RAIB

Rail Accident Investigation Branch

Rail Accident Report

Passenger trapped in train doors and dragged at Clapham South station
12 March 2015

Report 04/2016
March 2016

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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Passenger trapped in train doors and dragged at Clapham South station, 12 March 2015

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Summary

At around 08:00 hrs on Thursday 12 March 2015, a passenger fell beneath a train after being dragged along the northbound platform of Clapham South station, in south London. She was dragged because her coat had become trapped between the closing doors of a London Underground Northern line train.

The train had stopped and passengers had alighted and boarded normally, before the driver confirmed that the door closure sequence could begin. The train operator, in the driving cab, started the door closure sequence but, before the doors had fully closed, one set encountered an obstruction and the doors were reopened. A passenger who had just boarded, and found that the available standing space was uncomfortable, stepped back off the train and onto the platform, in order to catch the following train. The edge of this passenger's coat was then trapped when the doors closed again and she was unable to free it.

The trapped coat was not large enough to be detected by the door control system and the train operator, who was unaware of the situation, started the train moving. While checking the platform camera views displayed in his cab, the train operator saw unusual movements on the platform and applied the train brakes. Before the train came to a stop, the trapped passenger fell to the ground and then, having become separated from her coat, fell into the gap between the platform and the train. The train stopped after travelling about 60 metres. The passenger suffered injuries to her arm, head and shoulder, and was taken to hospital.

The investigation identified one learning point for the railway industry, relating to the provision of under platform recesses as a measure to mitigate the consequences of accidents where passengers fall from the platform. The RAIB has made one recommendation, addressed to London Underground, seeking further improvements in the processes used to manage risks at the platform-train interface.

Introduction

Key definitions

1 Metric units are used in this report, except when it is normal railway practice to give speeds 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 08:00 hrs on the morning of Thursday 12 March 2015, a passenger's coat became trapped in the doors of a northbound Northern line train at Clapham South station on the London Underground (figure 1). The train departed and the passenger was dragged along the platform, fell to the ground, became separated from her coat and then fell into the gap between the train and the platform.

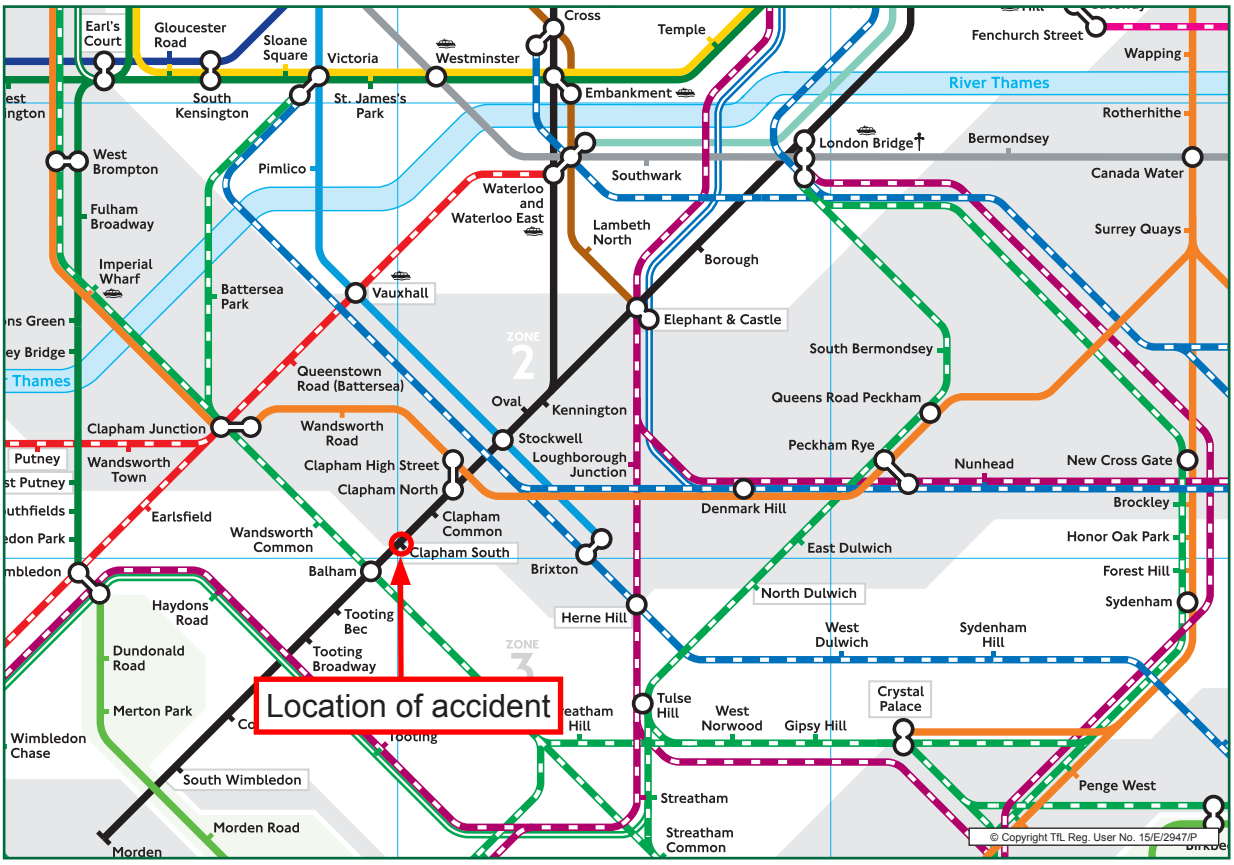

Figure 1: Extract from TfL map showing location of accident

4 The *train operator* saw unusual movements on the platform (figure 2) after the train had started moving and he immediately stopped the train. The electrical power supply to the train was switched off and the emergency services attended to the passenger.

5 The passenger sustained a broken arm, and injuries to her shoulder and face. There was no damage to the train, or to the railway infrastructure, and London Underground staff authorised reopening of the station at 09:11 hrs.

Context

Location

6 The accident took place on the northbound platform of Clapham South station, approximately 7 km from the Northern line's southern terminus at Morden.

Figure 2: Platform scene at the time of the accident (station CCTV courtesy London Underground)

7 The northbound platform is positioned on the right-hand side of the track, relative to the normal direction of train movement, and is in a single track tunnel. There is a right-hand curve along the entire length of the platform (figure 3).

Figure 3: Northbound platform at Clapham South station

Organisations involved

8 London Underground Ltd (London Underground) owns and maintains the infrastructure at Clapham South station. It also operates train services on the Northern line and was the employer of the train and platform staff involved.

9 Alstom Transport UK Ltd (Alstom) maintains the trains operated on the Northern line.

10 Both London Underground and Alstom freely co-operated with the investigation.

Train and equipment involved

11 The train consisted of 1995 tube stock that had been built by Alstom and entered service in 1997. It consisted of two coupled 3-car sets.

12 On each side of a car, there are two sets of sliding double doors and two single doors, one at each end (figure 4). The doors are hung on the outside of the car bodies and are operated pneumatically. All doors are intended for passenger use, with the exception of the single doors at each end of the 6-car train which give access to the train operator's cabs. An *interlock* system prevents the train moving unless all passenger doors are locked in the fully closed position (this locking does not prevent doors being opened slightly to release trapped objects as described in paragraph 44). A *pilot light* in the driving cab shows the train operator when this condition is met.

Figure 4: 1995 Northern line tube stock (non-incident train image courtesy of Joshua Brown)

13 The train was powered from London Underground's standard 630 volt DC electrification system which provides power using two *conductor rails*, one beneath the centre of the train and one beneath the side of the train. The latter can be beneath either side of the train but is always on the side of the train furthest from the platform in station areas.

14 The Northern line trains use a system of *automatic train operation* (ATO), with a train operator undertaking despatch duties at stations including the opening and closing of train doors. In normal operating mode, the mode applicable when the accident occurred, the train operator presses buttons[1] to start the train from a station and movement is then automatically controlled, with the train operator maintaining oversight, until the train stops at the next station.

15 Two sets of closed circuit television (CCTV) cameras are installed above the northbound platform at Clapham South station (figure 5). One set of cameras provides station staff (and others) with images of the platform. These are recorded and images from the time of the accident have assisted this investigation.

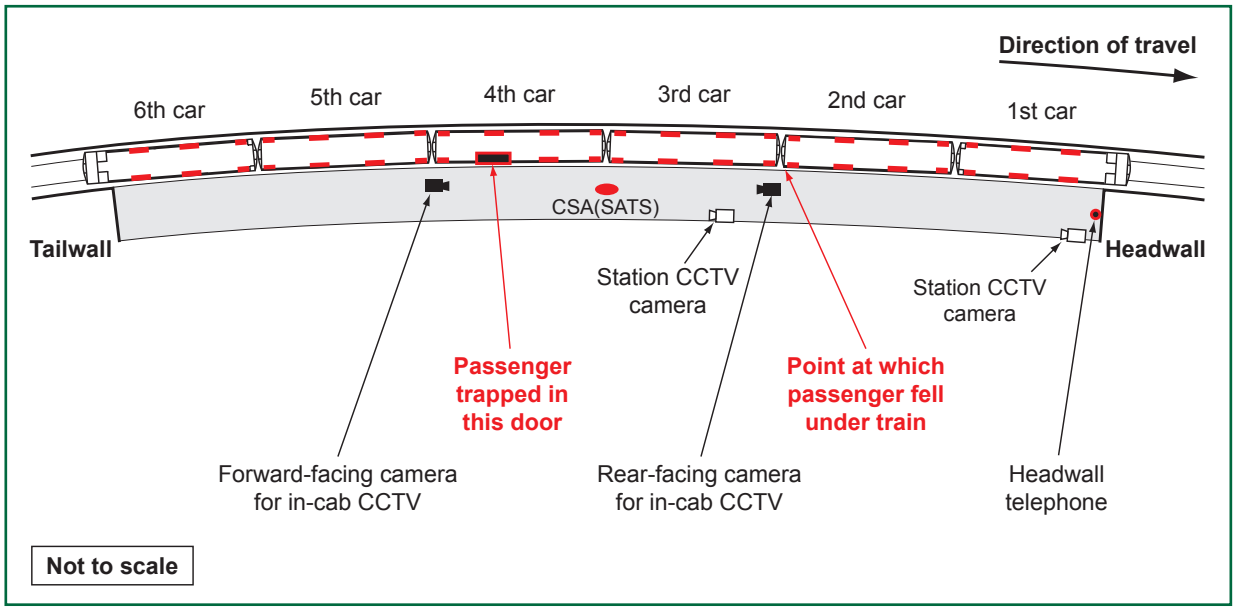

Figure 5: Layout of northbound platform

16 A separate pair of cameras supplies images to a monitor in the train's driving cab. These images start to be displayed shortly before a train stops in the station and remain displayed until the last coach has left the station. They are used by the train operator to monitor the *platform-train interface* (PTI) and to decide when it is appropriate for the train to start moving. These images are normally recorded but an equipment defect means that images relevant to the accident were displayed to the train operator but not recorded[2].

17 A yellow line had been painted along the platform 300 mm from the platform edge, as specified in London Underground standard S1131 (Premises - Station Platforms), to provide passengers with an indication of the distance they should stay back from the platform edge unless boarding or alighting from trains (figure 3). Alternative markings have been applied to the platform since the accident (paragraph 115g).

[1] Opening doors and starting the train each require the train operator to press two buttons in order to reduce the risk of the operator commanding an unintended action.

[2] A post-accident check by London Underground found 4 defective devices among the 150 devices which record this type of CCTV image on the Northern line.

People involved

18 The train operator had been driving trains on the Northern line for 14 years, and had also acted as an instructor operator for approximately 4 years.

19 The *customer services assistant* (CSA) on the platform had worked in that role for approximately 10 years, and frequently fulfilled *station assistant (train services) duties*, more commonly known as SATS duties. His normal location was Clapham South station, but he had worked in the same role at other stations.

20 The passenger injured in the accident (described as 'the passenger' in this report) was an able-bodied female who used the station routinely when commuting to and from work.

External circumstances

21 No abnormal environmental circumstances contributed to the accident.

The sequence of events

Events preceding the accident

22 The passenger entered the northbound platform at Clapham South station shortly before 08:00 hrs, wearing a coat and a small backpack held by two straps, one passing over each shoulder. On arrival of the first train, the doors opened, people alighted and boarded the train, and the passenger entered the fourth car using the rearmost double door.

23 The CSA on the platform then raised his *baton* to show the train operator that he had made the announcements required before the train doors were closed (figure 6). The train operator satisfied himself, from his view of the platform on the in-cab CCTV, that it was safe to close the doors and then pressed the 'close doors' button. Most of the train doors closed, but at least one did not close fully and so the in-cab pilot light indicating that all doors are closed did not illuminate. It is possible, but not certain, that the passenger's rucksack had obstructed the closing of that door. The train operator pressed the 'open doors' buttons to allow whatever was obstructing the doors to be removed.

Figure 6: Typical CSA baton used when signalling to train operator

24 While the doors were open, the passenger chose to step back out of the car to await the following train because her standing position on the train was not comfortable. Other people were already standing close to the yellow line so the passenger was only able to step into the gap of about 300 mm between the yellow line and the train. After the doors reopened, the CSA made an announcement for passengers to stand clear of the doors and continued to keep his baton raised.

25 After using his monitor to confirm that the CSA's baton was still raised and to satisfy himself that it was safe to close the doors, the train operator pressed the 'close doors' button again. The doors reclosed in response to this action, trapping the front corner of the left side of the passenger's coat between the door *leaves*. The train operator received confirmation from the pilot light that all doors were closed and locked.

Events during the accident

26 The passenger noticed that the coat was caught as soon as the door closed. Then, while facing the train, she tried to pull the coat out, but was unable to release it. However, the CSA on the platform and the train operator were unaware of the passenger's difficulty and so the operator pressed the start buttons and the train started moving.

27 As the train accelerated, the passenger was dragged along by her coat, bumping into several passengers on the platform, before falling over and sliding out of both her coat and her rucksack. She then fell into the gap between the train and the platform. People standing along the platform edge moved away from the train as the passenger was dragged past them, creating a 'wave' effect which was visible on the in-cab CCTV screen.

28 The train operator saw this unusual passenger movement on the in-cab screen, immediately applied the emergency brake and then used the train's radio to make a 'mayday' call asking that control room staff switch off the electrical supply to the conductor rails. The train had reached a maximum speed of 19 mph (31 km/h) before decelerating at a rate compatible with both the current London Underground braking standard and the standard applicable when the train was built[3]. The train stopped with the fourth car half way into the tunnel, having travelled a total of approximately 60 metres.

29 The CSA saw the passenger when she passed his position on the platform and ran after her, lowering his baton as he did so. Seeing that she was between the train and platform, he ran to the end of the platform where he lifted the *tunnel headwall telephone* in order to switch off the electrical supply to the conductor rails.

30 Table 1 summarises the timing of the sequence of events during the accident, in relation to the moment when the train started to move.

[3] The current standard is E6121 A2, Braking system performance (passenger stock), clause 9.3.2. London Underground has stated that the same requirement was included in standard RSE/STD/006 which was applicable when the train was built.

***Time** (seconds)*	***Event***
t - 37 s	Train stops
t - 36 s	Doors open (in response to the train operator pressing the open buttons)
t - 23 s	CSA raises baton (remains up until t + 4 secs)
t - 21 s	Train operator presses door close button
t - 17 s	Doors start to close (but do not fully close)
t -14 s	Train operator presses door open buttons because pilot light does not illuminate (an indication that the doors have not fully closed)
t - 12 s	Train operator presses door close button
t - 11 s	Doors open with normal delayed response from button operation at t - 14 s
t - 6 s	Doors start to close with normal delayed response from button operation at t - 12 s
t - 5 s	Doors closed (pilot light indicates doors fully closed)
t - 4 s	Train operator presses start buttons
t = 0	Train starts to move
t + 4 s	Passenger dragged past CSA
t + 4 s	CSA starts to run and lowers his baton
t + 6 s	Train operator applies emergency brake at train speed of 31 kph (19 mph)
t + 13 s	Train stops

Table 1: Events during the accident

Events following the accident

31 Another passenger on the platform pulled the coat from between the door leaves, where it was still retained, after the train had stopped. The zip was broken and the zip slider remained stuck between the door seals after the coat had been removed (figure 7).

32 The injured passenger was attended by paramedics at the site of the accident before being taken to hospital. The other passengers on the train were evacuated, after which the train was returned to Golders Green depot and the platform returned to service.

33 The RAIB attended Clapham South station to examine the scene of the accident, and Golders Green depot to examine the train. The RAIB, London Underground and Alstom carried out tests on the train doors and other systems immediately after the accident and subsequently as part of the investigation.

Figure 7: Zip slider, as found in door showing height above train floor

Key facts and analysis

Identification of the immediate cause

34 **The passenger's coat became trapped in the train door so that she was dragged and then fell beneath the train as it started to move out of the platform.**

Identification of causal factors

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

a. The passenger's coat became trapped in the door (paragraph 36);

b. The passenger was unable to remove the coat from between the door leaves after it became trapped (paragraph 40);

c. The train's door control system did not detect that an object was trapped between the door leaves (paragraph 65);

d. The design of the in-cab CCTV system did not allow the train operator to see that the passenger's coat was trapped before he started the train moving (paragraph 70);

e. The CSA was unaware that the passenger was trapped until after the train started moving (paragraph 87); and

f. The gap between the train and the platform was large enough for the passenger to fall through (paragraph 93).

Each of these factors is now considered in turn.

Factors relating to the train door

36 **The passenger's coat became trapped in the door.**

37 The passenger stepped back off the train, onto the platform and into the space between the train and other passengers waiting for the next train. These passengers were standing close to the yellow line positioned about 300 mm from the platform edge and so she was now standing very close to the train. She was unable to step further back because the waiting passengers did not make space for her.

38 The passenger was wearing a mid-length parka type coat which was unzipped at the time of the accident and so the lower part hung in front of the passenger. The bottom left corner of the coat, including part of a pocket, was trapped in a position which is consistent with the passenger stepping back off the train onto the platform (figure 8).

39 The zip slider was found trapped between the door leaves at about 0.5 metres above the train floor after the accident (figure 7). There is no evidence to show at what point during the accident sequence the coat was pulled from the position in which a large part of the corner was trapped, to having only the zip slider trapped. It is possible that this happened while the passenger was being dragged.

Figure 8: Coat hanging forward when unzipped

40 The passenger was unable to remove the coat from between the door leaves after it became trapped.

41 Witness evidence indicates that the passenger recognised that her coat was trapped very soon after the doors closed, while she was trying to step away from the train. Although she expected the doors to reopen if something was trapped between them, she tried to pull the coat out of the doors. However, she was unsuccessful in doing so before the train started to move, approximately 5 seconds after the doors had closed. The passenger continued to try to pull the coat out as the train started to move, while walking, and then running, alongside. The coat then remained trapped while the train dragged the passenger along the platform, until she lost her balance. The passenger subsequently slipped out of her coat and rucksack but the exact timing of this is uncertain.

42 The reasons why the passenger was unable to pull her coat from the doors have been established by considering:

a. the door design (paragraphs 43 to 49);

b. the maximum force that the passenger was likely to have used when trying to free her coat (paragraphs 50 and 51); and

c. the forces needed to pull the coat from between the door leaves (paragraphs 52 to 59).

Door design

43 The coat was trapped in a double door which comprised two leaves, each with a rubber *seal* on the edge which touches the seal on the opposite *leaf* when the doors are closed. An interlock system is intended to prevent the train starting if any of the doors are not detected as closed, but this system was not designed to identify small objects trapped between the leaves (paragraph 65). To facilitate the release of such objects, the rubber seals have some flexibility (paragraph 48) and the doors are designed so that, even if nominally closed, they can be opened slightly (paragraph 44). The forces required to withdraw small objects are defined as part of the train design specification (paragraph 61).

44 In order to allow slight opening of a nominally closed door, one leaf of each double door, and the leaf on single doors, are fitted with a *pushback* mechanism which allows them to open slightly if a force is applied. The other leaf on a double door is locked into a fixed position when the door is closed.

45 The rearmost leaf of the double door that the passenger's coat was trapped in was the fixed leaf on this journey, and the pushback leaf was leading. This configuration would have been reversed if the train had been travelling in the opposite direction.

46 The configuration at the time of the accident meant that, as the passenger was being dragged, the coat was pulling against the fixed leaf which was unable to move to allow the coat to be released (figure 9a). If the train had been moving in the opposite direction, then the coat would have been pulling against the pushback leaf which would probably have opened slightly and released the coat (figure 9b).

47 This door design is used on the majority of London Underground's trains, although the most recently built trains use different designs.

48 The door seals consist of hollow rubber extrusions, with the fixed leaf seal having a convex cross-section and the pushback leaf seal a concave cross-section (figure 10). The seals reduce draughts, water ingress and noise. They are able to compress around small objects when the doors close, but are intended to have sufficient flexibility, when combined with the pushback mechanism, to allow some trapped objects to be withdrawn. Door seal characteristics, particularly shape and flexibility, affect the ease with which trapped objects can be withdrawn from doors. The potential to modify sealing arrangements is discussed at paragraph 101.

49 A '*buggy bar'* is fitted inside the lower 535 mm of the door seals, with a tapered section on the top 60 mm (figure 15). The buggy bar restricts the ability of the seal to deform around small objects, and is intended to prevent the leaves closing sufficiently for them to be detected as fully closed when small objects, such as tubular parts of a child's push-chair, are still in the doorway close to ground level. The bar is intended to ensure detection of an 11 mm diameter object trapped in the bottom 450 mm of the door as required by London Underground standard 2 - 55, 'Rolling stock bodyside doors and door control system'.

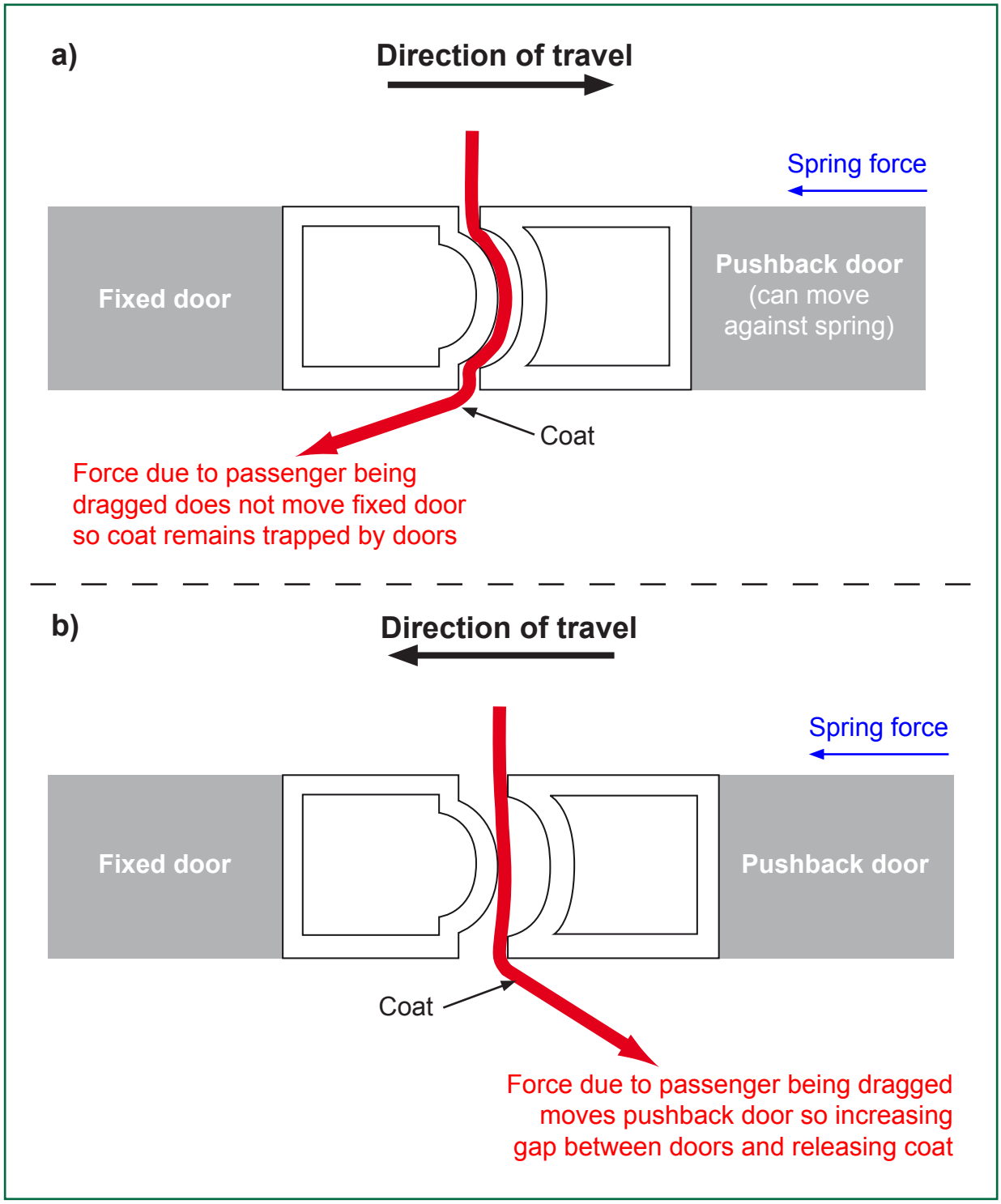

Figure 9: Effect of fixed door trailing

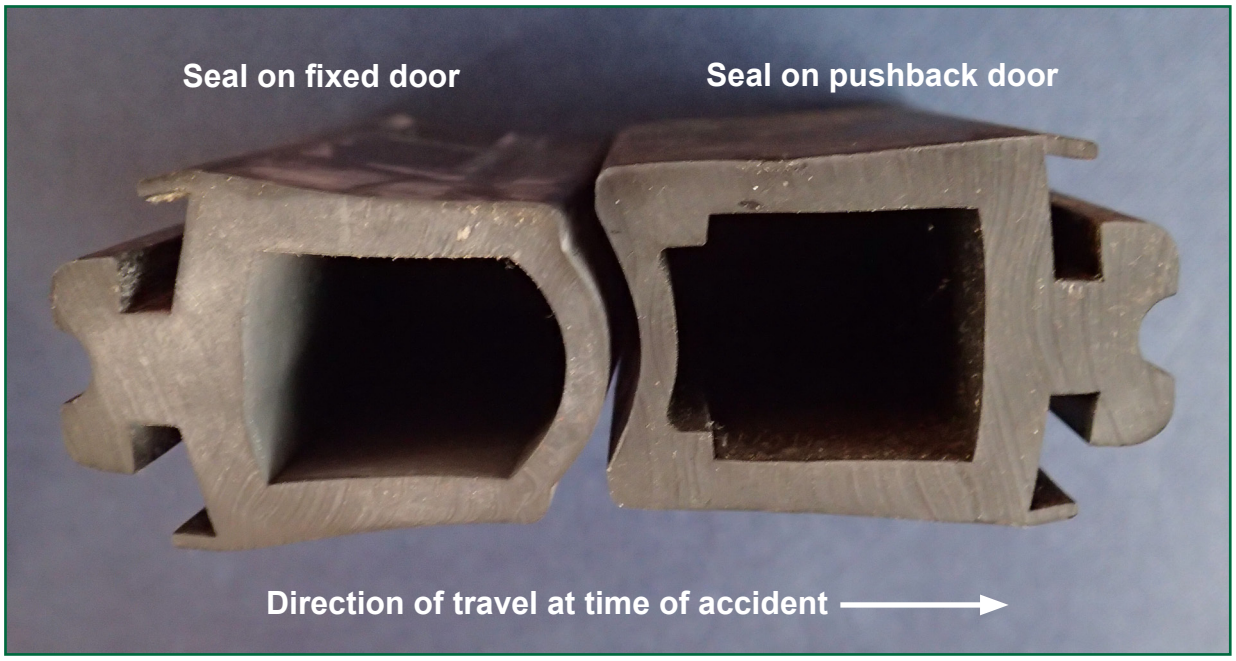

Figure 10: Door seal cross-sections

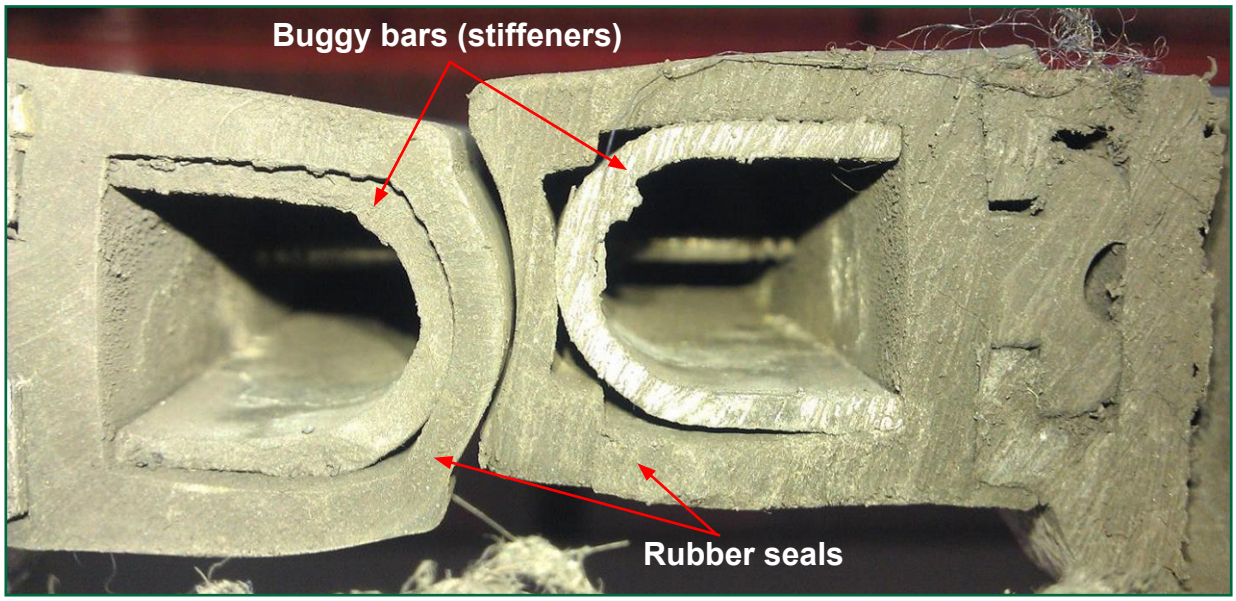

Figure 11: Buggy bars

Pull-out force tests

50 RAIB tests showed that a female of similar build to the passenger, and wearing a coat of the same type, could pull on the coat corner with a force of up to about 350 N (figure 12)[4]. However, the passenger only had a limited time (less than 5 seconds) to recognise her predicament before the train started to move and, until then, did not realise that the train would move with her still trapped. The force she could apply was probably limited because she was physically constrained to remain in the small space between the train and the passengers standing along the yellow line.

[4] 350 N is approximately equivalent to the weight of a 35 kg mass.

Figure 12: Testing pull-out force applied by person wearing incident coat

51 As a result, it is likely that, when standing beside the stationary train, and when walking and running beside the moving train, the passenger would have applied a force of less than 350 N. The force applied as the train started to drag the passenger and after she began falling to the ground is uncertain, but would have ceased after she slipped out of her coat.

52 The forces needed to pull the passenger's coat from between the doors were established by testing carried out on the incident train doors by the RAIB with assistance from Alstom and London Underground. The tests used a coat of the same type as that worn by the passenger with its bottom corner, including part of a pocket, trapped between the door leaves at a height of 0.5 metres above the train floor.

53 Witness evidence indicates that the pocket probably contained a security fob, keys, a credit card sized pass and a mobile phone when the coat was trapped. If any of the smaller items became trapped between the door leaves, or inside the train, it could have affected the force needed to pull the coat from the train.

54 Any object affecting pull-out of the coat during the accident must have been small or thin. A large object trapped between the leaves would have been detected (based on criteria given in paragraph 66) and train departure prevented by the interlock system. A large object trapped inside the train could not pass between the closed door leaves and so the coat would have been torn when it was pulled from the train after the accident (paragraph 31). The coat was not torn in this way.

55 It is therefore possible that, when the coat became trapped:

- the part of the pocket that became caught was empty; or
- a small or thin object in the pocket became trapped between the leaves; or
- a small or thin object in the pocket was caught inside the train and was pulled between the leaves during the accident.

56 The RAIB undertook tests intended to determine the force required to remove a coat with an empty pocket and a coat containing a thin object trapped between closed door leaves. These tests directly modelled the first two scenarios in paragraph 55. If an object was initially entirely inside the train (the third scenario), removal of the coat would be similar to the first scenario until the object was pulled between the leaves when the second scenario would apply. As details of any trapped object were not available, the RAIB used a plastic work pass, similar to a credit card, contained in a small holder with a maximum thickness of 4 mm.

57 The tests involved pulling the coat in a number of directions relative to the door faces (figure 13). These modelled the passenger pulling directly away from the train (the direction she probably pulled before the train started moving) and the passenger pulling towards the rear of the train (the likely situation while she was being dragged). Tests were also undertaken with forces applied towards the front of the train to demonstrate the differing responses of the fixed and pushback leaves.

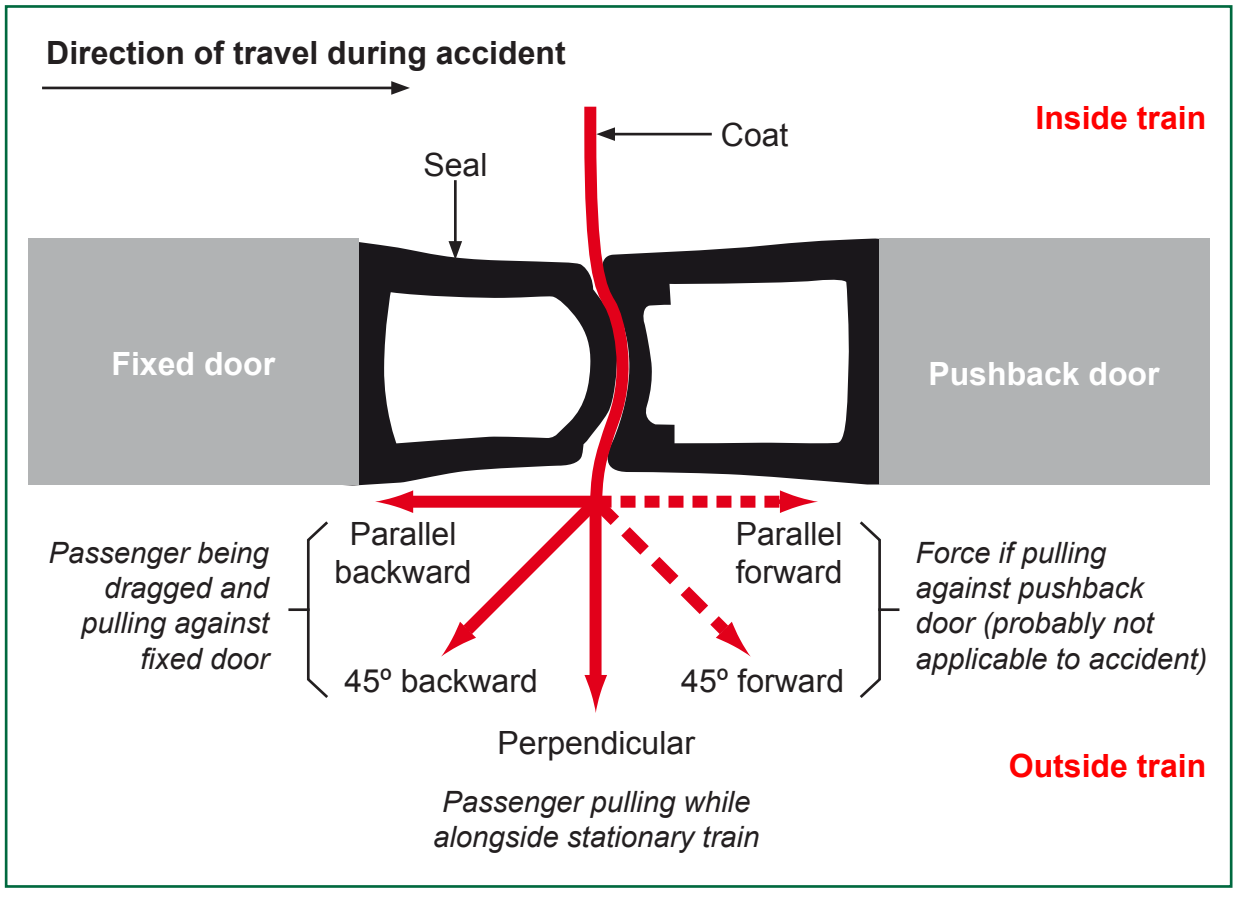

Figure 13: Pull test directions

58 In addition to tests using the coat, a further set of tests were carried out using London Underground's standard canvas test piece which is normally only used to check specified door pull-out forces during initial commissioning (paragraph 63). The results of the testing are detailed in table 2.

Scenario	***Pull direction***	***Coat (empty pocket)***	***Coat (work pass in pocket)***	***Canvas test piece***
Passenger being dragged and pulling against fixed leaf	Parallel backwards	>350 N*	>350 N*	180-220 N
	45º Backwards	>350 N*	>350 N*	170-190 N
Passenger pulling while alongside stationary train	Perpendicular	180-190 N	>350 N*	80-120 N
Force if pulling forwards against pushback leaf (probably not applicable to accident)	Parallel Forward	120 N	150 N	105 N
	45º Forwards	120-150 N	140 N	95-100 N
* Test forces were limited to avoid damaging the coat before completing the full test programme. Values in excess of 350 N were not required as this is the maximum force likely to have been applied when the passenger tried to pull her coat from the door.				

Table 2: Summary of pull-out testing results

59 The RAIB has compared these pull-out test results with the 350 N maximum force that the passenger was likely to have applied as established by RAIB tests (paragraph 50). A force greater than the passenger could reasonably have applied in good conditions was required to remove the coat when pulling at an angle backwards from the direction of travel (ie pulling against the fixed leaf), even if there was nothing in the pocket. When pulling perpendicular to the door with the test object in the pocket, the force required to pull the coat out was still higher than 350 N. Without the object in the pocket, the required force was smaller and it would have been feasible, but not easy in the cramped conditions and short time available, for the coat to be pulled out. All of the pulls at an angle forward of the direction of travel required much smaller forces to pull the coat out, regardless of whether the test object was in the pocket or not. This is because the pull was against the pushback leaf, which was able to move.

60 Tests with the canvas test piece (figure 14) showed that, for each direction of pull, the canvas could be pulled out with a lesser force than the coat. This difference is because the canvas piece was smoother and thinner than the coat.

61 London Underground standard E6721, 'Rolling stock (side sliding doors)', requires that the canvas piece can be removed from doors at a height of 1.25 metres above the floor with a perpendicular force of no more than 90 N. London Underground and Alstom carried out this test after the accident and a compliant pull-out force of 75 N was obtained.

Figure 14: Pull-out testing with canvas piece

62 RAIB testing included pulling the canvas piece perpendicular to the train in a manner similar to that given in standard E6721, but at a lower level of 0.5 metres above the floor. Some RAIB pull values exceeded the maximum permitted by standard E6721. It is likely that this was because the canvas piece wrinkled (rather than remaining smooth) during some tests. It is also possible that results at 0.5 metres height were affected by the buggy bar which reduces door seal flexibility in this area compared to the flexibility at the standard test height.

63 The pull-out force is not tested as part of routine train maintenance. However, this force is related to the condition of the door seals and the force required to move the pushback leaf. Train maintenance procedures require door seals to be inspected at a target frequency of 182 service days. London Underground reports that the last inspection before the accident was on 22 September 2014 with no resulting actions outstanding at the time of the accident. A post-accident inspection by the RAIB showed that the door seals were in satisfactory condition.

64 The maintenance procedures require pushback force to be tested every 460 service hours and London Underground reports that the last test before the accident was undertaken on 13 February 2015. Again, there were no actions outstanding at the time of the accident. Alstom and London Underground tested the pushback forces after the accident and found them to be compliant with the relevant Alstom work instruction, ATS-LIS-W1-00002[5].

[5] The measured pushback force of 120 N with a 15 mm door gap complied with the requirement of 120 N to 140 N and the measured force of 170 N with 115 mm door gap met the requirement of 160 N to 200 N.

65 The train's door control system did not detect that an object was trapped between the door leaves.

66 The design and maintenance of train doors is intended to ensure that they will not be detected closed (ie interlock will not be obtained) if there is an 8 mm gap, or more, between the door seals. Because of the profiles of the rubber seals, this equates to a 5 mm visible gap between the door seals when these are not compressed (figure 15).

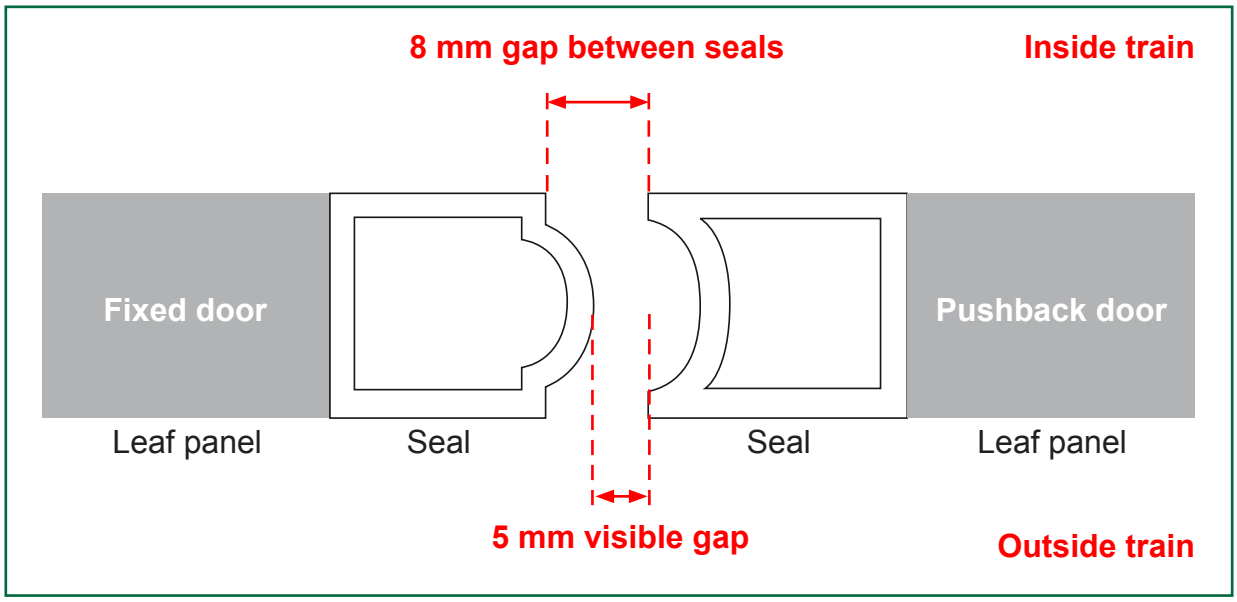

Figure 15: Door seal gap for loss of interlock

67 The train maintenance test specification requires a 5 mm thick block to be positioned between the door leaf seals, 1.2 metres above floor level, and the door held so that both seals touch the block but are not compressed. In this position, the door interlock should not detect that the door is closed. Post-accident testing by London Underground and Alstom confirmed that the interlock system complied with this requirement.

68 The ability of the system to detect an object is affected by both its height above train floor level and the flexibility of the door seals. Interlock is detected at the top of the doors and, because the doors are suspended from the top, the interlock is less sensitive to objects that are positioned lower down. The flexibility of the door seals allows them to compress around an object and so reduce the likelihood of a small object being detected.

69 During the accident the coat was trapped about 0.5 metres above floor level. RAIB tests showed that, when trapped in this position with an empty pocket, the coat material compressed and the gap between the outer faces of the door seals was only 4 mm. During RAIB testing (paragraph 56) interlock was obtained when the coat pocket contained a thin work pass trapped between the leaves.

Factors relating to train despatch

70 The design of the in-cab CCTV system did not allow the train operator to see that the passenger's coat was trapped before he started the train moving.

71 The train operator has a monitor in the cab which displays images from cameras located on the station platforms (paragraph 15). This monitor starts showing images shortly before the train stops in a station and continues to do so until the last car has left the station. The screen images allow the train operator to see the entire length of the side of the train when it is in the station. The images are intended to provide the train operator with an overview of a significant part of the platform area in addition to viewing the side of the train and the train doors.

72 The number of cameras varies depending on the station layout and the curvature of its platform. The northbound platform of Clapham South station is convex but less curved than some others on the Northern line. Two cameras are positioned near the station roof, close to the centre of the platform, facing opposite directions with overlapping views, each covering the length from the mid point to the end wall. The two camera views are arranged side by side on a single in-cab monitor which shows a view from one end of the train to the other (figure 16).

Figure 16: Train operator cab display at Clapham South station (image does not show accident situation)

73 The camera arrangement at Clapham South pre-dates the present standard for this type of equipment and London Underground has not been able to locate records showing the rationale for the arrangement. The current London Underground standard (1-150, Telecommunications - OPO CCTV) requires a risk assessment to be carried out for each station to determine the number of cameras required to achieve optimal coverage. It also requires that the number of cameras be kept to a practical minimum to reduce the number of separate images that the train operator has to monitor. The standard requires that, on an empty platform, the images should be sufficient to show at least the part of the platform within 1.3 metres of the train and, within this zone, a height of 2.4 metres above the platform. Actual coverage is shown on Figure 16 and there is no evidence that the extent of coverage was a factor in the accident.

74 When the platform is busy and some passengers do not board a train, the train operator cannot always see the full height of all of the train doors and so cannot be certain that nothing is trapped. This is because the camera view can be obscured by passengers (figure 17). In these circumstances, train operators are trained to look for unusual passenger behaviour and other signs that indicate a possible problem (paragraph 78).

Figure 17: Train operator's view of moderately busy northbound platform at Clapham South (in-cab monitor omitting outer edges of image and not showing accident situation)

75 When the passenger's coat became trapped, she tried to pull it out (paragraph 41). Neither the trapped coat, nor the passenger's actions would have been visible to the train operator because other passengers who had been unable to board the busy train, and were waiting for the next train, were obscuring the camera view. This has been established using a recording of the station CCTV which shows similar images to the unrecorded in-cab system (figure 2).

76 Witness evidence indicates that the passenger was shouting as she tried to free her coat, but this would not have been heard by the train operator. The absence of audio and visual clues before the train started moving meant that the train operator was not aware that the passenger was in difficulty until he saw the unusual movements of people on the platform after the train had started moving (paragraph 28).

77 The train operator's actions should be considered in the context of the London Underground processes for managing safety at the PTI. These are intended to maintain the throughput of trains needed to carry large numbers of passengers in an environment where a delayed train has the potential to quickly cause risks due to overcrowded platforms, overcrowding elsewhere in stations and crowded trains stopped in tunnels. This means that train despatch processes are intended to minimise the required *dwell time* in stations while simultaneously managing the PTI risk.

78 London Underground rule book 8, 'Managing the platform train interface', specifies that the train operator should 'check the entire platform train interface' before and after closing the doors, again after checking the starting signal permitting movement of the train and then (when an in-cab monitor is provided) as the train leaves the platform. The exact nature of these checks is not described in the rule book, but Northern line train operators are trained to watch the CCTV images for signs of unusual events continuously from when they initiate door closure until the train has left the platform.

79 The practice of looking for abnormal events on the platform, and accepting that it is not always possible for the train operator to see the full height of all train doors (paragraph 74) differs from that required on mainline railways in the UK. Mainline railway rule book GE/RT8000/SS1, 'Station duties and train dispatch', defines a specific 'train safety check' to be undertaken once, only after the train doors have been closed. This requires the driver, guard or platform staff to view the full length of the train in order to check that the train doors are properly closed, nobody is trapped in the doors (for example by their clothing) and that it is safe to start the train. The check can only be achieved by viewing all areas in which a passenger could be trapped. This difference between LUL and mainline practice should not be considered in isolation from other differences in their despatch processes (see paragraph 85).

80 London Underground has provided extracts from documentation dated 1997 and 1998 showing that PTI risk was considered both generally and in the context of introducing one person operation (OPO) on the Northern line. This change included train operators checking train doors using cameras instead of the check being undertaken by a guard looking along the train. These extracts do not give full details of all risks considered and do not explicitly mention risks associated with staff despatching trains when they cannot check every door, when their view is obscured by passengers standing near the platform edge. These risks existed when door checks were carried out by guards and are partly addressed by the training given to current train operators (paragraph 78).

81 The last fatal incident on London Underground due to a passenger being trapped in a closed door occurred on 21 October 1997 at Holborn station on the Piccadilly Line. In this instance, a child was dragged by the drawstring of his anorak after the drawstring toggle was trapped.

82 London Underground compiles statistics indicating the comparative PTI incident rates for each line. The incident rates take account of the number of passengers carried on each line and, in addition to events caused by people or objects trapped in doors, include slips, trips and other accidents at the PTI.

83 The statistics show that the PTI incident rate on the Northern line has slightly decreased since 2010, and has been relatively stable since 2012. It also shows that the PTI incident rate for the Northern line is similar or better than that for other comparable London Underground lines (figure 18).

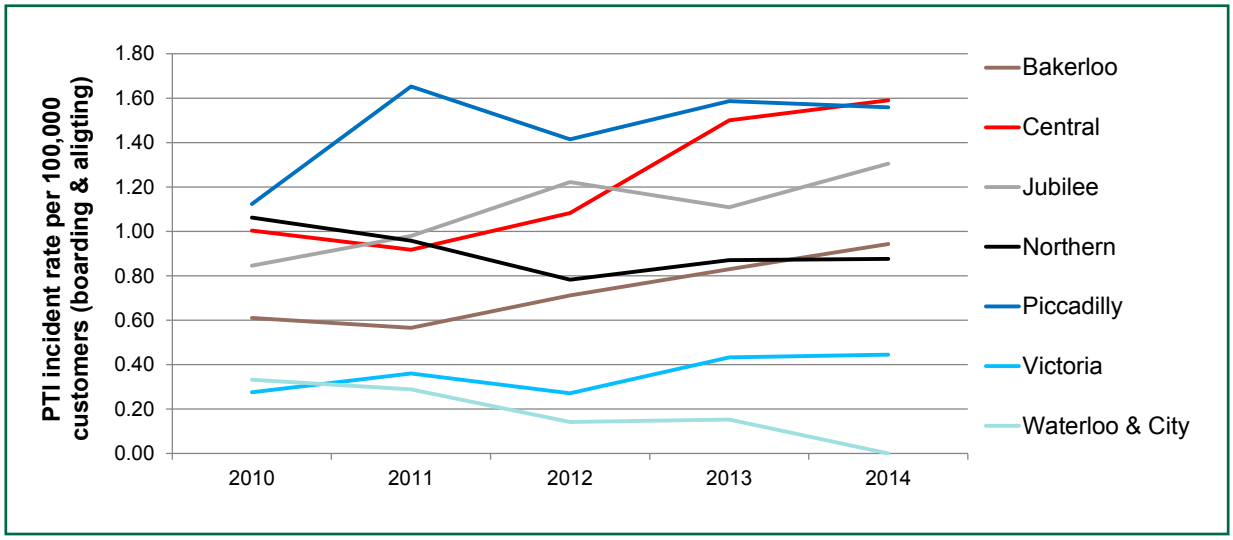

Figure 18: Normalised PTI incident rate on London Underground's tube network line

84 The RSSB[6] 'Annual Safety Performance Report 2014/15' provides statistics that allow a comparison of London Underground accident rates with those for the mainline railway for the period from 2009/10 to 2013/14. The data considers both fatalities and major injuries, with ten major injuries considered equivalent to one fatality. This combined measure is referred to as FWMI (Fatalities & Weighted Major Injuries).

[6] 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'.

85 The RSSB data shows that, for the period from 2009/10 to 2013/14, the FWMI for PTI accidents was 2.8 per billion journeys on London Underground and 5.7 per billion journeys on the mainline network. Although the total annual number of passenger journeys is similar on both networks (1.3 billion and 1.65 billion respectively in 2014/15), the risks experienced by passengers sometimes differ because the nature of journeys differ. The PTI statistics include many accidents that do not involve people or objects being trapped in doors and so do not allow a direct comparison of the differing despatch arrangements on London Underground and the mainline (paragraph 79). However, the statistics do show that the overall accident rate at the PTI is lower on London Underground than on the mainline.

86 London Underground has reported that 23 incidents involving passengers being dragged after becoming trapped in train doors occurred on its network between April 2010 and December 2015. No fatalities resulted but two of these incidents caused serious injuries, eight resulted in minor injuries and no injuries were reported in the remaining instances. There were around 7 billion passenger journeys in this period, and so the probability of an individual regular user[7] becoming trapped in train doors, and then being dragged, is approximately one in 600,000 per year.

87 **The CSA was unaware that the passenger was trapped until after the train started moving.**

88 The CSA was performing SATS duties during the busy morning peak at Clapham South station. These duties are described in the London Underground rule book 8, 'Managing the platform train interface', and involve managing passenger behaviour and movements on the platform to expedite prompt boarding of trains, thus allowing train throughput to be maintained. The rule book states that when it is time for a train to depart, the CSA should make departure announcements to passengers, raise their baton and keep it raised until the first car of the train has cleared the platform. The CSA is not required to check for objects trapped in doors because the train operator is responsible for ensuring safety during door closure and train departure. However, a CSA is expected to try and stop a train if they become aware of an emergency situation (paragraph 91).

89 When the train departed, the CSA was standing with his baton raised in the central part of the platform, about midway along the train (figure 5). This was within the area where London Underground expect staff to stand when carrying out SATS duties on the northbound platform at Clapham South. He was approximately 10 metres from the door where the passenger had become trapped but could not see that she was in difficulty because his view of her was obscured by people on the platform who had been unable to board the train.

90 Witness evidence indicates that, before the train started moving, the CSA heard shouting on the platform which he thought sounded more like an argument than someone in difficulty. The witness evidence, supported by CCTV footage, indicates that the CSA first became aware that the passenger was in difficultly when she was dragged past him as the train was departing.

[7] eg a commuter working 250 days/year, and so making approximately 500 journeys/year.

91 In the event of an emergency situation, rule book 8 and associated training material require a CSA to stop a train by waving both hands above their head or by switching off the train power using either the headwall tunnel telephone or a suitable plunger where provided. The CSA chose to use the tunnel telephone.

92 On this occasion the train operator and CSA became aware that the passenger was trapped at about the same time, and the CSA could not have stopped the train more quickly than the operator did by using the emergency brake. However, in other circumstances direct communication from the CSA to the train operator could be more appropriate as discussed at paragraph 111.

Factor relating to the station infrastructure

93 **The gap between the train and the platform was large enough for the passenger to fall through.**

94 Station CCTV images show that, when the train had stopped after the accident, the passenger was lying in the recess under the platform close to the front of the last (6th) car of the train. This means that she had fallen between the train and the platform somewhere between the rear double door of the 4th car and the front of the 6th car.

95 The gap between the train and the platform edge varies between 100 mm and 200 mm except at the connection between adjacent cars where there was a clear gap of approximately 250 mm over a length of approximately 400 mm (figure 19). It is probable that she fell between two cars because she would probably have sustained more serious injuries if she had fallen through the smaller gap at other locations. It is uncertain whether she fell between the 4th and 5th cars or between the 5th and 6th cars. The nature of her injuries suggest that she fell directly into the recess under the platform (paragraph 96).

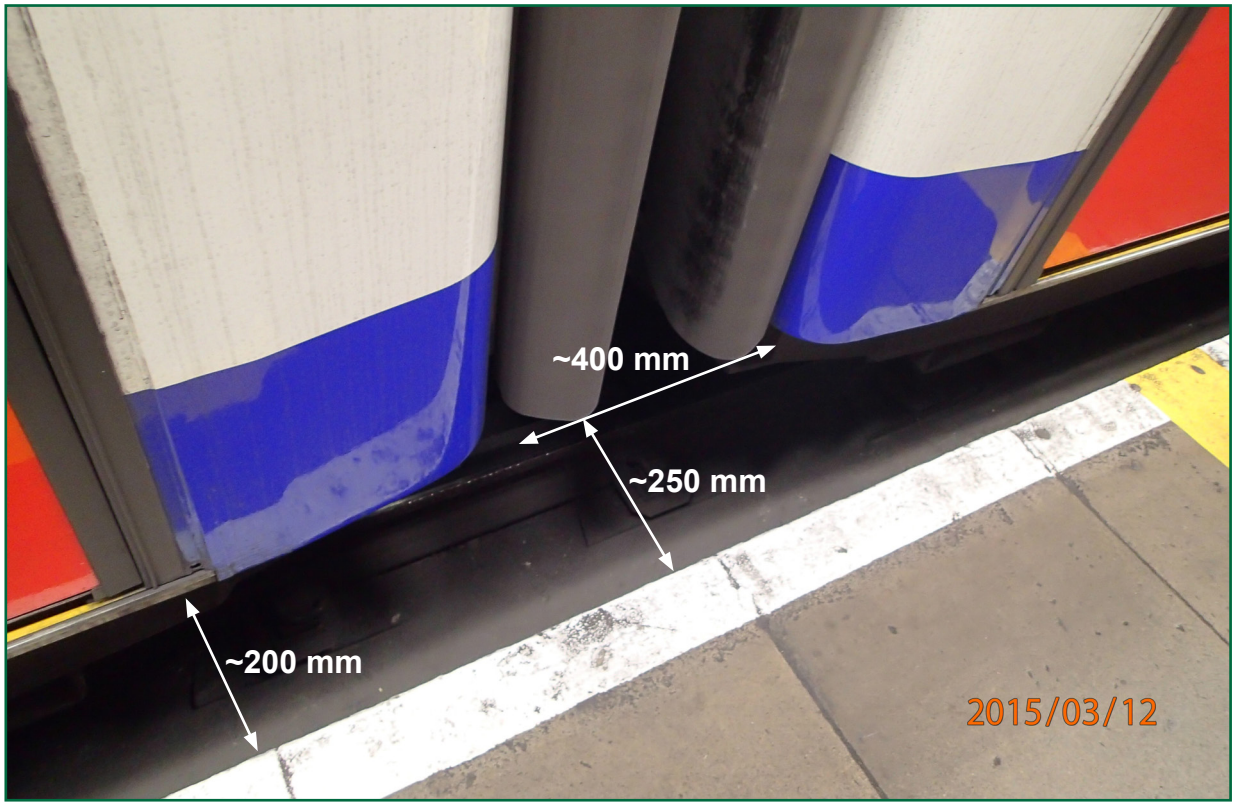

Figure 19: Platform gap at car ends

Factors affecting the severity of consequences

Platform design

96 **The platform has a recess into which the passenger fell, probably reducing her injuries.**

97 London Underground standard S1131 (Premises - Station Platforms) requires a 300 mm wide recess under new and altered platforms to provide a refuge in an emergency, unless platform edge doors are fitted. The northbound platform at Clapham South station pre-dates this standard and has a 280 mm recess (figure 20). Although slightly smaller than current requirements, the recess was sufficient to allow the passenger to be positioned clear of the train after she had fallen from the platform.

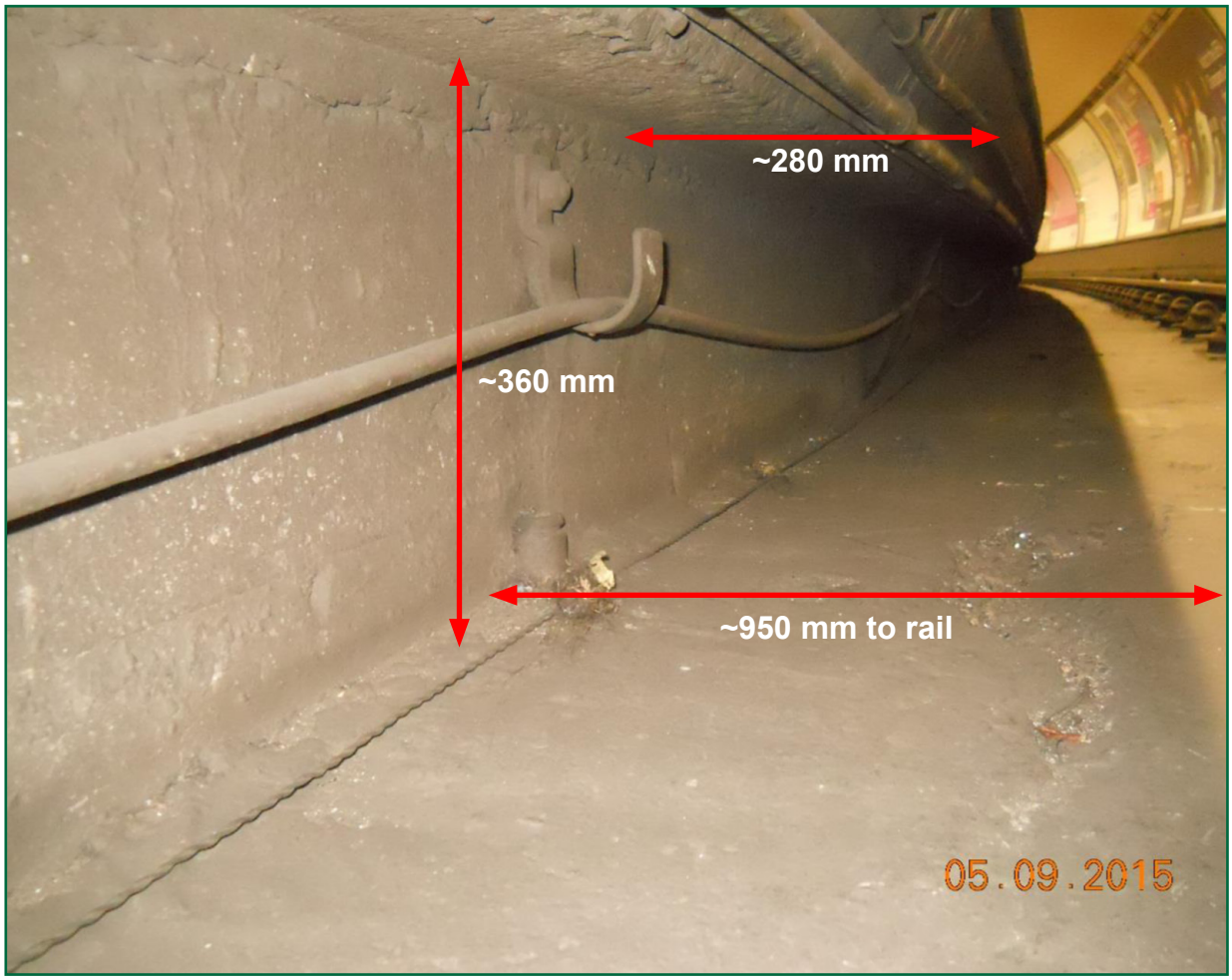

Figure 20: Clapham South platform recess

98 It is possible that both *bogies* of the 5th car, and certain that the leading bogie of the 6th car, passed the passenger after she fell from the platform (paragraph 95). It is likely that the recess reduced, and possibly prevented, her suffering injuries from these bogies and the live electrical equipment carried on the leading bogie of the 6th car.

Train operator actions

99 **The prompt actions of the train operator, using the in-cab CCTV system, may have reduced the consequences of the accident.**

100 During the accident, the train operator responded quickly when his in-cab monitor showed unusual passenger movements on the platform after the train departed. His prompt application of the brake meant that the rear bogie of the 6th car, which carries live electrical equipment, did not pass the passenger as she lay beneath the platform, avoiding the risk of additional injury.

Previous occurrences of a similar character

101 A passenger was dragged a short distance along the platform at King's Cross mainline station on 10 October 2011 after her hand was trapped in a train door. The RAIB investigation of this accident (RAIB report 09/2012) included a recommendation which has resulted in doors on a class 365 train, an *electric multiple unit* operating on the mainline, being retro-fitted with an improved (sensitive edge) object detection system. The train operator expects to start fitting the remainder of these trains with a similar feature in April 2016. Improved object detection systems are among the door modification options that should be considered by London Underground when implementing Recommendation 1 of this report (paragraph 117).

102 On 3 February 2014, a passenger was dragged about ten metres along the platform at Holborn station by a departing Piccadilly line train, after her scarf became caught between the closing doors of one of the cars. This accident was the subject of RAIB report 22/2014 which included a recommendation discussed at paragraph 108.

103 The RAIB has investigated one other trap and drag incident on London Underground infrastructure (Tooting Broadway, RAIB report 17/2008) and nine trap and drag events on other systems (eight on the mainline railway and one involving a tram). An RAIB investigation into a passenger being dragged at Hayes and Harlington station is currently in progress.

Summary of conclusions

Immediate cause

104 The passenger's coat became trapped in the train door so that she was dragged and then fell beneath the train as it started to move out of the platform (**paragraph 34**).

Causal factors

105 The causal factors were:

a. The passenger's coat became trapped in the door (**paragraph 36**, no recommendation).

b. The passenger was unable to remove the coat from between the door leaves after it became trapped (**paragraph 40, Recommendation 1**).

c. The train's door control system did not detect that an object was trapped between the door leaves (**paragraph 65, Recommendation 1**).

d. The design of the in-cab CCTV system did not allow the train operator to see that the passenger's coat was trapped before he started the train moving (**paragraph 70, Recommendation 1**).

e. The CSA was unaware that the passenger was trapped until after the train started moving (**paragraph 87, no recommendation**).

f. The gap between the train and the platform was large enough for the passenger to fall through (**paragraph 93, Recommendation 1**).

Factors affecting the severity of consequences

106 Factors that mitigated the consequences of the event were as follows:

a. The platform has a recess into which the passenger fell, probably reducing her injuries (**paragraph 96, Learning point 1**).

b. The prompt actions of the train operator, using the in-cab CCTV system, may have reduced the consequences of the accident (**paragraph 99**).

Previous occurrences of a similar character

107 Previous trap and drag incidents on the UK rail network have included eleven investigated by the RAIB, and two of these investigations related to London Underground trains (paragraphs 101 to 103).

Previous RAIB recommendations relevant to this investigation

108 The following recommendation made by the RAIB as a result of a previous investigation is relevant to the method used by CSAs performing SATS duties when they need to stop a train in an emergency (paragraph 92).

Accident at Holborn station on 3 February 2014, RAIB report 22/2014, Recommendation 1

Recommendation 1

London Underground Ltd should provide staff acting as Station Assistant (Train Services) (SATS) with an effective means of alerting the train operator to a dangerous situation that arises after the SATS has given the signal to start the door closing sequence, and before the train has begun to move.

London Underground Ltd should also review how the role of the SATS is described in Rule Book 8 and other company documents, so that the duty of the SATS to rapidly respond to dangerous events that occur during the despatch process is given appropriate emphasis.

109 The Office of Rail and Road (ORR) reported to the RAIB on 16 September 2015 that the first part of this recommendation will not be implemented and that the second part has been implemented.

110 ORR reported that London Underground has considered possible alternative means for CSAs to alert train operators to instances of dragging, and concluded that the cost of implementing these is disproportionate to any benefit gained. ORR reports that it considers that implementing any of these options would not be 'reasonably practicable' in accordance with law and therefore not enforceable by ORR.

111 Although the CSA at Clapham South could not have stopped the train significantly more quickly than the operator did (paragraph 92), there are other circumstances in which a CSA could become aware of a problem before the train operator. Some London Underground staff have stated that, although not explicitly stated in the rule book, they would expect a train operator to stop immediately if they saw a CSA waving their baton. This signal (or other warnings given with the baton) would be more obvious on a crowded station than waving hands above the CSA's head. It would be of particular value on lines, such as the Northern line, where in-cab monitors allow train operators to see the CSA until the full length of the train has left a station. Revisiting the ways in which CSAs can give warnings to train operators is included in recommendation 1 of the present report.

112 ORR also reported that, in response to the second part of the recommendation, London Underground has reviewed the SATS role and re-briefed it. London Underground has also confirmed that Rule Book 8, 'Managing the Platform train Interface', is expected to be amended in April 2016 to provide emphasis on responses to dangerous events during despatch.

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

113 London Underground reported that it had previously explored technical measures to address PTI risks but considered that the safety benefit did not justify the costs unless implemented as part of a major upgrade scheme. This has included the following measures:

a. Installation of platform edge doors on existing lines as already provided on tunnel sections of the most recently constructed part of the underground network (the eastern part of the Jubilee line).

b. Installation of sensitive edge object detection – a system which detects smaller objects than those detected by existing Northern line trains and which is fitted to the modern tube trains which operate on the Victoria Line.

c. Converting fixed leaves to pushback leaves on double doors (this would require considerable engineering change, and would have no effect on single leaf doors).

114 London Underground reported that it has trialled crowd control measures on the Northern line. Trials of some northbound trains not entering service until Tooting, in order to provide passenger space at Clapham stations, moved passenger crowding elsewhere and disrupted even passenger flows. Restricting passenger entry at stations was successful in reducing crowding at the platform, but led to overcrowded ticket halls and extended journey times.

115 In response to this accident, and in the light of other PTI accidents, London Underground has set up a team to action recommendations and to co-ordinate PTI risk management across all of its lines. Initially, this team is considering several potential measures to improve PTI safety. These include:

a. improving passenger awareness of the PTI risk at train doors using harder hitting, targeted safety messages;

b. localised briefing of CSAs allowing them to tailor announcements to suit individual station conditions;

c. encouraging CSAs to move around the platform to suit local circumstances rather than mandating a defined position when undertaking SATS duties;

d. using alternative types of baton including one incorporating a red emergency stop light;

e. providing platform staff with a portable means of stopping trains in an emergency;

f. repositioning, and reassessing the number of, CCTV cameras providing in-cab monitor images of the PTI (higher risk locations are being addressed in a programme which started in January 2016 and is expected to include relocating cameras, and providing an additional camera, on the Clapham South northbound platform); and

g. adjusting the configuration of yellow lines on platforms to alter passenger behaviour at doors (a trial at four sites, including Clapham South, started in November 2015).

Learning point

116 The RAIB has identified the following key learning point[8] which is already mandated on many parts of the UK rail and tramway network:

1 Designers of new and upgraded platforms should (unless shown to be unnecessary due to the provision of platform edge doors and/or other measures) include under-platform recesses to mitigate the consequences of accidents where passengers fall between the platform and trains or trams.

[8] '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.

Recommendation

117 The following recommendation is made[9]:

1 *The intent of this recommendation is to ensure that London Underground continues to improve management of PTI risks by building on work already started by a group established after the Clapham South accident. The time-bound, funded programme provides a means for London Underground to demonstrate its long-term commitment to reducing these risks where reasonably practical.*

London Underground should review the feasibility and effectiveness of measures to reduce risks associated with passengers being trapped in train doors and then dragged at the platform-train interface (PTI). The review should include measures already considered for all or part of the London Underground network, techniques already used by other railway operators, measures already considered by RSSB and measures made possible by the latest technology available when the review is undertaken. The review should include, but not be restricted to, consideration of:

- improving detection of objects trapped in train doors;
- improving the ability of passengers to pull out objects trapped in doors (including by improving door seal arrangements);
- improving train operator views of the PTI at despatch (eg increasing the number of CCTV cameras, repositioning cameras and providing larger monitors);
- enhancing the methods available to staff performing SATS duties when they need to alert train operators, or stop trains, in an emergency;
- using gap fillers or alternative means to reduce the gap between platforms and both moving and stationary trains;

continued

[9] Those identified in the recommendation have a general and ongoing obligation to comply with health and safety legislation, and need to take this recommendation 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, this recommendation is 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.

- adapting platform markings to reduce passenger crowding close to trains/doors; and
- raising passenger awareness of the safety risks associated with objects, fingers and hands becoming trapped in doors.

The review should conclude with a time-bound, funded plan for progressing development of potentially viable measures. This should, if appropriate, include solutions which are only applicable to some parts of the London Underground network.

Appendices

Appendix A - Glossary of abbreviations and acronyms

ATO	Automatic Train Operation
CCTV	Closed Circuit Television
CSA	Customer Services Assistant
FWMI	Fatalities & Weighted Major Injuries
OPO	One Person Operation
ORR	Office of Rail and Road
PTI	Platform-train interface
SATS	Station Assistant (Train Services)

Appendix B - Glossary of terms

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

Automatic train operation	Control of trains based on commands transmitted from line side equipment.
Baton	A handheld, lollipop-shaped object used by platform staff to give a signal to train operators (illustrated on figure 6).
Bogie	A metal frame equipped with two wheelsets and able to rotate freely in plan, used in pairs under rail vehicles.*
Buggy bar	U-shaped strip inserted in the lower part of a door seal to reduce seal flexibility so that small objects are detected and door interlock is not obtained (illustrated on figure 11).
Conductor rail	Rail through which electricity is transmitted to trains (the rail is not used by train wheels).*
Customer services assistant	A member of station staff whose duties involve assisting passengers.
Dwell time	The time that trains spend stationary in a platform.
Electric multiple unit	An electrically powered train consisting of one, two or more vehicles semi-permanently coupled together with a driving cab at both ends. Can be coupled to similar multiple units. All traction power and brakes on all vehicles can be controlled from the leading cab.*
Interlock (door)	An electronic or electro-mechanical system which prevents a train from being moved under power if all doors are not closed.
Leaf (door)	Sliding or swinging part of a door.
Pilot light	Indicator light which illuminates in the driving cab when interlock is achieved throughout a train.
Platform-train interface	The area a passenger crosses when moving from platform to train, and vice versa.
Pushback (door mechanism)	A mechanism allowing a door leaf to be pushed slightly open even when the door is nominally closed.
Seal (door)	Rubber or plastic strip on the edge of a door leaf.
Station assistant (train services) duties	A duty, often called SATS duty, intended to maintain passenger flow onto and off trains.
Train operator	Person who drives, or interfaces with the automatic train control system, on a London Underground train.

Tunnel headwall telephone	A wall mounted telephone at the end of the platform near the entry to the tunnel normally used by trains leaving the station. Use of this telephone usually removes traction power from trains in the immediate vicinity of the platform.

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) and other on-board systems;
- CCTV recordings taken from the station platform;
- site photographs and measurements;
- testing of the train carried out by the RAIB, London Underground and Alstom;
- London Underground standards, guidance, procedures and training material; and
- a review of previous RAIB investigations that had relevance to this accident.

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