RAIB

Rail Accident Investigation Branch

# Rail Accident Report



## Tram running with doors open on London Tramlink, Croydon
## 13 April 2013

Report 05/2014
March 2014

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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# Tram running with doors open on London Tramlink, Croydon, 13 April 2013

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# Summary

On Saturday 13 April 2013 between 17:33 and 17:38 hrs, a tram travelling from West Croydon to Beckenham Junction, on the London Tramlink system, departed from Lebanon Road and Sandilands tram stops with all of its doors open on the left-hand side. Some of the doors closed automatically during the journey, but one set of doors remained open throughout the incident. The incident ended when a controller monitoring the tram on CCTV noticed that it had departed from Sandilands with its doors open, and arranged for the tram to be stopped. Although there were no casualties, there was potential for serious injury.

The tram was able to move with its doors open because a fault override switch, which disables safety systems such as the door-traction interlock, had been inadvertently operated by the driver while trying to resolve a fault with the tram. The driver did not close and check the doors before departing from Lebanon Road and Sandilands partly because he was distracted from dealing with the fault, and partly because he did not believe that the tram could be moved with any of its doors open. The design of controls and displays in the driving cab contributed to the driver's inadvertent operation of the fault override switch. Furthermore, breakdowns in communication between the driver and the passengers, and between the driver and the controller, meant that neither the driver nor the controller were aware of the problem until after the tram left Sandilands.

The RAIB has made eight recommendations. Four of these are to Tram Operations Ltd, aimed at improving the design of tram controls and displays, as well as training of staff on, and processes for, fault handling and communications. Two recommendations have been made to London Tramlink, one (in consultation with Tram Operations Ltd) relating to improving cab displays and labelling and one on enhancing the quality of the radio system on the network. One recommendation is made to all UK tram operators concerning the accidental operation of safety override switches. The remaining recommendation is to the Office of Rail Regulation regarding the provision of guidance on ergonomics principles for cab interface design.

# Introduction

## Preface

1 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.

2 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.

3 The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of all other investigations, including those carried out by the safety authority, police or tramway operator.

## Key definitions

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

5 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

6 Between 17:33 hrs and 17:38 hrs on Saturday 13 April 2013, tram number 2548, which was en route from West Croydon to Beckenham Junction, departed from both Lebanon Road and Sandilands tram stops (figure 1) in Croydon, south London, with all of its doors open on the left (platform) side.

7 Some of the doors automatically closed during the journey from Lebanon Road to Sandilands, but one set of doors remained open throughout. The tram was stopped shortly after leaving Sandilands when a controller, who was based in the network's control room at Therapia Lane, noticed on a tram stop CCTV monitor that the doors were open.

8 The incident lasted for a total of approximately five minutes, during which time the tram was travelling for around 2 minutes 25 seconds with doors open. The tram travelled for nearly 600 metres and reached a maximum speed of 27 km/h with at least one set of doors open.

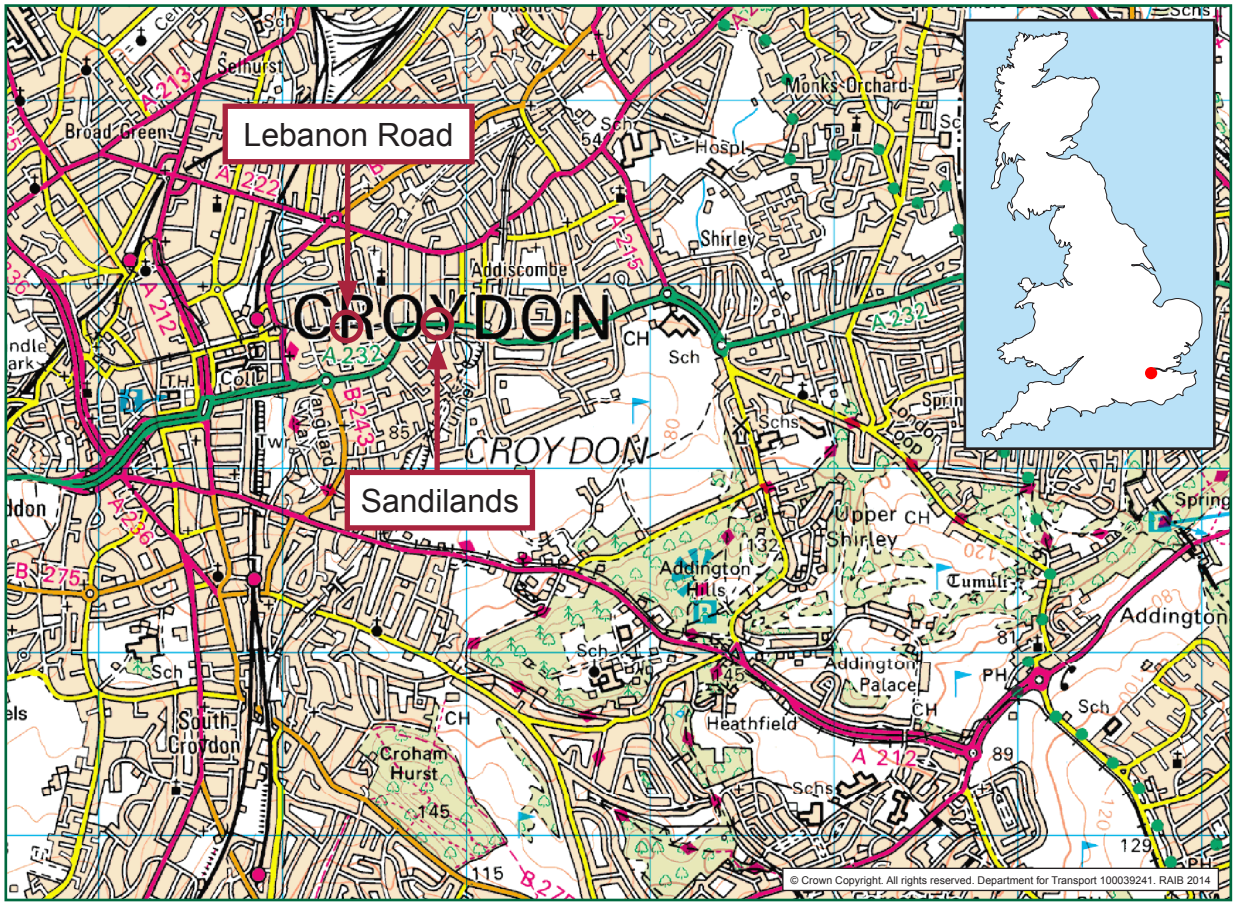


*Figure 1: Extract from Ordnance Survey map showing location of incident*

9 There were no casualties, but there was potential for serious injury as the tram was busy and several people were standing in the vicinity of the doors.

## Context

### Location

10 Lebanon Road and Sandilands tram stops are located in the London Borough of Croydon, to the east of the stop at East Croydon station (figure 2). They are part of the London Tramlink network, which runs from Wimbledon to Beckenham Junction, Elmers End and New Addington.

11 The tramway between Lebanon Road and Sandilands is double track, with one line each for trams running eastbound and westbound. The tramway runs along the street at Lebanon Road, but becomes segregated from the roadway between Lebanon Road and Sandilands.

12 The maximum permitted speed for trams running between Lebanon Road and Sandilands is 50 km/h.

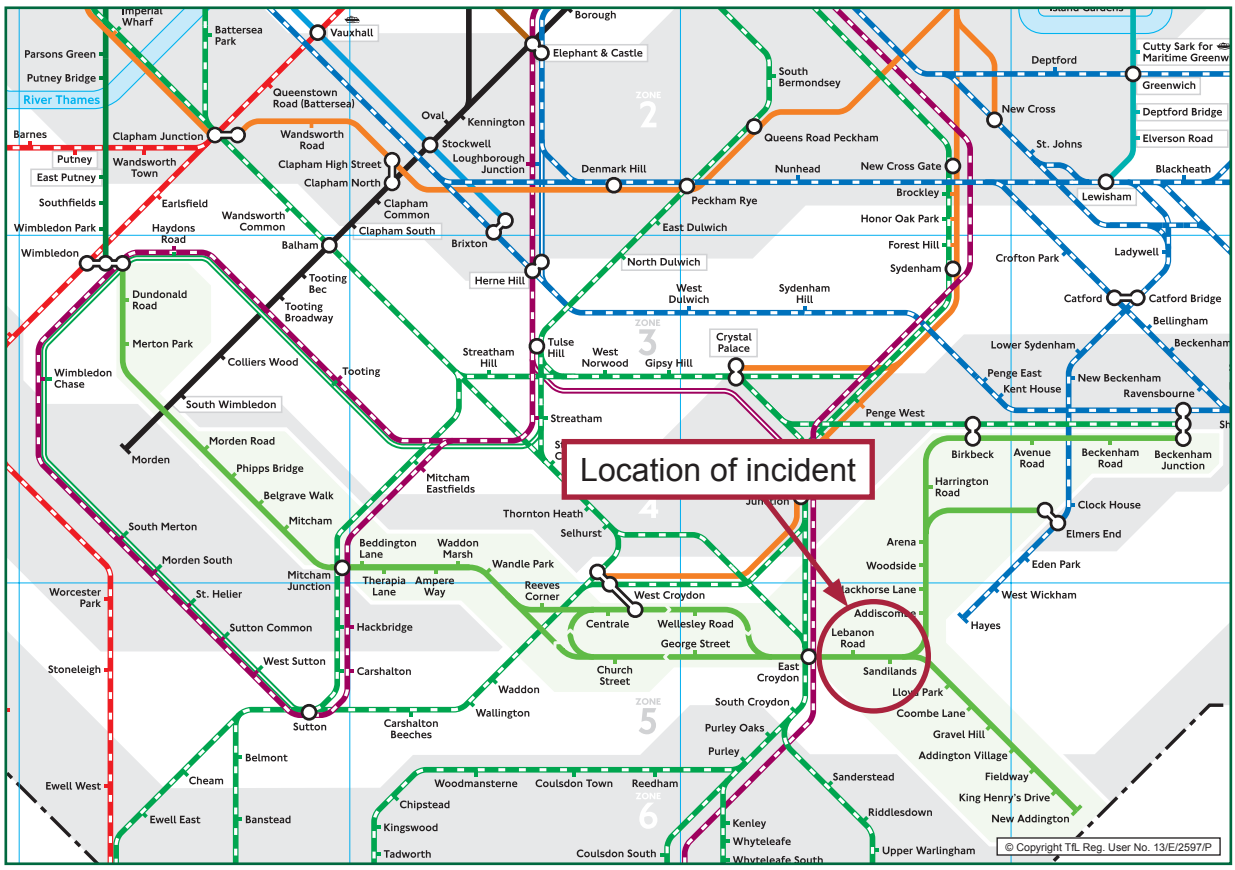


*Figure 2: Map of the London Tramlink network*

### Organisations involved

13 Tram Operations Ltd (TOL), which is part of First Group, operates the trams on the network under contract to Transport for London. It employed the driver of the tram, the controller and the control room duty manager involved in the incident.

14 London Tramlink, part of Transport for London, manages and maintains the tramway infrastructure. London Tramlink took over the running of the network in 2008 from Tramtrack Croydon Ltd, the consortium that developed and opened the network in 2000.

15 Bombardier Transportation manufactured the majority of the tram fleet on London Tramlink, including the tram involved in the incident, and maintains all vehicles in the fleet.

16 TOL, London Tramlink, Transport for London and Bombardier Transportation freely co-operated with the investigation.

## The tram

17 Tram 2548 is a Bombardier CR4000 model, one of 24 on London Tramlink that formed the original fleet when the network opened in 2000. It can carry up to 200 people with 70 seated, and has a maximum speed of 80 km/h.

18 The tram has four *double-plug* sliding doors on each side of the vehicle. At a tram stop, the driver can choose to operate the doors on the relevant side of the tram in three different ways by using the following pushbuttons:

- 'all doors open', which results in all four doors opening without any intervention from passengers;
- 'release', which doesn't open any doors, but enables pushbuttons on the doors, so that passengers wishing to board or alight can open doors individually;
- 'first door only', which opens the leading door on the tram.

19 After opening the doors, and in the absence of any action by the driver to close them, each door will close automatically after two minutes. A light beam across the door threshold detects obstructions and restarts this two-minute timer if the beam is broken. Usually, though, the driver initiates the door closing sequence by pressing the same button as had been used to open them. An audible alarm informs passengers that the doors are about to close. If the light beam is broken while the door close alarm is sounding, the doors will remain open for a further two minutes. If the beam is broken after the doors have actually started moving, the doors will stop and then try to re-close after three seconds. The driver can then either go through the whole opening and closing cycle again, or use a 'close override' button to close the doors, depending on the reason for the obstruction (eg if the tram is busy and passengers are standing near the doors, then the driver will probably use the close override).

20 The doors are *interlocked* with the tram's traction system, so that the tram cannot be driven if a door is open. However, a Fault Override switch in the driver's cab, which is used to enable a tram to be moved in the event of certain fault conditions, has the effect of bypassing this door-traction interlock when operated.

## Staff involved

21 The tram driver joined TOL in January 2006 as a driver, and was passed as competent by TOL to drive trams on 28 February 2006. His most recent annual assessment before the incident was in May 2012, and it re-affirmed his competence to drive trams.

22 The controller who dealt with the incident joined TOL in July 1999 as a driver, and became a controller in April 2008. He was assessed by TOL as demonstrating a good level of competence as a controller in his most recent assessment on 21 November 2012, which included recovery of a failed tram as one of the scenarios assessed. Controllers also maintain their competence to drive trams, and the controller's most recent driving performance check, on 7 December 2012, also confirmed his competence in this respect.

23 The duty manager in the control room at the time of the incident joined TOL as a controller in 1999. He was promoted to the position of duty manager in 2007. His competence was confirmed by TOL in a periodic monitoring check on 3 July 2012, and he also demonstrated good performance in a tram recovery assessment on 21 November 2012.

# The investigation

## Sources of evidence

24 The following sources of evidence were used:

- witness statements;
- the tram's *on-tram data recorder* (OTDR) and *fault log* data;
- Closed Circuit Television (CCTV) recordings of the tram's passenger saloon;
- voice recordings of the conversations between the controller and the driver;
- post-incident inspection and testing of the tram's cab controls and door close sequence;
- training and assessment records for the driver and controller;
- TOL's training modules and briefings;
- documentation regarding the design and procurement of the tram;
- documentation provided by London Tramlink concerning the management of the radio system; and
- a review of previous RAIB investigations that had relevance to this incident.

# Key facts and analysis

## Circumstances of the incident

### Sequence of events

25 At around 17:22 hrs, the driver of a tram that had just departed from West Croydon on its journey to Beckenham Junction received a fault message on his cab display: 'A057 Spring applied brake on B bogie will not release'. When the tram stopped at the next traffic signal, the driver informed the controller about the fault using the tram radio, and the controller instructed the driver to use the 'spring applied brake isolation' switch to see if this would clear the fault (figure 3).

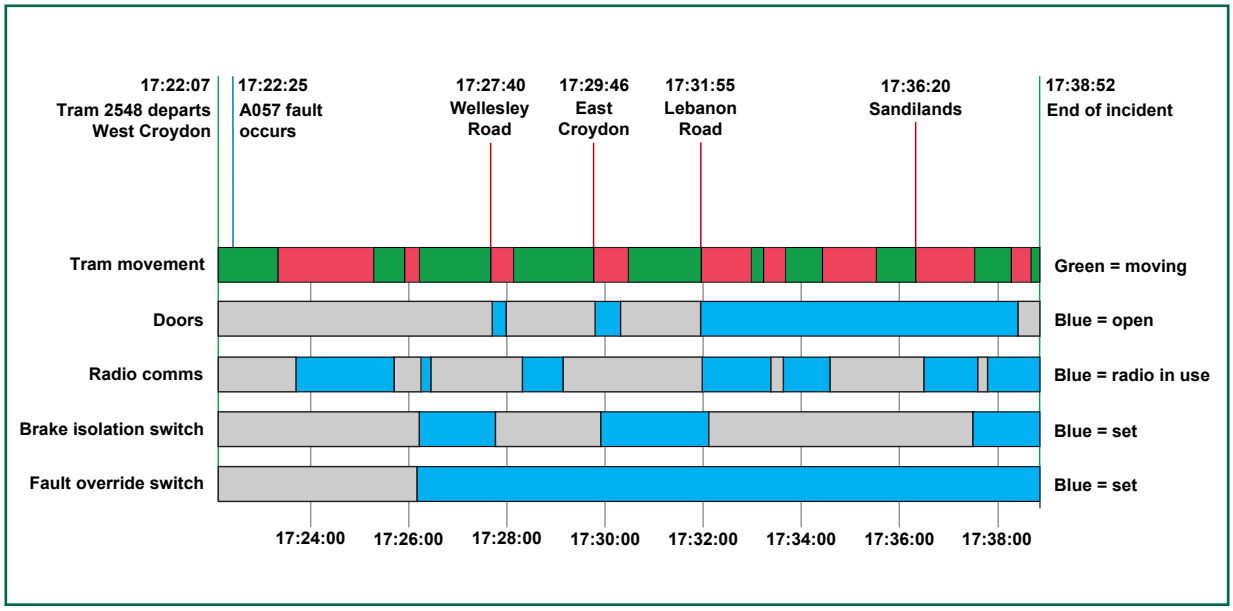


*Figure 3: Timeline of the incident*

26 The switch was sealed[1] and the driver found it difficult to break the seal, so he had to use two hands to operate the switch. During the period when he was attempting to operate the brake isolation switch, he inadvertently operated the adjacent switch at the same time (paragraph 58). The adjacent switch was the 'fault override' switch, which, amongst other things, had the effect of bypassing the interlock that prevented the tram from being moved with doors open (paragraph 20). Operating this switch also causes a status message to be presented on the cab display, reading '253 Fault override switch actuated'.

27 The controller had advised the driver to return the brake isolation switch to its normal position at Wellesley Road, the next tram stop, in the expectation that the fault would have cleared (paragraph 92). However, the fault had not cleared, so the controller told the driver to use the brake isolation switch again at the next stop, which was East Croydon. As instructed, the driver operated the brake isolation switch at East Croydon, and returned it to its normal position at the following stop, Lebanon Road, but the fault had still not cleared.

[1] The seals on these switches are made of tamper proof wire held in place by a lead seal. See paragraph 61 and figure 5.

28 At Lebanon Road tram stop, the driver was engaged in further dialogue with the controller about the fault on the tram. There was discussion of other messages on the cab display, and the driver briefly mentioned the fault override status message (paragraph 26), but its significance was not recognised by the driver or the controller at that time (paragraph 79). The dialogue continued for more than one minute, and was ongoing as the tram departed from Lebanon Road.

29 The driver omitted to close the doors before the tram departed from Lebanon Road. It was able to move with the doors open because the fault override switch had been operated (paragraph 26).

30 On departure from Lebanon Road, some passengers tried to notify the driver about the open doors through the internal cab door. The tram stopped approximately 30 metres beyond Lebanon Road, possibly because the driver was reacting to the passengers' efforts to tell him about the doors. The driver had been talking to the controller about the fault at the time and he informed the controller that he thought passengers were trying to tell him that he had forgotten to open the doors at Lebanon Road. The controller told the driver to continue to Sandilands, and so the tram set off again. Although three sets of doors closed automatically during the journey, the remaining set of doors remained open throughout (paragraph 37).

31 At Sandilands tram stop, the driver operated the controls to open all the doors for passengers to board and alight, and radioed control again about the fault. He again omitted to close the doors before departing.

32 At this stage, the control room was using the CCTV at the tram stop to monitor the tram and one of the controllers noticed the open doors. He immediately alerted his colleague to send an emergency stop radio message to the driver, and the tram stopped about 140 metres beyond Sandilands. The driver closed the doors using the 'close override' button and, under the direction of the controller, the tram was taken out of service at the next stop, and returned empty to the depot.

## The fault on tram 2548

33 The fault message received by the driver throughout the incident was 'A057 Spring applied brake on B bogie will not release'. After the incident, it was established that the fault was not with the brake itself; a defective cable was causing a false alarm.

34 The design of the tram was such that, when the tram was moving, its brakes were applied automatically within four seconds of the fault message first appearing. Operating the isolation switch for the brakes would normally by-pass this fault and enable the tram to be driven normally. On three occasions during the incident, the controller had instructed the driver to try operating this switch and then resetting it at the next tram stop, in the expectation that this would clear the fault (paragraph 92). However, because the problem was with a defective cable rather than the brakes, the fault did not clear.

35 On departing from Wellesley Road and Lebanon Road tram stops, the tram did not stop automatically four seconds after moving off, as had happened initially (paragraph 34), because the safety system had been overridden by the driver's inadvertent operation of the fault override switch[2] (paragraph 26). TOL driver training does not cover such a scenario in detail (paragraph 95), and so it is understandable that the driver would not notice the fact that it did not stop as indicating a subtle inconsistency in the tram's behaviour.

36 With the fault override switch operated, the tram is limited to 40 km/h. Because this speed threshold was not reached between Wellesley Road and Sandilands, the driver was not prompted by the speed limitation to realise that he had inadvertently operated the fault override switch.

## Door operation on the CR4000 tram

37 The door system on the CR4000 tram was programmed to keep each set of doors open for two minutes after its light beam had last been broken (paragraph 19).

38 Three of the doors did close between Lebanon Road and Sandilands when two minutes elapsed after the beam was broken by the last passenger boarding or alighting at Lebanon Road. The remaining set of doors remained open throughout because its light beam was obstructed by a passenger standing in the doorway.

39 In the original tram specification, the door close timer was set at three seconds, but because this caused problems for passengers, it was increased initially to 60 seconds, and later to 120 seconds. This meant that automatic door closure would only occur in practice at termini where trams might stand for a few minutes at a time.

40 Thus the decision to close the doors at all tram stops other than termini was, by design, left to the discretion of the driver. Had the door close timer been set to a lower value, this would have resulted in three of the four doors closing earlier than they actually did on the day of the incident. However, the door with the obstructed light beam would still have remained open throughout.

[2] The function of the fault override switch was to enable a tram with a persistent fault to be taken empty back to the depot, and it was thus necessary for it to be configured so that it overrode the operational limitations imposed as a result of any other faults being experienced at the time.

## Identification of the immediate cause[3]

41 **The driver drove the tram between tram stops with doors open.**

## Identification of causal[4] and underlying factors[5]

42 The tram departed from both Lebanon Road and Sandilands tram stops with doors open. There were three primary reasons why this happened:

- the driver did not close the doors before departure from both tram stops (paragraph 43);
- the driver did not check that the doors were closed before departure from both tram stops (paragraph 51); and
- the interlock which normally prevents a driver from taking power with the doors open had been overridden (paragraph 58).

### Closing the doors before departure

43 The driver omitted to close the doors before departing from Lebanon Road and Sandilands tram stops. The RAIB considers that there are two reasons why he omitted this key step:

- he was distracted while carrying out tram stop duties (paragraph 44); and
- he probably felt under stress as a result of the problems that he had experienced since departing from West Croydon (paragraph 48).

### *Distraction*

44 **While the tram was at Lebanon Road and Sandilands tram stops, the driver was engaged in dialogue with the controller regarding the fault with the spring applied brake. In both cases, this dialogue was ongoing as the tram left the stop and acted as a distraction to the driver.**

45 Because the original fault did not clear when the driver used the 'spring applied brake isolation' switch, he had to report this to control each time it recurred in order to discuss how to resolve it.

46 Although the driver had operated the fault override before the tram reached Wellesley Road, he closed the doors as usual before departure from both Wellesley Road and East Croydon stops. At this early stage, the conversation between the driver and controller related only to the setting and re-setting of the brake isolation switch. As the tram progressed to Lebanon Road and Sandilands, and it became apparent that the fault was not clearing, the conversation between driver and controller became more protracted, thereby increasing the potential for the driver to become distracted from his normal duties.

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

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

[5] Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

47 At Lebanon Road, the driver and the controller were in conversation for 1 minute 24 seconds, and the tram moved away from the stop during this time. Similarly at Sandilands, there was a radio call lasting 1 minute 6 seconds, which did not end until the tram left the stop.

*The effect of stress*

48 **The ongoing nature of the fault, coupled with the perceived pressure to avoid delaying following trams, placed stress on the driver.**

49 The original fault caused the tram to be stopped at a traffic signal for nearly two minutes while the driver contacted the control room and then attempted to break the seal on the spring applied brake isolation switch (paragraph 26). While the fault condition persisted as the tram progressed towards Sandilands, the driver had to deal with multiple fault messages (including the recurrence of the original fault message and a message associated with the operation of the fault override switch; paragraph 28), repeated operation of the spring applied brake isolation switch (paragraph 27), and six separate radio conversations with the controller, as well as his normal driving and tram stop duties. The radio calls lasted for a total of six minutes and 29 seconds, which was approximately 46% of the journey time from the point at which the driver first reported the fault to the tram departing from Sandilands. Some of these conversations occurred while the tram was moving, and the discussions became increasingly animated as the usual method of clearing faults was not working. This created a significant additional workload for the driver and a source of stress which would have shifted his focus away from his normal duties. The driver was also aware that his tram's slow progress through Croydon had the potential to cause delays to following trams (there is at least one tram every three minutes through the section of the network between West Croydon and Sandilands).

50 At East Croydon, the track divides for access to a third platform at the tram stop, before merging again to double track after the tram stop. When the fault did not clear after the first attempt to resolve it, a second controller in the control room suggested routing the tram into the centre platform at East Croydon, in order to allow other trams to pass around it and give them time to try and resolve the problem. However, the controller who was dealing with the tram believed the fault would clear, and so instead kept it on the main route. This is discussed further in paragraphs 90 to 97.

Checking that the doors were closed before departure

51 The driver did not notice that the doors were open before departing from Lebanon Road and Sandilands. Although he did not close the doors before departing from either stop, he would have realised his omission had he checked that the doors were closed before moving off. It is likely that the factors that caused him to omit closing the doors (distraction and stress) also caused him to omit checking that the doors were closed, since these are related tasks. However, there were additional factors that resulted in the 'doors closed' check being overlooked:

- poor indication in the driving cab as to whether the doors were closed (paragraph 52); and
- the driver's reliance on the door-traction interlock as proof that the doors were closed (paragraph 55).

## *Feedback in the driving cab*

52 **There was poor indication in the driving cab as to whether the doors were closed.**

53 The main means for drivers to check that the doors are closed is by observing that a red 'doors open' indicator light on the driver's display panel has extinguished and a corresponding green 'doors closed' light has illuminated (figure 4). The driver did not recall seeing that the red light was illuminated before departure (which would have told him that the doors were open). During testing, the RAIB found the red indicator light was not prominent and was similar in appearance to a red parking brake indicator light on the same panel. The parking brake indicator would also be lit at tram stops. This may have led to the driver not noticing the indicator before departing.

54 The tram also has exterior wing mirrors, but these do not provide a good view of the doors and, according to TOL's driver training modules, are primarily intended to be used for observing road traffic and to check that passengers are clear of the tram before departing from tram stops. Neither the driver training modules nor the Office of Rail Regulation's (ORR) 'Guidance on Tramways'[6] (referred to as Railway Safety Publication 2) explicitly mention using the mirrors to check whether doors are closed.


*Figure 4: Driver's cab panel showing door indicator lights for closed (green) and open (red)*

[6] ORR (2006) 'Guidance on Tramways'. Railway Safety Publication 2. Office of Rail Regulation.

*Reliance on the safety interlock*

55 **The driver relied on the safety interlock as proof that the doors were closed.**

56 The driver believed that the tram could not be moved with any of its doors open because of the door-traction interlock. Therefore, if he was able to take power, he considered that the doors must be closed. He stated that he was not aware that the interlock could be bypassed through the use of override switches. This was probably because his training and experience did not provide him with enough familiarity with the override systems.

57 TOL's driver training modules cover basic familiarity with vehicle controls, but do not provide drivers with a more detailed understanding of tram operation or the implications of different override modes (see also paragraph 95).

Operation of the fault override switch

58 Operating the fault override switch had the effect of disabling the safety interlock that prevents the tram from being moved with any door open. The fault override was operated during the driver's earlier efforts to operate the spring applied brake isolation switch (paragraph 26). At that point in the journey, the tram was stationary at a traffic signal, but the driver may have been focusing his attention on other tasks (eg monitoring the traffic signal) and not looking directly at the spring applied brake isolation switch while he was trying to operate it.

59 Although the driver received a message indicating that the fault override switch had been operated, and he relayed this message to the controller (paragraph 28), he did not recall using the fault override switch at any point during the journey. This evidence, combined with the factors described below, leads the RAIB to conclude that the driver's operation of the fault override switch between West Croydon and Wellesley Road tram stops was inadvertent. There were two factors that contributed to this situation:

- the design of the controls and displays, which caused the driver to inadvertently operate the fault override switch (paragraph 60); and
- the design of the system, which meant that the fault override mode bypassed the traction interlock (paragraph 67).

*Design of controls and displays*

60 **The safety interlock which prevents the tram from moving with the doors open had been overridden by the driver's inadvertent operation of the fault override switch.**

61 The emergency release switches were all protected by lead seals (figure 5). The seals are intended purely as a means of identifying when a switch has been used; TOL's procedures state that a driver is not permitted to operate any emergency release switch without authorisation from the controller. In practice, the driver found that the seal on the spring applied brake isolation switch was very difficult to break. In contrast, he operated the fault override switch without breaking the seal at all, because the wire of the seal was able to stretch enough to allow the switch to move to its 'on' position (as observed in the post-incident inspection of the driving cab). When the driver operated the fault override switch, he had just, with difficulty, broken the seal on the switch for the brake isolation a few seconds previously. Because the fault override switch could be operated without the resistance from breaking its seal, the driver might not have noticed that he had operated the wrong switch if he had been operating them through feel alone.

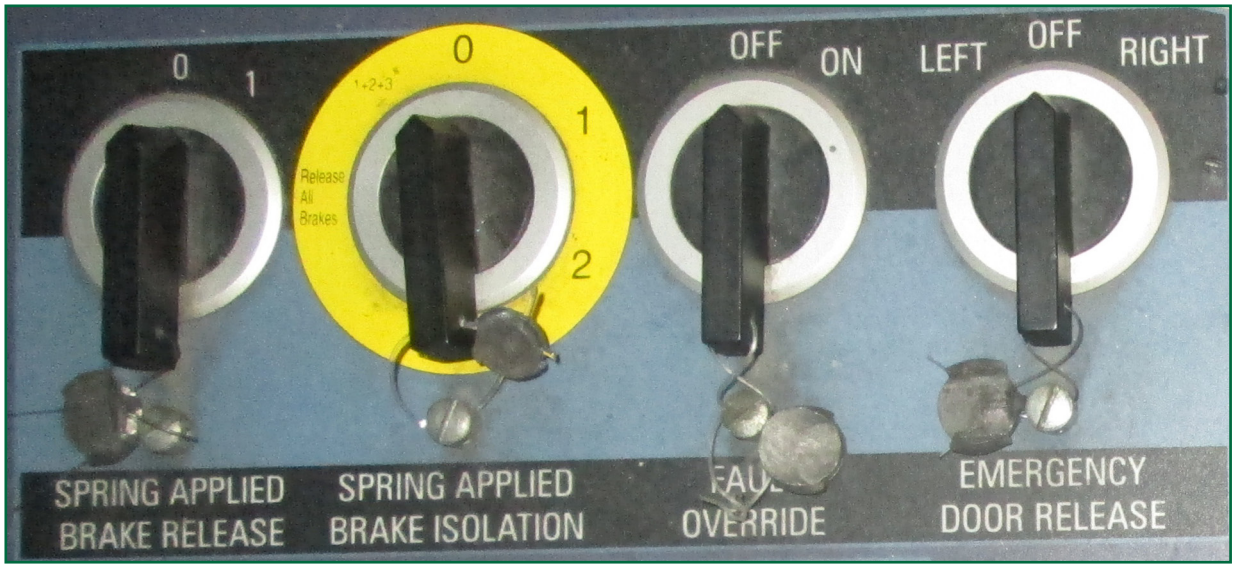


*Figure 5: Fault override and brake isolation switches*

62 The message display presented a status message to the driver that the fault override switch had been activated. Although the driver did report this message to the controller later in the journey (paragraph 28), he did not realise that the fault override switch had been operated. This was probably because the arrangement of the controls and displays did not promote an association in the driver's mind between the message and the switch, and because he did not notice the message immediately. The message display is located on the instrument panel forward and to the right of the driver's seat, while the switches for the fault override and spring applied brake isolation are on a horizontal panel to the left of the driver (figure 6). Moreover, the switch labelling and the associated display message – 'fault override' – was potentially misleading, in that it suggests a means of bypassing faults rather than bypassing safety systems. In the original design this switch was labelled 'system override'.

63 The fault override and brake isolation switches are located next to each other and are similar in design (figure 5). It was originally a deliberate design decision to group these switches as they all had safety implications. However, this could lead to the switches being confused with each other, especially if the driver was attempting to operate them without looking (paragraph 58).

64 Railway Safety Publication 2 states a generic requirement for ergonomic cab design in trams, but does not discuss specific examples or guidelines as to how this requirement may be implemented. It does refer to an older document, Railway Safety Principles and Guidance part 2F (Guidance on Trains), which offers specific guidance on protecting override facilities from accidental operation, but the ORR considers this document to be historical and it is not actively maintained. There is no other guidance available specifically for tram operators (eg in European standards) on this particular issue.

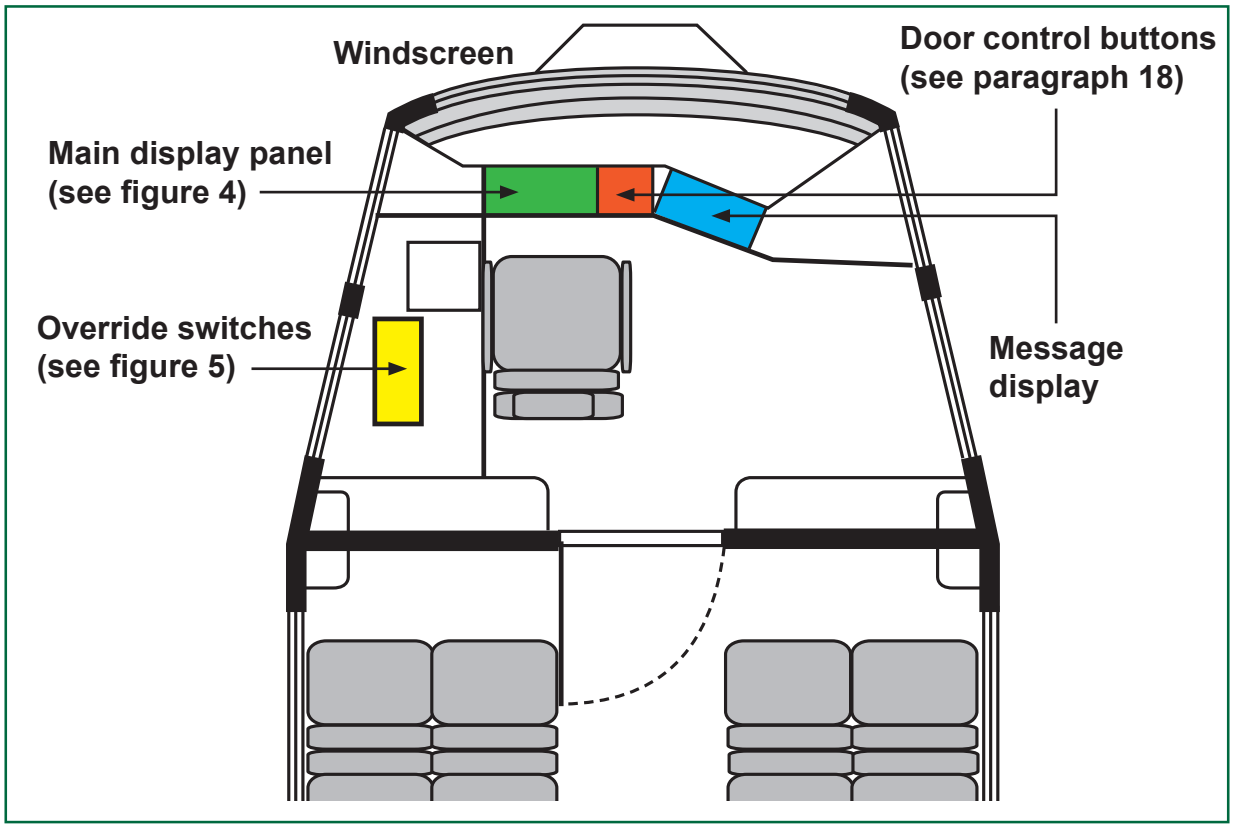


*Figure 6: Bombardier CR4000 cab layout (plan view)*

65 Tramtrack Croydon Ltd, who originally procured the CR4000 trams, had limited influence on the design of the tram, as it was essentially acquiring an off-the-shelf model that had been developed for other customers. Nevertheless, some relevant design changes were made, with early discussions during the procurement process focused on specific aspects of labelling (eg the change from 'system override' to 'fault override' mentioned above). The Operations Manager at the time of the procurement expressed concerns over some basic ergonomics elements of the driver's interfaces, such as the lack of an integrated approach to the cab layout.

66 TOL also runs a smaller fleet of newer trams manufactured by Stadler, which first entered service in 2012. The design process for these trams was more user-centred, as Stadler used *mockups* to gain feedback from drivers about the cab interface. Nevertheless, the equivalent function on the Stadler trams is still labelled 'fault override'.

*Design of the fault override system*

**67 The fault override switch bypasses the door-traction interlock, allowing the tram to move with its doors open.**

68 The RAIB could find no clear rationale for the decision to design the fault override system to bypass the door-traction interlock. If the fault override switch is operated, then the only means by which it can be assured that the doors are closed before departure is by implementation of a procedure (ie the driver's check that the doors are closed before departing). There is another means provided for drivers to overcome door problems which would otherwise result in a driver being unable to take traction power; the driver's emergency door release switch (next to the fault override switch in figure 5) also bypasses the traction interlock.

69 On the Stadler tram, operation of the fault override switch does not bypass the traction interlock; it uses a separate isolation switch for this purpose.

## Communication between the driver and the passengers

70 **Passengers did not succeed in alerting the driver to the fact that the doors were open. This was a causal factor.**

71 Some passengers had tried to communicate with the driver through the internal cab door and window (which, as is ordinarily the case, were closed during the journey), but their message was misunderstood (paragraph 30).

72 There are intercoms on the tram for passengers to speak with the driver, but these are not clearly signed or labelled (figure 7). For instance, the intercom is labelled 'Passenger intercom', which does not clearly signal that the device can be used to contact the driver. There is no other passenger emergency alarm on the CR4000 tram. Although the handle labelled 'Emergency door release' has the effect of bringing the tram to a stop before releasing the doors, this aspect of its functionality is not mentioned on the associated label.


*Figure 7: Passenger intercom and emergency door release*

73 Guidance on the passenger interface in Railway Safety Publication 2 is generic and high-level, only requiring that emergency door releases and intercoms exist, that they are clear and unambiguous, and that they deter non-emergency use.

74 The RAIB has examined other types of tram used in Britain for comparison, and found that there is little consistency between trams, with similarly unclear designs observed elsewhere. For instance, the Stadler Variobahn, also used on London Tramlink, presents more options to the passenger in the form of 'passenger alarm', 'passenger intercom', 'alarm', and 'emergency door release' (figure 8).


*Figure 8: Passenger interfaces on Stadler Variobahn tram*

75 RSSB published a research report in 2003 (project reference T052c) which investigated emergency door release labels for trains operating on the main line rail network. The project found similarly wide variability in labelling schemes. The report recommended that the design of controls and their signage should be standardised, and that *usability* testing should be carried out on the comprehension of emergency door release devices. These recommendations were carried forward into rail industry standards[7] for main line trains regarding vehicle safety and evacuation.

76 The RAIB found similar issues with passenger emergency alarms in its investigation into a train door incident at Huntingdon (report 11/2007). The investigation identified that the layout of emergency signs, instructions and controls on the train were of insufficient clarity for passengers to take immediate action to stop the train. The report recommended that such signage and controls should be reviewed and if necessary modified so as to optimise passenger reactions in an emergency. In response, the train operator redesigned its signage in line with the standards referenced above.

[7] GM/RT2130 Issue 4, 'Vehicle Fire, Safety and Evacuation';
GM/RC2533 Issue 1, 'Recommendations for Communication of Rail Vehicle Emergency & Safety Information';
AV/ST9005 Issue 2, 'Vehicle Interiors Communication of Safety and Emergency Information'.

## Communication with the control room

77 There were missed opportunities for staff in the control room to identify that the fault override switch had been operated by the driver. This is due to either or both of the following factors:

- the nature of the verbal communications used by the driver and the controller (paragraph 78); and
- the quality of reception on the radio system used on the London Tramlink system (paragraph 84).

### *Verbal communications between the driver and the controller*

78 **The controller did not understand a communication from the driver reporting the fault override status message.**

79 The driver's inadvertent operation of the fault override switch between West Croydon and Wellesley Road generated a '253 Fault override switch actuated' status message on his in-cab display (paragraph 28). This would have been quickly superseded by the recurrence of the A057 fault message, and although the 253 status message is stored, there is not enough space on the display to show anything other than the current message. Stored messages can be retrieved by the driver manually scrolling through the display, which he did at Lebanon Road when discussing with the controller about the persistence of the fault messages. He reported the 253 message to the controller at this point, but it was misheard by the controller as "2534 override", rather than "253 Fault override". The controller repeated the "2534" code back to the driver to check the message, but by this time passengers were knocking on the cab door (paragraph 30) and the driver's conversation with the controller moved on to discuss whether he had forgotten to open the doors at Lebanon Road, and what he should do about it.

80 The controller apparently did not understand this message, since no such 2534 message exists. There is a tram fault folder available at the controller's desk for reference, which does list the 253 status message, although this is listed in a separate section of the folder from the original (A057) fault message. Nevertheless, the 253 message has been highlighted in the folder with a marker pen, to bring attention to a memo at the front of the folder reminding controllers about the critical nature of the fault override switch. The memo states that the tram must not run in service carrying passengers while the fault override switch is activated, and use of the fault override is meant as a last resort to enable a failed tram to return to the depot.

81 The discussion about the 2534 message raised some concern in the control room about the possibility that the fault override switch had been operated. The controller specifically asked the driver about it between Lebanon Road and Sandilands. However, the controller referred to the "override switch" (not "fault override"), and asked whether it was in position "0 or 1" (rather than "off or on", as the switch is labelled). The controller was satisfied with the driver's response that the switch was in position "0" (not "off"), but given these ambiguities in communication it is possible that the driver was referring to a different switch.

82 At Sandilands, the driver again reported the 253 message to the duty manager (who had temporarily relieved the controller), but its significance was again missed amongst efforts to resolve the other tram faults, and no action was taken.

83 Within TOL, the standard of safety-critical communications is similar to that on the mainline railway, with the exception that *readbacks* are not required unless in an emergency. Prior assessments for the driver, controller and duty manager were all good; a RAIB review of the voice recordings confirmed that the protocol used during the incident met with the standards set by TOL.

### *The radio system on London Tramlink*

84 **The quality of radio signal reception possibly affected the controller's understanding of the driver's verbal communication.**

85 Witness evidence indicated that the radio system caused problems in communication between the controller and the driver during the incident.

86 London Tramlink, which maintains the radio system as part of its management of the tramway infrastructure, is aware of weak spots in the signal at certain locations on the network. Although these are subject to variations due to weather conditions, London Tramlink has been advised by its radio supplier that these weak spots are acceptable. However, the infrastructure manager at London Tramlink stated that he was unaware that drivers were using mobile phones instead of the radio in these areas (paragraph 98).

87 The radio system was installed at the same time as the network was built, around 1999, and the technology is largely obsolete now. When London Tramlink took over the running of the infrastructure from Tramtrack Croydon Ltd, one of its priorities was to upgrade the radio system to improve reception quality. The upgrade programme is currently ongoing, and London Tramlink estimates that it will be completed in the second half of 2015. In the meantime, a range of problems with the radio, not all of which relate to poor reception, continue to be reported regularly.

88 At the time of the incident, a loudspeaker on the controller's desk was not working. This loudspeaker provides the option for others in the control room to hear the driver's side of the conversation, and may be used during abnormal events. The fact that it was not working prevented an opportunity for the duty manager (or another controller) to detect the meaning of the 253 fault message.

89 London Tramlink is responsible for the radio system used by TOL. Although TOL stated that the loudspeaker problem had been verbally reported in liaison meetings, London Tramlink had no record of the issue in its fault reporting database. Although both TOL and London Tramlink had formal processes for recording faults with the radio system, the informal nature of the reporting in this case meant that the fault with the loudspeaker did not get properly recorded and tracked to resolution.

### The decision to keep the tram in service

90 Although the tram had developed a fault, the control room took the decision to keep it in operation rather than returning it to the depot for examination. This occurred because of a combination of:

- the lack of a standard process for dealing with relevant faults (paragraph 91); and
- the extent of training for drivers and controllers on fault handling (paragraph 95).

*Fault handling process*

**91 There was no standard process for dealing with faults.**

92 The controller's decision was to try to clear the tram fault (using the 'spring applied brake isolation' switch) rather than take the tram out of service, or arrange for it to be diverted into the centre platform at East Croydon tram stop, which would have enabled the driver and the controller to try to resolve the fault without delaying other eastbound trams. There were three attempts to clear the fault between Wellesley Road and the point at which the control room observed that the doors were open on the tram's departure from Sandilands. Witnesses indicated that if the fault had not cleared after the third attempt, then the tram would be taken out of service. However, this decision is based more on experience than written procedures.

93 The TOL training and assessment syllabus for Alpha faults such as fault A057 states that the controller would normally ask the driver to switch off power to the tram and then restart it in order to try to clear the fault. Alpha faults are described in TOL documentation as meaning that the tram cannot be driven. But this is meant as a statement of fact rather than an operational rule; TOL's position is that if the fault can be cleared, then the tram can remain in service.

94 An early design decision was taken that the driver's information display would not show 'return to depot' for Alpha faults as had been specified originally; TOL wanted the controller to be able to decide whether the fault could be fixed or if the tram should return to the depot.

*Fault handling training*

**95 Training on fault handling for drivers and controllers is largely based on procedures, and focuses on recovering the tram rather than diagnosing the fault.**

96 While the driver's, controller's and duty manager's assessment records for fault handling were all good, the training itself does not provide any detailed understanding of the faults, fault codes, or fault overrides. Their responses to abnormal scenarios are therefore dependent on simple procedures, with a fault code essentially invoking a lookup action (which is often stated on the driver's cab display at the press of a button). The training conveys no deeper understanding of the meaning of the fault or of the effects of operating critical override switches.

97 Although there is emphasis in training, briefings, and additional memos on using the fault override switch only as a last resort and only with the controller's permission, this had no relevance on this occasion because neither the tram driver nor the controller realised that the driver had operated the fault override switch.

## Observation[8]

Use of mobile phones

98 It became apparent during the investigation that controllers and drivers were often forced to use mobile phones to communicate in areas of poor radio reception. This occurred during the recovery of tram 2548 after the incident, including during times when the tram was moving at speeds of up to 40 km/h.

99 The TOL training module on communications states that the use of personal mobile phones by drivers when driving is illegal, which is consistent with road traffic laws that are designed to prevent driver distraction. TOL training also states that the tram mobile phone is restricted to emergency use, only when the radio system has failed, and only when stationary.

[8] An element discovered as part of the investigation that did not have a direct or indirect effect on the outcome of the accident but does deserve scrutiny.

# Summary of conclusions

## Immediate cause

100 The driver drove the tram between tram stops with doors open (**paragraph 41**).

## Causal factors

101 The causal factors were:

a. While the tram was at Lebanon Road and Sandilands tram stops, the driver was in dialogue with the controller regarding the fault with the spring applied brake. In both cases, this dialogue was ongoing as the tram left the stop, which acted as a distraction to the driver (**paragraph 44, Recommendation 1**).

b. The ongoing nature of the fault, coupled with the perceived pressure to avoid delaying following trams, placed stress on the driver (**paragraph 48, Recommendation 2**).

c. The driver relied on the safety interlock as proof that the doors were closed (**paragraph 55, Recommendation 2**).

d. The safety interlock which prevents the tram from moving with the doors open had been overridden by the driver's inadvertent operation of the fault override switch (**paragraph 60, Recommendations 3, 4 and 5**).

e. Passengers did not succeed in alerting the driver to the fact that the doors were open (**paragraph 70, Recommendation 6**).

f. The controller did not understand a communication from the driver reporting the fault override status message (**paragraph 78, Recommendations 1 and 2**).

g. The tram was not taken out of service despite the indication of a brake fault because there was no standard process for dealing with faults (**paragraph 91, Recommendation 2**).

102 It is probable that the following factors were causal:

a. there was poor indication in the driving cab as to whether the doors were closed (**paragraph 52, Recommendation 3**);

b. the quality of radio signal reception possibly affected the controller's understanding of the driver's verbal communication (**paragraph 84, Recommendations 7 and 8**); and

c. training on fault handling for drivers and controllers is largely based on procedures, and focuses on recovering the tram rather than diagnosing the fault (**paragraph 95, Recommendation 2**).

## Underlying factor

103 The fault override switch bypasses the door-traction interlock, allowing the tram to move with its doors open (**paragraph 67, no recommendation**).

## Observation

104 Although not linked to the incident on 13 April 2013, the RAIB observes that controllers and drivers often used mobile phones to communicate in areas of poor radio reception (**paragraph 98, Recommendation 1**).

# Previous RAIB recommendations relevant to this investigation

105 The RAIB investigated a similar incident on London Underground on 11 July 2011, in which a train departed from Warren Street station with its doors open because the driver overrode the door interlock (report 13/2012). One recommendation that was made had some relevance to the circumstances of the incident on 13 April 2013.

*Recommendation 3*

*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; 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.*

In response to this recommendation, London Underground reported to the ORR that it is reviewing its competence management system, that it will include out-of-course events in its competence management cycle from 2013, and that it will remind Train Operators of their responsibilities from the next cycle. The ORR considers this action to be ongoing.

106 London Underground and London Tramlink both fall under the oversight of Transport for London. TOL reviewed the Warren Street report when it was published, noting that the competency issues related principally to drivers, whereas the authority for operating the fault override switch on the London Tramlink system resides with the controller.

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

107 On 18 April 2013, TOL issued a memo to controllers reminding them that the fault override switch should only be used as a last resort to enable a failed tram to return to the depot, and that trams must not run in service carrying passengers when the fault override switch is activated.

108 On 20 June 2013, TOL issued an operational notice to drivers reminding them that sealed switches must not be used without the authorisation of the controller. This notice also encourages drivers to look at the switch being operated and to ensure that no other switches are inadvertently operated. It further informs drivers of a new green plastic seal on the fault override switch, and instructs drivers to stop the tram and inform the control room if a '253 fault override' message appears on the display.

109 Bombardier Transportation subsequently developed a modification to the fault override switch, protecting it with a key-operated cover incorporating the green plastic seal, in order to prevent inadvertent operation (figure 9). This modification has been installed across London Tramlink's CR4000 fleet. It was supported by a briefing to controllers and drivers (on 5 and 9 August 2013 respectively) and a new procedure involving walking through the tram to physically check that all the doors are closed before operating the fault override.

110 In August 2013, London Tramlink installed new radio terminals at all three desks in the control room to fix a problem with the duty manager's radio. This also resolved the problem of the non-functioning loudspeaker on the controller's desk.


*Figure 9: Bombardier key switch modification for fault override.*

# Recommendations

111 The following recommendations are made[9]:

1 *The intention of this recommendation is to minimise driver distraction from communicating or attempting to resolve faults while on the move, and to improve safety-critical communications in abnormal working conditions.*

Tram Operations Ltd should revise its policy on verbal communications to:

- reinforce rules on the avoidance of communicating with drivers by mobile phone while trams are moving (paragraph 104);
- minimise, where possible, communication by radio while trams are moving particularly for complex issues (such as the resolution of faults) (paragraph 101a); and
- enhance the use of readbacks for safety-critical communications in abnormal, degraded and emergency scenarios (paragraph 101f).

2 *The intention of this recommendation is to improve the fault handling responses of drivers and controllers by providing them with a better understanding of fault modes, overrides, and resolution options.*

Tram Operations Ltd should revise its training modules and procedures on fault handling to achieve:

- improved awareness amongst drivers and controllers of critical fault modes, the effects of operating override switches (including the fault override and the driver's emergency door release) and how to respond to faults, including guidance on co-operation between drivers and controllers (paragraphs 101b, 101c, 101f, and 102c); and
- clarification of the procedure for handling critical faults such as Alpha faults, including explicit guidance for defined circumstances (such as how many attempts should be made to rectify a fault and when the tram should be taken out of service) (paragraph 101g).

*continued*

[9] 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.

3 *The intention of this recommendation is for improvements to be made to the driver's cab displays and labelling to minimise the chance of the driver not noticing that the doors are open and of misunderstanding the operation of override switches.*

London Tramlink, in conjunction with Tram Operations Ltd, should improve cab displays and labelling in all of its trams. This should include, but not be limited to:

- a prominent indication of the status of the doors (for example, by changes to the cab panel indicator light, or by introducing an audible warning) (paragraph 102a); and
- information provided to the driver about the fault override function and other safety-critical overrides (such as the emergency door release), including the switch label and the associated alert on the message display, to clarify its purpose and effects of its operation (paragraph 101d).

4 *The intention of this recommendation is to minimise the risk of incidents involving accidental operation of safety override devices occurring elsewhere on UK tram networks.*

UK tram operators should conduct an assessment of controls in driving cabs in their current and future fleets to identify those which override safety systems, the risk of drivers inadvertently operating those controls and, where reasonably practicable, design and implement solutions to minimise such risk based on the lessons from this investigation (paragraph 101d).

5 *The intention of this recommendation is to ensure that appropriate guidance on ergonomics principles for cab interface design is constantly available to tram operators, particularly in terms of protecting safety-related controls from accidental operation.*

The Office of Rail Regulation should ensure that UK tram operators publish suitable guidance on ergonomics principles for cab interface design (with reference to appropriate tramway, railway and European standards), and identify where such guidance is to be found in the long term. This shall include guidance on protecting safety-related controls from accidental operation (paragraph 101d).

6 *The intention of this recommendation is to improve the design of passenger controls and displays (emergency alarms, intercoms etc.), through shape, colour, symbols and/or signage, so as to make their operation more obvious and intuitive to the user in the event of an emergency.*

Tram Operations Ltd should take steps to improve the clarity and consistency of passenger controls and displays on its trams, taking into account the findings of RSSB project T052c as appropriate (paragraph 101e).

7 *The intention of this recommendation is to minimise the potential for miscommunications on London Tramlink by enhancing the quality of the radio system.*

London Tramlink should develop and implement a programme to prioritise and expedite the planned upgrade of the radio system, to achieve an improvement in signal coverage and strength across the whole network (including tunnels) and reliable operation in adverse weather conditions (paragraph 102b).

8 *The intention of this recommendation is to enhance fault reporting between the operator, the infrastructure manager and the maintainer so that reported faults that could impact on safe running of the network are recorded properly and followed up within appropriate timescales.*

Tram Operations Ltd should improve its fault reporting processes to ensure that faults are properly logged and tracked to resolution (paragraph 102b).

# Appendices

## Appendix A - Glossary of acronyms and abbreviations

| | |
|---|---|
| CCTV | Closed circuit television |
| LUL | London Underground Limited |
| ORR | Office of Rail Regulation |
| OTDR | On-tram data recorder |
| RAIB | Rail Accident Investigation Branch |
| TOL | Tram Operations Limited |

## Appendix B - Glossary of terms

| | |
|---|---|
| Double-plug (door) | A sliding door with two leaves that sits flush to the vehicle body when closed, and pops outwards in order to slide open along the body side. |
| Fault log | A separate type of data recorder that specifically records fault codes, messages and the position of override switches. |
| Interlock | A mechanical, electrical or software system for preventing conflicting functions. |
| Mockup | A model or early prototype of a design used to gain feedback from users and evaluate designs early in the design process. |
| On-tram data recorder | A data recorder fitted to trams collecting information about the performance of the tram, including speed, power controller and brake control positions, and activations of horn, bell etc. |
| Readback | A practice used in safety-critical verbal communication whereby the listener repeats the message that they have received word-for-word in order to check that it has been received correctly. |
| Usability | The effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments. |

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