RAIB
Rail Accident Investigation Branch

Rail Accident Report

Collision at New Addington on Croydon Tramlink, 23 November 2005.

Department for Transport

Report 11/2006
July 2006

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby
DE21 4BA

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

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Contents

Introduction

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

2 The RAIB does not establish blame, liability or carry out prosecutions.

3 Tramtrack (Croydon) Ltd (TCL) and Tram Operations Ltd (TOL) freely enabled access to staff, data and records.

4 Appendices at the rear of this report contain the following:

- acronyms and abbreviations are explained in the Glossary at Appendix A;
- certain technical terms (shown in italics within the body of this report) are explained in the Glossary at Appendix B;
- references used within the body of the report are detailed in Appendix C;
- the history of 'Signals Passed at Stop' (SPAS) events between King Henry's Drive and New Addington tramstops are listed in Appendix D.

Summary

5 On 23 November 2005 at 08:16 hrs, tram 2538 was travelling southbound with about 10 passengers from Croydon towards the New Addington terminus in thick fog. The tram passed KHD02 signal which was displaying 'STOP'. This signal, beyond King Henry's Drive tramstop, protects the entry into the short *single line* section leading to New Addington. The tram came to a stand partially blocking the adjacent line to Croydon.

6 About the same time, tram 2533, left the New Addington terminus for Croydon with more than 25 passengers on board. It immediately entered the single track section and accelerated to a maximum of 27 km/h. The brakes were only applied when the tram was about 1.5 m from tram 2538, resulting in a collision. Tram 2533 then travelled another 18 m before stopping. Neither tram was derailed, however the collision significantly damaged the leading ends of both trams and one side of tram 2533. There were no injuries to passengers or staff that were reported at the time. Subsequently two whiplash injuries were reported.

7 The immediate cause of the accident was that the driver of tram 2533 did not react in a timely manner to the obstruction caused by tram 2538.

8 Significant contributing factors were:

- tram 2538 passing signal KHD02 whilst it displayed a stop aspect;
- the non-use of the *hazard brake* by the driver of tram 2538;
- the limited *over-run distance* between signal KHD02 and the point where a collision would result (known as the *fouling point*);
- the absence of SPAS indicators providing a local warning that a SPAS event had occurred on the single line section between King Henry's Drive and New Addington.

9 A secondary contributing factor was:

- the reduced conditions of visibility caused by the fog.

10 Four recommendations are made to improve the safety of Croydon Tramlink following this investigation. One recommendation for possible application to future tramways or tramway extensions is also made. These recommendations are found at Paragraph 66 of this report

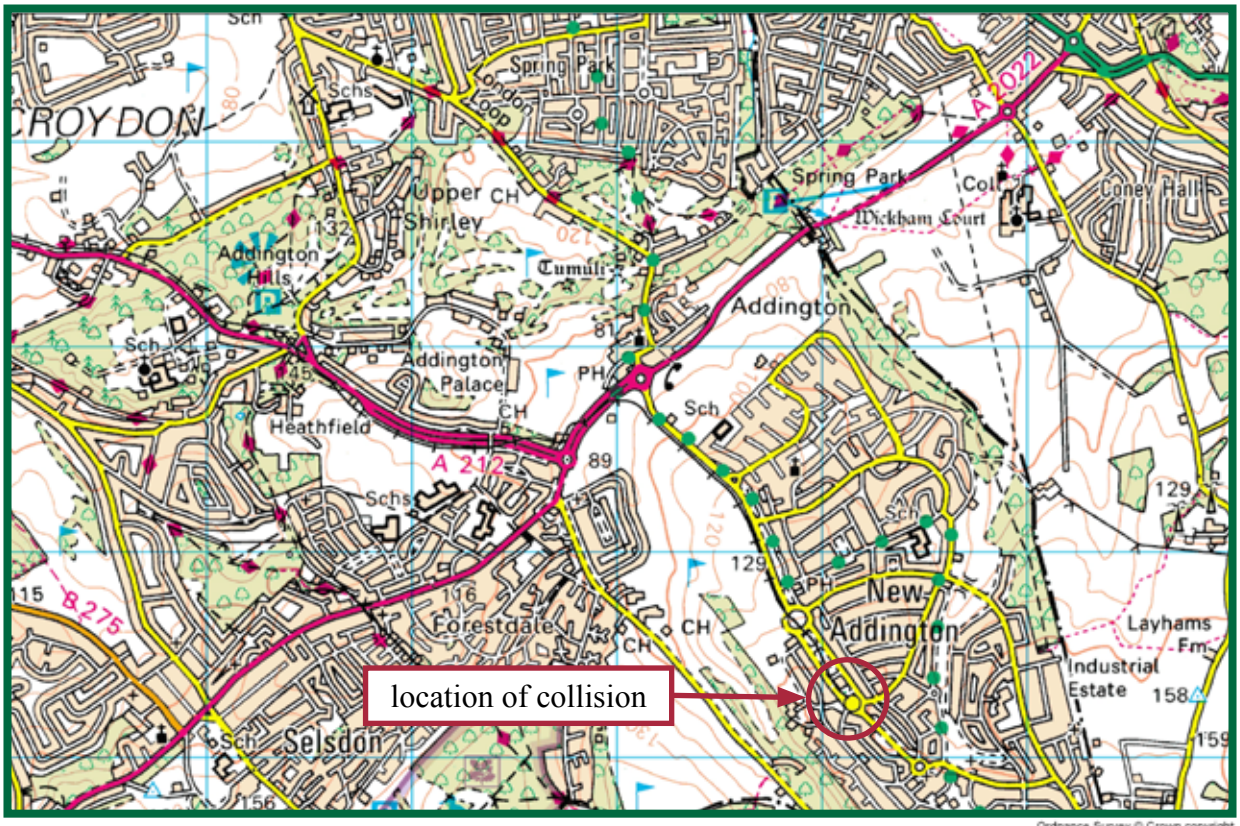

Figure 1: Extract from Ordinance Survey map showing location of incident.

Figure 2: Site of the collision looking towards King Henry's Drive tramstop, showing the rear of tram 2533 (on left) and the front of tram 2538 (on right). The rear of KHD02 signal is on the shorter post to the right of tram 2538.

The Investigation

Background

11 The Croydon Tramlink system, which opened in 2000, is run on behalf of Transport for London by Tramtrack Croydon Ltd (TCL) under a 99-year concession. TCL is made up of a consortium of companies. Separate from TCL, the operator of the system is Tram Operations Ltd (TOL), part of First Group, rolling stock is maintained by Bombardier Transportation Ltd, and maintenance of the infrastructure is contracted to Mowlem plc.

12 A fleet of 24 trams is operated on Croydon Tramlink. They were built by Bombardier Transportation in Austria in 1998. Each tram comprises a three-bogie articulated unit, 30.1 m long, with a maximum speed of 80 km/h (50 mph). They are operated as single units. Electric power for the trams is supplied at 750 v DC through overhead wires. The trams involved in the collision were numbers 2533 and 2538.

13 Operation over the whole of Croydon Tramlink is by means of 'line-of-sight' driving. This requires tram drivers to control the progress of their tram so that they can stop short of any obstructions. Obstructions are a familiar occurrence on the street running sections of the system where road vehicles and pedestrians are regularly encountered. Line of Sight running is common on tramway systems. Signals are provided at certain off-street locations and at the entry to single line sections to regulate the progress of trams; a tram passing a signal displaying 'STOP' will register an alarm at the control centre.

14 The tram's mechanical service brakes operate by releasing hydraulic pressure from a brake actuator, the disk brake forces being applied by a spring. An electric brake, which uses the traction motors as generators, forms part of the normal service brake. Sanding equipment is also fitted.

15 The designated service braking rate of the trams on level straight track is 1.3 m/s². There is a service *brake application time* of about 1 second between movement of the traction brake controller to a service brake position and the demanded rate being achieved. The application time is however dependent upon the time taken to pull the lever from the release position through to the final demand position, and the response time of the service brake equipment.

16 In addition to the service braking systems, trams are equipped with an emergency magnetic track brake. The magnetic track brake is electrically powered and has an application time of 0.5 seconds or less.

17 The hazard braking rate, using the emergency track brake and service braking systems, is 2.75 m/s². This is similar to the rates used by other tramway systems both in the UK and on the European mainland, and also that achieved on buses. It should be noted that the full hazard brake rate application time is a combination of the times for the service brake and the magnetic track brake; the relationship between the brake force and time is thus complex. Sand is automatically dropped during a hazard brake application.

18 When using the hazard brake, drivers are aware that a 'jerk', particularly at the end of the deceleration, can cause passengers to lose their balance and luggage, pushchairs and other objects to be propelled forward. Immediately before restarting the tram they are instructed to use the public address system to ask that anyone who is injured should make themselves known to the driver. This is part of the training that all drivers receive from TOL, their training module assessments 4.1c and 4.2c relate to this procedure.

19 Each tram is fitted with a data recorder that records speed and distance information, along with the state of certain controls. In addition two CCTV cameras record the forward and rearward facing views from the tram, whilst four other cameras record the interior. These data and CCTV records have enabled the sequence of events to be clearly established.

20 The Croydon to New Addington line of the Tramlink system runs in a generally NW-SE direction throughout its 8.4 km length. It is double track throughout apart from a short 100 m section of bi-directional single track between New Addington and King Henry's Drive, and a section of uni-directional single track in central Croydon.

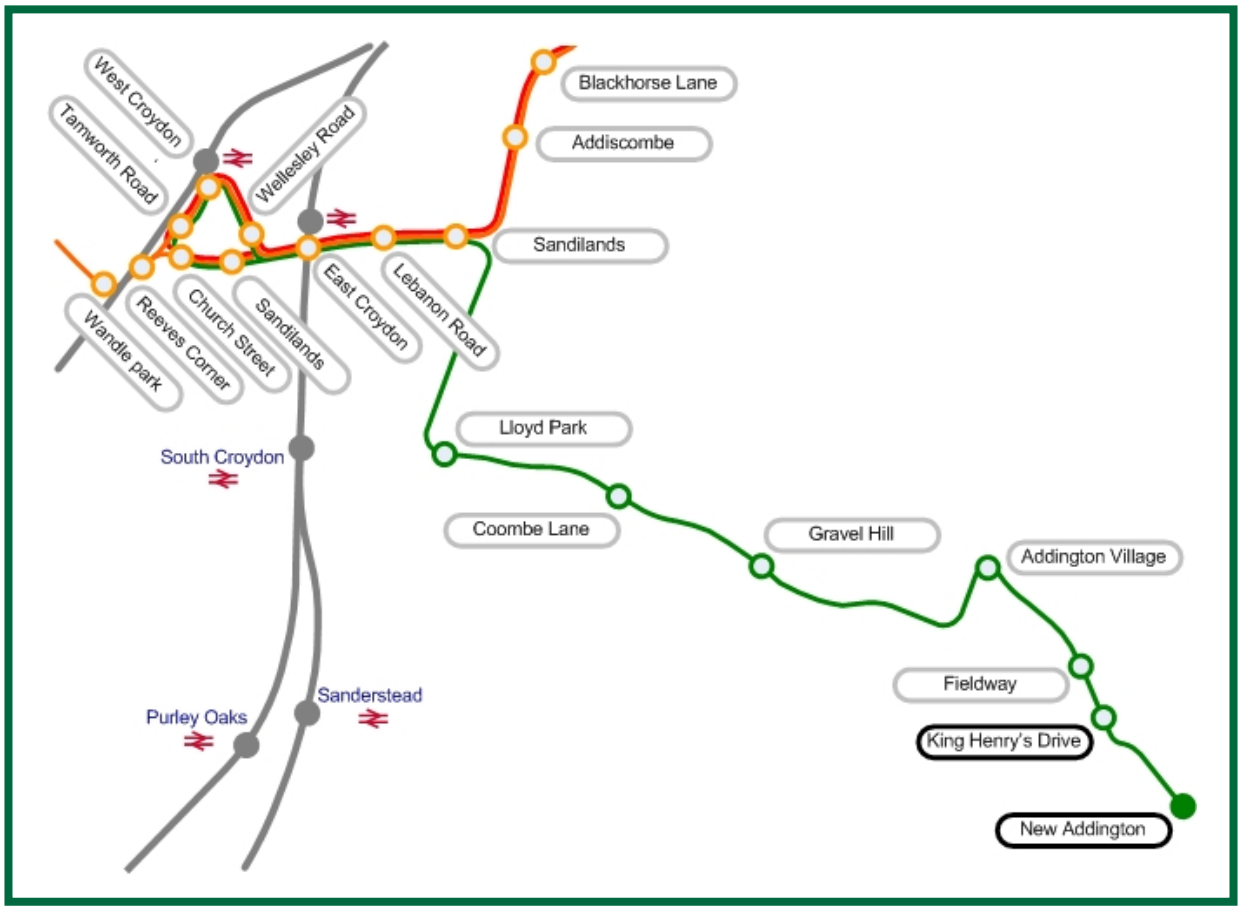

Figure 3: Diagram showing the south eastern part of Croydon Tramlink Line 3 between Croydon and New Addington is shown in green

21 The single track section is located immediately north-west of the New Addington terminus; the reason for this is its proximity to a building (used as a Health Centre) where there is inadequate room for double track. It is located on the apex of 0.68% and 0.63% rising gradients from New Addington and King Henry's Drive respectively. A shallow right hand curve is apparent on departure from New Addington. The entry to the single line is controlled by a motorised point and NAD04 and NAD07 signals at New Addington and a *spring point* and KHD02 signal from King Henry's Drive. *Points Indicator*s are provided at both ends of the single line. Good sighting of the collision point is possible from at least 50 m distance under conditions of moderate visibility.

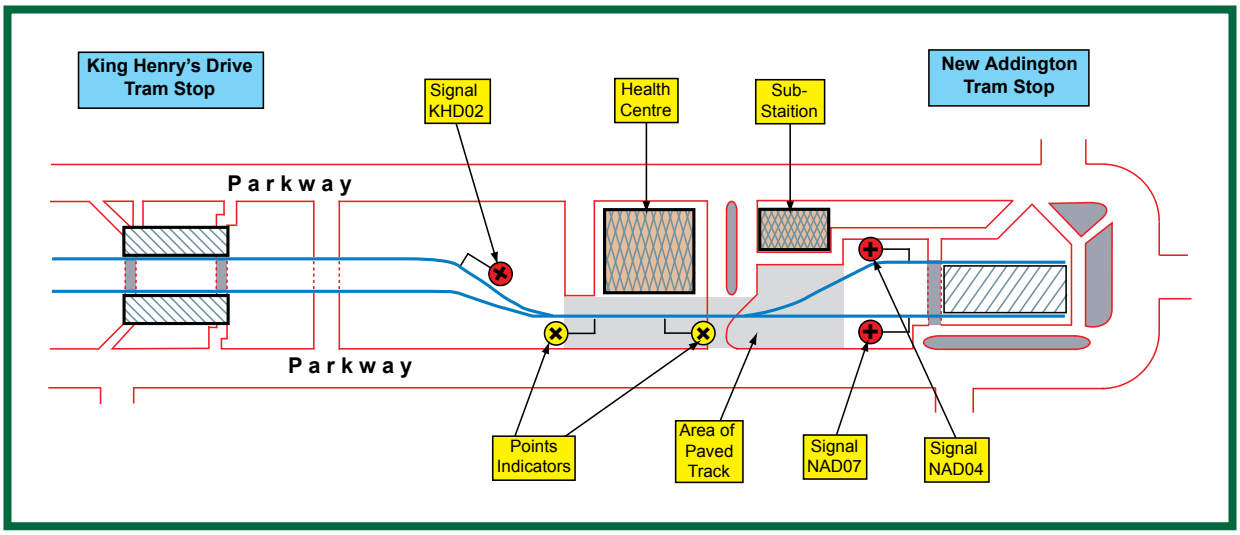

Figure 4: Diagramatic representation of the line between King Henry's Drive and New Addington

22 The entry to the single line at New Addington is controlled by signals at each end. The controls are triggered by track-located sensors, one at King Henry's Drive tramstop and one adjacent to KHD02 signal. Similar sensors are provided at New Addington. Apart from the sensor at King Henry's Drive tramstop which operates automatically, a proceed request is activated by the driver initiating a 'Ready-to-Start' signal from the cab. The system normally operates on an automatic first come – first served basis, although manual over-ride from the control centre at Therapia Lane Depot is possible.

23 A number of single line sections exist on Tramlink. All except the section from New Addington are fitted with SPAS Indicators which consist of a series of flashing blue lights alongside the line. They are not normally illuminated, but are activated by a tram passing a detection loop at the entry to the single line section with the entry signal showing STOP. The lights are visible from either direction of travel and indicate that the driver should stop immediately. The section from New Addington is very short; a tram positioned at the *toe of the points* at one end of the section can be seen from a tram at the toe of the points at the other end. It is however important to note that full visibility is not possible between the fouling points of the double lines. During the design of Tramlink various safety reviews were undertaken; they concluded that SPAS Indicators were not required on this section because of the short length of the section, and the good visibility from one end to the other.

24 The position of signals in relation to fouling points follows normal tramway practice in that prescribed over-run distances are not necessarily provided. In some locations, an over-run is present; at KHD02 signal this is about 10 m.

25 Excluding those caused by technical reasons, such as signalling equipment failures, there have been nine SPAS incidents on the single line at New Addington since 23 June 2002 when TOL's current database came into use. These are listed in Appendix D. There is no significantly predominant cause.

26 Both TOL and TCL regularly review safety events. These reviews have not identified any significant difference for SPAS events at the entry to other single line sections when compared with the King Henry's Drive to New Addington section.

The incident

27 On 23 November 2005 at 08:16 hrs, tram 2538, a three-section articulated unit, was travelling southbound with about ten passengers from Croydon towards the New Addington terminus on the '*out-bound*' line in conditions of thick fog. The tram passed KHD02 signal, which was displaying a STOP aspect. This signal, positioned near the end of the double track section from King Henry's Drive tramstop, protects the entry into the short single line section just before New Addington. The tram came to a stand 12.3 m beyond the signal partially blocking the adjacent '*in-bound*' line, see Figure 14 following Paragraph 46.

28 About the same time, tram 2533 of the same design, departed the easterly platform at New Addington terminus towards Croydon with more than 25 passengers on board. It immediately entered the single line section and accelerated to a maximum of 27 km/h. The driver made a service brake application when tram 2533 was about 1.5 m from 2538, but collided with the other tram. Tram 2533 came a stand about 18 m beyond the initial point of impact. The collision significantly damaged the leading end of tram 2538 and the leading end and one side of tram 2533. There were no injuries to passengers or staff that were reported at the time; subsequently two whiplash injuries have been notified to TOL.

Events preceding the incident

29 On the morning of 23 November, trams 2533 and 2538 were operating on the Line 3 service from Croydon to New Addington (Figure 3). Thick fog had descended during the night and remained in the area until late morning reducing visibility to approximately 70 m (this is estimated from witness commentaries and CCTV records). Rail conditions were very damp and the southbound line adjacent to KHD02 signal was visibly contaminated with a rusty sludge or paste. There is no evidence of poor wheel-to-rail adhesion which would have adversely affected the braking capability of the tram. Consequently the presence of this sludge does not appear to have had any bearing upon the accident.

Figure 5: Rail condition in the vicinity of KHD02 signal

30 The driver of the tram 2533 has more than 6 years experience of tram driving. The driver of tram 2538 has more than 4 years experience of tram driving. Both are employees of TOL and both came on duty early that morning. The records relating to their training, assessment, and monitoring were reviewed as part of the investigation. The driver of tram 2538 had returned from leave 3 days before the collision. The relevance of this is a matter that has been addressed within reports published by the Railway Safety and Standards Board (RSSB); see References 1 and 2 in Appendix C. Apart from a number of driving errors by the driver of tramcar 2533 during the year 2000, no immediate personal factors relevant to this accident were identified.

31 Both drivers had booked on duty normally at Therapia Lane Depot on the morning of 23 November 2005. After having taking over the previously prepared tram, the driver of tram 2533 completed the prescribed depot checks and then drove 31.3 km without incident prior to the accident. This comprised the depot to New Addington, followed by one complete round trip from New Addington to Croydon and back to New Addington. The driver of tram 2538 had undertaken two complete round trips, also without incident, following the initial trip from the depot; a total of 48.3 km.

32 The driver of tram 2533 was suffering from a cold on the day of the incident. During the trips the driver had switched both cab heaters to full to avoid feeling cold. The driver reported that with the heaters on this setting the noise they generated drowned out many of the sounds from outside, including any vehicle horns. During subsequent cab riding by RAIB inspectors it was confirmed that external sounds could become appreciably less noticeable with the cab heaters working.

Events during the incident

33 It should be noted that the time stamps recorded on the data records for tram loop operation, and the data logger and CCTV records fitted to trams 2533 and 2538 are not synchronised with each other, nor are they precisely accurate with respect to Greenwich Mean Time. Inspection of the CCTV recording from tram 2538 indicates that the period between coming to a stand and the collision was 20 seconds. The tram loop data confirms this order of difference. Comparison of the time stamps on the two tram data logger records indicates a time difference; the time stamp from tram 2533 thus required a correction time of minus 15 seconds. Corrected times for tram 2533 are shown in the paragraphs below.

34 Tram 2538 left King Henry's Drive tramstop with a load of about ten passengers (estimated from the CCTV record) at 08:15:48 hrs, and the data recorder shows that it accelerated to a maximum of 35 km/h. The permitted line speed is 35 km/h until just before KHD02 signal. A 25 km/h speed restriction applies over the *trailing spring points* leading onto the single line.

Tram 2538

35 On approaching KHD02 signal the driver of tram 2538 initially thought that the signal was displaying a proceed aspect and drove the tram in the appropriate manner for this signal aspect. The driver's sighting of the signal was not as clear as normal because of the fog, but with recently fitted high intensity lights, the signal was still visible, as demostrated by the CCTV recording. In fact the signal was showing 'STOP'. When the driver realised the signal was not displaying 'PROCEED', the full service brake was applied. It should be noted that KHD02 signal would often clear upon the approach of a tram (see also paragraph 47). It is possible that anticipation of this happening may have conditioned the driver's actions, however this cannot be confirmed.

36 Using data from the on-board data-logger, the tram initially braked down to 24.5 km/h on the approach to KHD02 signal. This was followed by a short period of coasting and then low rate motoring until the tram was close to the signal; the speed did not drop below 22.3 km/h during this part of the journey. It was only when the tram was 3.2 m from the signal that maximum service braking was applied. The tram came to rest 12.3 m beyond KHD02, foul of the other line, with its front right hand side encroaching upon the *swept path* of the other line. The driver did not apply the hazard brake.

37 Prior to passing signal KHD02 the driver of 2538 began to initiate speech communication with Tramlink Control using the tram communication system. This was followed shortly afterwards by an alarm in the control centre indicating that a SPAS event had occurred at the signal. Upon coming to a stand at 08:16:14 hrs the driver of tram 2538 maintained contact with Tramlink Control, however in the period of 20 seconds between the SPAS event and the collision, no effective verbal message regarding the potential hazard was relayed to Tramlink Control. As a consequence no warning was given to the driver of tram 2533. CCTV images indicate that the *hazard warning lights* (flashers) were not switched on immediately before the collision. The driver of tram 2538 did sound the horn immediately before the collision prompted by the sight of the approaching tram.

38 The TOL driver training focuses upon 'hazard lights switched on while stopping' (typical reference: Depot Assessment, Section 5.3). This is reflected in other modules. The Main Line Assessment Part 2 for Out of Course Situations, Unit 6 SPAS requires a), 'that the tram stops immediately', followed by b), 'prompt reporting of the incident'. Use of the hazard lights is not included. No direct guidance is contained in TOL publications that clearly identify the continued use of the hazard lights after a tram has come to a stand in a potentially hazardous position. TOL operational procedures do reference the Highway Code which includes guidance on the use of hazard lights in hazardous situations (sections 248 and 257).

Tram 2533

39 At 08:16:03 hrs tram 2533 left the easterly platform at New Addington terminus after a slightly shortened turn round of 4 minutes (rather than 6) at that terminus. There is no evidence that this was other than a satisfactory time for such a turn round. From the CCTV tram 2533 was well loaded with seated passengers, but there were few, if any, standing passengers. It obeyed the 25 km/h speed limit over trailing points and then accelerated up to a maximum of 27 km/h beyond the 35 km/h speed limit board, passing over the slight summit in the line at 08:16:24 hrs. Although tram 2538 could now be easily seen the driver did not recognise that it was foul of the line, believing it to be standing at KHD02 signal. The forward looking CCTV recording taken from the tram confirms this (see Figures 6 - 9).

40 At 08:16:33 hrs a service brake was applied on tram 2533 when it was only 1.5 m from tram 2538. It took about 1 second before the demand from the traction brake controller became effective in beginning to slow the tram, by which time the collision had occurred. The driver did not apply the hazard brake prior or subsequent to the collision.

41 The collision occurred when tram 2533 was travelling at 26.1 km/h. It caused damage to the offsides of both cabs and further damage to the offside of 2533 whilst it travelled a further 18 m before coming to a stand.

Figure 6: CCTV record from Tram 2533.
Tram 2538 not visible.

Figure 7: CCTV record from tram 2533.
First sighting of headlights of tram 2538.

Figure 8: CCTV record from tram 2533.
Tram 2538 outline and headlights just visible

Figure 9: CCTV record from tram 2533.
Tram 2538 clearly foul of running line

Figure 10: Tram 2533: leading end of front section

Figure 11: Tram 2533: trailing end of front section

Figure 12: Tram 2538: leading end of front section

Figure 13: Tram 2538: leading end of front section

Events following the collision

42 CCTV records show that after a brief pause all the passengers evacuated the trams in an orderly manner without intervention of the drivers.

43 Emergency response staff from TOL and TCL were at the site within 25 minutes. They secured the site for the RAIB investigation. Following completion of site investigations, minor attention was given to make the trams safe for movement. They were then moved under their own power to Therapia Lane Depot.

44 There was no track damage. There was no evidence of malfunction, or allegations against the performance of any tram, signalling, track or other infrastructure or control equipment.

45 Both drivers were tested for drugs and alcohol following the accident, with negative results.

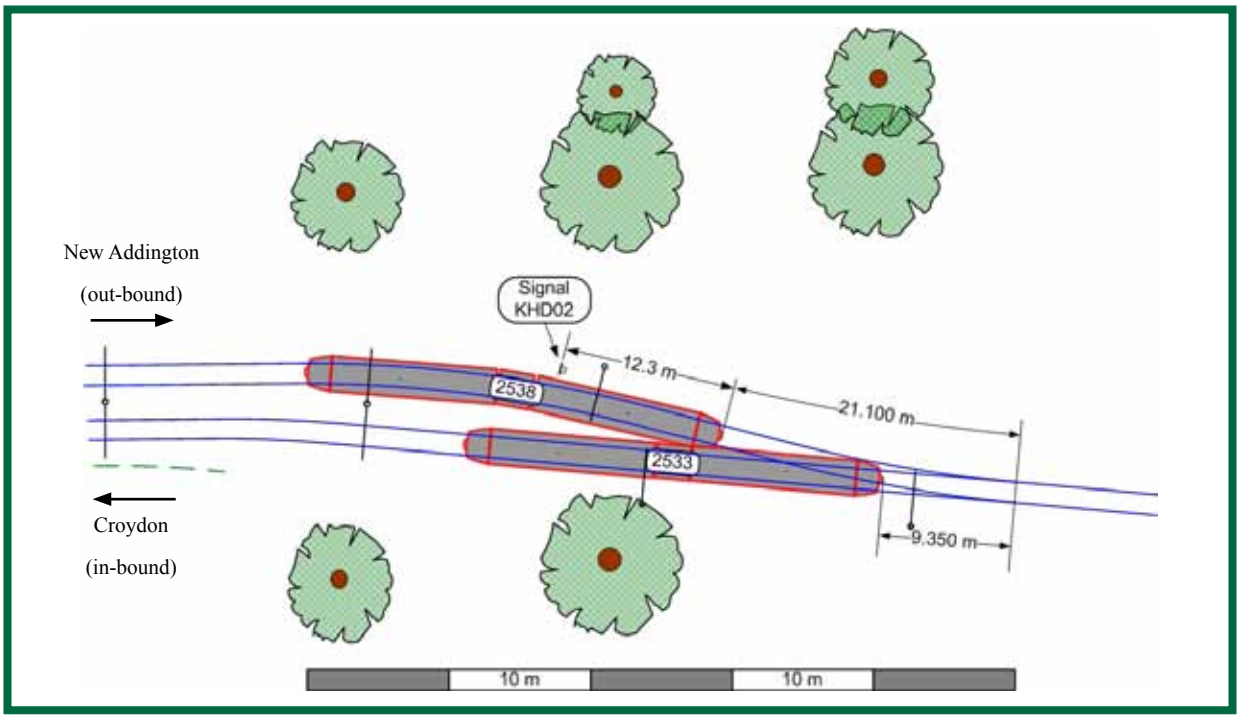

Figure 14: Diagram showing final positions of trams 2533 and 2538 in relation to toe of points

Analysis

46 Analysis of the tram data logger tapes has enabled a good understanding to be obtained of the relative positions, velocities and control commands before and after the collision. The speed / distance graphs plotted for each tram whilst they travelled over the 20 m leading up to the collision shows clearly both the performance of the drivers and of the trams. These graphs follow paragraphs 47 and 48 of this report. Data from the recorders was supplemented by measurements of the site and the final resting places of the trams.

47 Prior to the accident the driver of tram 2538 was fully familiar with the approach to KHD02 signal which usually cleared on approach to show a proceed aspect. This was a feature of the timetable which for much of the operating day plans for one tram to arrive at New Addington followed quickly by the departure of another. This provides a layover time of about 6 – 7 minutes and ensures that a tram is waiting for intending passengers. It is only when the service is slightly disrupted that the sequence is altered. Just prior to the collision, KHD02 signal did not clear because the 'Ready-to-Start' switch had already been operated at New Addington, clearing signal NAD04 and giving authority for tram 2533 to proceed over the route. The driver of tram 2538 expected signal KHD02 to clear as evidenced by the traction brake controller only being moved to a service braking condition when the tram was 3.2 m from the signal. Using a service brake, the tram came to rest 12.3 m beyond the signal and approximately 2.3 m beyond the fouling point. Had the driver applied the hazard brake at the same position as the service brake was applied the tram would have come to a stand at least 1.5 m before the fouling point – see calculations at Figures 16 and 18. The conditions for a collision would thus have been avoided.

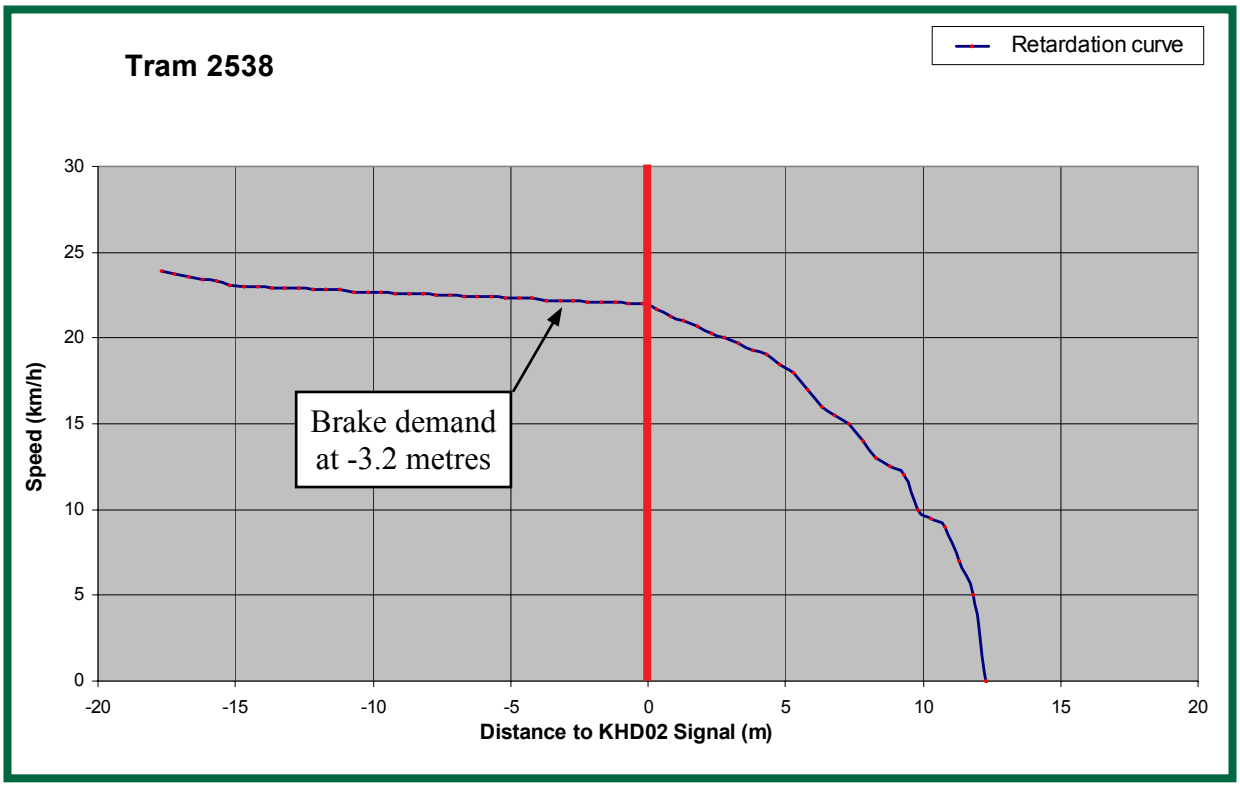

Figure 15: Speed - Distance record for tram 2538, (Negative distances are on approach to signal)

Calculation of hazard braking distance for tram 2538:

Speed at signal = 21.9 km/h (6.1 m/s)
Retardation rate = 2.75 m/s^2

Retardation distance = $\frac{(\text{entry speed})^2}{2 \times \text{retardation}}$ = $\frac{(6.1)^2}{5.5}$
= **6.8 m**

Brake application distance = **4.6 m**
(assuming a hazard brake application time of 0.75 seconds)

Total stopping distance **= 11.4 m**

Predicted over-run of KHD02 = (11.4 - 3.2) m
= **8.2 m**
(assuming same location for application of the brake)

Predicted distance short of fouling point = (10.0 – 8.2) m
= **1.8 m**

Figure 16: Calculation of hazard braking Distance for tram 2538. For further details of assumptions see paragraph 49.

48 The driver of tram 2533 departed normally from New Addington after a slightly shortened layover. From inspection of the CCTV record, at 10 m from the toe of points, even with the poor visibility then present, tram 2538 can clearly be seen to be foul of the line. Had a hazard brake application been made here, the tram would have come to rest about 15 m from tram 2538. If the hazard brake application had been made still later, at the toe of the points, a collision would still have been avoided. The driver did not take any action until the distance between the trams was only 1.5 m, only then applying a full service brake.

No explanation has been found of why the other tram was not recognised as an obstruction. Action was only taken when it was already too late to avoid the collision. It is possible that the effects of a cold and the warm atmosphere generated by the cab heater could have slowed reaction, but there is no evidence to support or discount this idea.

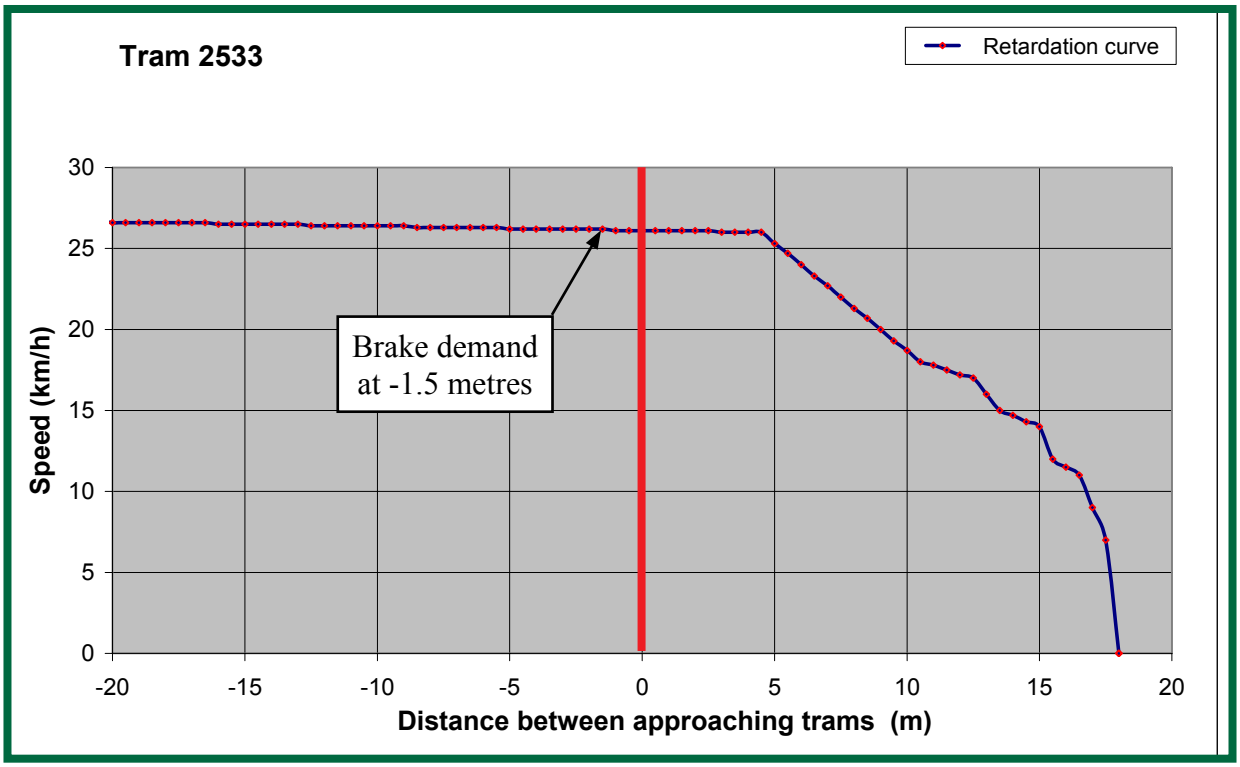

Figure 17: Speed - Distance record for tram 2533 (negative distances are on approach to point of collision)

Calculation of hazard braking distance for tram 2533:

Speed at toe of points = 26.7 km/h (7.4 m/s)
Retardation rate = 2.75 m/s^2

Retardation distance = $\frac{(\text{entry speed})^2}{2 \times \text{retardation}}$ = $\frac{(7.4)^2}{5.5}$
= **10.0 m**

Brake application distance = **5.5 m**
(assuming a hazard brake application time of 0.75 seconds)

Total stopping distance = **15.5 m**

Distance, toe of points to front of 2538 = **20.9 m**

Predicted distance between trams = (20.9 – 15.5) m
= **5.4 m**

Figure 18: Calculation of hazard braking distance for tram 2533. For further details of assumptions see paragraph 49.

49 It should be noted that the above calculations, undertaken to determine the possible course of events if hazard braking had been applied, include a number of assumptions. The hazard braking rate will be provided by the emergency track brake force (giving 1.4 m/s² retardation achieved in less than 0.5 seconds), plus the maximum service brake force (giving 1.3 m/s² retardation achieved after approximately 1 second). From these parameters it has thus been calculated that the majority of the hazard braking rate will be achieved in marginally less than 0.75 seconds. Inertial effects and frictional losses due to curvature and gradient effects have been ignored. Overall the calculated distances are slightly longer than would occur in practice.

50 Both drivers applied only a service brake. No explanation has been forthcoming of why the hazard brake was not used. Commentary from other drivers during later cab riding by an RAIB inspector confirmed a cautious use of the hazard brake to preclude injuries being caused to passengers. This conditioning of driver reaction to potentially hazardous events may have been initiated or reinforced by the need for drivers to request that any passengers injured during the hazard brake application make themselves known immediately to the driver, as described in paragraph 18. Use of the hazard brake is covered thoroughly during the initial training of drivers, and is included as a specific item during subsequent performance monitoring. Feathering of the brake (easing back from hazard to service just before the tram stops) to ease the jerk as the tram halts is also covered by initial training and drivers are monitored to ensure that they use this technique. A number of operating staff expressed the view that regular use of the hazard brake was inappropriate due to some (undefined) technical limitation. Whilst there is a limit (due to long term energy and thermal constraints) this is not a factor for limiting regular and repeated use of the hazard brake during training and performance monitoring. Drivers appear to be reluctant to use the hazard brake, and this reluctance, in the case of tram 2538, is a contributory factor to the collision (Recommendation 1).

51 The training of drivers by TOL includes the concept of defensive driving. Also included in their training is the approach to be taken in adverse weather conditions. The approach adopted by TOL to both these features was reviewed during the investigation and found to be both adequate and appropriate to TOL's operations.

52 Some railway operators have noted that drivers are more likely to pass a signal showing a stop aspect in the early days following a period of leave. This feature has been reported by the Rail Safety and Standards Board. This was considered in the case of the driver of tram 2538, however the absence of evidence indicating any other lapse of attention has resulted in this facet being eliminated as a contributory factor.

53 The noise from the cab heater is appreciable and can obviously detract from exterior sounds. This is no different to other road vehicles where driver compartment sound proofing, engine noise, general traffic sounds and even a radio could reduce the effectiveness of a warning horn. This feature has thus been eliminated as a factor that could have prevented this accident.

54 The entry to the *s*ingle line section from King Henry's Drive is similar to many other single to double line connections on Tramlink. It is however dissimilar to other single line sections in that it has no SPAS indicators (see paragraph 56). In addition to the use of 'drive-on-sight' priciples, it is fitted with controlling signals at each end; signal KHD02 near the site of the collision has an over-run distance of about 10 m. The distance travelled during the brake application time (whilst the equipment reacted to the drivers commands) would be approximately 6 m. The normal braking distance at 1.3 m/s² deceleration, from line speed at the signal, is 14.3 m. Thus if a driver applied the brakes when passing the signal the tram could not stop before passing the fouling point. The section from King Henry's Drive tramstop to the single line is entirely on *reserved formation*. There are no obvious operational or engineering constraints on the positioning of KHD02 sufficiently far back to allow a tram to stop before the fouling point; the position of signal KHD02S is thus seen as a contributory factor to the collision (Recommendation 2).

55 The non-fitment of SPAS indicators on the single line section was decided at the time of design approval; it has been justified by a number of safety arguments which include the low (35 km/h) speed limit over the section (25 km/h over spring points), driving on line-of-sight and the ability for end-to-end sighting. The latter is only partially valid because drivers cannot see from fouling point to fouling point, nor in conditions of poor visibility. Nevertheless, driving with appropriate allowance for these factors should adequately compensate for any limitation on end-to-end sighting. A further constraint is that flashing blue lights (as used by SPAS indicators) are prohibited on the public highway. This legal restriction would not however provide any constraint on the use of SPAS indicators alongside the ballasted single track section immediately adjacent to the site of the collision.

56 There have been a number of violations of the signalling (9 incidents spanning 4 years). This rate is comparable with other double-to-single connections on the system. Where the situation is clearly obvious, ie an opposing tram is approaching on the single line section, then driver reactions with line-of-sight driving have been adequate to avoid a collision. This particular incident was different in that tram 2358 was not clearly in a hazardous position when the driver of Tram 2533 first sighted its headlights. Although SPAS indicators need a finite time in which to activate, had they been fitted to this section then it is possible that the driver of tram 2533 might have reacted sooner and thus have avoided the collision. A further advantage of SPAS indicators is that they would be equally useful in the event of a SPAS from the starting signals at New Addington (signals NAD04 and NAD07). The lack of SPAS indicators at the New Addington to King Henry's Drive single line section is unique on the Croydon tramway, and is a contributory factor to the collision (Recommendation 3).

57 Although not a causal or contributory factor it would be useful for the guidance document on tramways published by the Office of Rail Regulation to include mention of over-run distances and where it may be appropriate, to adopt them (Her Majesty's Railway Inspectorate, Railway Safety (Principles and Guidance), Part 2G "Guidance on Tramways") (Recommmendation 4).

58 Following the SPAS of KHD02, the driver of tram 2538 did not switch on the hazard warning lights before the collision occurred. To have any possibility of affecting the outcome of events, the hazard warning lights would have needed to be switched on as a first action following tram 2538 coming to a stand. However, once foul of the other running line it is likely that the headlights of tram 2538 would have been much more visible than the hazard warning lights, especially in the foggy conditions present at the time. Even though the flashing of the hazard warning lights would have been an exceptional or abnormal condition, for this situation it is unlikely that they would have alerted the driver of tram 2533 earlier than occured. On balance, non-use of the hazard warning lights has not been considered a significant contributory factor to the collision. It should be noted that the use of hazard warning lights are covered by the Road Traffic Act on road sections of the tramway, and by certain training and procedures issued by TOL for general use throughout the system. As an observation resulting from the investigation, all drivers should nevertheless be reminded to use hazard warning lights as a simple and quick first action whenever a potentially hazardous situation occurs. The hazard warning lights should remain switched on for as long as the hazard remains. TOL should review their operating instructions and driver assessments, which may need to include simulated conditions, to ensure that drivers follow this procedure (Recommendation 5).

Conclusions

59 The immediate cause of the accident was that the driver of tram 2533 did not react in a timely manner to the obstruction caused by tram 2538.

60 Causal factors were:

- tram 2538 passing signal KHD02 whilst it displayed a STOP aspect;

61 In addition, the following factors were considered to be contributory:

- the non-use of the hazard brake by the driver of tram 2538.
- the limited over-run distance between KHD02 and the fouling point;
- the absence of SPAS indicators on the single line section between King Henry's Drive and New Addington;
- the reduced conditions of visibility caused by the fog.

62 The following factor affected the severity of the incident:

- The final stopping point of tram 2538 was only just foul of the other running line. Had this tram stopped several metres further forward a serious head-on collision could have occurred.

Actions already taken or in progress relevant to this report

63 TCL has not yet made any changes to the infrastructure at New Addington. It is however participating (where appropriate) in the investigations listed under paragraph 64.

64 TOL is in the process of reviewing its operational procedures, operational guidance and training:

- OP25 Adverse weather conditions;
- swept path awareness;
- use of hazard warning lights;
- use of hazard braking.

65 TOL is engaged upon a number of further investigations that may subsequently lead to changes in equipment and assets:

- audibility of tram horns;
- performance of the radio system;
- arrangement of Control Room alarms;
- marking of fouling points;
- provision of SPAS warning lights;
- signal location and over-run distances.

Recommendations

66 Implementation of the recommendations below is the responsibility of the organisations identified in each one. When they have considered the recommendations, the organisations should establish a priority and timescale for the necessary work, taking into account their health and safety responsibilities and the risk profile of their activities.

Resulting from the incident:

1 Tram Operations Ltd should carry out a programme to re-train all their drivers on the necessity to use the hazard brake in an emergency. Training and routine assessments should include understanding and demonstration by the driver in the operation of the hazard brake. The process of 'feathering' to avoid the final jerk should be retained (paragraph 50).

2 Tramtrack Croydon Ltd should assess the possibility of moving signal KHD02 to a position at least 21 m from the fouling point, and if it is reasonably practicable should carry out that relocation (paragraph 54).

3 Tramtrack Croydon Ltd should assess the possibility of fitting SPAS indicators to the King Henry's Drive to New Addington section thus making it similar to all other single track sections on the tramway. If Recommendation 2 has not been applied, Tramtrack Croydon Ltd should install SPAS indicators if it is reasonably practicable to do so (paragraph 56).

4 The Office of Rail Regulation (Her Majesty's Railway Inspectorate) should consider reviewing Railway Safety (Principles and Guidance), Part 2G "Guidance on Tramways" to include the provision of suitable over-run distances, and/or detection and warning systems at the design stage of tramway systems where they are a simple and cost effective means to mitigate against fouling point collisions at the entry to single line sections (paragraph 57).

Resulting from observation:

5 Tram Operations Ltd should carry out a programme to remind all drivers on the importance of using the hazard warning lights whenever a potentially hazardous situation occurs. Training and routine assessments should include practice in the immediate use of hazard warning lights (paragraph 58).

Appendices

Glossary of abbreviations and acronyms — Appendix A

CCTV	Closed-Circuit Television
RSSB	Railway Safety & Standards Board
SPAS	Signal Passed At Stop
TCL	Tramtrack (Croydon) Ltd
TOL	Tram Operations Ltd

Glossary of terms — Appendix B

brake application time	The time between a brake command being requested, eg by moving a handle to a braking position, and the demanded brake rate being substantially achieved.
fouling point	The position on the track beyond which a tram will be certain to be hit by a tram on a conflicting track or route.
hazard brake	A brake that provides a high rate of retardation for use in emergency situations. The rate is higher than would normally be acceptable to passengers. Passengers and luggage may fall over when the hazard brake is applied.
hazard warning lights	Yellow or amber flashing lights that illuminate at each corner of the vehicle. They are similar to those provided on all road vehicles under the Road Traffic Act.
in-bound	Tram services operating towards the centre of Croydon.
out-bound	Tram services operating away for the centre of Croydon.
over-run distance	The distance beyond a signal which a tram can occupy without fouling an adjacent line or causing a hazard to another tram.
point indicator	An illuminated sign by the side of the track that shows the route set by facing (or diverging) points.
reserved formation	A section of off-street tramway that is available exclusively for trams.
single line	A section of route that permits trams to operate in either direction over a single track.
spring points	Points which are set for one direction of a diverging route. They do not require to be reset when approached from the other route in the trailing (or converging) direction. The points return to the preset position by spring force after the wheels have passed through.
swept path	The profile that a tram requires as it moves along the track in order to avoid contacting anything else. It includes all allowances, eg for side-to-side sway, changes in suspension height due to passenger load, etc.
toe of (the) points	The moving end of the switch blades of a point which divert a tram from one route to another.
trailing	The direction of approach to a set of points that provides routes which converge. It is the opposite of the facing (or diverging) direction.

References Appendix C

1 Analysis of the May/Summer Peak in SPAD Occurrences
Produced by Human Engineering Ltd for RSSB
Ref: HEL/RS/02799a/RT1, 6th June 2003
(Section 3.7.2 contains specific data).

2 Human Factors Support to SPAD Management in the Southern and Scotland Zones – Summary Report
Produced by Human Engineering Ltd for RSSB
Ref: HEL/RSSB/03963/RT3, 7th June 2004
(Section 5 provides commentary upon drivers returning from holiday).

‘Signals Passed At Stop’ at New Addington — Appendix D

The following data relates to those events clearly attributable to driver error. It comprises events occuring since 23 June 2002. Other events have been excluded.

	Date	KHD02 Events (from King Henry’s Drive)
1.	27 Jul 2003	Driver misread signal aspect, stopping immediately on seeing another tram in section
2.	1 Nov 2003	Driver failed to check signal aspect; stopped tram upon sight of oncoming tram. Both trams used normal service brake to stop. Adjacent line fouled.
3.	17 May 2004	SPAS driver error. Tram passed signal whilst at STOP aspect whilst second tram exited on a proceed aspect. Tram brought to a halt when oncoming tram sighted by driver.
4.	11 Aug 2004	Driver error: late braking on approach to signal remaining at STOP aspect; vehicle came to a halt just past signal.
5.	27 Aug 2004	Driver reported misjudging stopping distance (due to distraction), tram came to a rest foul of the points. Driver of oncoming tram stopped immediately on sight of other vehicle.

	Date	NAD04 and NAD07 Events (from New Addington)
1.	27/10/2002	Driver failed to press “Ready to Start” switch and departed without a proceed; stopped when he saw another tram coming.
2.	26/02/2003	Driver error SPAS event.
3.	01/05/2003	Driver misread signal, stopped briefly as in-coming tram cleared points and proceeded.
4.	26/09/2003	Driver pressed RTS but failed to check signal aspect. Stopped short of fouling point upon sight of an on-coming second tram.

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Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

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