RAIB

Rail Accident Investigation Branch

Rail Accident Report

Train departed with doors open, Warren Street, Victoria Line, London Underground 11 July 2011

Department for Transport

Report 13/2012
July 2012

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.

Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Email: enquiries@raib.gov.uk
Telephone: 01332 253300
Fax: 01332 253301
Website: www.raib.gov.uk

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

Train departed with doors open, Warren Street, Victoria Line, London Underground 11 July 2011

Contents

This page is left intentionally blank

Summary

At 17:29 hrs on 11 July 2011, a loaded passenger train on the Victoria Line of London Underground departed from Warren Street station with all the passenger saloon doors open on the platform side of the train. When the train reached 8 km/h, a safety system on the train closed the doors, but not before the train had entered the tunnel with the leading set of saloon doors open. No-one was hurt in the incident.

The train, consisting of new 2009 tube stock, is fitted with sensitive edge doors designed to apply the brakes if a thin object trapped by the doors is detected. The sensitive edge system was activated when the train stopped at the previous station, Oxford Circus.

The train left Warren Street station with the doors open because the train operator had omitted to close them, having previously disabled the train door interlock (a safety system that requires the doors to be closed before a train can start). The train operator was unable to reset the sensitive edge system between Oxford Circus and Warren Street, and became more and more confused in his attempts to resolve it. The RAIB found that the modification to allow train operators to override an activated sensitive edge system had changed the operation of an indication light, which probably misled the train operator. Deficiencies in the train operator's competence had not been identified and this lack of competence was also a probable factor leading to the train operator's confusion.

The RAIB has made four recommendations to London Underground Ltd covering a review of the guidance and instructions to train operators relating to resolving activated sensitive edge systems; the process of managing engineering change; the competence management of train operators; and the requesting of operational and technical support by train operators.

Introduction

Preface

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and to improve railway safety.

2 The RAIB does not establish blame or liability, nor carry out prosecutions.

Key definitions

3 All dimensions and speeds in this report are given in metric units.

4 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.

The incident

Summary of the incident

5 At 17:29 hrs on 11 July 2011, a northbound Victoria Line train departed from Warren Street underground station (figures 1 and 2) with all the saloon doors open on the platform side of the train. The train's destination was Seven Sisters and the service number was 237.

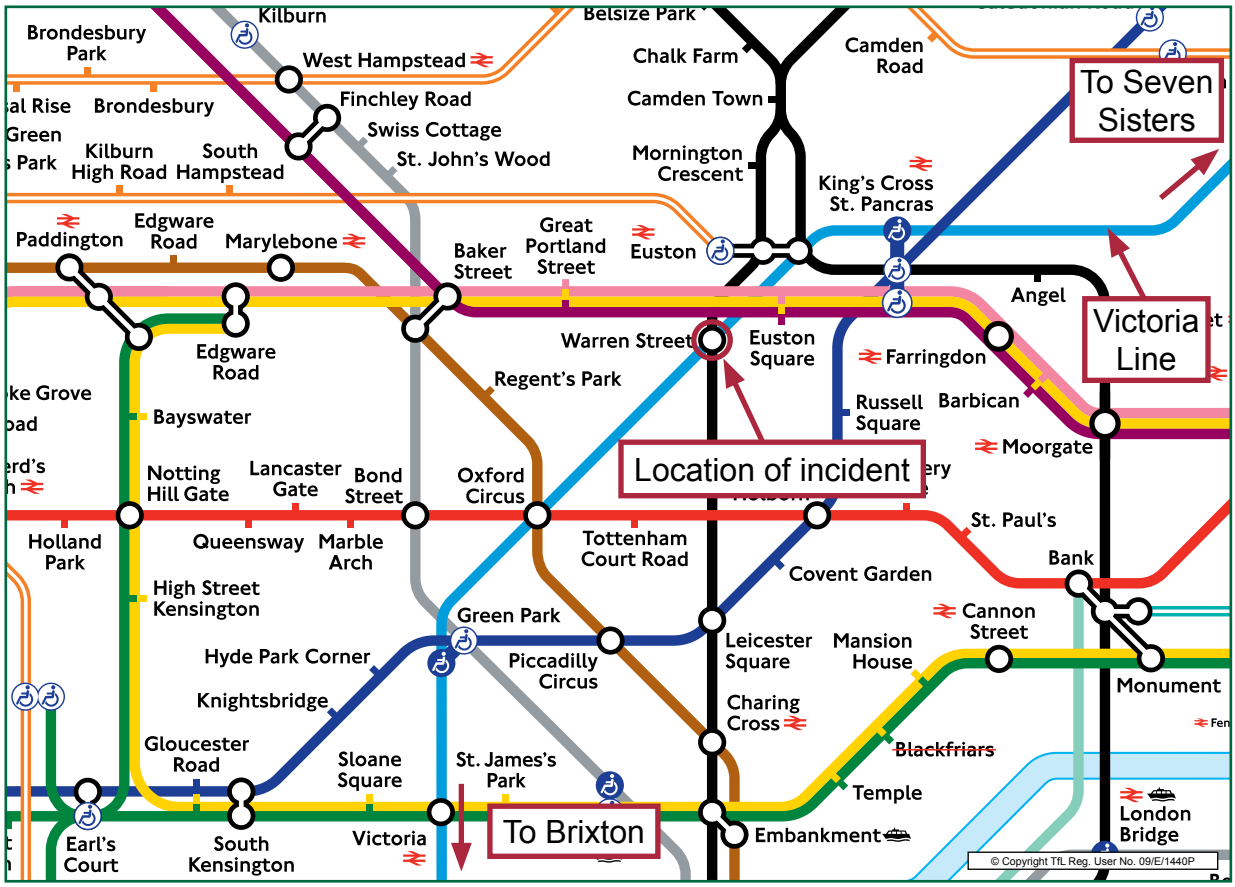

Figure 1: Extract from Transport for London map showing location of incident

6 After the train had been moving for about three seconds, and when the train reached 8 km/h, a safety system on the train automatically closed the doors. By this time, the first car had entered the tunnel with the leading set of passenger doors open.

7 When the train reached 11 km/h, and on realising that something was wrong, the train operator applied the service brake and then the emergency brake to stop the train, by which time it had travelled 14 metres. Around 13 metres of the distance travelled was into the tube tunnel immediately beyond the end of the platform.

8 After the train stopped, station staff de-trained the passengers, and the train was taken out of service. It then ran empty to the depot at Northumberland Park for examination.

9 No passengers were injured in the incident.

Figure 2: Northbound platform at Warren Street, Victoria Line (by courtesy of London Underground)

Organisations involved

10 London Underground Limited (LUL) operated and maintained the train. It also employed the staff directly involved in the incident.

11 LUL is a subsidiary of Transport for London, the local government body responsible for the provision, co-ordination and, where appropriate, licensing of all public transport within Greater London. LUL's day-to-day management of each line is carried out by a general manager reporting to the Chief Operating Officer who is responsible for the overall running of all LUL's operations.

12 The rolling stock engineering function of LUL is part of LUL's Capital Programmes Directorate and consists of an engineering standards organisation and project teams responsible for managing the rolling stock aspect of line upgrades, such as the introduction of the new Victoria Line trains.

13 Bombardier Transportation designed and built the train involved in the incident at its works in Derby.

14 Both LUL and Bombardier freely co-operated with the investigation.

Train involved

15 The train was formed of *2009 tube stock* that had recently been introduced into service on the Victoria Line as part of an upgrade of the trains and signalling.

16 Each train consists of eight cars, made up from two four-car units that are semi-permanently coupled together and can accommodate 252 seated passengers and 1196 standing passengers. The total length of a train is 133.28 metres.

17 On each car there is a set of double sliding doors at a third and two thirds of the way along each side. In addition, the cars without a driving cab have single leaf sliding doors giving access to the passenger saloon at each end; cars with a driving cab have single leaf sliding doors giving access to the saloon at the non-cab end. The layout of the doors is shown later in the report in figure 5.

18 The trains normally operate in *automatic mode* and only require the train operator to open the doors on arrival at a station, and then close the doors and press the *start buttons* (figure 3) if it is safe for the train to depart.

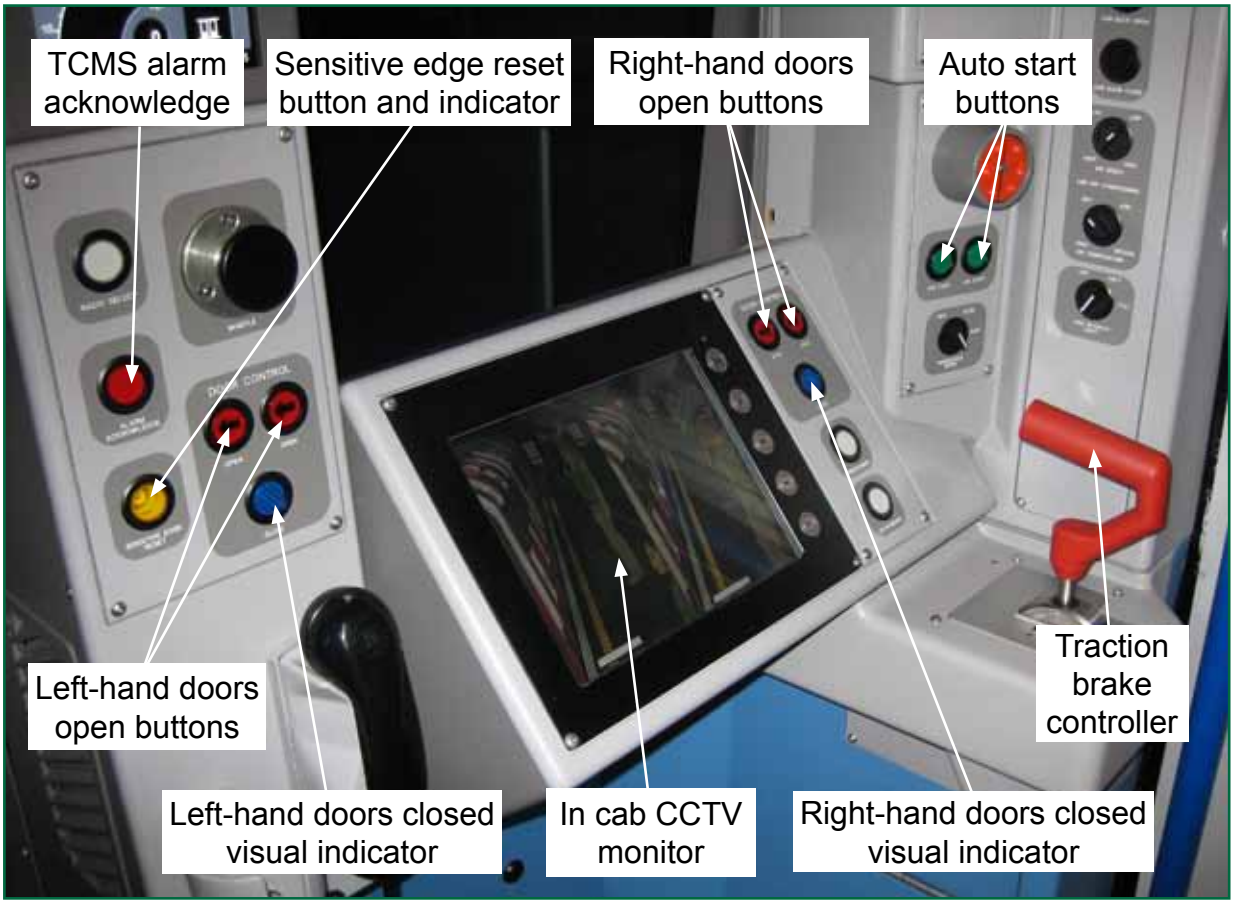

Figure 3: Layout of relevant cab controls in the driving cab of 2009 tube stock

Train equipment and systems involved

Train door systems

19 The train doors are hung on the outside of the cars (figure 2), and are driven open and closed by electric motors that are controlled by electronic door control units. The doors incorporate an obstacle detection system to detect large objects that prevent the doors fully closing, and a sensitive edge system to detect thin objects that have been trapped by the closing doors, but do not prevent the doors closing fully.

20 The obstacle detection system works when the train operator closes the doors. Should a closing door encounter an obstruction, it will stop and reopen by 25 mm to 75 mm, then pause for 0.5 seconds before attempting to re-close again. If the obstruction remains, the door will make two further attempts to close by opening and then closing again, and the train operator will be prevented from obtaining traction power.

21 The train operator can only get traction power to start the train if an electrical circuit, known as the train doors interlock circuit, is completed. This is achieved when all the train doors are fully closed and proved to be closed. This is indicated to the train operator by the illumination of the *doors closed visual indicator* (figure 3).

22 The sensitive edge system is also provided to prevent a person who is trapped, for example by part of their clothing, being dragged along the platform when the train starts. If the doors close fully but have trapped a thin object which is detected by the sensitive edge system, an immediate emergency brake application is demanded either:

- when the train operator attempts to start the train in a station; or
- if the train is already in the process of departing from a station when the system is activated (eg a trapped object may not activate the sensitive edge system until a person attempts to pull it free, by which time the train may have started).

23 The sensitive edge system is provided by parallel conductors in the door rubbers on the vertical edge of all the saloon doors. These are normally separated, but if they are squeezed together by a trapped object, the conductors will contact each other causing the *sensitive edge brake relays* to de-energise resulting in an emergency brake application.

24 When a sensitive edge is activated while a train is stopped at a station, the train is prevented from moving when the train operator presses the start buttons because the brakes will not release. A 'sensitive edge reset' push button also illuminates after the start buttons have been pressed as an indication to the train operator that the sensitive edge system has been activated (figure 3). The train operator should then check for anything trapped on the outside of the train, using the in-cab closed-circuit television (CCTV) showing the train doors, and should open and close the saloon doors to attempt to clear the cause of the sensitive edge trigger. The sensitive edge reset button must then be pressed to release the brakes.

25 As originally designed, the doors were not intended to have the sensitive edge system, but were to be fitted with the same type of system as fitted to most other London Underground trains. In this system one of each pair of double leaf doors and each single leaf door is fitted with a spring (known as a push-back spring) against which a trapped person can push back up to 115 mm in order to release themselves.

26 When the first two trains were being tested, it was found that the doors were opening far enough during emergency brake applications to lose the doors closed visual indication. This was because the train doors are so heavy that their momentum was sufficient to overcome the push-back springs.

27 The stiffness of the push-back spring could not be increased to prevent the doors opening because it would then require too much effort for a trapped person to push against. A different solution was investigated by LUL and Bombardier with the result that doors with sensitive edges were adopted instead of push-back springs.

28 The introduction of sensitive edge doors provides additional information to the train operator to assist with the safe departure of trains from stations. A train is prevented from being started in error if someone is trapped by the doors, because an immediate emergency brake application then occurs. Doors with push-back springs rely on the vigilance of the train operator to check that no-one is trapped by the doors before starting the train.

Sensitive edge override modification

29 The sensitive edge system was modified to provide train operators with a means to override an activation of the system. This modification was developed because significant service delays were occurring on the Victoria Line, caused by passengers' clothing being trapped from the inside of the train (about three a day causing delays of more than two minutes, and many more unrecorded incidents causing a shorter delay).

30 The modification was implemented in December 2010 and requires the train operator to push in the sensitive edge reset button and hold it depressed, while having also pressed and released the start buttons in automatic, until the train is outside *station limits*.

31 Before overriding the sensitive edge system, the train operator must check first that no-one is trapped on the outside of the train and therefore that the cause of the sensitive edge activation is from the inside of the train.

Cut out switches

32 In the event of specific fault conditions (which may then require the train to be taken out of service at the next station), the train operator is able by procedure to cut out safety circuits, using rotary switches that are mounted behind a lockable cover on the back wall of the cab. The following cut out switches are relevant to this investigation:

- Round train circuit - a switch that disables the safety circuit which proves the train is complete, coupled correctly and that the safety devices on the train are in the reset or normal position. The round train circuit ensures that the right conditions are met to enable the brakes to be released. Any interruption to the round train circuit will cause the emergency brake to be applied.
- Sensitive edge brake - a switch that disables that part of the control circuitry which detects the presence of thin objects caught in the closing doors.
- Train door interlock - a switch that disables that part of the control circuitry which requires the train doors to be closed in order that traction power can be obtained.

Driving modes

33 The 2009 tube stock can be driven in the following modes:

- automatic
- *protected manual*
- *restricted manual*

Each mode is selected using the *master control switch* (figure 4).

Figure 4: Master control switch 2009 tube stock

34 The normal mode in passenger service is 'automatic' in which the system accelerates, brakes and accurately stops the train, as required, after the train operator has pressed the two start buttons. This is known as *automatic train operation* (ATO). The train is prevented from colliding with another train by a system called *automatic train protection* (ATP).

35 The manual modes of driving are the 'protected' and 'restricted' modes and are used following the occurrence of some fault conditions and while driving within the limits of the depot at Northumberland Park. The manual modes are not normally used while trains are in passenger service. In the protected mode, the train is prevented from colliding with other trains by the ATP system and the maximum permitted speed is 80 km/h. ATP is not available in the restricted mode where the maximum permitted speed is limited to 16 km/h.

36 In order to use the manual driving modes, the train operator must operate the master control switch to the appropriate position and then drive the train using the *traction brake controller* (figure 3).

Train control management system (TCMS)

37 The TCMS is an on-train computer system which monitors, records and displays fault and other event conditions associated with a train's electrical and electronic control systems. The interface between the TCMS and the train operator is a touch sensitive display screen in the driving cab, which allows the train operator to view data displayed by the TCMS and to respond appropriately to the information provided.

38 The TCMS provides messages about the condition of the train and suggests technical actions that the train operator should take in response. It does not include operational procedures, because these are likely to change periodically and are covered by training and briefing.

39 There are three categories of messaging based on the impact of the event on the train and the ability of the train operator to take any action in response. The event category, decided by a group made up of LUL and Bombardier representatives, determines whether the message will be displayed immediately or when the train is next stationary at a station. The messages are accompanied by an audible alarm which the train operator must acknowledge. There is a further category of message known as an operational advisory which is accompanied by an audible single momentary alert.

40 For events causing an alarm, which the train operator has acknowledged, the message displayed on the TCMS screen can be cleared from the screen by acknowledging the touch screen button, once the cause of the message has been resolved.

Staff involved

41 The train operator joined London Underground as a station assistant at Oxford Circus station in November 2001. In October 2003, he progressed to the grade of train operator on the Northern Line, based at Golders Green depot. In October 2006, he transferred to a train operator post at Seven Sisters depot on the Victoria Line.

42 The train operator undertook LUL training and assessments in order to drive trains, and also undertook specific training and assessment on the new 2009 tube stock. He was deemed to be competent by LUL and had a licence to undertake safety critical work covering train operation that was valid until 22 December 2013.

43 In the minutes leading up to the incident, and immediately following it, the train operator was in radio communication with two of the service controllers on duty in the Victoria Line *service control*. The Victoria Line service control monitors the operation of the Victoria Line and takes action when necessary to manage the train service and minimise the operational consequences of out-of-course events.

The investigation

Sources of evidence

44 The following sources of evidence were used:

- witness evidence;
- relevant documentation concerning the training and competence of the train operator;
- relevant documentation concerning the use of the sensitive edge system;
- relevant documentation concerning the implementation of the sensitive edge override modification;
- data from the train's *on train data recorder* (OTDR);
- CCTV images recorded at Warren Street station;
- CCTV images recorded at Oxford Circus station;
- recordings of voice communications between the train and the service control centre; and
- a review of previous occurrences of sensitive edge incidents.

Key facts and analysis

Sequence of events

Events preceding the incident

45 The train operator booked on duty at 15:18 hrs on 11 July at Seven Sisters depot following two days off duty. He then travelled to the nearby depot at Northumberland Park to pick up his train, which entered passenger service when it reached Seven Sisters station. He drove the train to the southern terminus at Brixton and left that train to join the following terminating train which he drove, as train 237 to Seven Sisters, departing from Brixton at 17:04:30 hrs.

46 The download of the OTDR shows that train 237 arrived at Oxford Circus at 17:17:23 hrs and the train operator closed the doors at 17:17:56 hrs. The doors closed visual indicator (figure 3) illuminated, indicating the doors were closed, and he pressed the start buttons. At this point, the brakes would not release and the sensitive edge reset button (figure 3) illuminated to indicate that the sensitive edge system had activated. The TCMS sounded an alarm and displayed a message advising the location of the door which had activated the system.

47 The message displayed related to the third car of the train, car number 13066, and advised 'SE door DBW side 1'. Doors D, B and W are located as shown in figure 5. The message further advised: 'Emergency brake applied, once cause of activation is known press Sensitive Edge push button for brake release'.

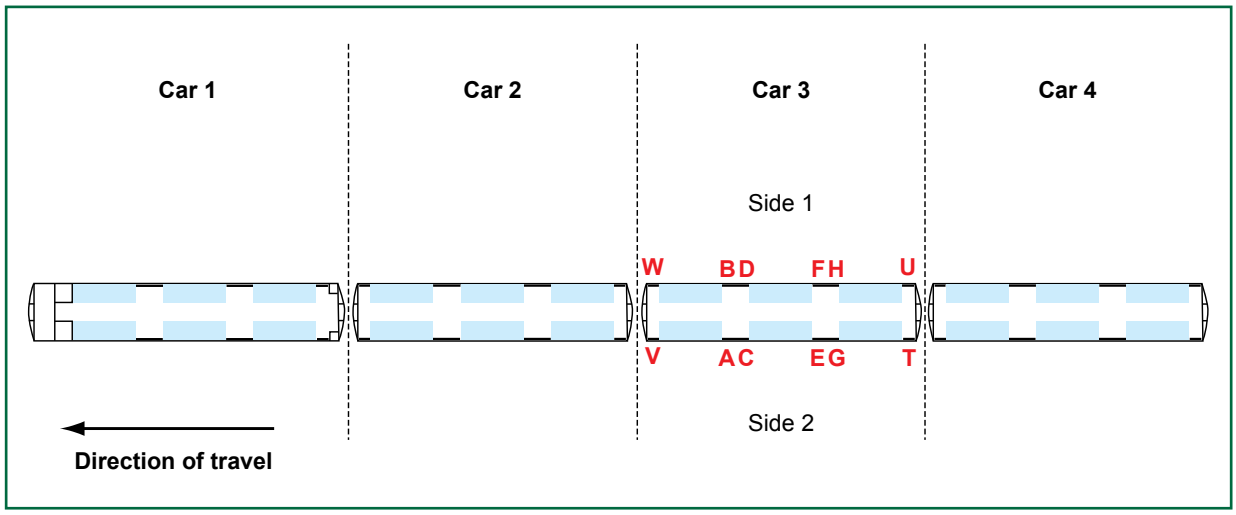

Figure 5: Layout and designation of train doors 2009 tube stock

48 The train operator pressed the sensitive edge reset push button and the light extinguished. He then pressed the start buttons, but the train would not move because the sensitive edge system was still activated. The sensitive edge reset button re-illuminated.

49 The train operator made further attempts to reset the sensitive edge system by pressing the reset button with no effect. He then overrode the sensitive edge system (paragraph 29). This required him to hold in the reset button while pressing the start buttons and to keep the reset button depressed until the train was outside station limits. This action allowed the train to depart from Oxford Circus station at 17:18:26 hrs.

50 After 13 seconds, an emergency brake application occurred because the train operator released the sensitive edge reset button 53 metres before the train had left the Oxford Circus station limits (paragraph 30). The RAIB has not been able to establish why the train operator released the button too soon. The rear of the train was still in the platform.

51 The train operator made several unsuccessful attempts to regain power by pressing the sensitive edge reset button and by switching to the protected manual driving mode. He also turned the master control switch to shutdown, causing the round train circuit to be broken, and then to protected manual. This action did not restore the round train circuit because the door closed relays had de-energised as a result of going to shutdown. Following this, he operated the sensitive edge brake cut out switch to isolate the sensitive edge system, but this had no effect because the door closed relays had de-energised.

52 When the train operator turned the master control switch to shut down and then back to protected manual, a second, duplicate, message was also displayed by the TCMS relating to the activated sensitive edge. The duplicate message however referred to the opposite side of the train and occurred due to a known bug in the TCMS software.

53 After many further attempts at taking power, the train operator operated the sensitive edge brake cut out switch to normal and also isolated the round train circuit by using the cut out switch. He then took power in the restricted manual mode. In response to a call from service control for an update, the train operator advised the controller of the actions he had taken. The train had been stationary for 5 minutes 46 seconds.

54 The train was then driven to Warren Street station where it arrived at 17:27:10 hrs. Three emergency brake applications, causing the train to stop, occurred on the way to Warren Street because the train operator, driving in the restricted manual mode, attempted to control the train's speed by manually using the traction brake controller and consequently exceeded the maximum permitted speed (16 km/h). The correct technique in the restricted manual mode is to operate the traction brake controller to full power and allow the train to control its own speed. Following the third brake application, the train operator switched to protected manual for the remaining distance to Warren Street.

55 The train operator opened the doors on the platform side when the train arrived at Warren Street but these were on the opposite side to those opened at Oxford Circus. The cause of the activation of the sensitive edge system therefore remained trapped.

Events during the incident

56 While stationary at Warren Street, the train operator made numerous, unsuccessful, attempts to clear the sensitive edge system by pressing the reset button. He then reinstated the round train circuit and operated the train door interlock cut out switch (paragraph 32).

57 After further, unsuccessful attempts to clear the sensitive edge system by pressing the reset button, the train operator again operated the round train cut out switch. He then took power in protected manual without having closed the train doors, or observing the status of the doors closed visual indication. The train had been stationary at Warren Street for 2 minutes 21 seconds.

58 As the train departed with the doors open, two passengers on the train jumped off onto the platform. Then, when the train reached 8 km/h, the train doors closed automatically as they are designed to do. A passenger also operated one of the *passenger emergency alarms*, but this had no effect because the round train circuit had been cut out.

59 Four seconds after starting, when the train reached 11.07 km/h, the train operator applied the service brake and then the emergency brake after hearing shouts from within the saloon behind the driving cab and realising something was wrong. The train stopped 13 metres into the tunnel having travelled 14 metres.

Events following the incident

60 Immediately after the train stopped, the train operator momentarily attempted to take power to move the train, but there was insufficient time for the brakes to release. Just over a minute later, the station supervisor discharged the *traction current* preventing any further movement of the train and took control of the incident by supervising the evacuation of the passengers and recharging the traction current to allow the train, when empty, to proceed.

61 Station staff operated emergency opening devices to open one set of double doors in each car to allow the passengers to disembark on to the platform, and to continue their journeys by other means.

62 London Underground found that the cause of the activation of the sensitive edge system was the strap of a passenger's bag that had caught between the doors when they closed at Oxford Circus. These were now on the non-platform side at Warren Street. The bag was released from the doors.

63 The train operator attempted further isolations to move the (now) empty train, but was unsuccessful because of the passenger emergency alarm that had been operated (this was now active because the train operator had reinstated the round train circuit). Eventually, the train operator succeeded in being able to take power in the restricted and protected manual modes and drove the train to Seven Sisters where he was relieved of duty. A different train operator drove the train to Northumberland Park for investigation.

Identification of the immediate cause[1]

64 **The immediate cause of the incident was that the train operator omitted to close the doors of train 237 before starting the train, having previously disabled the train door interlock.**

65 The train operator had also cut out the round train circuit to enable the brakes to be released and the train to start with the sensitive edge system activated.

66 Neither the disabling of the train door interlock nor the cutting out of the round train circuit were the correct actions to take while dealing with an activation of the sensitive edge system.

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

Identification of causal factors[2]

The train was not taken out of service before it departed from Warren Street

67 **The train operator did not take the train out of service in accordance with LUL's instructions. This is a causal factor.**

68 LUL has mandatory instructions relating to defective trains that describe the action to be taken when defects arise in service. They are issued to train operators and controllers and both have responsibilities to follow the instructions.

69 Although the train involved in the incident was not defective, the train operator probably gained the impression that it was because of the problems he encountered in trying to resolve the activated sensitive edge system (this cannot be stated with certainty). The train operator was familiar with the instructions relating to defective trains but did not consider taking the train out of service at Warren Street.

70 When train 237 arrived at Warren Street station, the round train circuit had been cut out and there was a sensitive edge activation which he could not reset. The train operator had previously operated the sensitive edge brake cut out switch and then reinstated it (paragraphs 51 and 53). A round train circuit that has been cut out and a sensitive edge which will not reset are both grounds for withdrawing a train from service in accordance with the instructions covering defects in service.

71 The train operator's disabling of the train door interlock prior to departure from Warren Street and described in paragraphs 76 to 78 also requires a train to be taken out of passenger service in accordance with the instructions covering defects in service.

72 The train operator gave evidence that he was determined to work the train through to its destination at Seven Sisters where it could be removed from service and worked to the maintenance depot at Northumberland Park. This is a further factor.

73 The RAIB has been unable to establish why the train operator was so determined to keep the train in service; a likely reason is that he wished to minimise the delay to following services.

74 The Victoria Line service control, located within the depot complex at Northumberland Park, was also aware that the train operator had carried out isolations but did not instruct the train operator to take the train out of service at Warren Street. The control believed that if the train could reach the next station at Euston, the problem would be resolved because the trapped object triggering the sensitive edge system would be released when the doors were opened (the platform at Euston is on the same side as at Oxford Circus where the sensitive edge system was initially activated).

75 LUL's policy is that train operators are responsible for resolving train defects and the control will only intervene if the train operator asks for help, or continues in service against the requirements of the instructions. In this case, the train operator did not ask for any help and it is possible that the control concluded that he was successfully dealing with the sensitive edge activation, particularly when advised by the train operator that he had reinstated the round train circuit while at Warren Street (paragraph 56).

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

The train operator disabled the train door interlock

76 **Before starting the train from Warren Street station, the train operator disabled the train door interlock using the cut out switch. This is a causal factor.**

77 It is unclear why the train operator disabled the train door interlock, but it is likely that he did so because he was in a growing state of confusion (paragraphs 87 and 88) and had tried many other measures to reset the sensitive edge system without success. He was also determined to keep the train in service and minimise delays (paragraphs 72 and 73) and this is again a factor. This action permitted the train to obtain traction power with the doors open and without a doors closed visual indication.

78 While the electrical circuit containing the train door interlock is separate from the sensitive edge door circuit, and therefore unrelated to it, the train operator's decision to disable the train door interlock was a direct consequence of his inability to deal with a routine activation of the sensitive edge system (paragraphs 79 to 86).

The train operator's response to the sensitive edge system being activated at Oxford Circus

79 **The sensitive edge system was activated when train 237 was at Oxford Circus station and the strap of a bag belonging to a passenger was trapped between the closing doors and not released. This was a routine event, but the train operator's response in attempting to resolve it is a causal factor.**

80 If the train operator had reopened the train doors at Oxford Circus, it is likely that the trapped bag (paragraph 62) would have been released and the sensitive edge system reset.

81 Activations of the sensitive edge system caused by objects trapped in the doors are a normal, routine event for LUL and train operators are expected to be able to deal with them. LUL's expectation delivered through its training, briefing and ongoing assessment of train operators is that following an activation of the sensitive edge system train operators should reopen the doors if the train has not left the platform. If this fails to clear the sensitive edge system, the train operator should first check that no-one is trapped on the outside of the train and then use the sensitive edge override. The action to be taken if the sensitive edge system activates while the train is leaving a station is also covered.

82 There is also guidance in the 'Train Operator's 09TS Defect Handling Guide' stating that if the train has not left the platform, the doors should be re-opened but does not include the option of using the override if the sensitive edge system fails to clear. The defect handling guide further states that if the train has partly left the platform, the train operator should press and hold the sensitive edge reset button and depart in automatic, releasing the button when the light extinguishes. The train operator gave evidence that he was familiar with the contents of the defect handling guide.

83 The TCMS displays a message to advise the train operator of the location of the door which has activated the sensitive edge system (paragraph 46). When the sensitive edge system was activated at Oxford Circus, the TCMS displayed the message: 'Emergency brake applied, once cause of activation is known press sensitive edge push button for brake release' (paragraph 47).

84 The wording of the TCMS message was changed in May 2011. The previous wording was: 'Emergency brake applied, once cause of activation is resolved press sensitive edge push button for brake release'. The wording was changed to remind train operators that they did not have to clear the obstruction which has activated the sensitive edge system in order to use the override.

85 The train operator in the incident said that the action he would normally follow if the sensitive edge system activated would be to carry out a manual release of the trapped object. This would require him to leave the driving cab and either walk down the platform (if the train is still wholly at the platform), or inside the cars (if the train is not wholly at the platform) to the location as indicated by the TCMS where the sensitive edge system had been activated. This is likely to take much longer than reopening and closing the train doors from the driving cab. This option was covered when the train operator was trained on the new trains (before the override was introduced) for the release of an obstruction from a door on the opposite side to the platform.

86 The train operator has stated that he was not thinking clearly but thought that reopening the doors, or walking back down the train, would increase the delay to the train at a time when both the train and the platform were busy with passengers. After going through a cycle of repeatedly pressing the sensitive edge reset button and the start buttons, the train operator used the override but did not do so correctly (paragraph 50). The desire to minimise delay is again a factor (paragraph 73).

The train operator was in a state of confusion

87 **As a result of the activated sensitive edge system which he was unable to reset, the train operator was in a growing state of confusion. This is a causal factor.**

88 The train operator's growing state of confusion occurred due to the following probable and possible factors which acted in combination:

Probable factors:

- the sensitive edge reset light extinguished when first pressed even though the system was still activated; and
- the train operator lacked the necessary competence to respond correctly when under pressure while dealing with an out-of-course event.

Possible factors:

- the train operator was distracted by matters external to his work, and his concentration was affected by the medication he was taking;
- the train operator did not request assistance to resolve the activated sensitive edge system; and
- the train operator did not fully understand the operation of the sensitive edge override.

The above factors are discussed more fully in the following paragraphs.

The sensitive edge reset light extinguished even though the system was still activated

89 When the train operator pressed the sensitive edge reset button at Oxford Circus, and the light extinguished, the train operator may have been misled to believe that the activation of the sensitive edge system had cleared.

90 Following a sensitive edge activation, the train operator has to press the sensitive edge reset button, which illuminates after the ATO start buttons are pressed, in order to release the brakes. The functionality of the sensitive edge reset light changed when the modification to provide an override was commissioned.

91 Before the modification in December 2010 (paragraph 30), pressing the illuminated sensitive edge reset button only extinguished the light and permitted the brakes to be released if the cause of the activated sensitive edge system had cleared.

92 Following the modification, pressing the illuminated reset button caused the light to extinguish whether or not the sensitive edge system was still activated, but the brakes could only be released either by clearing the cause of the activated sensitive edge system, or by using the modification to override the braking system. This change to the functionality of the sensitive edge reset button light was a consequence of the design of the circuitry to provide the override, but it had not been identified as a possible error causing mechanism. The RAIB has not been able to confirm whether the change to the functionality of the sensitive edge reset button light was a deliberate intention of the design, or was an unintended consequence of the way it was carried out.

93 While under pressure, the changed functionality of the sensitive edge reset button light probably led to the train operator believing that the cause of the activated sensitive edge system had been removed, when in fact it was still present. This misunderstanding would have contributed to his confusion as to why the brakes would not release.

94 The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS) (as amended) require that a change-management process is in place to identify and control new risks. In addition, if a project introduces new or altered vehicles, which could create significant new or different safety risks an independent competent person (either from outside or inside the company) must be appointed to carry out safety verification with the aim of ensuring that the risk of the change is assessed and suitably controlled. It is in any case customary good practice[3] when making changes to engineering systems to start with a definition of the requirements of the change, including its aims and the extent of the change. This should include an assessment of whether and to what extent the proposed change might introduce hazards and risks. LUL has procedures covering this in its standard 1-538 'Assurance'.

[3] For example: Engineering Safety Management (The Yellow Book), Volumes 1 and 2, Fundamentals and Guidance, issue 4 (www.yellowbook-rail.org.uk); BS EN 50126 Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS).

95 Although LUL concluded that the override modification did not require safety verification, it documented a safety justification to support the introduction of the modification, and carried out a *human factors* assessment. However, the implementation of the override was not covered by any systematic definition of the requirements, including the identification of the risks of making the change (required by standard 1-538), but was initiated by LUL through alterations to the door system schematic diagrams and passed to Bombardier to implement. The hazard arising from the change to the operation of the sensitive edge reset button light was not identified.

96 Bombardier carried out a risk assessment of the technical aspects of the modification. The scope of this assessment did not cover the operational aspects because these were identified as being within LUL's scope. Bombardier did carry out a hazard and operability study (HAZOP)[4] which identified some single point failures in the schematic diagrams which were then eliminated prior to implementing the modification.

97 The possible error causing mechanism introduced by the change to the operation of the sensitive edge reset button light was also not identified when the modification was tested, both statically by Bombardier and dynamically by LUL (during test runs of a train fitted with the modification), to validate the design. Had the functional and detailed requirements of the modification been defined, it is more likely that the safety analysis and testing would have identified the hazard arising from the changes to the status indicated by the reset button's illumination.

98 For this reason, it is considered that the absence of any systematic definition of the functional and detailed requirements in respect of this modification is a further probable factor.

The train operator lacked the necessary competence

99 The competence management system did not identify that the train operator found it difficult to assimilate new information or to respond correctly to out-of-course events.

100 The RAIB reviewed the train operator's training and competence records since he was first appointed to that post. The records relating to his initial selection, training and competence on the Northern Line and his initial passing out on the Victoria Line were incomplete.

101 Although the train operator was passed as competent to drive on the Northern Line in December 2003, concerns were expressed by his assessors about his ability to deal with out-of-course events and remember the correct procedure to follow. The RAIB has been unable to determine whether these concerns were acted upon at the time. The train operator, once passed out, appears to have worked satisfactorily on the Northern Line for nearly three years and then subsequently on the Victoria Line for five years.

[4] A structured and systematic study of a design or process to identify and evaluate any potential risks to safety and/or operational efficiency presented by the design or process under consideration.

102 The competence management system on the Victoria Line is based on a two year cycle of assessments (although, in practice, an 18 month deadline is worked to). Depot managers carried out the assessments using a mixture of announced (where the train operator is aware the assessment is taking place) and unannounced assessments. Within this period, there is a more formalised annual continual development programme lasting three days, run by the network operational learning organisation of LUL. This covers two days on rules and regulations and one day on rolling stock handling, including responding to faults and failures, all of which are assessed.

103 When the train operator undertook the continual development programme in October 2007, he failed the written assessments on responding to faults and failures and on the rolling stock (which at that time was the earlier 1967 generation of tube trains). As a result, a corrective action plan was formulated which the train operator completed on 30 October 2007. He passed all other assessments carried out before the introduction of the 2009 tube stock.

104 In preparation for the introduction of the new 2009 tube stock, all Victoria Line train operators were required to attend an eight day training course on the new stock that was organised and run by network operational learning. The train operator in the Warren Street incident attended this course during March 2010 but failed the course assessment at the first attempt and had to retake the course. He passed the assessment at this second attempt in May 2010.

105 There was a briefing on the sensitive edge override in December 2010, just before it was implemented. The briefing was delivered by instructor operators attached to the depot and consisted of video footage about how to use the override, supported by written briefing material, including a leaflet. Both the video footage and the leaflet referred to opening and closing the saloon doors as a way of clearing a sensitive edge activation (paragraph 81). There is evidence that the train operator in the Warren Street incident attended this briefing although no direct formal written record confirms that he did.

106 Network operational learning ran a three day course in April 2011 which the incident train operator attended. This covered the new signalling being installed on the Victoria Line, matters relating to the new trains that had been covered on the original training course (including the sensitive edge override), and rules and regulations. It also included use of the simulator. Although there was no assessment, the trainer was concerned about the incident train operator's ability to respond correctly to operating irregularities. These concerns were passed to the train operator's local depot management, who responded by re-briefing the train operator on the correct response to the operating irregularities that had been tested, and by proposing a programme of additional monitoring. This had not been put into effect before the Warren Street incident occurred.

107 The evidence referred to in the paragraphs above suggests that the train operator found it difficult to remember new information and to respond correctly to out-of-course events.

108 Since there were some concerns raised about the train operator's ability when first appointed to the role in 2003, it indicates that the selection process at that time was unable to assess how well potential applicants for the train operator role would retain and apply knowledge. This is a further probable factor.

The train operator was distracted by matters external to his work and was taking medication which might have affected his concentration

109 The train operator's concentration might have been affected by matters external to his work and the prescribed medication that he was taking.

110 LUL was aware of the matters external to the train operator's work and gave him the support he required.

111 LUL's occupational health department monitored the medication being taken by the train operator. While he had not declared any side effects arising from either the medication or the underlying conditions, the existence of such effects can not be ruled out. In rare cases, one of the drugs (simvastatin) that he was taking can give rise to cognitive impairment, but LUL believed that the likelihood of this was low and the train operator was safe to continue in that role. Competence assessments carried out since he started taking the medication had not identified that the medication was having any effect on the train operator's competence to drive.

112 The train operator gave evidence to the RAIB that following the incident, he visited his own general practitioner because he was finding it difficult to concentrate. As a result, he stopped taking simvastatin and reported that he then found it easier to focus on things.

113 The RAIB has been unable to confirm whether the presence of the drug had any effect on the train operator's ability to deal with the incident.

The train operator did not request assistance to resolve the activated sensitive edge system

114 The incident might have been prevented if the train operator had requested assistance to resolve the activated sensitive edge system.

115 LUL's policy is that train operators are primarily responsible for resolving train defects and they are trained and assessed so that they can do so (paragraph 75). If they are unable to rectify a defect, train operators can call for assistance through service control. The train operator at Warren Street was unable to rectify the sensitive edge activation which occurred, but he did not ask the Victoria Line service control for assistance in resolving the sensitive edge problem.

116 LUL's assessment process as part of its continuous development programme (paragraph 102) covers defect handling and the movement of failed trains. This includes:

- promptly informing the controller if any problems are identified in the performance of the train or communication equipment; and
- informing the controller of the failure situation and whether or not assistance will be required to move the train.

117 After the sensitive edge system was activated at Oxford Circus, the train operator had regular conversations with the control. However, the conversations that took place showed that the control did not have complete information about the nature of the problem and relied upon the information given to them by the train operator. Also, the controllers and signallers do not have a detailed knowledge of the faults and failures that can arise on the rolling stock, and the isolations that train operators can make to deal with them.

118 There are two train technicians based on the Victoria Line who are able to deal with technical problems. At the time of the incident, they were at Seven Sisters and Brixton and therefore not close to the incident train at Warren Street. The train operator could not contact them directly (eg by radio), but could have done so by making a request through control.

119 Operational advice could have been obtained from the instructor operators, who deliver training and briefing to train operators and carry out assessments, but as in the case of the train technicians, there was no means available for the train operator to contact them directly and a request would have to have been made through control.

120 The control did request that the station staff at Warren Street meet the train operator on arrival to assist with resolving the sensitive edge problem. In the event, although the station assistant walked to the driving cab, no conversation took place with the train operator, because the latter indicated by hand signal that he was going to proceed.

The train operator did not fully understand the operation of the sensitive edge override

121 The evidence shows that the train operator did not fully understand the operation of the sensitive edge override and this is a possible factor. In the incident at Warren Street, he released the sensitive edge reset button when using the override too soon (paragraph 50) and unnecessarily kept the auto start buttons depressed. It is not recorded to what extent he had used the override before the incident at Warren Street, and whether he had used it correctly on those occasions (discussed further in paragraph 124 below).

122 Although the briefing on the override included video footage about how the override should be used, the learning required was not reinforced by the opportunity to apply this in practice. The cab simulator at Northumberland Park depot could have been used for this purpose (paragraph 106) if the override had been incorporated into its functionality, but this modification to the simulator did not occur until the end of 2011.

123 The content of the leaflet issued to train operators at the briefing on the override (paragraph 105) was inconsistent with the actual operation of the sensitive edge reset button light following the override modification. The leaflet stated that on pressing the sensitive edge reset button: 'if the sensitive edge reset button illumination clears, acknowledge TCMS and continue to next station in auto'. The leaflet may therefore have further reinforced the belief of the train operator that all he needed to do to enable the brake to be released was to press the sensitive edge reset button, and when the light extinguished this was an indication that the cause of the sensitive edge activation had cleared.

124 The train operator gave evidence that he had used the sensitive edge override when previous activations of the sensitive edge system had occurred, but there is only one written record (because LUL only requires a written record when a delay of more than two minutes occurs) of when he had to deal with a sensitive edge activation following the implementation of the override. This occurred at Blackhorse Road station on 12 February 2011. In this incident, the train operator did not use the override but turned the master control switch to shutdown and then back to automatic. On finding that this did not clear the sensitive edge, he left the cab to investigate, and on returning to it found the cause of the sensitive edge activation had been removed. The irregular manner in which the train operator dealt with this incident (turning the master control switch to shutdown) was not identified by LUL when the information could have been used as part of the ongoing review of competence.

125 In the incident at Warren Street, the train operator also turned the master control switch to shutdown and then back (to protected manual) in an attempt to obtain brake release (paragraph 52), but this caused further problems because the action de-energised the door close relays. He may have done this because he had carried out the same action previously at Blackhorse Road.

The train operator omitted to close the train doors

126 **The train operator omitted to close the train doors and confirm the status of the doors closed visual indication (paragraph 21) before starting the train from Warren Street station. This is a causal factor.**

127 By the time that the train operator was ready for the train to depart from Warren Street station, he had become greatly distracted and was probably stressed by the problems he had experienced from Oxford Circus in keeping the train moving with a sensitive edge system activated which he could not reset. In combination with his determination to keep the train in service to its destination at Seven Sisters (paragraphs 72 and 73), it is likely that his possible confusion at the time caused him to forget to close the train doors.

Observations

128 While between Oxford Circus and Warren Street, the train operator turned the master control switch to shutdown and then back to protected manual (paragraph 52). This action caused the door close relays to de-energise causing the sensitive edge override and sensitive edge cut out switches to be ineffective. Train operators had not been briefed on this and it made it more difficult for the train operator to resolve the activated sensitive edge at Warren Street.

Previous occurrences of a similar character

129 The RAIB has investigated two accidents on LUL involving engineering plant where the adequacy of the design process was also a factor in both accidents. The recommendations made applied to engineering trains and plant and did not include passenger rolling stock, and are therefore not directly relevant to this incident. The accidents were:

a. The minor collision between an engineering unit and two manual trolleys near St John's Wood on 25 October 2007 (Report 24/2008). In this accident, an engineering unit (a motorised electric track trolley able to carry four persons and two loaded trailers) failed to slow down at the rate the driver expected and collided at slow speed with two manual trolleys. One of the factors identified was that the design, testing, acceptance and approval process did not detect that the design of the braking system was deficient. Recommendations were made covering the preparation of specifications; the validation of designs and testing; and the suitability of the process for acceptance and approval.

b. The runaway of an engineering train from Highgate on 13 August 2010 (Report 09/2011). In this accident, an engineering train consisting of a self-propelled diesel-powered unit designed for re-profiling worn rails ran away along part of the Northern Line. This occurred after it had failed and had been coupled to an empty passenger train using an emergency coupling. The coupling device fractured causing the (unbraked) engineering train to run away down a gradient. The investigation found that the emergency coupling was not strong enough and had been inadequately designed and procured. Recommendations were made covering the processes of design, checking, approval and testing.

Summary of conclusions

Immediate cause

130 The immediate cause of the incident was that the train operator omitted to close the doors of train 237 before starting the train, having previously disabled the train door interlock (**paragraph 64**).

Causal factors

131 The causal factors were:

a. The train operator did not take the train out of service in accordance with LUL's instructions (**paragraph 67**).

b. Before starting the train from Warren Street station, the train operator disabled the train door interlock (**paragraph 76**).

c. The train operator's response to the routine event of the sensitive edge system being activated when train 237 was at Oxford Circus station due to the strap of a bag belonging to a passenger being trapped between the closing doors and not released (**paragraph 79, Recommendation 1**).

The train operator's determination to keep the train in service and minimise delays is a factor leading to causal factors 131a, b and c (**paragraphs 72 and 73**).

d. As a result of the activated sensitive edge system which he was unable to reset, the train operator was in a growing state of confusion (**paragraph 87**).

The train operator's growing state of confusion occurred due to the following probable and possible factors which acted in combination:

Probable factors:

i. the sensitive edge reset light extinguished even though the system was still activated (**paragraph 89 and paragraph 134**);

ii. the absence of any systematic definition of the functional and detailed requirements in respect of the override modification (**paragraph 98, Recommendation 2**);

iii. the train operator lacked the necessary competence to respond correctly when under pressure while dealing with an out-of-course event (**paragraph 99, Recommendation 3**); and

iv. the selection process undergone by the train operator did not assess the ability to retain and apply knowledge (**paragraphs 108 and 133**).

Possible factors:

v. the train operator was distracted by matters external to his work and was taking medication which might have affected his concentration (**paragraph 109**);

vi. the train operator did not request assistance to resolve the activated sensitive edge system (**paragraph 114**, **Recommendation 4**);

vii. the train operator did not fully understand the operation of the sensitive edge override (**paragraphs 121 and 135**); and

viii. the briefing leaflet was inconsistent with the actual operation of the sensitive edge reset button light following the override modification (**paragraph 123**).

e. The train operator omitted to close the train doors before starting the train from Warren Street station (**paragraph 126**).

Observations

132 Although not linked to the incident at Warren Street, the RAIB observes that:

a. While between Oxford Circus and Warren Street, the train operator turned the master control switch to shutdown. This action caused the door close relays to de-energise causing the sensitive edge override and sensitive edge cut out switches to be ineffective. Train operators had not been briefed on this and it made it more difficult for the train operator in the Warren Street incident to resolve the activated sensitive edge (**paragraphs 128 and 136**).

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

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

133 LUL fundamentally changed its selection process for train operators in 2006, and the current process now includes an assessment of the ability to retain and apply knowledge (paragraphs 108 and 131d.iii).

134 LUL has decided to change the functionality of the sensitive edge reset button light, so that it remains illuminated if a train operator presses the button but the sensitive edge system is still activated. The implementation of this change has been allocated to Bombardier to carry out (paragraph 131d.i).

135 LUL is re-training all its Victoria Line train operators in aspects of the new trains, including the use of the sensitive edge override and the technique for driving in the manual modes. This training includes the use of the simulator (paragraph 131d.vii).

136 The circuitry is to be modified so that turning the master control switch to shutdown does not de-energise the door closed relays, or cause the sensitive edge override to be no longer available. The implementation of this change has been allocated to Bombardier to carry out (paragraph 132a).

Other reported actions

137 LUL is investigating whether the sensitive edge doors can be modified so that they are biased towards detecting objects trapped on the outside of the train. The work was in its early stages at the time of publication.

138 The TCMS software has been modified to eliminate the display of a duplicate message concerning a sensitive edge activation, but referring to the opposite side of the train, which occurred when the train operator turned the master control switch to shutdown and then back to protected manual (paragraph 52).

139 The TCMS software has also been modified so that the train operator receives an audible warning and message on the TCMS display screen if he attempts to start a train with the train door interlock cut out.

140 The skill level of instructor operators is being increased and a culture which encourages train operators to ask for help when they need it is being promoted.

Recommendations

141 The following recommendations are made[5]:

1 *The intention of the recommendation is that train operators should be issued with clear instructions on the action that they should take in the event of an activation of the sensitive edge system and should be briefed on their content.*

In the light of the Warren Street incident, LUL should review the current instructions on the action that train operators should take in the event of the sensitive edge system being activated. This should include, in particular:

- the options available to train operators for dealing with activations of the sensitive edge system and which option should be used first in specific circumstances;
- under what circumstances the sensitive edge override should be used; and
- the information provided by the TCMS to see whether there is suitable and sufficient information to train operators about using the override.

Any necessary changes to the instructions should be implemented, and train operators briefed and/or trained, as appropriate, on the changes made (paragraph 131c).

continued

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

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail Regulation 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.raib.gov.uk.

2 *The intention of the recommendation is to identify why LUL did not follow good practice for the introduction of the sensitive edge override modification and why this was not detected.*

In relation to the sensitive edge override modification, LUL should review how its process for managing engineering change and the associated management controls was not followed, and why it did not adequately identify the risks associated with the design modification. The review should include:

- why good and established practice in engineering change management was not followed during the design and introduction of the sensitive edge override modification with particular reference to the specification of requirements and the risk assessment of the proposed changes; and
- why the management system and controls did not identify or correct the design deficiencies relating to the sensitive edge override modification.

LUL should implement any necessary changes to its process for managing engineering change and associated management controls (paragraph 131d.ii).

3 *The intention of the recommendation is that LUL's competence management arrangements for train operators should:*

a) identify those who are unable to reliably and correctly respond to out-of-course events (including faults and failures); and

b) incorporate arrangements designed to eliminate or resolve the competence deficiencies identified.

In the light of the findings of this investigation, LUL should review those elements of its competence management system that relate to the ability of train operators to respond to out-of-course events, faults and failures. This should take into account:

- how the evidence from train operators' performance in practical training and instruction is captured and dealt with by the competence management system;
- how the evidence from train operators' performance in incidents in service is captured and dealt with by the competence management system (paragraph 124); and
- how LUL acts on any deficiencies identified from the above, relating to a train operator's ability to recognise and correctly respond to an out-of-course event, with the aim of eliminating any competence deficiencies identified, including how corrective action plans are developed, implemented and monitored to successful conclusion.

LUL should implement any necessary changes to the competence management system (paragraph 131d.iii).

continued

4 *The intention of the recommendation is that train operators should be aware that operational or technical advice is available when required and they should know how to obtain it so that they can effectively resolve faults and failures and avoid mistakes which could reduce safety.*

LUL should review how and in what circumstances train operators should request assistance following defects in service and implement any changes found necessary. This should include the adequacy of the competence management system and competence assessment of train operators in requesting assistance when needed. In addition:

- train operators should be reminded of the availability of operational and technical advice when they are unable to resolve train defects and how they can obtain it; and
- service controllers should be reminded that they should challenge train operators if they believe them to be acting outside LUL's mandatory instructions (paragraph 131d.vi).

Appendices

Appendix A - Glossary of abbreviations and acronyms

ATO	Automatic Train Operation
ATP	Automatic Train Protection
CCTV	Closed-Circuit Television
LUL	London Underground Limited
OTDR	On Train Data Recorder
TCMS	Train Control Management System

Appendix B - Glossary of terms

2009 tube stock	The type of train used on the Victoria Line of LUL, built by Bombardier Transportation. The trains entered service in July 2009 and finally replaced the previous trains of 1967 tube stock on the Victoria Line in June 2011.
Automatic mode	The normal driving mode when the 2009 tube stock is in passenger service. The train accelerates and brakes automatically once the train operator has pressed the start buttons after the train's doors have been closed.
Automatic train operation	Trains which are driven automatically with little or no human intervention.
Automatic train protection	The system which ensures that train movements are undertaken safely with the prevention of collisions between trains.
Doors closed visual indicator	A light on the train operator's desk which when illuminated indicates that the doors are detected as closed, also commonly known as the pilot light.
Human factors	The environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work.
Master control switch	A rotary switch on the back wall of the driving cab that the train operator uses to select the different driving modes.
On train data recorder	The equipment on a train which records parameters such as speed, distance run and the position of controls.
Passenger emergency alarm	A handle in each vehicle to enable passengers to gain the attention of the train operator in an emergency.
Protected manual	The manual mode of driving using the traction brake controller where the train is protected by the ATP system and where the speed is limited to that allowed by the ATP system.
Restricted manual	The manual mode of driving where the maximum speed of the train is automatically limited to 10 mph (16 km/h). The train is not protected by the ATP system in this mode.
Sensitive edge brake relays	Relays that de-energise when the sensitive edge system is activated resulting in an emergency brake application.
Service control	The organisation based at the service control centre at Northumberland Park depot that is in charge of the operation of the Victoria Line.
Start buttons	The two buttons that the train operator must press simultaneously in order to start a train of 2009 tube stock in automatic mode.

Station limits	The section of line that includes the station platform and the length of a train either side of it.
Traction brake controller	The handle operated by the train operator to accelerate and brake the train when driving in the protected manual driving mode.
Traction current	The electrical power available to trains from the conductor rails at a nominal traction voltage of 630 volts direct current.

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

Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Telephone: 01332 253300
Fax: 01332 253301
Email: enquiries@raib.gov.uk
Website: www.raib.gov.uk