within the slipstream); and
- the distance from the passing train (the airflow is strongest closest to the train and decays as the distance from the train increases).

27 The moving air within a slipstream will exert a force on any object in the slipstream, such as a wheelchair. The magnitude of the force is a function of:

- the square of the slipstream velocity;
- the density of the air;
- the area of the object perpendicular to the slipstream; and
- the *drag coefficient* of the object.

28 From the early 1970s, British Rail became concerned about the effects of train slipstreams, on both passengers at platforms and trackside staff. These concerns were related to the impending introduction of high-speed passenger trains of various types, and also due to a series of accidents involving the slipstreams of certain types of freight trains (paragraph 71).

29 Research initiated by British Rail, and continued by various organisations to the present day, developed an understanding of train slipstreams. This body of research indicated that, amongst other findings, it was possible for freight slipstreams to generate sufficient force to move a braked pushchair[5].

[5] Testing at Northallerton, Appendix B to RSSB research project T425 Safety of slipstream effects produced by trains, C.W.Pope, 2007.

The wheelchair

30 The wheelchair involved was manufactured by Otto Bock Healthcare during 2010 and was the 'Discovery' model (figure 11). This design of wheelchair can only be propelled and braked by a carer; it cannot be operated by the user. The combined weight of the wheelchair and the girl at the time of the accident was approximately 90 kg.

31 The wheelchair is fitted with drum brakes operated by the carer using levers, one on each handle. There is one drum brake on each rear wheel controlled using a cable from the corresponding handle. The brakes operate independently of each other. A cam mechanism, operated by the cable (figure 12), causes brake pads to press outwards onto an annular inner surface within the wheel hub to apply the brake.

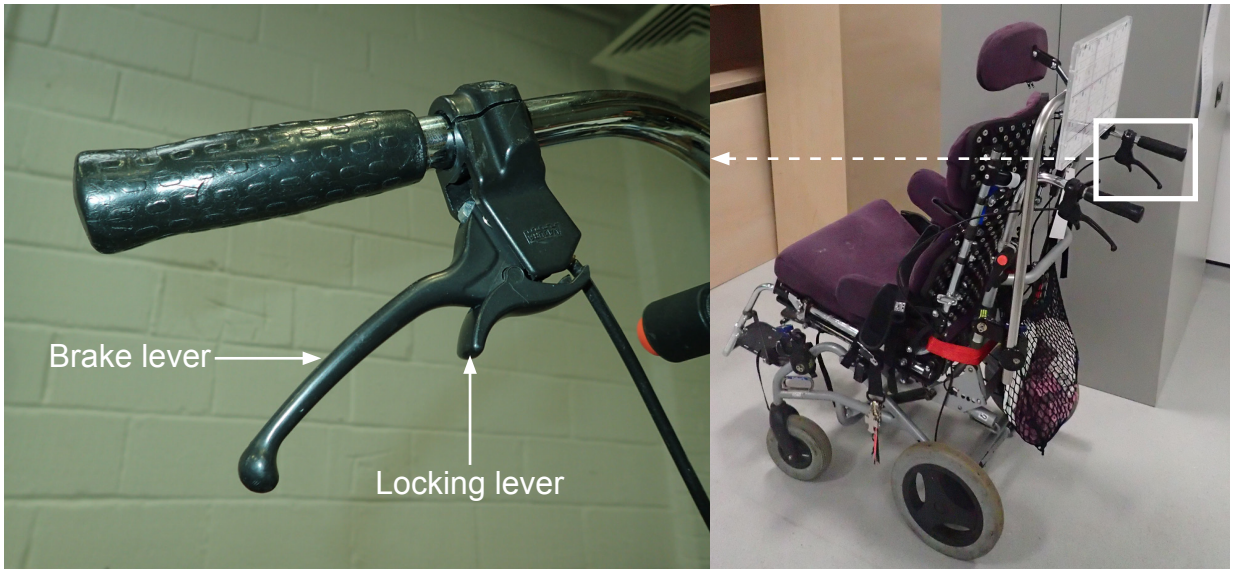

Figure 11: The wheelchair involved in the accident

32 Each brake lever has a separate smaller lever (figure 11) which allows the carer to lock the brakes into one of three steps, until released.

33 As part of its product acceptance process, this type of wheelchair was tested by the manufacturer in accordance with EN12183:1999 'Manually propelled wheelchairs – Requirements and test methods' and ISO7176 part 3 'Wheelchairs – Determination of the effectiveness of brakes' to check the adequacy of the brakes. A wheelchair was loaded with a test dummy and placed on an inclined surface. The total mass of chair and dummy was 131 kg. The brakes were applied with a maximum pull force on the handles of 72 Newtons (N). This force corresponds to step 2 on the brakes of the Discovery wheelchair design. The inclination on the surface is then increased until either the wheelchair starts to roll or it starts to slide. The greater the angle of inclination achieved, the stronger the brake. The minimum acceptable inclination is 7 degrees. The test report for the Discovery wheelchair design, dated August 2004, showed that it achieved a 10.7 degree inclination, equating to a brake force of 239 N.

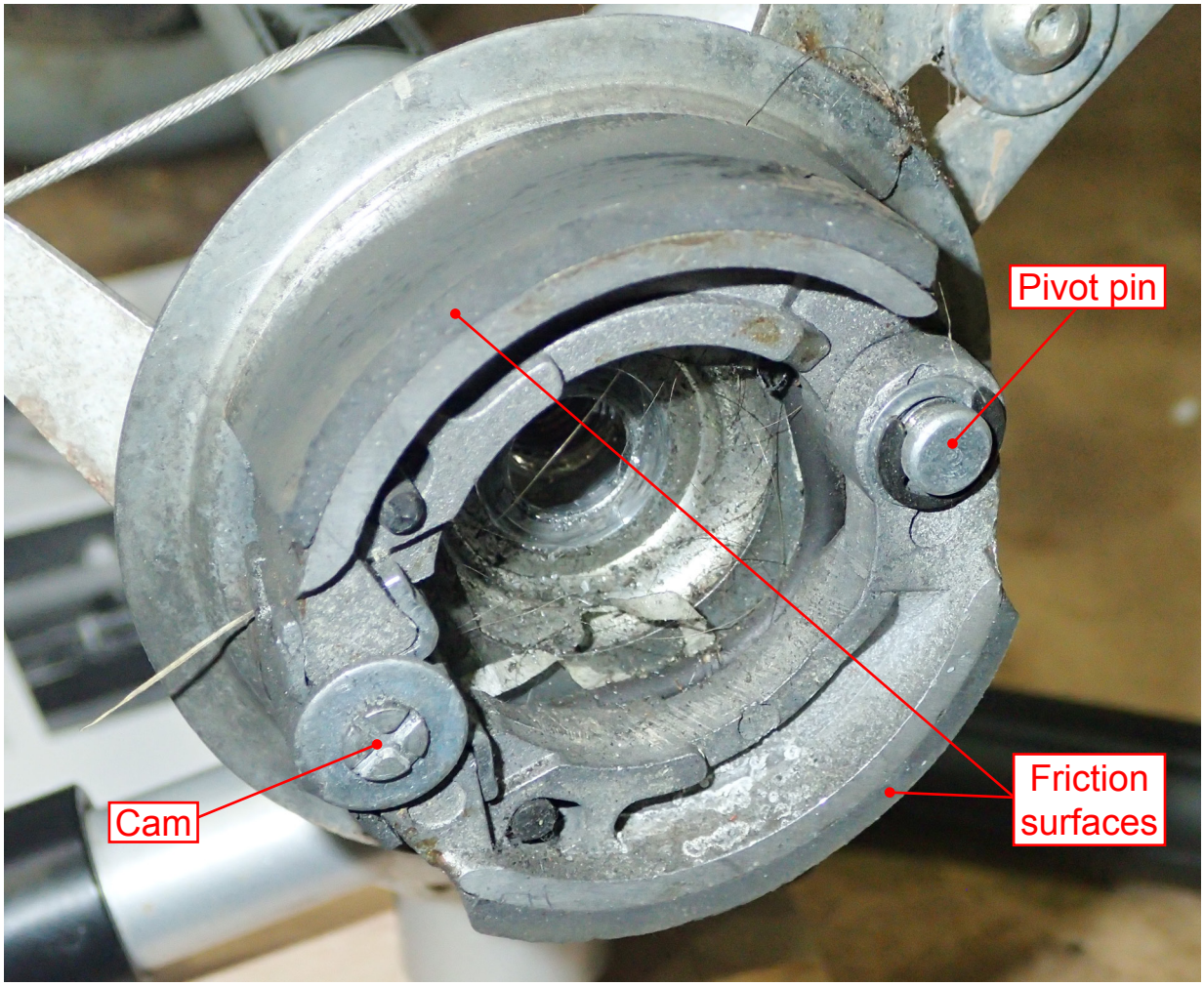

Figure 12: The wheelchair brake mechanism

Identification of the immediate cause

34 **The wheelchair was pushed into contact with the passing freight train by the aerodynamic effects of the train's slipstream.**

Identification of causal factors

35 The accident occurred due to a combination of two causal factors:

- The air flow along platform 4 at Twyford station generated a force which exceeded the braking force of the wheelchair.
- The mother was unaware of the hazard from the slipstream of the passing train and therefore did not take any additional precautions.

Each of these factors is now considered in turn.

The air flow generated by the passing train

36 **The air flow along platform 4 at Twyford station generated a force which exceeded the braking force of the wheelchair.**

37 The air flow along platform 4 at the time of the accident consisted of a combination of the train's slipstream and the ambient wind.

38 The RAIB gathered data from three weather stations located in the vicinity of Twyford station. These indicate that the wind was blowing at approximately 2 to 3 metres per second in broadly the same direction as the movement of the freight train. This wind speed corresponds to force 2 on the *Beaufort Scale* and is classified as a 'Light Breeze'. The wind speed data corresponds with observations from Closed Circuit Television (CCTV) at Twyford station at the time, which shows slight movement of the hair and clothes of people waiting at the station.

39 Train 7A09 was travelling at, or very close to, its maximum permitted speed of 45mph (72 km/h) when it passed through Twyford station.

40 Station CCTV showed that the initial movement of the wheelchair occurred when the passing wagon type changed from boxes to hoppers (paragraph 14). The CCTV also showed a marked change in the strength of the air flow on the platform at this time, which could be seen by increased movement of the hair and clothes of people on the platform.

Testing at Twyford station

41 In order to understand the magnitude of the slipstreams generated by trains passing through Twyford station, the RAIB commissioned tests by the University of Birmingham during August 2016. The tests were undertaken at night. Due to overnight engineering work, trains passing through Twyford station during the testing period went through platform 2 so the testing had to be done on this platform instead of platform 4[6]. Slipstream measurements were made by means of four *sonic anemometers* positioned 2.4 metres from the platform edge (figure 13), which was the distance from the platform edge of the centre line of the wheelchair before it started moving (paragraph 20). The anemometers were spaced approximately 17 metres apart along the platform. The anemometers recorded air flows as trains passed, and also recorded the ambient conditions in the absence of a train. The ambient wind measured during the testing was negligible. The speed of passing trains was measured using a radar speed gun.

42 During the course of three nights testing, data was recorded from 28 passing freight trains. Ten of these trains were 'Mendip' stone trains, and two trains had consists of box and hopper wagons very similar to that of train 7A09 on 7 April 2016.

43 Measurements for the trains of a similar configuration to train 7A09 were analysed. Figure 14 shows the slipstream velocities measured by an anemometer when such a train passed through platform 2. It should be noted that there was significant variability in the anemometer measurements between trains and also between anemometers during the passage of a single train.

[6] There are physical differences between the layouts of platforms 2 and 4, such as the proximity of station buildings to the track and the presence of the kiosk on platform 4. However, a comparison between the anemometer readings obtained for platform 2 suggests that these physical differences would not have resulted in significantly different results had the tests been carried out on platform 4.

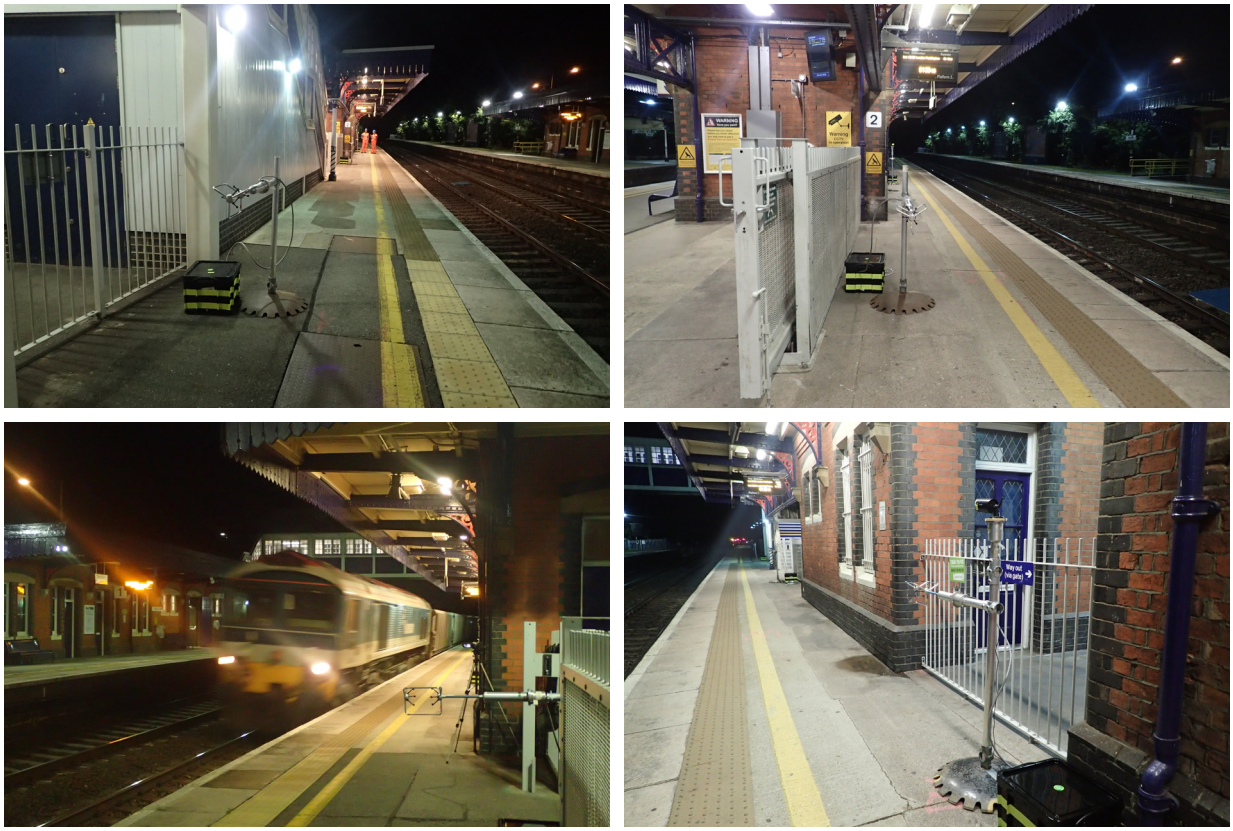

Figure 13: Anemometers set-up at Twyford station platform 2

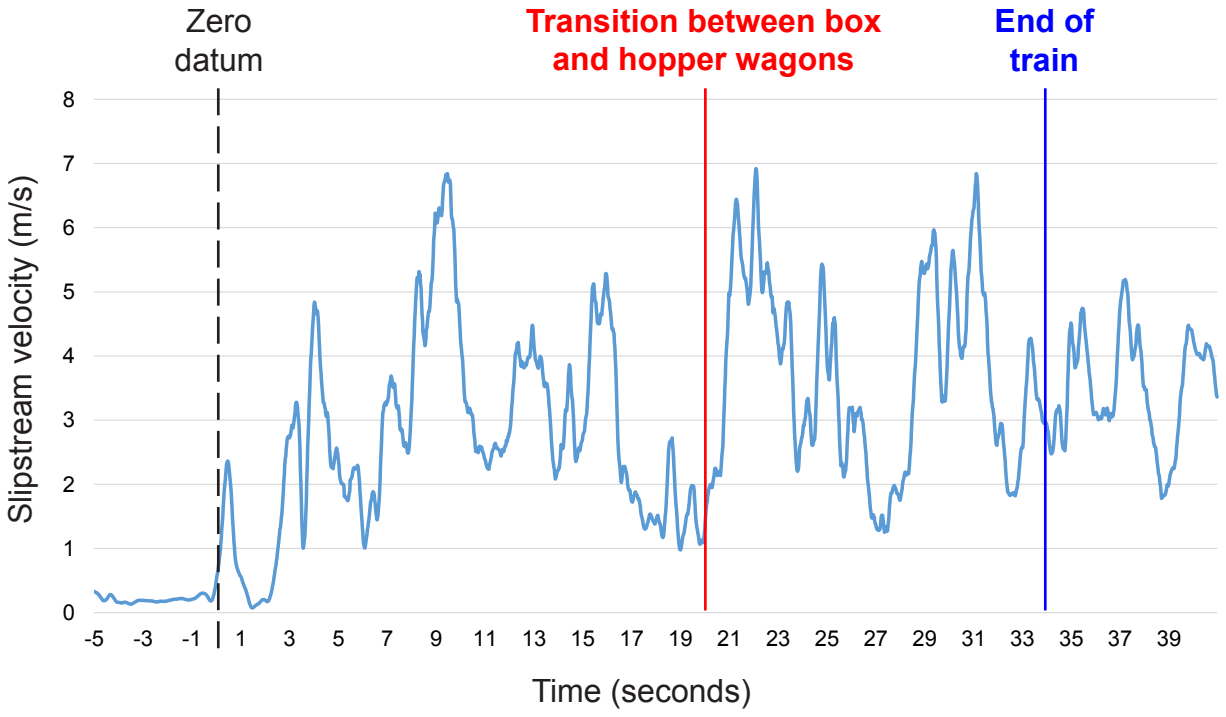

Figure 14: Typical measured slipstream velocity against time graph for the passage of a single train similar to 7A09. Data is taken from the passage of train 7A91 through Twyford station at 02:05 hrs on 9 August 2016.

44 From the slipstream velocity measurements, the force which could have been exerted on the wheelchair at the time of the accident was calculated using the following data:

- The air flow generated by the train slipstream. Since the air flows within a slipstream are highly variable, complex and turbulent, a statistical process was used to analyse the anemometer data from several train passes and estimate a peak gust velocity representing the mean of the moving average values plus two standard deviations[7].
- The ambient wind as recorded in the vicinity of Twyford on the day of the accident (see paragraph 38).
- The area of the wheelchair presented to the air flow.
- The drag coefficient of the wheelchair. This was estimated using published data taking account of a large flat board mounted on the rear of the wheelchair which would have tended to increase the drag force.
- The density of air. A standard value for the ambient temperature on the day of the accident was used.

A correction was made to normalise the trains' speeds to 45 mph (72 km/h) if the measured train speed differed from this; this correction was made to ensure that a comparison could be made to the forces generated by train 7A09 on the day of the accident. This correction was small, since the measured stone trains were travelling at, or close to, 45 mph (72 km/h).

The calculated force exerted by the air flow could then be compared to the force exerted by the wheelchair brakes.

Testing of the wheelchair brake force

45 The RAIB undertook tests on the brakes of the wheelchair. The wheelchair was appropriately ballasted to simulate the weight of the girl, and the force required to move the wheelchair against its brake was measured using a force measuring gauge, pulling horizontally on the frame. Tests were carried out with the wheelchair in each of the three brake steps (paragraph 32) and repeated on different surfaces to assess the variability.

46 The average forces to just start movement of the wheelchair for each parking brake step for a smooth tarmac[8] surface were as follows:

- No brakes applied – 18 N.
- Step 1 – 26 N.
- Step 2 – 87 N.
- Step 3 – 181 N.

47 The tests also showed that the brake on the right wheel was more effective than the brake on the left wheel. Hence, when both brakes were applied, the wheelchair tended to turn towards the right.

[7] The methodology for calculation of 'gust velocity' is as specified by CEN Railway applications - Aerodynamics - Part 4: Requirements and test procedures for aerodynamics on open track, CEN EN 14067-4:2005+A1, 2009.

[8] The smooth tarmac surface was judged to be similar to the surface of the platform at Twyford station.

48 The measured brake forces were lower than those achieved by Otto Bock Healthcare during the product acceptance tests (paragraph 33). The mother reported to the RAIB that she had never had any concerns about the performance of the wheelchair brakes, and that they were adequate for the range of activities for which the wheelchair was used.

49 Testing also showed that the brake locking levers (paragraph 32) had a natural tendency to engage in step 2 when the brakes were applied. To engage step 3, it was necessary to apply the brake lever with greater force and simultaneously engage the brake locking lever to ensure it did not naturally slip back into step 2.

50 The RAIB arranged for Otto Bock Healthcare to examine the wheelchair. It noted that there was more wear on the left hand brake than the right. The effect of this wear would be that the right side brakes would have been more effective. Otto Bock Healthcare has advised the RAIB that the usual reason for a reduction in the effectiveness of the brakes on this type of wheelchair is stretch in the operating cables. It cannot be confirmed if the cables fitted to the wheelchair at the time of the accident had been subject to stretching since the original length of the cables fitted to the wheelchair is unknown[9].

Motion of the wheelchair

51 In order to explain the motion of the wheelchair, analysis was carried out to compare the force which could have acted on the wheelchair during the accident due to the air flow generated by train 7A09 combined with the ambient wind (paragraph 44), with the retardation force provided by the wheelchair brakes (paragraph 46). This analysis showed that:

- Had the wheelchair brakes been off or in step 1, the wheelchair would have moved earlier, just after the locomotive at the front of the train passed. The lack of any wheelchair movement at this early stage shows that the retardation provided by the wheelchair's brakes was greater than that provided by step 1.
- With the wheelchair brakes in step 2, calculations undertaken by the University of Birmingham following testing (paragraph 44) showed that there are circumstances in which the force generated by the air flow would exceed the force generated by the wheelchair's brakes, setting the wheelchair into motion. CCTV showed that the wheelchair turned towards the right (paragraph 21) once it was in motion. This turn was probably caused by the differential braking effect of the right side brake being more effective than the left side brake (paragraph 47). The slight platform slope towards the railway (paragraph 7) would also have contributed to this curving motion.
- Had the wheelchair brakes been in step 3, the wheelchair could not have moved because the brakes would not have been overcome by the force generated by the air flow.

[9] The cables fitted to the wheelchair at the time of the accident were not supplied by Otto Bock Healthcare.

- As the wheelchair approached the platform edge, the force exerted by the air flow would be expected to increase. Research undertaken by British Rail in 1976[10] found that the velocity of the slipstream increases towards the platform edge, and provided data that quantified this effect. That data indicates that the force on the wheelchair could have increased by a factor of around 2.7 by the time the wheelchair was 1.2 metres from the platform edge (ie half the distance from its starting point to the edge).
- The tactile strip (paragraph 7) may have had a small retarding effect, but the increased force exerted by the air flow as the wheelchair moved closer to the platform edge overcame any such effect.

From the above analysis, the RAIB concluded that the wheelchair brakes at the time of the accident were in step 2. Once the wheelchair was set in motion towards the platform, the increasing aerodynamic force pushed it towards the platform edge and into contact with the train.

Awareness of the hazard from train slipstreams

52 **The mother was unaware of the hazard from the slipstream of the passing freight train and therefore did not take any additional precautions.**

53 When train 7A09 approached Twyford station, the mother was looking west, the direction from which the train was approaching and the direction from which the ambient breeze was blowing. She explained that although she was aware of the approaching train, she did not perceive that the train, which was travelling at a modest speed (45 mph or 72 km/h) posed any hazard to her daughter sat in the wheelchair. Apart from applying the brakes, she was unaware of any need to take any additional precautions such as keeping a hold on the wheelchair.

Information provided at Twyford station about the risks from passing trains

54 Signs are in place on platforms 1, 2 and 3 at Twyford station to warn station users that passing trains may generate air turbulence. A sign on platform 3 (figure 15) reminds station users to 'secure pushchairs and prams'. A nearby sign on platform 2 states that users should 'secure pushchairs and prams behind the yellow line'. There is no signage on platform 4, on which the accident happened, which offers similar warnings.

55 Yellow lines are painted on all the platforms at Twyford. Those on platform 4 are 1.2 metres from the edge of the platform. The wheelchair and the mother were well behind the yellow line (paragraph 20). These yellow lines are painted adjacent to the tactile strip near platform edges and serve to warn passengers that they are close to the platform edge. At platforms where passenger trains are permitted to pass through at greater than 100 mph (161 km/h) or freight trains at greater than 60mph (97 km/h), the yellow line must be located at 1.5 metres from the platform edge. The purpose of this is to reduce the exposure of station users to the effects of train slipstreams.

[10] British Rail Research Report TM-AERO-10, Aerodynamic effects on the station environment due to passing trains, Gawthorpe, May 1976.

Figure 15: Warning signs on platforms 2 and 3

56 At Twyford station, announcements are made over the public address system warning of the approach of passing trains. However, the same announcement is made for the very frequent trains which pass through platforms 1 and 2 as for the less frequent trains which pass through platforms 3 and 4. This is despite there being no public access to platforms 1 and 2 for the majority of the station opening hours. The announcements of passing trains at platforms 1 and 2 therefore serve no purpose when access is not permitted to these platforms. Furthermore, the frequent announcements on platforms 1 and 2 may undermine the impact of announcements about trains passing platforms 3 and 4.

57 The visual *Customer Information System* units located on each platform change their displays to indicate that a passing train is approaching. CCTV evidence confirmed that the display changed to indicate the approach of a passing train approximately 22 seconds before the front of train 7A09 passed the wheelchair.

Identification of underlying factors

58 **There was no requirement in Railway Group standard GI/RT7016 to carry out an aerodynamic risk assessment for platform 4 at Twyford station and hence mitigate the risks from passing trains. This was a probable underlying factor.**

Current standards for the mitigation of the aerodynamic risk from passing trains

59 Railway Group standard GI/RT7016 'Interface between Station Platforms, Track and Trains' Issue 5 March 2014 specifies how the station operators are required to assess and mitigate the risk to station users from passing trains. This standard requires that action is taken to mitigate the aerodynamic risk from passing trains when:

- passenger trains pass at speeds greater than 100 mph (161 km/h); or
- freight trains pass at speeds greater than 60 mph (97 km/h).

60 The standard does not mandate any risk assessment for platforms 3 and 4, because the permitted speeds for passenger trains passing these platforms is 90 mph (145 km/h) and 60 mph (97km/h) for freight trains.

61 However, a risk assessment and mitigation exercise should have been carried out for platforms 1 and 2 at Twyford station because trains are authorised to pass these platforms at up to 125 mph (201 km/h). However, no such risk assessment had been undertaken for platforms 1 and 2.

RSSB research project T248

62 In 2003, *RSSB* commissioned project T248 'Review of train slipstream effects on platforms'. The main objective of this project was to carry out a review of previous work in this field from the UK and internationally in order to assess the extent to which the safety risk to station users could be quantified, and to make recommendations to improve the management of risk. The project produced recommendations for changes to relevant standards at that time.

63 One recommendation from project T248 was that the minimum freight train passing speed for an aerodynamic risk assessment to be undertaken should be reduced from 60 mph (97 km/h) to 45 mph (72 km/h). The accident at Twyford showed that this minimum speed is still sufficient to move a wheelchair. It is possible, but less likely, that a train travelling slower than 45 mph (72 km/h) could also have caused the wheelchair to move. While the likelihood of a passing train generating sufficient aerodynamic effects to cause a wheelchair to move reduces the speed below which the risk becomes negligible, taking into account reasonably expectable ambient wind conditions for particular train compositions is not currently known.

64 The report commentary which accompanies project T248 tabulates how the report recommendations were transposed into Railway Group standards. However, there is no entry in this table for the recommendation to reduce the speed threshold for carrying out a risk assessment for passing freight trains.

RSSB research project T749 and guidance note GI/GN7616

65 In February 2012 RSSB provided guidance to the railway industry on carrying out aerodynamic risk assessments at stations. This was developed as RSSB project T749 'Guidance on protecting people from the aerodynamic effects of passing trains'. The output from this project was contained in Rail Industry guidance note GI/GN7616 'Guidance on Interface between Station Platforms, Track and Trains' Issue 2 March 2014. Although project T749 contains 26 suggestions for mitigating the risk from train slipstreams, only one of these relates to vulnerable station users, and this specifies 'pushchair users'. Project T749 suggested that pushchair users could be targeted with 'best practice' information, such as a safety leaflet given out when issuing tickets. Other vulnerable station users and in particular wheelchair users are not addressed by project T749.

66 The RAIB noted that there was an inconsistency between the requirements of GI/RT7016 Issue 5 (paragraph 59) and the template aerodynamic risk assessment provided in appendix G of GI/GN7616. The mandated standard does not require risk assessments to be conducted for freight train passing speeds of 60 mph (97 km/h) or less. However, the non-mandatory guidance document indicates that a risk assessment is required for all platforms except bay platforms and platforms where non-stopping trains do not pass.

Observations

Signage and announcements at other stations

67 The RAIB visited a number of stations on the Midland and the West Coast main lines in order to observe how the need to take precautions when trains passed platforms was communicated to station users.

68 Many stations had signs which warned of passing trains, and to stand behind yellow lines painted on platforms. In some cases, public address systems repeated the message to stand behind yellow lines. However, in the accident at Twyford, the wheelchair was behind the yellow line by a distance of 1.2 m (paragraphs 20 and 55) and therefore this measure alone does not ensure the safety of all station users.

69 The relevance of the warnings provided by public address systems was variable. In some cases, warnings were broadcast covering platforms to which the public did not have access. In other cases, the warning was not made until after the train had passed through the station. Announcements warning of approaching trains are triggered by the train occupying a track section on the approach to the station. This train detection system[11] is part of the railway signalling and telecommunications function, controlled and managed by Network Rail.

70 Some stations had posters or signs advising users to keep hold of, or secure pushchairs, but no specific guidance was provided to wheelchair users. The Association of Train Operating Companies (ATOC)[12] published a booklet[13] to assist wheelchair users to gain access to train services. This booklet does not caution wheelchair users about the potential risks from passing trains, and the need to mitigate such risks. The RAIB has not found any specific research which has investigated the risks to wheelchair users from the slipstreams of passing trains.

Previous occurrences of a similar character

71 RSSB project T425 'Effective management of risk from slipstream effects at trackside and platforms' published in 2007, reviewed the situation concerning accidents caused by train slipstreams. The objective of this project was to review research and data as available at that time. This report identified thirteen incidents involving pushchairs between 1972 and April 2005. Of these, ten involved freight trains. Data for accidents since 2005 indicates that such events continue to occur. Relevant examples are:

- An incident at Berkhamsted station in 2010, in which an empty pushchair was blown along a platform by a passing freight train and destroyed when it collided with a fixed object. This was treated as 'property damage' rather than a near-miss by the station operator. The railway industry does not centrally record such property damage incidents.

[11] Train detection can be by means of a track circuit or an axle counter.

[12] From 24 October 2016, ATOC adopted Rail Delivery Group (RDG) as a single name for the organisation.

[13] 'Advice and information for wheelchair users at stations and on trains' available on the RDG website.

- An incident at Newark Northgate station in 2012, in which a station user was blown off her feet by the passage of a freight train. The internal report compiled by the station operator stated that this was the third time in a year that such an event had occurred.

72 In 2013 and 2014, RAIB investigated two accidents involving wheelchairs and pushchairs rolling off sloping platforms ('Accidents involving a wheelchair rolling onto the track at Southend Central, 28 August 2013 and a pushchair rolling onto the track at Whyteleafe, 18 September 2013', RAIB report 17/2014). Recommendation 3 called for ATOC to review the risks to wheelchairs and pushchairs and seek measures that could most effectively influence the behaviours of passengers using wheelchairs and pushchairs on railway platforms.

Summary of conclusions

Immediate cause

73 The wheelchair was pushed into contact with the passing freight train by the aerodynamic effects of the train's slipstream (paragraph 34).

Causal factors

74 The causal factors were:

a) The air flow along platform 4 at Twyford station generated a force which exceeded the braking force of the wheelchair (paragraph 36, Learning point).

b) The mother was unaware of the hazard from the slipstream of the passing freight train and therefore did not take any additional precautions (paragraph 52, **Recommendations 1, 2, 3, 4 and 5**).

Probable underlying factor

75 There was no requirement in Railway Group standard GI/RT7016 to carry out an aerodynamic risk assessment for platform 4 at Twyford station and hence mitigate the risks from passing trains (paragraph 58, **Recommendation 3**).

Observations

76 Although not linked to the causes of this accident, the RAIB observed that:

a) The warnings provided to station users on platforms when passing trains are approaching are inconsistent in terms of message content and timing (paragraphs 68 and 69, **Recommendation 5**).

b) There is a lack of clarity about what specific actions should be taken by station operators and wheelchair users to minimise the risk from passing trains (paragraph 70, **Recommendation 2**).

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

77 GWR has informed RAIB that it has commenced a project to carry out aerodynamic risk assessments for all the station platforms for which it is responsible.

78 RSSB has advised the RAIB that it has commenced the process to amend Railway Group standard GI/RT7016 (paragraphs 59 to 64) to mandate aerodynamic risk assessments for platforms where freight trains pass at 45 mph (72 km/h) or greater.

Recommendations and learning point

Recommendations

79 The following recommendations are made[14]:

1 *The intent of this recommendation is that in advance of the implementation of Recommendations 2 to 5 below, members of the public are made aware, as quickly as possible, by the railway industry, of the potential hazard from train slipstreams at railway stations and the need to keep hold of wheelchairs and pushchairs.*

The Rail Delivery Group, in consultation with passenger groups, including those representing the interests of disabled persons, should seek to provide station users, in an expedient and appropriate way, with both advance information (such as published advice or leaflets) and real time information (such as announcements and customer information system displays) that:

- trains passing through platforms, particularly freight trains, can generate slipstreams which are strong enough to move wheelchairs and pushchairs, even if the brakes are on; and
- brakes should be applied to the maximum extent possible and carers should keep a firm hold on a wheelchair or pushchair when a train passes by (paragraph 74b).

2 *The intent of this recommendation is that operators of stations where trains pass through at speed have a consistent set of measures they can take to ensure the safety of wheelchairs and pushchairs from train slipstreams, following appropriate risk assessment in accordance with Railway Group standards.*

RSSB, in consultation with the railway industry, should investigate and identify mitigation measures which can be applied by station operators to inform station users about what they should do to prevent wheelchairs and pushchairs from being moved by trains passing through stations at speed. Suitable and specific guidance should then be issued to the railway industry to be used in conjunction with the revised standard for risk assessment (see Recommendation 3) (paragraphs 74b and 76b).

[14] 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.

3 *The intent of this recommendation is that RSSB review the current Railway Group standard requirement for station aerodynamic risk assessments.*

RSSB, in consultation with the railway industry, should review the minimum freight train passing speed for which station aerodynamic risk assessments are required. This review should be carried out with reference to previous research such as RSSB project T248 and the findings of this investigation. Following this review, the appropriate Railway Group standard should be updated to document the revised requirements (paragraphs 74b and 75).

4 *The intent of this recommendation is that Great Western Railway completes the station aerodynamic risk assessment work it has begun*.

Great Western Railway should complete its current project to undertake aerodynamic risk assessments for all station platforms for which it is responsible. Following completion of these risk assessments, the company should implement risk mitigation measures as appropriate to warn station users, including users of wheelchairs and pushchairs, about the potential risks from train slipstreams, and what users should do to remain safe on platforms (paragraph 74b).

5 *The intent of this recommendation is to ensure that Great Western Railway's station announcements to warn users of passing trains are timely and effective.*

Great Western Railway, in conjunction with Network Rail, should review how it warns station users of the approach of passing trains so that such warnings are timely and as effective as possible. This review should also address the issue of potential distractions and desensitisation of station users by unnecessary or inappropriate warnings from other platforms (for example, warning of approaching trains on platforms not accessible to the public). Great Western Railway should then implement practicable improvements identified by the review (paragraphs 74b and 76a).

This recommendation may also apply to other station operators.

Learning point

80 The RAIB has identified the following key learning point[15]:

1 Wheelchair users and other vulnerable station users should be aware that trains passing platforms, particularly freight trains, can generate slipstreams which are strong enough to move wheelchairs and pushchairs even if the brakes are on, especially if the effectiveness of the brakes has deteriorated with age or wear. It is always better to park well away from the platform edge and to hold onto the wheelchair or pushchair when a train passes by, even if the brakes or wheel locks have been applied.

[15] '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

ATOC	Association of Train Operating Companies
CCTV	Closed Circuit Television
GWR	Great Western Railway
ISO	International Standards Organisation
RDG	Rail Delivery Group

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.

Beaufort scale	A system of recording wind speed, devised in 1806, to help sailors estimate the winds by visual observations of the sea state. The scale ranges from 0 (calm) to 12 (hurricane). The Beaufort scale is still used today to estimate wind strengths.
Box wagon	A basic open wagon comprising four sides and a fixed floor.
Consist	The list of vehicles making up a train.*
Customer Information System	A system of television monitors providing destination, platform and departure time information to passengers.*
Down line	The railway line used to convey traffic away from London.
Drag coefficient	A means of quantifying the resistance of an object in air (or any fluid).
Hopper wagon	A wagon which discharges its load through doors in the bottom area of the wagon.
Main line	The principal track on a railway.*
Multiple unit train	A Train consisting of one or two or more vehicles semi-permanently coupled together, that can be marshalled with other similar trains to make a formation that has a driving cab at both ends.*
Relief line	An additional running line which runs alongside a main line.
RSSB	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'.
Sonic anemometer	A device used for measuring air flows. Ultrasonic signals are passed between emitter and receiver probes. Air flowing in the gap between the probes changes the time between a signal being emitted and received. The probes are arranged such that air flows in three dimensions can be measured.
Tactile strip	An area of a railway platform which is formed with a series of slightly raised areas in the paving. The purpose is to alert a person with restricted vision that they are approaching a platform edge.
Up line	The railway line used to convey traffic towards London.

Appendix C - Investigation details

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

- information provided by witnesses;
- closed circuit television (CCTV) recordings taken from Twyford station;
- site photographs and measurements;
- weather reports and observations at the site and from nearby weather stations;
- information derived from the Network Rail signalling system;
- testing and other support provided by the University of Birmingham;
- review of published research papers
- a review of previous reported accidents and incidents; and
- a review of previous RAIB investigations that had relevance to this accident.

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