



Rail Accident Investigation Branch

# Rail Accident Report



**Pedestrian struck by a tram at Sandilands tram  
stop, Croydon  
16 May 2012**

Report 03/2013  
February 2013

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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# Pedestrian struck by a tram at Sandilands tram stop, Croydon, 16 May 2012

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## Summary

At approximately 09:44 hrs on Wednesday 16 May 2012, a pedestrian was struck by a tram as she crossed the tramway on a foot crossing on the approach to Sandilands tram stop in Croydon. The impact resulted in the pedestrian falling into the space between the platform and the tram. She remained trapped in that position as the tram continued into the platform and suffered serious injuries.

The investigation found that the pedestrian had not looked for an approaching tram before she crossed. However, there was a possible obstruction to the pedestrian's view of approaching trams as she walked towards the entrance to the tram stop and the configuration of the crossing meant that she approached it with her back to trams running on the nearest track.

Risk assessments had been undertaken in relation to safety at Sandilands foot crossing (and other foot crossings on the Croydon tram network) in 2008/9 and 2011. The investigation found that methodology employed in the 2008/9 assessment was not a suitable basis for prioritising the foot crossings for safety improvements. With the agreement of the Office of Rail Regulation, London Tramlink mainly prioritised crossings remote from tram stops for safety improvements from 2009 onwards. The 2011 risk assessment, while intended for the purpose of assessing whether the track at tram stops should be filled in between the rails, also identified that the foot crossing at Sandilands represented the highest risk of the 52 crossings that were considered in the review. London Tramlink did not make any safety improvements to reduce the probability of a pedestrian being struck on the foot crossing at Sandilands in response to the findings. Although London Tramlink had taken some action to help it understand the generality of the risk at foot crossings on its network, and had introduced a speed restriction of 25 km/h for trams passing over foot crossings on the approach to all tram stops, its processes for managing the risk at individual crossings were not effective.

The investigation also found that two factors affected the consequences of the accident. Firstly, the tram driver did not apply the hazard brake (which achieves a higher rate of retardation than the brake normally employed for stopping trams) after the tram struck the pedestrian. Secondly, there was enough vertical and horizontal clearance to create a survival space for the pedestrian in the position where she fell after the accident.

The RAIB has made five recommendations. Three recommendations have been made to London Tramlink in relation to risk assessment at foot crossings, processes for ensuring pedestrians have clear sight of approaching trams and improving organisational competence in safety decision-making. One recommendation has been made jointly to London Tramlink and Tram Operations Ltd in relation to investigation of accidents and incidents. One recommendation has been made to the Office of Rail Regulation in relation to reissuing guidance on various aspects of the design of tram stops and foot crossings.

The RAIB has also identified a learning point for tram operators regarding use of the hazard brake when a tram has struck a pedestrian.

# 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.

## Key definitions

- 3 All dimensions and speeds in this report are given in metric units.
- 4 The report contains abbreviations, which are explained in appendix A.

## The accident

### Summary of the accident

- 5 At approximately 09:44 hrs on Wednesday 16 May 2012, a pedestrian was struck by a tram as she crossed the tramway on a foot crossing at Sandilands tram stop in Croydon (figures 1 and 2).

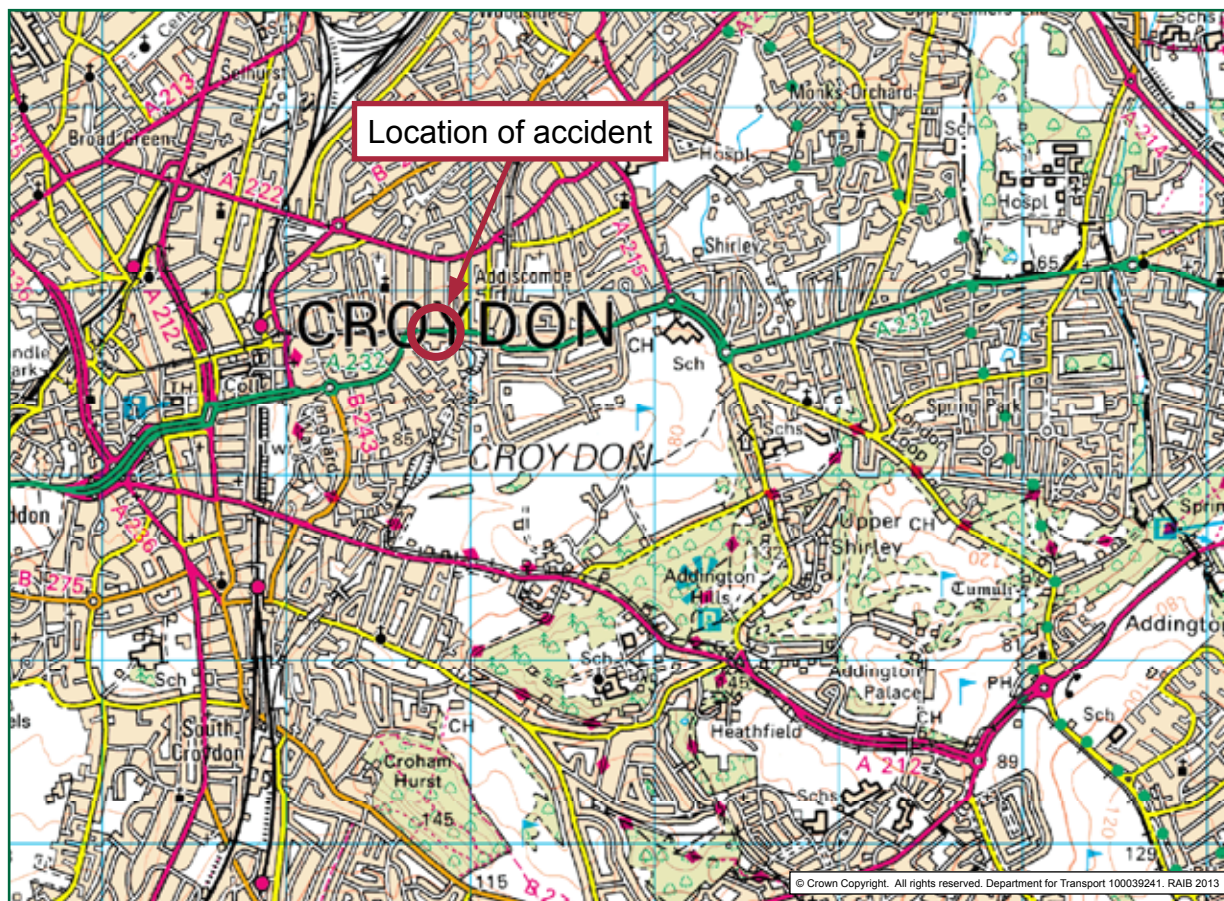


Figure 1: Extract from Ordnance Survey map showing location of accident

- 6 The tram was travelling at 26 km/h at the time of the accident. The impact resulted in the pedestrian falling into the space between the platform face and the rail closest to the platform. She remained trapped in that position as the tram continued into the platform to its normal stopping point. The pedestrian was seriously injured.



Figure 2: Sandilands tram stop showing the crossing at the west end where the accident happened

## Context

### Location

- 7 Sandilands tram stop is located on a two-track section of tramway to the east of Croydon town centre. It has two platforms and a passenger shelter on each platform. There is a foot crossing at the west end of the stop and a road/foot crossing at the east end of the stop. The tramway is segregated by a pavement (and, in places, a grass verge) from the adjacent A232, which is a busy road linking Croydon with Shirley and West Wickham. Several bus routes use the road and there is a bus stop alongside Sandilands tram stop, thus creating a busy transport interchange. It is also a tram interchange, with the junction for the routes to New Addington and Beckenham Junction/Elmers End being situated immediately to the east of the tram stop.
- 8 A fence separates the tram stop and the pavement, which are at different heights. Pedestrians going towards the platform and the foot crossing at the west end must walk a short distance on the pavement before reaching the entrance to the tram stop. At this point, it is necessary for them to turn back on themselves in order to reach the eastbound platform and the foot crossing to the westbound platform (figures 3 and 4).
- 9 At the time of the accident, there were no signs provided at the crossing to warn pedestrians to look for approaching trams.



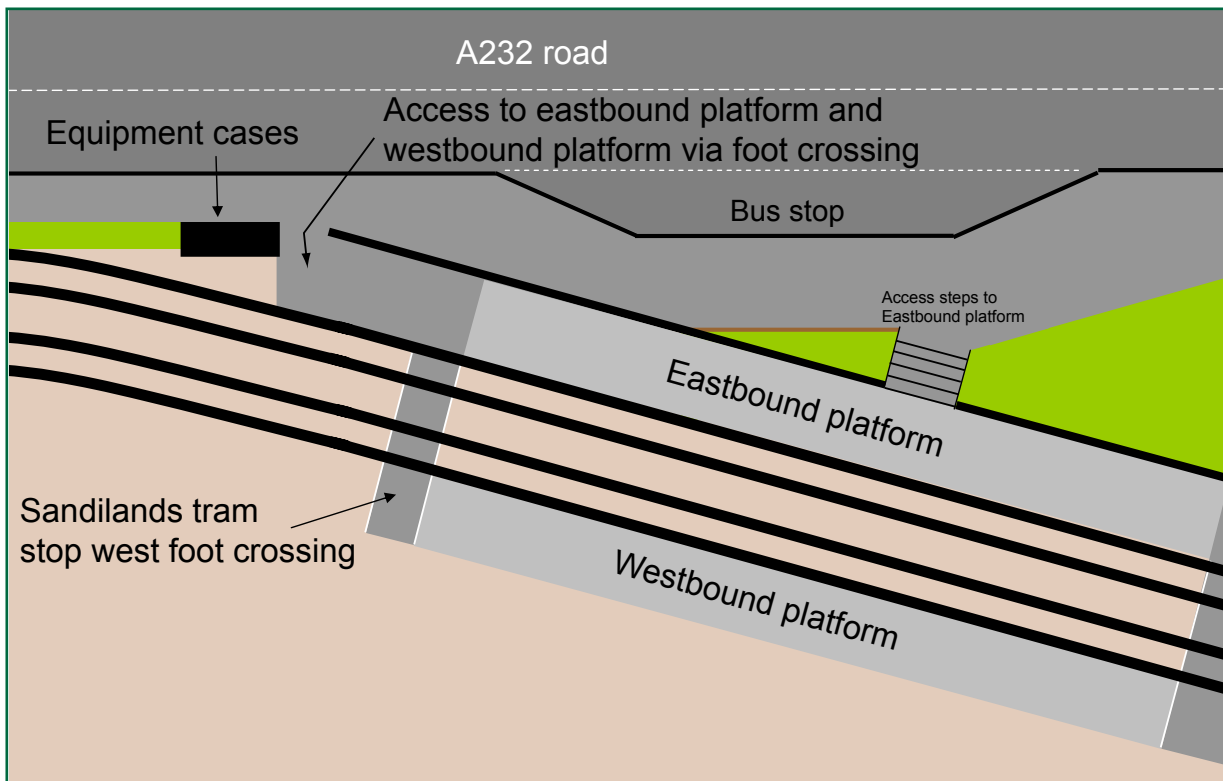


Figure 3: Layout at Sandilands tram stop

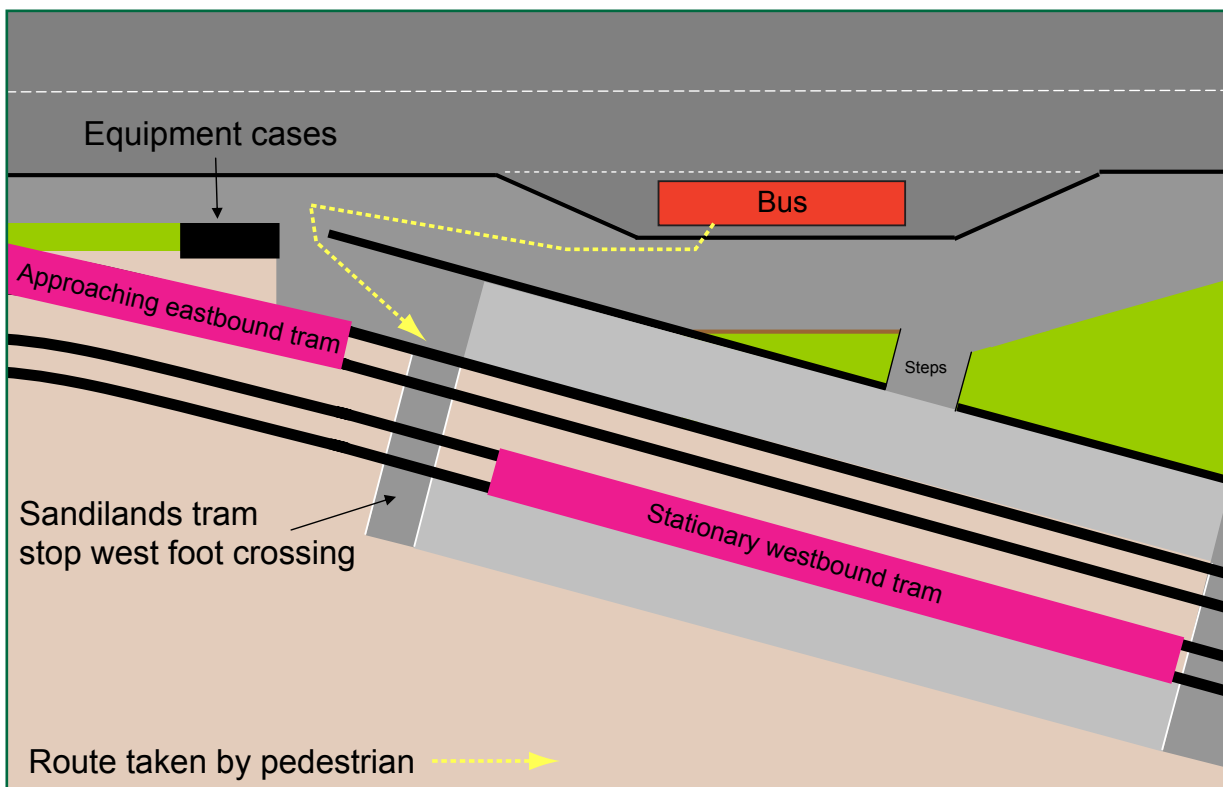


Figure 4: The pedestrian's route from a bus to the westbound platform at Sandilands

### Organisations involved

- 10 The London Tramlink system, which opened in 2000, is owned and managed by Transport for London (TfL) through its subsidiary Tramtrack Croydon Limited, which trades as London Tramlink. It is responsible for the maintenance of the tramway including the tram stops and employed the staff who undertook safety and risk assessments of Sandilands tram stop. It is referred to as London Tramlink in the remainder of this report.
- 11 The tramway is operated under contract to TfL by Tram Operations Ltd, which is part of First Group. Tram Operations Ltd employed the driver of the tram involved in the accident.
- 12 The Office of Rail Regulation (ORR) is the safety regulator for the Croydon tram network.
- 13 London Tramlink, Tram Operations Ltd and ORR freely co-operated with the RAIB during the investigation.

### Tram involved

- 14 The vehicle involved was tram 2544, one of 24 units that made up the initial Tramlink fleet. It was built by Bombardier Transportation in Austria in 1998. The circumstances of the accident gave no reason for the performance of the tram to be called into question. The vehicle was taken to the depot after the accident where it was later examined by Bombardier staff, who reported that all systems, including the brakes, lights and bell, were working correctly.
- 15 The tram was equipped with a forward facing closed circuit television (FFCCTV) camera and an on-tram data recorder (OTDR). The OTDR recorded, among other things, key parameters such as the vehicle speed and the driver's operation of power and brake controls and the bell. Both the FFCCTV and OTDR were functioning at the time of the accident and the evidence obtained from them has been used by the RAIB in its investigation.

### Staff involved

- 16 The driver of the tram involved in the accident had been employed as a driver by Tram Operations Ltd for four years and had been passed by his employer as competent to drive trams on 2 August 2008. He was subsequently subject to periodic competence assessments in accordance with Tram Operations Ltd's driver monitoring processes.
- 17 Tramtrack Croydon Ltd was previously an independent company which held the concession to operate the Croydon tram system, and was bought out by TfL in June 2008. The post of Safety, Health, Environment and Quality Manager, with responsibility for providing advice, monitoring compliance and undertaking allocated tasks within the designated scope, was filled by a consultant to TfL until a permanent appointment to the post was made in February 2009.

### Environmental conditions

- 18 The accident occurred in daylight, it was dry and visibility was good. Environmental conditions played no part in the accident.

## Events preceding the accident

- 19 The pedestrian involved in the accident alighted from a bus at Sandilands and walked westwards towards the entrance to the tram stop. As she did so, she saw that a westbound tram was already stationary in the tram stop and quickened her pace in order to cross the tramway using the foot crossing at the west end of the stop. Evidence from the FFCCTV equipment on the tram waiting at the westbound platform shows that after turning eastwards, she walked diagonally from the entrance to the tram stop towards the crossing with her back to trams approaching on the nearest track to her, and stepped onto the crossing without looking back.
- 20 In the meantime, tram 2544 (operating a service between Croydon and Beckenham Junction) was approaching eastbound towards the stop. The tram was coasting up the gradient on the approach to the 25 km/h speed limit that commenced at the foot crossing at the west end of the tram stop. As the tram approached the foot crossing, the driver started to brake in order to stop at the platform immediately beyond the crossing. The driver stated that at almost exactly the same time, he became aware of the pedestrian approaching from his left and then starting to cross in front of the tram. He rang the tram's bell in an attempt to warn the pedestrian.

## Events during the accident

- 21 The pedestrian was struck by the tram just after she stepped onto the crossing, with the point of impact being left of centre at the front of the tram (in the tram's direction of travel).
- 22 The impact resulted in the pedestrian falling into the space between the face of the platform and the rail closest to the platform edge.
- 23 The driver of the tram continued into the platform, stopping with the front of the tram approximately 40 metres from the crossing at the normal stopping point for trams. As the tram ran into the platform, the pedestrian was dragged to a position approximately 17 metres from the crossing.

## Events following the accident

- 24 The driver of the stationary tram in the westbound platform (paragraph 19) witnessed the accident and made an emergency call to the control centre. Staff in the control centre called the emergency services. The other driver also made an emergency call after stopping his tram, although the control centre was already aware of the accident because of the call from the driver of the westbound tram.
- 25 The pedestrian suffered extensive injuries. She was airlifted to hospital and remained there for several weeks. She is now recovering.

## The investigation

### Sources of evidence

26 The following sources of evidence were used:

- witness statements;
- data from the eastbound tram's OTDR;
- images from the FFCCTV equipment carried on both eastbound and westbound trams;
- site photographs and measurements;
- a reconstruction of the accident;
- documentation relating to risk assessments and other reviews at Sandilands tram stop;
- a review of previous reported occurrences at the crossing; and
- a review of previous RAIB investigations that had relevance to this accident.

## Key facts and analysis

### Identification of the immediate cause<sup>1</sup>

**27 The pedestrian walked onto the crossing as the tram was approaching.**

28 Evidence from the FFCCTV equipment in the tram involved in the accident, and in the tram standing in the westbound platform, confirms that the pedestrian arrived on the crossing at exactly the same moment as the tram.

### Identification of causal factors<sup>2</sup>

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

- The pedestrian may not have been able to see the approaching eastbound tram as she walked from the bus stop to the entrance of the tram stop because her view could have been obstructed by the presence of lineside equipment cabinets (possibly causal);
- The pedestrian did not look to see if an eastbound tram was approaching as she hurried from the entrance of the tram stop to the crossing (causal);
- The approach to the foot crossing at the west end of the tram stop had not been configured to encourage people to look both ways before crossing (probably causal);
- The risk at Sandilands tram stop and its associated foot crossings was not fully understood by London Tramlink because:
  - the risk ranking process that had been applied by London Tramlink in 2008/2009 did not provide a suitable basis for evaluating risk at foot crossings (causal); and
  - London Tramlink prioritised other crossings for the application of risk mitigation measures (probably causal).
- No works were planned for Sandilands tram stop to reduce the likelihood of a pedestrian being struck by a tram despite a further risk assessment in May 2011 (which had been undertaken for other purposes) identifying that the crossing at the west end represented the highest risk of any foot crossing at a tram stop outside the town centre, and recommending that measures be taken to address the risk (causal).

30 Each of these factors is now considered in turn.

#### The pedestrian's view of approaching trams when walking from the bus stop

**31 The pedestrian may not have been able to see the approaching tram as she walked from the bus stop to the entrance to the tram stop, because her view could have been obstructed by lineside equipment cabinets. This was a possible causal factor.**

<sup>1</sup> The condition, event or behaviour that directly resulted in the occurrence.

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

- 32 Paragraph 8 describes the route taken by pedestrians alighting from a bus to reach the entrance to the tram stop. As pedestrians walked towards the entrance, their view of approaching eastbound trams could be obscured by lineside equipment cabinets (figure 5), although this would not be the case if they walked close to the edge of the pavement. If they walked close to the fence separating the pavement from the platform, they were denied a view of approaching eastbound trams until they were approximately eight metres from the crossing. The RAIB has been unable to determine the exact position of the pedestrian as she walked along the pavement towards the entrance to the tram stop.



Figure 5: The obstruction to the pedestrian's view of approaching eastbound trams at Sandilands tram stop

### The actions of the pedestrian

- 33 **The pedestrian did not look for an approaching eastbound tram as she hurried from the entrance to the tram stop to the foot crossing. Had she done so, she would have seen that the approaching tram was close to the crossing. This was a causal factor.**
- 34 FFCCTV evidence obtained from both trams shows that at no stage after she walked through the entrance to the tram stop did the pedestrian look to see if a tram was approaching on the track closest to her.
- 35 Although she has no recollection of events immediately before the accident, it is likely that she was focused on getting over the foot crossing to the far platform where her tram was waiting to depart.

- 36 It is possible for pedestrians to see trams as soon as they turn into the tram stop entrance (which is eight metres from the foot crossing), providing that they look over their right shoulder. When the pedestrian involved in the accident was eight metres from the crossing, the tram was approximately 22 metres away (around 30 metres from the crossing). The pedestrian was struck approximately four seconds after the tram could have become visible to her.

The configuration of the approach to the foot crossing at the west end of the tram stop

**37 The approach to the foot crossing at the west end of Sandilands tram stop had not been configured to encourage pedestrians to look both ways before crossing, or to make it easy for them to do so. This was a probable causal factor.**

- 38 On 23 August 2007 a tram struck and injured a pedestrian on a foot crossing at Arena tram stop. The circumstances of this accident were almost identical to those of the accident at Sandilands on 16 May 2012. The pedestrian involved in the accident at Arena was intending to catch a tram that was already in the opposite platform, hurried towards the crossing with his back to a tram approaching from behind and was struck as he stepped onto the crossing.
- 39 Following the accident at Arena, the concessionaire at the time, Tramtrack Croydon Ltd (paragraph 17), recognised the hazard of pedestrians approaching Arena tram stop with their backs to approaching trams and installed barriers which had the effect of encouraging pedestrians to approach the crossing at right angles, thereby making it easier for them to see trams approaching from either direction. Figure 6 shows the configuration of barriers that are currently in place at Arena tram stop; the barriers that were installed at Arena after the accident in August 2007 are shown in Figure 7 of the RAIB's investigation into another accident which occurred at Morden Hall Park footpath crossing in September 2008<sup>3</sup>.
- 40 Although Tramtrack Croydon Ltd recognised the specific hazard of the approach to the foot crossing at Arena tram stop, it did not carry out a review of other stops on the network where the same hazard existed, such as Sandilands, and similar mitigation was not applied elsewhere.
- 41 Guidance is provided by ORR on tramway design and operation<sup>4</sup>. It states that fencing or pedestrian guard rails should be provided where necessary, to guide pedestrians to face oncoming trams before they cross the track. However, this is guidance and does not therefore constitute a requirement. The arrangements at Sandilands tram stop had been approved in May 2000 by the safety regulator, which at that time was Her Majesty's Railway Inspectorate, part of the Health and Safety Executive. The wording of the guidance is discussed later in this report (paragraph 102 and 103).

<sup>3</sup> The RAIB published its findings in March 2009, 'Fatal accident at Morden Hall footpath crossing, 13 September 2008', RAIB report 06/2009. All RAIB investigation reports are available online at [www.raib.gov.uk](http://www.raib.gov.uk).

<sup>4</sup> Guidance on Tramways, Railway Safety Publication No. 2, Office of Rail Regulation, November 2006. The document is available from the ORR website. It is not mandatory and does not apply retrospectively, but it does describe good practice.



Figure 6: Barriers installed at Arena tram stop

### Lack of safety improvements at Sandilands tram stop following an assessment of the risk in 2008/2009

- 42 Commencing in October 2008, London Tramlink undertook an assessment of the risk at all tram stop foot crossings, but the foot crossing at Sandilands was not prioritised for risk mitigation measures. This was because:
- the risk assessment did not provide a suitable basis on which to prioritise risk mitigation measures; and
  - London Tramlink prioritised other types of crossing for risk mitigation.

### Tram stop risk assessment 2008/2009

43 **The methodology adopted by London Tramlink in 2008/2009 to assess the risk at all foot crossings on the Croydon tram network did not provide an accurate basis for doing so, and did not enable easy identification of crossings where risk mitigation should be provided. It resulted in the risk at Sandilands being under-estimated and its foot crossing not being prioritised for risk mitigation measures. This was a causal factor.**

- 44 The 2008/2009 exercise to assess risk at foot crossings on the Croydon tram network was initiated following a fatal accident that occurred on 13 September 2008 at Morden Hall Park footpath crossing (paragraph 39). Although the accident occurred at a crossing located between two tram stops and involved a cyclist rather than a pedestrian, it shared the common feature with the accident at Sandilands on 16 May 2012 that the person involved had gone onto the crossing without looking to see if a tram was approaching, and the configuration of the crossing had been a factor in the causal chain.



- 45 After the accident, ORR issued an Improvement Notice to London Tramlink requiring it to assess the risk to users at each foot, bridleway, vehicular access and cycle crossing on the network and identify further action, if any, to reduce risk.
- 46 London Tramlink appointed consultants to undertake the assessment of risk. The overall requirements for the assessment were agreed by London Tramlink's Director and by TfL's Director of Health, Safety and Environment, London Rail who sat on London Tramlink's Board. The methodology was jointly developed by London Tramlink's acting Safety Manager (paragraph 17) and the consultants. It comprised a simple risk assessment based on scores being applied to a number of key factors, which permitted the crossings to be ranked relative to each other in terms of the risk arising from the factors considered.
- 47 The assessment of risk required the following factors to be considered for each crossing:
- track layout (single, double, straight, curved);
  - permitted speed of trams;
  - visibility of approaching trams for pedestrians;
  - crossing environment (open space, built-up area, town centre, parkland);
  - quality of the surface of the crossing;
  - average number of users per hour, based on site surveys undertaken during three one-hour slots (morning and evening peak periods and middle of the day);
  - type of user seen during the survey (adult, adults and children, pedestrians and cyclists, pedestrians and cyclists unfamiliar with site); and
  - the crossing's accident and incident (near-miss) history.
- 48 For each factor, a score between 1 and 4 was assigned, based on the assessor's evaluation and data available, with the higher scores indicating higher risk. The maximum score (highest risk) that could be assigned to any crossing was 32. Sandilands was assessed by the appointed consultant on 25 and 26 November 2008 and scored 21; table 1 shows the scores allocated for each parameter.

Parameter	Score
Track layout	4
Line speed	2
Visibility of approaching trams for pedestrians	3
Crossing environment	2
Quality of the surface of the crossing	1
Average number of users per hour	4
Type of user	2
Accident and incident history	3

*Table 1: Scores allocated to the foot crossing at Sandilands tram stop in the November 2008 risk assessment*

- 49 The methodology adopted indicated that the circumstances of the Morden Hall Park footpath crossing accident (paragraph 44) had influenced the assessment:
- for crossing environment, the highest score of 4 was to be allocated to parkland (Morden Hall Park crossing was located in the vicinity of parkland); and
  - for type of user, the highest score of 4 was to be allocated to pedestrians and cyclists unfamiliar with the site (a cyclist had been involved in the accident at Morden Hall Park).
- 50 A key factor in determining the probability of a pedestrian being struck by a tram is the number of trams operated over the crossing. This factor was not included in the assessment of risk. The number of tram movements and the number of crossing users (sometimes described as the 'crossing moment') are both significant because they represent the underlying opportunity for vehicles and pedestrians to be in conflict with each other. It is likely that the assessment significantly under-estimated the risk at Sandilands because:
- Sandilands has the highest passenger usage of the 31 tram stops outside the central Croydon area; it is the only one with over one million passengers boarding and alighting per year; and
  - Sandilands is one of only 3 stops on the 39-stop network which is served by all three<sup>5</sup> tram routes in both directions, resulting in a very high frequency of tram movements. East Croydon and Lebanon Road are the other two; both are located in the city centre section where the trams are running in the street.
- 51 The scores obtained from the assessment of 75 crossings ranged from 25 (highest) to 13 (lowest). Sandilands crossing was assigned a score of 21, and ranked in 23<sup>rd</sup> place amongst the 75 crossings assessed (where the crossing ranked first was deemed to be the highest risk crossing). The lack of differentiation between the eight factors chosen for the assessment in terms of their relative importance, the non-consideration of numbers of tram movements and the influence exerted by the causes of the Morden Hall Park footpath crossing accident contributed to the under-estimate of risk at Sandilands.
- 52 The purpose in assessing the risk at each crossing was to address the requirement in the Improvement Notice to identify whether further controls were necessary. The risk arising from a specific event should take into account the likelihood of the event occurring and the severity of its consequences. This can be used to derive an estimate of 'collective risk'<sup>6</sup>, the total risk of harm occurring at the crossing. The effectiveness of proposed mitigation measures can then be evaluated by comparing the estimated reduction in risk with the cost of the mitigation measure concerned. However, the approach taken by London Tramlink to the assessment of risk provided no basis for such an evaluation and therefore offered no guidance on where money should be spent to mitigate risk at foot crossings.

<sup>5</sup> There were three routes passing through Sandilands tram stop at the time of the assessment; this has since been increased to four.

<sup>6</sup> An estimate of 'individual risk' can also be made, which in this case would have focused on the risk to a 'most exposed' frequent user of the crossing. Estimates of individual risk focus on the likelihood of fatality and are used to determine, in absolute terms, whether risk is tolerable or not. There have been no fatal accidents on Sandilands foot crossing.

London Tramlink's approach to prioritising crossings for risk mitigation works

- 53 **London Tramlink did not prioritise work to reduce risk at foot crossings in accordance with the results from the 2008/2009 assessment of risk, which meant that Sandilands was not considered as a priority for the application of risk mitigation measures. This was a probable causal factor.**
- 54 Following completion of the assessments of risk, London Tramlink reviewed the results. The crossings were divided into three categories:
- type A – crossings located on street running sections of the system, primarily in Croydon town centre;
  - type B – off-street crossings associated with tram stops (Sandilands foot crossing fell within this category); and
  - type C – off-street crossings remote from tram stops (Morden Hall Park footpath crossing fell within this category) or crossings at tram stops where there is a reason other than accessing the tram stop for a pedestrian to use the crossing, eg there is a footpath or other facility beyond.
- 55 Of the 75 crossings that were subject to risk assessment, 22 were categorised as type A, 21 as type B and 32 as type C. The 22 crossings with a higher risk score than Sandilands foot crossing comprised:
- 7 type A crossings;
  - 7 type B crossings; and
  - 8 type C crossings.
- 56 Despite each of the three crossing types being similarly represented in the higher risk group, London Tramlink decided to prioritise all the type C crossings for risk mitigation. Witness evidence indicates that its justification for so doing was that those crossings were more likely to be used by people who were not expecting to encounter a tramway and they were therefore at greater risk of being surprised by the approach of a tram. London Tramlink also observed that the consequences of being struck by a tram were likely to be much more serious 'between stops', where trams operate at higher speeds. A quantified risk assessment undertaken by consultants in 2003 had concluded that risk at crossings located on higher speed sections of the tramway was higher than risk at crossings where tram speed was lower. However, the risk assessment grouped crossings according to speed and was not suitable for making decisions about risk mitigation at individual crossings. Representatives from London Tramlink also stated that they considered that recommendation 1 from the RAIB's Morden Hall Park investigation led them to focus on the type C crossings (this is discussed further at paragraph 107).

- 57 It can be assumed that tram speed will be one of the factors that affect the severity of an accident involving a person being struck by a tram. The likelihood of such an accident occurring will be affected by a whole series of factors, the most significant of which is 'exposure', ie the number of people exposed to the hazard of being struck (paragraph 50). The likelihood of such accidents is therefore much greater at intensively used tram stop crossings than at relatively infrequently used crossings between stops<sup>7</sup>. It is also debatable whether the issue of pedestrian 'familiarity' increases or decreases the probability of an accident. London Tramlink considered that unfamiliarity increased risk. It is, however, equally possible that people encountering a 'railway' crossing away from a stop might exercise more caution than those for whom crossing at tram stops is a familiar and frequent occurrence and where they may become distracted by focusing on their need to catch a tram.
- 58 Data supplied by Tram Operations Ltd on accidents involving people being struck by trams on crossings in Croydon since the beginning of 2003 indicates that the accident history at type A and type B crossings was significant, when normalised by the number of each type of tram stop. Tables 3 and 4 (following paragraphs 78 and 112 respectively) show that at the time that London Tramlink took the decision to focus improvement works on type C crossings at the beginning of 2009:
- two accidents had occurred on a type A crossing (both at East Croydon), equivalent to an annual frequency of 0.015 accidents per crossing<sup>8</sup>;
  - eight accidents had occurred on type B crossings, equivalent to an annual frequency of 0.063 accidents per crossing; and
  - five accidents had occurred on type C crossings, equivalent to an annual frequency of 0.026 accidents per crossing.
- 59 Although ORR's Improvement Notice made reference to London Tramlink assessing the risk at all crossings on the network, ORR and London Tramlink reached a consensus that it was the type C crossings that represented the highest risk and which should be prioritised for improvement works. ORR closed its Improvement Notice in the knowledge that London Tramlink's intention was to prioritise work to reduce risk at the type C crossings.

<sup>7</sup> The RAIB investigated an accident that occurred on a station pedestrian crossing at Elsenham on 3 December 2005. Appendix F to the investigation report (RAIB report 23/2006) identified a series of hazards for which the associated risk may be higher at a station crossing than at a crossing remote from any station. While some of the hazards are only relevant to main line railway stations with a train service that is relatively infrequent in comparison with the intensive service operated on tramways, others such as potential for stepping out behind a stationary vehicle, and the noise of moving vehicles masking the sound of another approaching tram are relevant to stations on both tramways and railways.

<sup>8</sup> Calculated by dividing the number of reported accidents (tables 2 and 3) by the number of each type of crossing (paragraph 55), and then dividing the result by the number of years' data (6).

- 60 The first three crossings selected for improvement were the type C crossings at Morden Hall Park, Belgrave Walk and Waddon Marsh, ranked 8<sup>th</sup>, 23<sup>rd</sup> and 40<sup>th</sup> respectively in the risk assessment<sup>9</sup>. London Tramlink stated that it used local intelligence in determining priorities. By July 2010, improvement works had been completed at a further 15 crossings (principally the provision of chicanes). All were type C crossings. Three of them (Addington Village, Mitcham and Mitcham Junction) were at tram stops rather than between stops (see definition of type C crossings in paragraph 54). All proposals for modifying crossings were considered and approved by the Modifications Panel, which had been established to consider changes to tramway infrastructure, and, in order to ensure that all views were considered, included representatives from the tramway's maintainers and operators as well as London Tramlink.
- 61 Sandilands foot crossing was one of a group ranked 23<sup>rd</sup> for risk in the original assessment (paragraph 51). By prioritising type C crossings for risk mitigation, Sandilands slipped further down the ranking, which meant that it was even less likely to be considered for risk mitigation between 2009 and 2011.
- 62 London Tramlink did take some actions to address risk at foot crossings. Those actions included crossing sighting assessments and a programme of general housekeeping at tram stops and their crossings. Representatives from London Tramlink also took a prominent role in the drafting of guidance on the assessment of tramway crossings, which included sighting assessments and factors that could affect risk (the guidance was adopted by UK tram operators). From 3 November 2011, London Tramlink and Tram Operations Ltd introduced a requirement for the speed of trams to be limited to 25 km/h at the foot crossing on the approach to tram stops (before that date, the 25 km/h speed restriction had applied from the top of the platform ramp).
- 63 London Tramlink also commissioned consultants to update the quantified risk assessment for its foot crossings (paragraph 56). The full report was first issued in December 2009 (version 1.0), and finalised in May 2010 (version 2.0). The report used data from relevant accidents on the tram network, human factors assessments, tram operating data, estimates of crossing usage and some expert judgement as the basis for the risk estimate. In order to estimate the risk, factors affecting both the likelihood of such a collision and its consequences were considered.
- 64 The consultants estimated the collective risk (paragraph 52) from collisions between trams and pedestrians to be 0.85 fatalities per year. They also estimated a collective risk of 'equivalent fatality'; equivalent fatalities include risk from major and minor injuries, weighting major injuries as 0.1 of a fatality and minor injuries as 0.005 of a fatality (fatalities are weighted as 1). The equivalent fatality risk was estimated as 1.02 equivalent fatalities per year.

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<sup>9</sup> Because of the coarseness of the risk scoring process applied, several crossings received the same score, eg eight crossings received a score of 21, including Sandilands (not prioritised for risk mitigation) and Belgrave Walk (one of the first crossings to benefit from risk mitigation).

65 The methodology adopted by the consultants divided the risk at crossings into three groups: crossings where tram speed was 25 km/h or less; those where tram speed was in the range 26 km/h to 48 km/h, and those where speed was greater than 48 km/h. The results from the assessment are shown in table 2.

Tram speed at crossing	Fatality risk (per year)	Percentage of total fatality risk	Equivalent fatality risk per year	Percentage of total equivalent fatality risk
≤25 km/h	0.21	24.7	0.32	31.4
26-48 km/h	0.12	14.1	0.14	13.7
>48 km/h	0.52	61.2	0.56	54.9
Total	0.85	100	1.02	100

Table 2: London Tramlink's consultants' estimates of risk from collisions between trams and pedestrians on Croydon's tram system

66 Table 2 shows that in terms of fatality risk and equivalent fatality risk, the totality of the crossings located on sections of route where trams could run at speeds greater than 48 km/h was higher than the risk from the totality of all crossings on the network. It did not, however, constitute evidence that the risk at every crossing on sections of route where speeds were greater than 48 km/h was higher than the risk at any of the other crossings on the network. As with the earlier risk assessment (paragraph 56), it was not a suitable basis upon which to prioritise type C crossings for risk mitigation.

[Lack of safety improvements at Sandilands tram stop following an assessment of the risk in 2011](#)

**67 The foot crossing at Sandilands was not prioritised for risk mitigation works after May 2011, despite a further risk assessment identifying that it was the highest risk crossing at a tram stop outside of the town centre. This was a causal factor.**

68 The track at tram stops outside of the town centre in Croydon normally features the rails being laid on sleepers and ballast. Although not a requirement at the time that the Croydon tramway was being constructed, this is contrary to current advice contained within ORR guidance (paragraph 41), paragraph 169 of which states:

'The design of the infrastructure adjacent to platforms and pedestrian crossings at tramstops should be such as to minimise injury to a person struck by a tram. The surrounding surface should be at a level relative to the rail that allows the tram's pedestrian *underrun protection* to operate effectively.'

- 69 The underrun protector (figure 7) is a device located underneath the front of the tram that is intended to keep a pedestrian who has been struck by a tram from going underneath the wheels. For it to be effective, the clearance between the bottom of the underrun protector and the surface beneath it needs to be as small as possible, but allowing enough clearance to avoid it striking the ground in normal operation. Paving up to rail level at tram stops allows this clearance to be minimised; the use of ballast generally increases the clearance and thereby decreases the effectiveness of the underrun protector. At Sandilands, the clearance between the bottom of the underrun protector and the sleepers was 255 mm. Paving up to rail level would reduce it to around 105 mm, thereby increasing the likelihood of the underrun protector performing its function. The RAIB examined issues in relation to the design of tram underrun protectors in its investigation into a fatal accident at Piccadilly Gardens, Manchester on 5 June 2011<sup>10</sup> and recommended that research should be undertaken into the potential for the reduction of injuries to pedestrians involved in front end collisions with trams.



Figure 7: Front of tram showing underrun protector

- 70 During 2010, London Tramlink commissioned a consultant to investigate the costs and benefits of paving between the rails at tram stops where ballast was currently provided (all tram stops outside of Croydon town centre). In order to undertake the evaluation of costs and benefits, it was necessary for the consultant to estimate the risk of an accident involving a pedestrian being struck by a tram at each tram stop as this would help to establish the magnitude of risk that could be mitigated by the provision of through paving.

<sup>10</sup> RAIB report 08/2012, available at on the RAIB website [www.raib.gov.uk](http://www.raib.gov.uk).

- 71 The consultant's risk assessment, which drew upon the quantified risk assessment that had been undertaken in 2009/2010 (paragraphs 63 to 65), took account of factors that could affect the likelihood and consequences of trams striking people at each crossing including:
- numbers of passengers using the crossing;
  - number of pedestrians using the crossing;
  - travel patterns;
  - tramstop and crossing layout;
  - frequency of trams; and
  - human error probabilities for passengers, pedestrians and tram drivers.
- 72 The consultant applied the risk assessment to 52 crossings. Relevant findings from the assessment were:
- the west end crossing at Sandilands (where the accident happened) accounted for 9.7% of the total risk from the 52 crossings assessed;
  - the east end road/foot crossing accounted for 7.4% of the total risk; and
  - the two crossings at Sandilands tram stop alone therefore accounted for 17.1% of the total risk from all 52 crossings.
- 73 These findings were contained in version 1.0 of the consultant's report issued to London Tramlink on 15 May 2011. The report's findings were not confined to the issue of the costs and benefits of providing paving at tram stops, but also contained advice to London Tramlink on other measures that might reduce risk. In particular, for Sandilands, the consultant:
- suggested that consideration should be given to designing the footpath approach to the crossing at the west end of the platforms to force users to face oncoming trams before crossing; and
  - recommended that the crossing should be painted yellow and signage included to 'beware of trams' or 'look both ways'.
- 74 Both of these measures were aimed at reducing the probability of a tram striking a pedestrian, rather than dealing with the consequences of such an event as would be the case with through paving. The report also contained the following conclusion regarding longer-term measures:
- 'Sandilands, Waddon Marsh and Fieldway tramstops may benefit from a thorough review of their layout and consideration of a 'staggered platform' design to radically reduce approach crossing risk.'
- 75 The findings from the assessment were discussed at the London Tramlink Executive Health Safety & Environment Meeting in May 2011. The minutes recorded that the cost benefit analysis undertaken by the consultant did not support partial paving through tram stops, indicating that it was true of all locations including Sandilands, which the minutes recognised as representing the highest risk of incident. The minutes do not mention the consultant's findings referred to in paragraphs 73 and 74.



- 76 London Tramlink did not act on the conclusions, recommendations or factors for consideration identified in paragraphs 73 and 74, or the finding that the risk associated with the crossing at the west end of Sandilands tram stop accounted for almost 10% of the risk from the 52 crossings assessed. London Tramlink has stated that the consultant's list of suggestions and recommendations was reviewed, but staff present at the time have been unable to recall any of the discussions on its findings in relation to Sandilands.

## Identification of underlying factors<sup>11</sup>

### Intelligence gathered from previous accidents

**77 The possible role played by the configuration of the infrastructure had not been considered in previous accidents at Sandilands that had occurred in similar circumstances because the investigations focused on the actions of the tram driver. This was an underlying factor.**

- 78 Since trams started running on the Croydon network, there have been four accidents recorded at Sandilands<sup>12</sup>. Their details are included in table 3.

Date	Details
25/03/04	At 08:49 hrs, a pedestrian (wearing headphones) walked onto the foot crossing and into the cab side of an approaching tram. The person fell, injuring the side of their head and right leg.
28/05/04	At 20:07 hrs, a person walked into the path of a tram at the crossing in order to catch a tram in the opposite direction, suffering head and shoulder injuries.
17/03/08	At 16:53 hrs, a pedestrian walking on the pavement alongside the track with her back to an approaching eastbound tram turned without looking to use the foot crossing and into the side of a tram. She was uninjured.
08/12/10	At 19:05 hrs, a passenger who had alighted from a westbound tram walked into the side of the same tram as it departed while focused on a bus that he wished to catch from the stop adjacent to the eastbound platform. He was taken to hospital complaining of a headache.

Table 3: Previous accidents and incidents Sandilands tram stop foot crossing

- 79 All four accidents occurred on the foot crossing at the west end of the tram stop. All except the accident on 8 December 2010 involved a pedestrian crossing towards the westbound platform. The accident on 28 May 2004 was very similar in circumstances to the accident on 16 May 2012.

<sup>11</sup> Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

<sup>12</sup> The first two incidents occurred before the RAIB became operational in October 2005 and neither of the other two accidents was reported to the RAIB (there was no requirement for these two accidents to be reported because neither resulted in serious injuries to the individuals concerned).

- 80 Tram Operations Ltd conducted an investigation into the circumstances of each accident. The focus of each investigation was the actions of the tram driver, with no consideration of any contribution that the configuration of the infrastructure (tram stop or crossing) might have made to the accident. However, the later investigation undertaken by Tram Operations Ltd into the accident on 16 May 2012 did identify the equipment cases as a possible obstruction to a pedestrian's view of approaching trams (paragraph 31) and the report was reviewed by London Tramlink. Although there was no discussion of the part that the pedestrian having to approach the crossing with her back to eastbound trams played in the accident, the Lead Investigator did recommend that, in conjunction with London Tramlink, the operator should establish a review of the design of the approach area to the foot crossing. This resulted in changes to the approach to the crossing (see paragraph 121 and its associated figure 9).
- 81 An accident involving a pedestrian being struck by a tram is always investigated by Tram Operations Ltd. London Tramlink would not normally be part of the investigation team, although it would have the opportunity to review the investigation report. Tram Operations Ltd is able to invite London Tramlink to participate in an investigation, but does not normally do so.
- 82 For accidents involving pedestrians being struck by trams, it is important that an investigation considers infrastructure issues as well as operational issues, particularly as the behaviour of pedestrians can be influenced by the configuration of the infrastructure.

#### London Tramlink's management of risk at foot crossings

#### **83 London Tramlink's processes for managing the risk associated with foot crossings on its network were not effective.**

- 84 When TfL took over from the previous concessionaire in 2008 (paragraph 17), there was no process for foot crossing risk assessment in place. The Improvement Notice imposed by ORR resulted in such an assessment being undertaken, but for the reasons described in paragraphs 43 to 51, it did not provide a reliable means for establishing the actual level of risk at different foot crossings on the tramway, or for making decisions about where available money should be spent to maximise risk reduction.
- 85 When a risk assessment produced for 52 of the crossings on the network (paragraphs 71 to 74) provided evidence of a significant risk from trams striking pedestrians at specific type B crossings including Sandilands, London Tramlink did not act on its suggestions or recommendations or extend it to crossings that were not part of the original scope. This was because London Tramlink focused on the original purpose of the risk assessment (whether there was a case for infill between the rails at tram stops) and did not recognise that the report contained valuable information which allowed it to rank crossings according to risk and prioritise spending accordingly.

- 86 London Tramlink had not fully implemented a process for ongoing risk assessment at foot crossings, which would have been desirable because changes in key factors such as extent of use by people or trams, or use by vulnerable people such as children or the elderly, could affect the risk. It had developed guidance in this area (paragraph 62), but the most recent assessment seen by the RAIB for Sandilands was principally focused on issues such as sighting distances from fixed points at the crossing and whether there were obstructions to sighting such as overgrown vegetation. It did not include data for some of the required measurements, and there was no qualitative or quantitative assessment of risk, although the assessment had been signed-off.
- 87 London Tramlink did not identify the obstruction to a pedestrian's view of approaching trams that was caused by the equipment cases at the west end of Sandilands tram stop (paragraph 31), or the angle at which pedestrians could approach the foot crossing at the west end of the tram stop in relation to approaching eastbound trams.

## Discounted factors

### The actions of the tram driver up to the point of impact

- 88 As trams approach Sandilands tram stop heading east, there is a requirement for drivers to reduce the speed of the tram to 30 km/h at 85 metres from the foot crossing and then to 25 km/h by the time it reaches the leading edge of the crossing (paragraph 62).
- 89 Evidence from the tram's OTDR shows that the driver reduced the speed of the tram on the approach to the 30 km/h speed restriction although it was still travelling at 34 km/h when it passed the start of the restriction and travelled for a further 55 metres before speed fell to 30 km/h. The tram was travelling at around 27 km/h as it passed the leading edge of the crossing, but its speed was reducing and was at 25 km/h before the tram reached the platform ramp.
- 90 The tram's FFCCTV images show that, from the tram driver's perspective, the pedestrian first appears from behind the equipment cabinets approximately three seconds before the accident. However, the tram driver stated that his attention at that stage was drawn to the westbound tram and the possibility of people who had alighted from it using the crossing. He had sounded the tram's bell when the tram was around 35 metres (about 4.5 seconds) from the crossing in response to seeing another pedestrian cross from the eastbound to the westbound platform. At this stage the pedestrian involved in the accident was starting to execute the 180° turn from the pavement to the entrance to the tram stop (paragraph 8) and the audibility of the bell may have been affected by the equipment cases (paragraph 32) and by the continuous flow of traffic on the adjacent road. The driver said that he only saw the pedestrian approaching from the left just before the tram struck her. The FFCCTV images show that it would only have been possible to be certain that the pedestrian was intending to cross rather than continue up the ramp to the eastbound platform when the tram was approximately one second away from the crossing (around 7 - 8 metres in distance).

- 91 The RAIB does not consider that the tram driver's actions caused the accident. The driver's actions after the tram struck the pedestrian are discussed in the following paragraphs.

## Factors affecting the severity of consequences

### The driver's non-use of the hazard brake

- 92 When the driver became aware that his tram had struck a pedestrian, he continued braking normally into the tram stop. At no point did he use the hazard brake, which is designed to achieve a much higher level of retardation than the brake normally used for stopping the tram. The tram stopped at the normal stopping point for eastbound trams at Sandilands tram stop with its front approximately 40 metres from the crossing. The pedestrian was trapped under the tram between the platform face and the rail, being dragged to a position approximately 17 metres from where she was initially struck. Data on braking capabilities supplied by London Tramlink indicates that had the tram driver applied the hazard brake at about the time that his tram struck the pedestrian, the tram would have stopped about 13-14 metres from the crossing. It cannot be established with certainty how far the pedestrian would have been dragged, but it would have been significantly less than the 17 metres that she was dragged during the incident.
- 93 The training given by Tram Operations Ltd emphasises to drivers the need to use the hazard brake in circumstances such as those of the accident at Sandilands on 16 May 2012. Records held by Tram Operations Ltd show that in the ten years from 8 July 2002, there were 1241 incidents of the driver using the hazard brake to avoid striking people or road vehicles, which equates to an average of more than two applications per week. Tram Operations Ltd advises that it has taken disciplinary action against drivers who have been involved in incidents and not used the hazard brake when it would have been appropriate to do so. It estimates that it encounters such circumstances approximately once every two years.
- 94 Tram drivers employed by Tram Operations Ltd are subject to biennial competence assessments. After the driver had been passed out for driving duties in August 2008, he was assessed on 24 May 2009 and 10 April 2011. During these assessments he was observed practising use of the hazard brake. In addition, he had been subject to anonymous performance checks by qualified members of staff from Tram Operations Ltd, most recently on 4 January 2012 and 12 March 2012; his performance on both occasions was deemed 'fully acceptable', although these checks would not have included appropriate use of the hazard brake.
- 95 The driver was shocked by the impact and did not apply the emergency brake. He did not realise that the pedestrian had become trapped between the tram and the platform. He accepted afterwards that he should have used the hazard brake as soon as he was aware that his tram had struck the pedestrian.
- 96 While some of the injuries sustained by the pedestrian would have occurred in the initial impact, others arose from her being dragged in a confined space. Therefore, the driver's non-use of the hazard brake probably affected the severity of the consequences suffered by the pedestrian.

### The configuration of the tram stop

97 The size of the gap where the pedestrian was found after the tram had stopped is shown in figure 8. The limited space available meant that she was partly dragged by the tram, although the fact that she was only carried 17 metres beyond the crossing and not the full 40 metres traversed by the front of the tram, indicates either that the pedestrian was stationary for some of the time that the tram was moving or that she was being dragged at a slower rate than the tram was travelling.



Figure 8: Key dimensions in the gap between the platform face, platform-side rail and a tram

- 98 There are two reasons why the pedestrian survived the accident, both of which relate to the space available:
- The surface between the platform face and the rail comprised ballast which did not reach the height of the rail. Had the rails been set in slab up to rail height, the available vertical space would have been reduced by approximately 150 millimetres.
  - There was a recess under the platform, providing an additional 40 millimetres of horizontal clearance.
- 99 Paragraph 163 of ORR's guidance on the design of tram stops (paragraph 41) states:
- 'A recess below a platform coping is not required for tram platforms'.

- 100 The tram's underrun protector, which is designed to prevent a person lying in the path of the tram from going under the tram's wheels, does not extend laterally beyond the wheels (figure 7), and is not angled towards the platform so the pedestrian must have fallen into the gap between the rail (and therefore the wheel) and the platform on impact. Any reduction in either the horizontal or vertical dimension in the space formed by the ballast, recessed platform face and the tram may have made the pedestrian's injuries worse, or possibly fatal.
- 101 On 15 December 2011, a fatal accident occurred at St Peter's Square tram stop in Manchester, when a partially sighted person fell from the platform as a tram approached and was crushed between the tram and the platform. No recess was provided below the platform. Although it would have made no difference to the outcome of this accident, the RAIB wrote to ORR on 11 January 2012, observing that in slightly different circumstance, a recess might have provided survival space for someone falling from the platform in front of a tram. The RAIB asked ORR to reconsider the statement regarding no need for a recess beneath a platform (paragraph 99) when ORR reissues guidance on the design of tram stops (this has not yet happened).

## Observations<sup>13</sup>

### The wording of ORR guidance on configuration of the approaches to foot crossings

- 102 Paragraph 68 of ORR's guidance on tramway design and operation states:

'Fencing or pedestrian guard rails should be provided where necessary, to guide pedestrians to face oncoming trams before they cross the track...'

- 103 The RAIB considers that this wording could be clarified. The optimum arrangement is one where pedestrians are guided to approach crossings in a way that encourages them to look for trams approaching on the nearer track in situations when their focus is on catching a tram at the platform on the far side of the crossing.
- 104 During the RAIB's investigation into the accident at Sandilands, witnesses from London Tramlink expressed concern about ambiguities that they perceived in the interpretation of standards and the application of risk control measures. The configuration of approaches to foot crossings was cited as a specific example where there was uncertainty over whether highway or railway practices should apply. The representatives asserted that if, for example, the foot crossing at Sandilands was judged in the same way as a highway crossing, it is unlikely that risk mitigation such as barriers/chicanes (paragraphs 39 and 121) would be justified because of the low volume of 'road' traffic at around 22 vehicles per hour in each direction. If the crossing was judged in the same way as a railway crossing, such mitigation was more likely to be justified because usage of 22 trains per hour would be seen as very high.

<sup>13</sup> 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.

### The response of London Tramlink and ORR to recommendation 1 from the RAIB's investigation into the accident at Morden Hall Park footpath crossing

105 Paragraph 44 refers to the fatal accident at Morden Hall Park footpath crossing on 13 September 2008. The RAIB's report into the accident was issued in March 2009.

106 Recommendation 1 from the investigation was that

‘...London Tramlink should, following its assessment of the risks at footpath crossings on its system, and where it is appropriate and practicable to do so, modify the crossings so that users are influenced to look both ways before crossing, and cyclists are encouraged to slow down sufficiently (by means such as the provision of barriers, signs and/or markings) to give them time to become aware of approaching trams.’

107 On 30 April 2009, London Tramlink provided its response to ORR on how it had addressed the RAIB's recommendation<sup>14</sup> stating its belief that ‘the action taken to achieve compliance with the Improvement Notice served on London Tramlink (15 October 2008) by ORR (assessment of risk, identification of measures to reduce risk so far as is reasonably practicable) and the subsequent programme of works demonstrated implementation of the RAIB recommendation in full’. In reaching that judgement, London Tramlink had considered the term ‘footpath’ in the recommendation to apply in its highway sense (‘a public right of way not adjacent to a highway’), which implicitly precluded foot crossings at tram stops that did not have a footpath associated with them (in other words, type ‘A’ and type ‘B’ crossings). No such restricted definition had been intended by the use of the term ‘footpath crossing’ in the recommendation, and other sections of the report, including the conclusion that led to recommendation 1, had used the term ‘foot crossing’, which thus included all types of crossings for pedestrians within the scope of the recommendation.

108 The inspector from ORR who was responsible for this matter had also considered that London Tramlink should focus on the crossings between tram stops, despite the findings of the 2008/2009 risk assessment. On 6 May 2009, the same inspector commented on whether the actions taken by London Tramlink were sufficient to close RAIB recommendation 1. The ORR inspector classified London Tramlink's actions as ‘credible’ and recommended no further action by ORR. Evidence suggests that his decision was based on:

- London Tramlink's assertion that the work undertaken to address the requirements of ORR's Improvement Notice also addressed the requirements of RAIB recommendation 1;
- the programme for improvements at the three type C crossings; and
- other initiatives proposed by London Tramlink that were not related to the 2008/2009 risk assessment, which are described at paragraphs 62 to 65.

109 ORR notified the RAIB of the above position on 28 July 2009.

<sup>14</sup> As required by Regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005.

110 The evidence presented at paragraphs 46 to 61 indicates that while London Tramlink had taken actions in response to the Improvement Notice and the RAIB recommendation, it had applied a risk assessment methodology that did not form a suitable basis on which to determine priorities for risk mitigation works at crossings, or to determine the reasonable practicability of different types of mitigation at individual crossings. There was no plan for risk mitigation at any crossings other than those classified as type C. Even if ORR considered that London Tramlink had done sufficient work to enable the Improvement Notice to be closed, London Tramlink had not met the intent of RAIB recommendation 1.

### Previous occurrences of a similar character

111 Tram Operations Ltd has records of accidents involving people being struck by trams on foot crossings, dating from 2002. Table 3 (following paragraph 78) provides information on all recorded incidents of tram/pedestrian contact on the foot crossing at Sandilands tram stop.

112 The records show that since the beginning of 2003, there have been 19 other accidents involving pedestrians being struck by trams on foot crossings on the Croydon tram system (the list excludes incidents involving glancing blows where the pedestrian has been standing slightly too close to a tram at the time). Those that are particularly relevant to the circumstances of the accident at Sandilands on 16 May 2012 are shown in bold in table 4, below.

Date	Location	Crossing type (see paragraph 54)	Details
02/05/03	East Croydon	A	At 10:02 hrs a wheelchair user moved onto crossing as tram approached and was struck by the tram The person was shaken.
03/07/03	Blackhorse Lane	B	<b>At 16:38 hrs, a passenger for a westbound tram stepped onto the foot crossing in front of an approaching eastbound tram without looking both ways and suffered minor injuries to arm and head.</b>
19/05/04	East Croydon	A	At 07:59 hrs, a 13 year old girl walked into the side of an approaching westbound tram on the foot crossing at the eastern end, injuring her wrist and cutting her left cheek.
23/02/05	Arena	B	<b>At 16:20 hrs, a tram collided with a cyclist who turned suddenly onto the foot crossing immediately in front of an approaching tram. The cyclist suffered arm injuries</b>
02/03/07	Merton Park	B	<b>At 09:05 hrs, a pedestrian walking towards the eastbound platform stepped without looking onto tram stop foot crossing as an eastbound tram approached and was struck, but unhurt.</b>
03/05/07	Arena	B	<b>At 05:33 hrs, a pedestrian walking towards the eastbound platform from the footpath stepped onto foot crossing in order to cross track, without looking and his arm was struck by an approaching tram. No apparent injuries.</b>
23/08/07	Arena	B	<b>At 0910 hrs a tram approaching Arena tram stop, eastbound, struck a pedestrian at the western end foot crossing. The pedestrian suffered a fractured collar bone and laceration to leg.</b>



Date	Location	Crossing type (see paragraph 54)	Details
01/11/07	Phipps Bridge	C	At 16:51 hrs, a pedestrian crossing the tramway was struck by a tram leaving the tram stop. The pedestrian suffered a fractured hip.
20/01/08	Purley Way	C	At 18:23 hrs, an eastbound tram collided with a child riding a bicycle across the foot-crossing west of Purley Way Bridge. The child suffered a broken arm and pelvis and cuts to head.
18/07/08	Belgrave Walk	C	At 08:45 hrs, a boy aged 7 rode his bicycle across the foot crossing and was struck by an approaching tram, suffering cuts and bruises.
21/08/08	Waddon Marsh	C	<b>At 07:47 hrs, a pedestrian was walking on the footpath alongside track, turned onto the foot crossing without looking and was struck. He is believed to have suffered minor injuries.</b>
13/09/08	Morden Hall Park	C	At 14:37 hrs an eastbound tram struck a cyclist on Morden Hall Park footpath crossing with fatal consequences.
13/10/09	Arena	B	<b>At 09:32 hrs, a pedestrian was struck by an eastbound tram after walking out in front of it at Arena tram stop. The pedestrian suffered head injuries</b>
04/05/10	East Croydon	A	At 15:00 hrs, a pedestrian walked into the path of an approaching tram without looking and was struck. No injury (low-speed collision)
22/06/10	Waddon Marsh	C	<b>At 07:26 hrs, a person walking on the footpath alongside the eastbound track turned right onto the foot crossing without looking and was struck. He was apparently uninjured.</b>
15/11/10	Fieldway	B	At 08:15 hrs, a child was hit by a westbound tram at Fieldway tram stop, suffering serious injuries to his pelvis and legs.
05/04/11	East Croydon	A	At 08:00 hrs, an eastbound tram struck a pedestrian who stepped out after looking in the wrong direction for approaching trams. The pedestrian suffered a broken arm and head injuries.
09/05/11	King Henry's Drive	C	<b>At 08:43 hrs, a young male was walking along the footpath running parallel to the tram stop and stepped onto the foot crossing at western end directly into the path of an approaching eastbound tram. He was struck, sustaining cuts, grazes &amp; bruises to both arms.</b>

Table 4: Accidents and incidents on foot crossings on the Croydon tram network between 2002 and 16 May 2012 (those that are particularly relevant to the circumstances of the accident at Sandilands on 16 May 2012 are in bold text)

## Summary of conclusions

### Immediate cause

113 The pedestrian walked onto the crossing as the tram was approaching (**paragraph 27**).

### Causal factors

114 The causal factors were:

- a. The pedestrian did not look for approaching eastbound trams as she hurried from the entrance to the tram stop to the foot crossing. Had she done so, she would have seen that the approaching tram was close to the crossing (**paragraph 33, see paragraph 121**).
- b. The methodology adopted by London Tramlink in 2008/2009 to assess the risk at all foot crossings on the Croydon tram network did not provide an accurate basis for doing so, and did not enable easy identification of crossings where risk mitigation should be provided. It resulted in the risk at Sandilands being under-estimated and its foot crossing not being prioritised for risk mitigation measures (**paragraph 43, Recommendation 1**).
- c. The foot crossing at Sandilands was not prioritised for risk mitigation works after May 2011, despite a further risk assessment identifying that it was the highest risk crossing at a tram stop outside the town centre (**paragraph 67, Recommendation 1**).

115 It is probable that the following factors were causal:

- a. The approach to the foot crossing at the west end of Sandilands tram stop had not been configured to encourage pedestrians to look both ways before crossing or to make it easy for them to do so (**paragraph 37, see paragraph 121**).
- b. London Tramlink did not prioritise work to reduce risk at foot crossings in accordance with the results from the 2008/2009 assessment of risk, which meant that Sandilands was not considered as a priority for the application of risk mitigation measures (**paragraph 53, Recommendation 1**).

116 It is possible that the following factor was causal:

- a. The pedestrian may not have been able to see the approaching tram as she walked from the bus stop to the entrance to the tram stop, because her view could have been obstructed by lineside equipment cabinets (**paragraph 31, Recommendations 2 and 3**).

## Underlying factors

- 117 The possible role played by the configuration of the infrastructure had not been considered in previous accidents that had occurred in similar circumstances at Sandilands (**paragraph 77, Recommendation 4**).
- 118 London Tramlink's processes for managing the risk associated with foot crossings on its network were not effective (**paragraph 83, Recommendations 1 and 5**).

## Factors affecting the severity of consequences

- 119 Factors that affected the consequences of the event were:
- a. The tram driver did not apply the hazard brake after the tram struck the pedestrian (**paragraphs 92 to 93, Learning Point 1**).
  - b. There was enough vertical and horizontal clearance to create a survival space for the pedestrian between the tram, the platform face and the rail closest to the platform (**paragraphs 97 to 99, Recommendation 3**).

## Additional observations

- 120 Although not linked to the accident on 16 May 2012, the RAIB observes that:
- a. There were no signs provided at the crossing to warn pedestrians about approaching trams (**paragraph 9, see paragraph 123**).
  - b. The wording of ORR's guidance on tramways in relation to guiding pedestrians before they cross the track is open to misunderstanding (**paragraphs 102 and 103, Recommendation 3**).
  - c. London Tramlink had not taken the action necessary to meet the intent of recommendation 1 of the RAIB's investigation into the fatal accident at Morden Hall Park footpath crossing on 13 September 2008 (**paragraphs 105 to 109, see paragraph 122 and Recommendation 1**).

## 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

- 121 A chicane has been installed at the Sandilands tram stop foot crossing, which has the effect of discouraging pedestrians from approaching the foot crossing diagonally and increases the likelihood that they will see a tram approaching from either direction (figure 9 and paragraph 115a).



*Figure 9: Revised arrangements for pedestrians, including a chicane, at the west end of the eastbound platform at Sandilands tram stop*

122 Recent annual reports published by the RAIB have highlighted a general concern about the completeness of responses to recommendations. With this in mind, the RAIB and ORR have agreed an approach to the management of recommendations that is designed to ensure that both parties share a common understanding of the intent of each recommendation and the extent to which actions taken meet that intent. The key elements of this approach, which complements the existing process of consultation between ORR and the RAIB on the emerging findings of investigations and linked recommendations, are:

- following publication, early engagement between representatives from ORR and the RAIB to inform ORR's evaluation of the actions proposed or already taken by those in receipt of recommendations; and
- in those cases where full implementation is not proposed, ORR inspectors will seek the views of their counterparts in the RAIB and take those views into account before ORR decides whether this is an appropriate response by the duty holder.

### Other reported actions

123 Signs have been provided at the crossing to warn pedestrians to look for approaching trams (paragraph 120a).

124 A 10 km/h speed restriction for trams approaching Sandilands foot crossing was applied, pending improvements to arrangements for pedestrians using it.

125 London Tramlink installed an infill between the rails at Sandilands on the tram stop side of the crossings at the east and west end of the stop to improve the effectiveness of a tram's underrun protector in circumstances where a pedestrian is struck while lying between the rails.

## Learning Point<sup>15</sup>

126 The RAIB has identified the following key learning point.

1. Tram Operators should use the circumstances of this accident in their training and briefing material for tram drivers to illustrate the importance of using the hazard brake in circumstances where a pedestrian has been struck and to highlight the consequences of not doing so.

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<sup>15</sup> Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

## Recommendations

127 The following recommendations are made<sup>16</sup>:

- 1 *The intent of this recommendation is for London Tramlink to improve its approach to foot crossing risk assessment in order that it can clearly identify those locations where risk is highest and also identify the factors that need to be considered to reduce risk. The revised approach should consider, but not necessarily be limited to, all of the factors identified in the 2011 risk assessment and be extended to all foot crossings on the system.*

London Tramlink, in conjunction with Tram Operations Ltd, should continue to develop its process for periodically assessing risk at all foot crossings, taking into account the findings from this report in relation to factors that could affect all aspects of the safety of crossing users. The process should include the requirement to use the findings from the periodic risk assessments to identify those crossings where there are reasonably practicable measures that can be taken to reduce the risk and to produce and update a prioritised programme for safety improvements. The process should include a reference to a range of possible safety improvement measures, which should take account of good practice from elsewhere in the rail and tram industry and good practice in highway design (paragraphs 114b, 114c, 115b, 117 and 120c).

*continued*

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<sup>16</sup> 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 167 to 171) can be found on RAIB's website [www.raib.gov.uk](http://www.raib.gov.uk).

- 2 *The intent of this recommendation is for London Tramlink to consider the need for removing the obstruction to pedestrians' view of approaching trams at Sandilands tram stop, to identify and take action as appropriate to deal with similar obstructions at other tram stops and to implement a process to prevent the installation of equipment in locations which are detrimental to pedestrian safety in the future.*

London Tramlink should:

- a. taking into account the improvements made to the configuration of the approach to the foot crossing at the west end of Sandilands, consider whether further action is desirable to improve pedestrians' view of approaching trams as they walk from the bus stop towards the entrance to the west end of Sandilands tram stop, and implement any changes that they deem to be reasonably practicable;
  - b. conduct a review of the approaches to all other foot crossings on the system from all credible directions to determine whether similar obstructions exist elsewhere, and if so, whether they can be removed; and
  - c. embed within its processes for new works in and around the tramway the requirement to consider pedestrian sight lines from all credible approaches to the crossing before approving the positioning of equipment and other infrastructure (paragraph 116a).
- 3 *The intent of this recommendation is for ORR to re-evaluate its guidance to tram operators on optimising sight lines for pedestrians and tram drivers in the vicinity of foot crossings, physically guiding pedestrians as they approach foot crossings so that they are encouraged to look for approaching trams and the need or otherwise for recesses under tram stop platform and paving up to rail level through tram stops. The guidance should be amended in accordance with ORR's findings.*

ORR should re-evaluate and revise its guidance to tramway operators on:

- a. the need for operators to take into account pedestrian and tram driver sight lines from all credible approaches to foot crossings when planning new works on tramways (paragraph 116a);
- b. the optimum angle of approach for pedestrians at crossings over the tramway (paragraph 120b); and
- c. the need for a recess under tram stop platforms and the desirability of paving up to rail level between the platform-side rail and the platform face (paragraph 119b).

Pending the re-issuing of guidance, ORR should consider how modified advice should be provided to tram operators.

*continued*



- 4 *The intent of this recommendation is for London Tramlink and Tram Operations Ltd to conduct joint investigations into defined accidents and incidents on the Croydon tram network so that infrastructure issues as well as those associated with tram operations are identified.*

London Tramlink and Tram Operations Ltd should jointly review and amend their procedures and/or practices for investigating accidents and incidents on the Croydon tram system so that joint investigations are always carried out if there is any possibility that the infrastructure might have contributed to the circumstances of the accident. Joint investigations should be mandatory for all significant incidents involving pedestrians being struck by trams (paragraph 117).

- 5 *The intent of this recommendation is for London Tramlink to take measures that will secure a high quality of safety decision-making within the organisation.*

London Tramlink should conduct a review of its arrangements for taking and prioritising safety decisions and take any necessary steps to secure for the organisation sufficient competence in safety and risk management techniques so that key personnel have a clear understanding of the factors that affect risk, the constituent elements of a competent risk assessment and how to use the results to prioritise actions (paragraph 118).

## Appendices

### Appendix A - Glossary of abbreviations and acronyms

FFCCTV	Forward Facing Closed Circuit television
ORR	Office of Rail Regulation
OTDR	On-tram data recorder
RAIB	Rail Accident Investigation Branch
TfL	Transport for London

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