



Rail Accident Investigation Branch

Rail Accident Report



**Fatal accident at Bayles and Wylies footpath crossing, Bestwood, Nottingham
28 November 2012**

Report 19/2013
September 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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Contents

Summary	5
Introduction	6
Preface	6
Key definitions	6
The accident	7
Summary of the accident	7
Context	7
The investigation	11
Sources of evidence	11
Key facts and analysis	12
Background information	12
The sequence of events	13
Identification of the immediate cause	15
Identification of causal factors	15
Discounted factors	21
Previous occurrences of a similar character	25
Summary of conclusions	26
Immediate cause	26
Causal factors	26
Previous RAIB recommendations relevant to this investigation	27
Actions reported as already taken or in progress relevant to this report	28
Recommendations	29
Appendices	31
Appendix A - Glossary of abbreviations and acronyms	31
Appendix B - Glossary of terms	32

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Summary

At around 19:00 hrs on 28 November 2012, a young person who was using the crossing over the tramway at Bayles and Wylies crossing, Bestwood, Nottingham was struck and fatally injured by a tram that was travelling at 70 km/h (43 mph).

The young person moved into the path of the tram as it approached the crossing and appeared to be unaware of the tram's approach. The RAIB has been unable to positively establish why she seemingly did not see and react to the approaching tram or respond to the horn. Apart from a break of 0.3 seconds, this was sounded continuously as she walked towards and onto the tram track.

Closed-circuit television coverage from the front of the tram indicates that she did not look towards the tram after she entered the crossing through a chicane on its west side. However, there is no clear evidence to indicate what actions she took at the chicane; it is possible that she may not have looked towards the approaching tram, or looked but not seen it. Furthermore, although there is no direct evidence, it can not be ruled out that she saw the tram approaching and thought that she had enough time to cross, or that it would stop or slow down.

Bayles and Wylies crossing consisted of two separately managed crossings of the Nottingham tramway and a parallel Network Rail route. Network Rail closed the crossing in February 2013 pending the construction of a footbridge to replace it. This obviated the need for the RAIB to make any recommendations to improve the crossing.

The RAIB has made four recommendations. These cover the manner in which persons in the path of a tram are audibly warned; the marking of the boundary of pedestrian crossings of tramways; the prompts to pedestrians to look for approaching trams; and the best means to illuminate pedestrian crossings to avoid glare that could affect the ability of pedestrians to detect approaching trams.

Introduction

Preface

- 1 The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability.
- 2 Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.
- 3 The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

Key definitions

- 4 All dimensions and speeds in this report are given in metric units. Where appropriate the equivalent imperial value is also given.
- 5 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B.

The accident

Summary of the accident

- 6 At approximately 19:00 hrs on Wednesday 28 November 2012, a 13 year-old girl, Lindsey Inger (referred to in this report as the young person), was struck and fatally injured by a northbound tram travelling at 70 km/h as she crossed Bayles and Wylies footpath crossing in Bestwood, Nottingham (figure 1). She was crossing from west to east and was walking a short distance behind three friends.

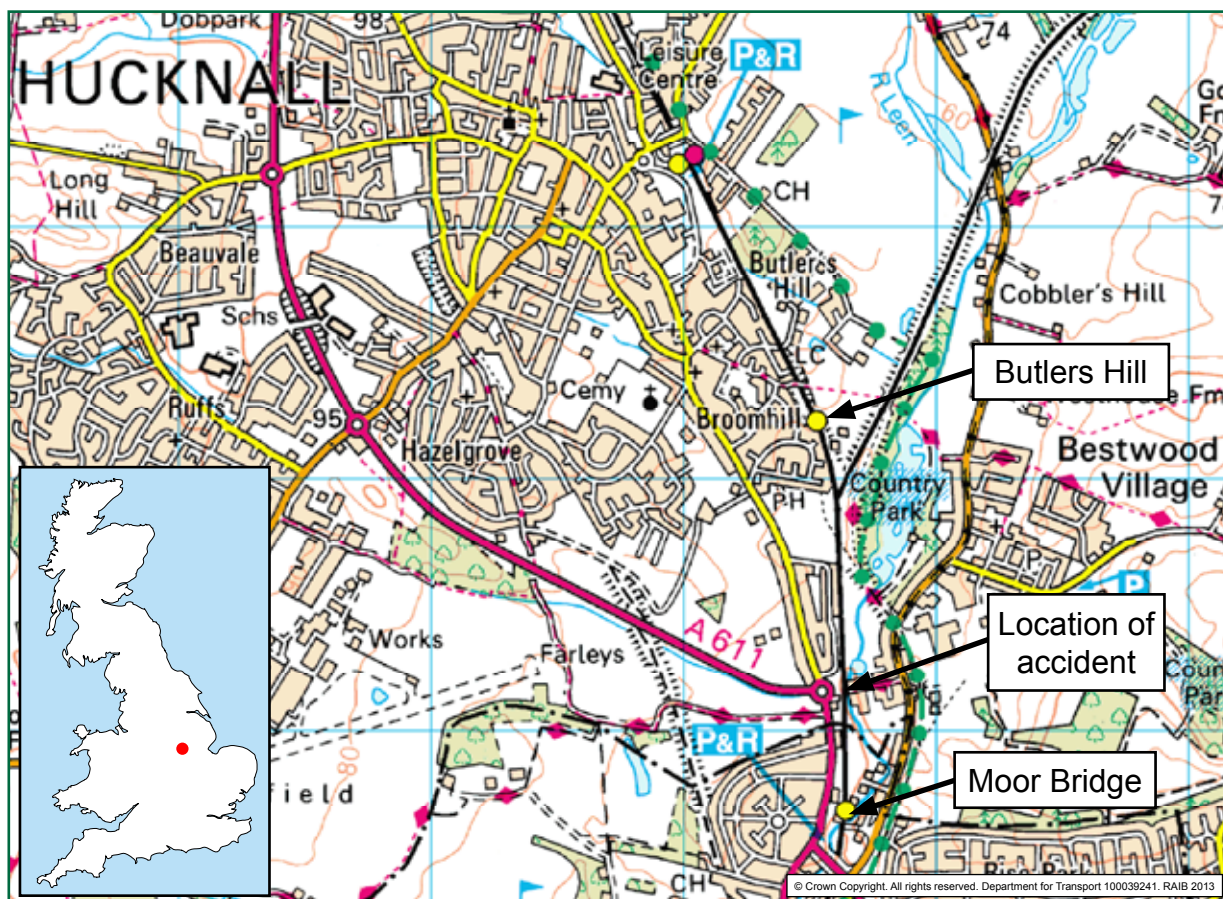


Figure 1: Extract from Ordnance Survey map showing location of accident

Context

Location

- 7 Bayles and Wylies crossing (figure 2), now closed¹, was a public footpath crossing that was crossed by the single line tramway from Nottingham Station Street to Hucknall, operated by Nottingham Trams Ltd (NTL), and by a single line railway, managed by Network Rail, which runs from Nottingham to Worksop.

¹ About two months after the accident, Network Rail obtained an *emergency closure order* for the crossing over both the railway and the tramway pending the construction of a footbridge, which was already being planned before the accident occurred on 28 November 2012.



Figure 2: Bayles and Wylies footpath crossing

- 8 The crossing was located (figure 1) between the tram stops of Moor Bridge, to the south, and Butlers Hill, to the north, at a point where both the NTL line and the Network Rail line run approximately north to south on a straight alignment. The crossing was aligned from west to east.
- 9 At the crossing location, trams and trains run in both directions on their respective lines with the maximum permitted speed of trams over the crossing being 80 km/h.
- 10 The crossing was well-used by pedestrians, as it connected Bestwood village on its east side to various facilities, such as schools and bus services, on its west side. It was also on the route of the 'Robin Hood Way', a way-marked long distance footpath.
- 11 There is more detail on the layout and design of the crossing in paragraphs 32 to 35.

Organisations involved

- 12 NTL is responsible for the operation and maintenance of the tramway infrastructure at Bayles and Wylies crossing. It also operated the tram involved in the accident and employed its driver. Alstom Transport is responsible for the maintenance of the trams.
- 13 Network Rail owns and manages the railway infrastructure at Bayles and Wylies crossing.
- 14 All parties freely co-operated with the investigation.

Tram involved

- 15 The tram involved, number 211 (figure 3), is one of 15 trams manufactured by Bombardier Transportation for the opening of the Nottingham tram system in 2004. All 15 are of the type known as the Incentro model. On the day of the accident, tram 211 had just been released into service following a major maintenance examination. Alstom recorded that the tram had no defects following maintenance. At the time of the accident, the tram was working the 18:30 hrs service from Nottingham Station Street to Hucknall.



Figure 3: The tram involved in the accident, tram 211, approaching Bayles and Wylies crossing

- 16 Throughout the Nottingham network trams are operated on the 'line of sight' principle in which drivers have to be prepared to stop short of any stationary obstruction on the line in the same way that road vehicles are driven on the highway.
- 17 As well as a service brake, trams are fitted with an emergency track brake in conjunction with automatic sanding providing a higher level of retardation than a normal full service brake.
- 18 Each tram is fitted with a bell and a horn. The bell is the normal means to warn pedestrians that a tram is approaching during street running, and the horn is used to warn people about the tramway where it runs on its own segregated track. It is also used to give an emergency warning to pedestrians during street running.
- 19 Trams have normal automotive type headlights, lit at all times when they are in service. During darkness, when the tram is running on segregated sections of route, the driver should operate the headlights to main beam. There is also a dimmer third white light mounted centrally above the windscreen, which is lit when the headlights are on. Further illumination from the front of the tram is provided by the destination indicator and by its lit interior, visible through the driving cab.

- 20 The tram is equipped with forward facing closed-circuit television (FFCCTV) and an on-tram data recorder (OTDR). The FFCCTV recorded the accident, and the OTDR recorded key parameters such as the tram's speed, application of power, braking and use of the horn.
- 21 Alstom Transport staff carried out post-accident testing of the tram following the accident in the presence of Nottinghamshire Police and reported that they found no defects with the brakes, speedometer, horn or bell. The RAIB's analysis of the OTDR also indicated that these systems operated as designed.
- 22 Following the accident, the dipped beam filament of the right-hand (in the direction of travel) headlight bulb was found to be broken and was changed. Nottinghamshire Police investigated this failure and concluded that it had broken as a result of the impact. They reported that the bulb was not lit at the time of the accident because the headlights were set to main beam.

Staff involved

- 23 The tram driver started his employment with Arrow² (the Nottingham Tram Consortium) in January 2004, and he first worked as a conductor while waiting for a driver training course. Following training and assessment, Arrow passed him competent to drive trams on 22 December 2004.
- 24 In accordance with company procedures, the records indicate that the driver has undergone regular assessments of his competence since he qualified. The last assessment, by NTL, before the accident was on 2 May 2011. He was given positive feedback at this assessment and had a good driving record.
- 25 In accordance with NTL's procedures, the driver was tested for drugs and alcohol following the accident and found to be clear.

The pedestrian

- 26 The young person lived locally about 300 metres from the west side of the crossing. According to witness evidence, one of her friends in the group of three, which she had only just met, lived on the east side of the crossing and the group was going to her home. This was most easily reached by using Bayles and Wylies crossing.
- 27 Witness evidence suggested that the young person was not familiar with the crossing and may not have used it previously.
- 28 The RAIB found no evidence that she had any impairment in her vision or hearing.

External circumstances

- 29 Local weather records indicate that the weather at the time of the accident was cold, dry and clear with a light breeze blowing from the north-west. Although it was dark, there was some ambient light from the light illuminating the crossing surface on the Network Rail side of the crossing.
- 30 It is very likely that there would have been background noise arising from the adjacent A611 road running parallel to the tramway and from the River Leen, flowing close to the Network Rail side of the crossing.

² Arrow was the original operator of the Nottingham Tram system before NTL.

The investigation

Sources of evidence

31 The following sources of evidence were used:

- site examination, photographs and measurements;
- witness statements and reports provided by Nottinghamshire Police;
- data from the tram's OTDR;
- FFCCTV recordings from the tram, enhanced by a specialist consultancy;
- copies of the records of the tram driver's training and competence assessment, the risk assessment of the crossing and other relevant documentation provided by NTL;
- a report by an optical and acoustic specialist concerning the *conspicuity* of the tram involved in the accident on the approach to the crossing and the audibility of its horn;
- a human factors assessment concerning possible features in the crossing environment and other influences which may have contributed to the accident;
- documentation and witness evidence provided by Network Rail concerning the action taken following the previous accident on the Network Rail side of the crossing on 22 November 2008; and
- a review of previous RAIB investigations that had relevance to this accident.

Key facts and analysis

Background information

The design of Bayles and Wylies footpath crossing

- 32 Figure 4 shows the general layout of the crossing. The crossing walkways over each infrastructure were at right angles to the track and the crossing design was such that pedestrians had to assure themselves that it was safe to cross by checking for approaching trams/trains before doing so.

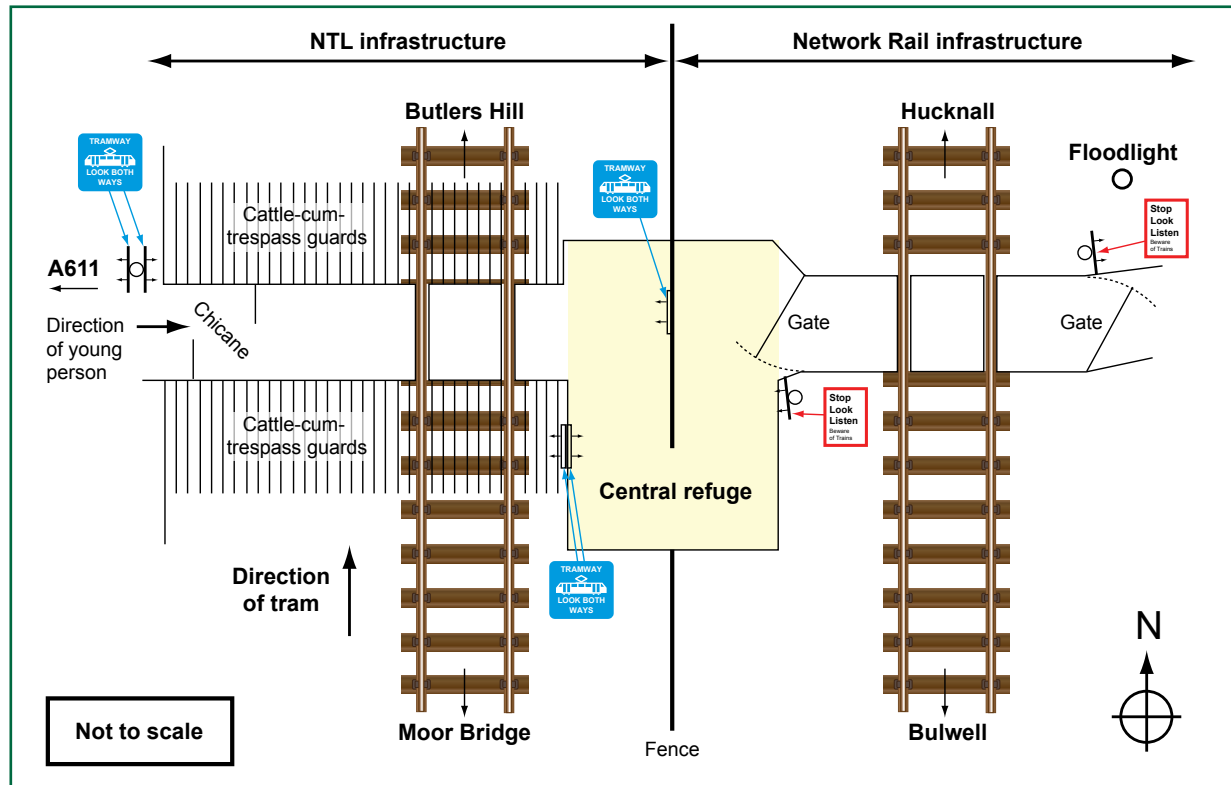


Figure 4: Layout of Bayles and Wylies crossing

- 33 Access to the crossing over the tramway from its west side was provided through a chicane (figure 2), about 3 metres from the tram track. This consisted of a separated pair of railings, with the intention of both preventing pedestrians making a direct route on to the tramway and guiding them to face oncoming trams before they crossed the track³. Once across the tramway, pedestrians entered a refuge between NTL's tramway and Network Rail's railway, also containing a chicane, before crossing the railway.

³ The *Office of Rail Regulation's* Railway Safety Publication 2 'Guidance on Tramways' provides guidance on the design of crossings. In particular, paragraph 68 of this guidance states that 'fencing or pedestrian guard rails should be provided where necessary, to guide pedestrians to face oncoming trams before they cross the track, or to direct their attention to pedestrian crossing lights'.

- 34 Before reaching the chicane on the west side of the tramway, from the A611 road, any visibility of approaching trams was severely restricted by vegetation. However, once at the chicane, there was good visibility in both directions along the tramway. This meant that, provided pedestrians looked for approaching trams at the chicane, there was sufficient *warning time*. Northbound trams could be seen from the chicane as they departed from Moor Bridge tram stop, about 475 metres away, and took about 50 seconds to reach the crossing. The view of an approaching tram was partially obstructed by the closest overhead electrification mast to the crossing as it passed around 200 metres away, but was fully in view again by 180 metres away. The tram would have been fully in view when the first three girls crossed the tramway and when the young person was at the chicane and then walked on to the crossing.
- 35 The crossing surface, consisting of wooden boards topped with a smooth non-slip surface and edged in white paint, was illuminated by a light on the Network Rail side, but angled so that it lit up the whole of the crossing surface, including the tramway crossing. This was fitted following an accident on the Network Rail part of the crossing on 22 November 2008, which was investigated by the RAIB (report 32/2009) (paragraphs 99 to 102 refer).

The sequence of events

- 36 The sequence of events set out below is based on the RAIB's analysis of data recorded by the tram's OTDR and footage from the FFCCTV. The distances and times quoted for the locations of the girls are best estimates given that the FFCCTV footage is not continuous and normally advances by three frames per second.
- 37 Tram 211 departed from Moor Bridge tram stop at 18:58 hrs, entered the single line section to the following tram stop at Butlers Hill, and accelerated. The driver switched the headlamps to the full beam setting as soon as the tram left the tram stop.
- 38 At 18:59:05 hrs FFCCTV appears to show that the first three girls of the group entered the crossing from the chicane (figures 2 and 4) at its west side, and to cross at a brisk walking pace. At this point, the tram was about 100 metres from the crossing and, in response to his first sight of them, the tram driver sounded the horn and kept it sounding continuously for 5 seconds, apart from a break of 0.3 seconds, until the tram had passed over the crossing.
- 39 It appears that the first three girls reached the first rail of the tram track when the tram was about 60 metres from the crossing. The young person, who was the last of the group to arrive at the crossing, was at the chicane at this time, following about 3 metres behind (figure 5). The three girls in front continued over the tram track and appear to reach the central refuge at 18:59:08 hrs. It was not possible to discern from the FFCCTV whether or not any of them looked towards the tram while crossing or waiting in the central refuge. At this point the tram was about 25 metres from the crossing, and the young person was about 0.5 metre from the tram track.



Figure 5: View of the crossing from tram 211 about 60 metres away⁴

- 40 When the tram was about 30 metres from the crossing, the tram driver momentarily stopped sounding the horn in response to the first three girls reaching the central refuge, but about 0.3 seconds later reapplied it, probably in response to seeing the young person on the crossing. He also fully applied the tram's service brake.
- 41 The rearmost young person appeared to walk at a normal walking pace and stepped into the middle of the tram track when the tram was only about 10 metres away from the crossing. The evidence from the FFCCTV indicates that she did not appear to be aware of the tram's approach.
- 42 When the tram was around 5 metres from the crossing, the driver applied the emergency brake, but it was too close to the crossing to have other than a marginal effect in further reducing the speed of the tram before it struck and fatally injured the young person in the middle of the crossing. This occurred at 18:59:10 hrs, about 5 seconds after the first three girls entered the crossing through the chicane. The tram was travelling at 70 km/h when the collision occurred.
- 43 The tram travelled 49.7 metres beyond the crossing before it stopped, having sustained some damage as a result of the collision. The tram driver immediately contacted NTL's control who called the emergency services.

⁴ There is a discrepancy in the time recorded by the FFCCTV and the actual time, which is not relevant to the accident.

Identification of the immediate cause⁵

44 The young person moved into the path of the tram as it approached Bayles and Wylies crossing.

45 The young person entered the crossing from the chicane when the tram was about 60 metres away. While it cannot be discerned whether or not she looked towards the approaching tram while at the chicane, the evidence from the FFCCTV indicates that she did not look towards it as she walked from the chicane to the tram track.

Identification of causal factors⁶

46 The RAIB has been unable to positively establish why the young person seemingly did not see and react to the approaching tram or respond to the horn. She was not using a mobile phone, or wearing earphones as she crossed, and appeared to be unaware of the tram's approach.

47 While at the chicane, it is possible that she may have either:

- not looked towards the approaching tram (paragraph 63); or
- looked in the direction of Moor Bridge tram stop but not seen the tram which would have been about 60 metres away (paragraph 71).

These are both possible causal factors.

In either case, the young person did not respond to the sound of the horn of the approaching tram (paragraph 50). This is a causal factor.

48 Although there is no direct evidence, it can not be ruled out that the young person saw and/or heard the tram approaching and thought incorrectly that she had time to cross safely, or that it would stop or slow down.

49 The evidence given to the police by the first three girls to cross is that they did not see the approaching tram, did not hear its horn, and first became aware of the tram when the collision occurred. Analysis of the OTDR and witness evidence from a passenger on the tram and a local resident indoors confirmed the tram horn was sounded. The RAIB has not been able to establish why the three girls may not have heard the tram horn, or seen the tram approaching.

The young person's lack of response to the tram horn

50 The young person did not respond to the sound of the horn of the approaching tram.

51 Once through the chicane, the FFCCTV indicates that the young person did not respond to the tram horn and showed no awareness that it was being sounded. The RAIB has not been able to positively establish why this was the case. However, there are two possible factors that may have caused her not to react to it, namely:

- she may not have heard and been alerted to it due to the manner in which it was sounded (paragraph 61) and;
- she may have believed that it was from another vehicle (paragraph 62).

⁵ The condition, event or behaviour that directly resulted in the occurrence.

⁶ Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

- 52 The RAIB commissioned specialist consultants to carry out acoustic tests to investigate the audibility of the tram horn as the tram approached the crossing and to assess whether it complied with any relevant standards. The tests on the approach to the crossing were carried out at the same time of day as the accident and when the wind speed and direction was similar (paragraph 29). Figure 6 shows the measurements of the *sound pressure levels* above the background level⁷ from the horn at different distances along the tram line away from the crossing.

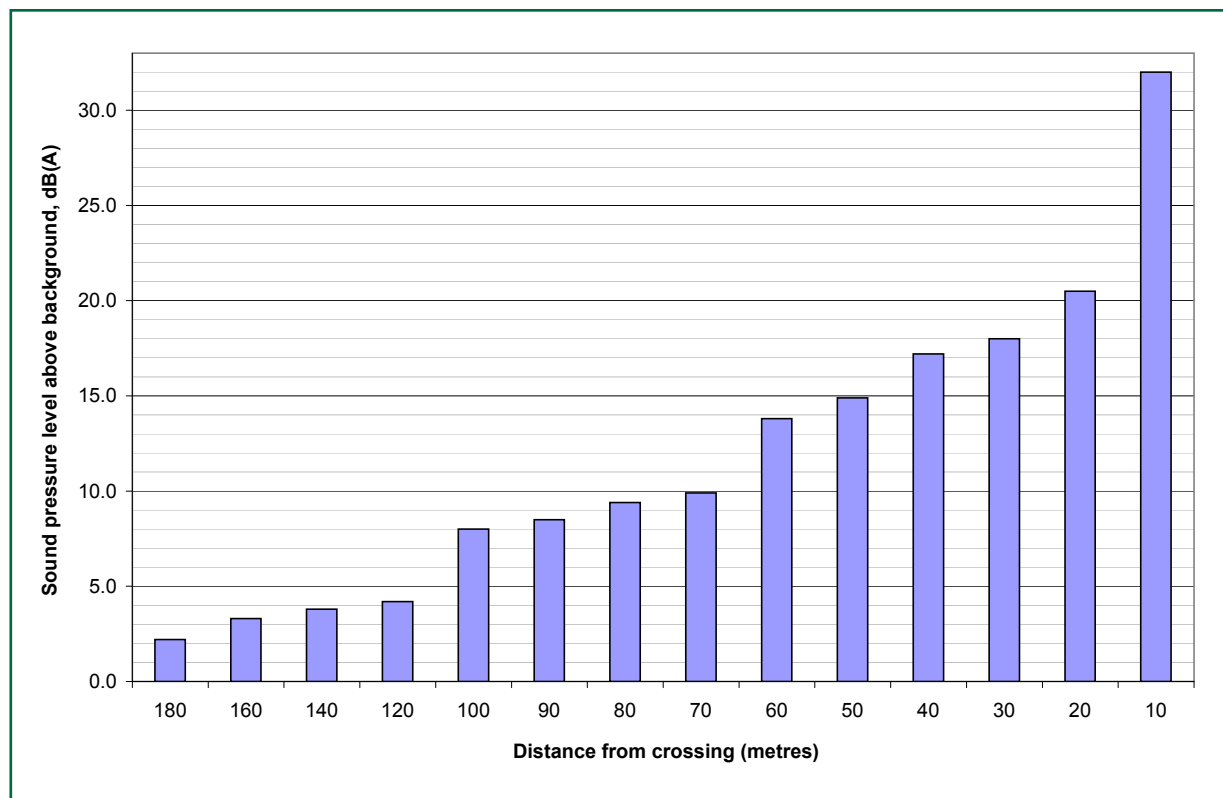


Figure 6: Results of tram horn tests at Bayles and Wylies crossing

- 53 Although there are no specific requirements for the audibility of tram horns, there are two possible documents against which their acceptability could be judged, namely the standard for motor vehicles⁸ and the ORR's guidance on tramways (paragraph 33). The standard for motor vehicles is relevant because trams run in and among road vehicles at similar speeds while running along street sections.
- 54 The warning horns fitted to both ends of tram 211 complied with the standard requirement for motor vehicles of 105 – 118 dB(A), measured at a distance of 2 metres, within the defined *frequency* range. The sound pressure level of the 'A' end of the tram was 106.9 dB(A), and the 'B' end, the end leading at the time of the accident, was 107.0 dB(A).

⁷ The background level was found to fluctuate between approximately 53 dB(A) and 65 dB(A) with short duration increases up to 84 dB(A) during accelerating road traffic. The sound pressure level of the tram horn was measured when the background level settled to within a range of 50.5 dB(A) to 56.8 dB(A).

⁸ UN ECE R28 (1958), 'Uniform provisions concerning the approval of audible warning devices and of motor vehicles with regard to their audible signals'.

- 55 The ORR's guidance on tramways advises that the warning device fitted to trams should be loud enough to indicate the approach of a tram without causing injury or undue alarm to those in the proximity. The guidance also refers to a supporting document, the ORR's 'Tramway Technical Guidance Note 6', which states that 'it may be necessary to consider the sound level of the warning device such that it will be audible to staff or pedestrians on the track at the service braking distance of the approaching tram.
- 56 The results of research⁹ indicate that the reliable detection of a horn being sounded is marginal when it is between 5 and 15 dB(A) above the background level, but should be reliably detected when more than 15 dB(A) above background. This is consistent with the findings of another study¹⁰ stating that for the reliable detection of ambulance sirens, a warning sound should produce a sound pressure level of 15 – 25 dB(A) above background. The service braking distance of a Nottingham tram from a speed of 80 km/h is 179 metres and figure 6 shows that at this distance the sound pressure level during the tests was 2.2 dB(A) above the background noise level for the ambient conditions at Bayles and Wylies crossing. This is just above the level of audibility and unlikely to have been detected by a person at the crossing if the horn had been sounded from 179 metres away. However, the horn was not sounded until the first three girls entered onto the crossing when the tram was about 100 metres away (paragraph 38). The acoustic testing found that at this distance, the sound pressure level was 8.0 dB(A) above background and 13.8 dB(A) above background at 60 metres, the approximate distance the tram was from the crossing when the young person passed through the chicane.
- 57 During the tests, the sound pressure level of the horn was greater than 15 dB(A) above background once the tram was closer than 50 metres, and about 2.5 seconds away, from the crossing (figure 6). At this distance the horn should have been readily detectable at the crossing, if there was the same background noise level when the accident occurred. The RAIB has not identified any factors that would have increased the background noise level at the time of the accident compared with the steady background noise level that was measured when the tests were carried out. There was, for example, no train on the Network Rail line in the vicinity of the crossing when the accident occurred.
- 58 Figure 6 shows that the tram may not have met the ORR's guidance when travelling at 80 km/h, with the background level of noise present at Bayles and Wylies crossing, because the sound pressure level above background was only just above the threshold of human audibility. However, according to the acoustic tests, the horn should have been readily detectable when the young person passed through the chicane onto the crossing because the tram was much closer to it.

⁹ Referred to in RSSB/AEATR-PC&E-2004-002 Issue 3 'Audibility of Warning Horns', AEJ Hardy, 2004.

¹⁰ Catchpole, K. & McKeown, D. (2007). A framework for the design of ambulance sirens. *Ergonomics* 50(8), 1287 - 1301.

- 59 A possible explanation for why the young person did not register the horn was because of the way in which it was sounded. The horn started when she was approaching the chicane, but at this time, at this location, the sound level was not high enough to be detectable. As she entered the crossing and the tram got closer, the sound increased to a level that should have been readily detectable above the background noise. However, advice from the RAIB's specialist consultant and from a university professor in auditory human factors was that a gradually increasing sound may only become readily detectable when it reaches a greater sound level above the background noise than that for which a new sound would be recognised. The effect of this characteristic would have been to delay the time at which the young person became aware of the tram. However, the RAIB has been unable to find any published work in support of this theory.
- 60 The 0.3 second break in the sounding of the horn (paragraph 40) could have provided a slight, but unquantifiable, increase in audibility because of the apparent new sounding of the horn. However, any small fluctuation in the level of background noise, or other discrete noise event such as a noisy road vehicle on the nearby road, would have masked this increase and caused it to be missed.
- 61 The RAIB's specialist consultant advised it is possible that audibility would have been improved had a series of short duration soundings been made (as required by the rules covering trains on Network Rail's infrastructure) rather than the continuous sounding. NTL's instructions to tram drivers did not require the horn to be applied as a series of short duration soundings.
- 62 It is also possible that the young person believed that the tram horn, sounded for about 5 seconds (paragraph 42) was from another vehicle in the area such as a road vehicle or a train. Although the frequencies of the tram warning horn are different from cars and trains, there is no reason why the young person would have been aware of this. She was reported not to have been familiar with the crossing (paragraph 27) and might therefore not have been aware of the sound of a tram horn.

The young person not looking before crossing the tramway

63 The young person may not have looked towards the approaching tram when she was at the crossing chicane.

- 64 The RAIB has identified two possible factors that may have contributed to the young person not looking towards the approaching tram. They are discussed in paragraphs 65 to 70 below.

Attention and distraction

- 65 As the young person approached the crossing, she was following her friends who, from the FFCCTV, appeared to be about 3 metres ahead of her. Her friends reached the central refuge before she had started to cross the tram track, and it is possible that her attention was on them rather than the tramway. It is also possible that she took her cue that it was safe to cross the tramway because her friends had just done so, or she felt she needed to catch up with the others in the group. The RAIB however cannot be certain if either of these factors existed, or influenced her behaviour, or attentiveness in looking for an approaching tram.

The design of the crossing

- 66 According to the ORR's guidance on tramways (paragraph 33), the purpose of the chicane (figure 2) at the entrance to the crossing over the tramway was to guide pedestrians to face oncoming trams, which could come from either direction, before they made the decision to cross the track. The RAIB observes that the chicane also provides the demarcation of the crossing. However, the extent of the change in direction imposed on pedestrians by the chicane was very mild because the railings did not overlap and they were 1.33 metres apart. This minimised the effectiveness of the barriers as a 'gateway' to entering the crossing and allowed pedestrians to walk through without being guided by the chicane to face the direction of approaching trams.
- 67 The RAIB commented on the design of the chicane at Morden Hall Park footpath crossing on the London Tramlink system, which operates in and around Croydon, in its investigation of the fatal accident to a cyclist on 13 September 2008 (report 06/2009). The investigation found that the chicane was not effective in guiding pedestrians to face oncoming trams. The RAIB made a recommendation that following an assessment of the risks, and where appropriate and practicable to do so, crossings should be modified so that users are influenced to look both ways before crossing (by means such as the provision of barriers, signs and/or markings).
- 68 As a result of the accident at Morden Hall Park crossing, London Tramlink installed a new chicane at the crossing. The railings overlap requiring cyclists to slow down more and pedestrians to follow around them to get through rather than being able to walk straight through as was formerly the case. Figure 7a shows the chicane at the time of the accident, and figure 7b shows it after the changes had been made¹¹.



Figures 7a and 7b: Changes to the chicane at Morden Hall Park footpath crossing, London Tramlink

¹¹ The path leading to the crossing at Morden Hall Park runs parallel to the rails, so pedestrians have their backs to an approaching tram in one direction as they approach.

- 69 The tramway at Bayles and Wylies crossing runs on a segregated former railway formation at relatively high speed (80 km/h) and therefore has a number of similarities to a normal railway, even though trams are driven on line of sight. Standard arrangements at railway footpath crossings are to have outward opening gates on each side. Such gates provide a clear demarcation of the railway boundary and require a definite action on the part of a pedestrian to operate. They are more likely to promote greater awareness of a crossing and the care required to use it.
- 70 On behalf of the main line railway industry, RSSB¹² has commissioned research (project T984) into the causes of pedestrian accidents at all types of level crossings, to understand why they occur, and to evaluate both novel and established solutions that could improve pedestrian safety. It is possible that the results of this research, ongoing at the time of publication, could have relevance to the design of pedestrian crossings on tramways.

The young person not seeing the tram

71 The young person may have looked in the direction of Moor Bridge tram stop but not seen the tram.

- 72 It can not be ruled out entirely that the young person looked as she entered the crossing but failed to see the approaching tram because of a phenomenon known as 'looked but failed to see'. This more commonly occurs in road accidents and was the subject of a study carried out in 2009¹³. It occurs particularly at road junctions in which a vehicle driver fails to register the approach of another vehicle despite it being clearly visible and where it is thought to contribute to almost 21% of accidents. The RAIB has concluded that 'looked but failed to see' was unlikely to have been a factor in this accident because it is most commonly associated with familiar routine, repetitive tasks, and where the approaching vehicle, such as a motorcycle, is relatively small. In the case of the accident, the young person was reported to be not familiar with the crossing (paragraph 27), and the approaching vehicle was a relatively large one.

Glare from the light provided to illuminate the crossing surface

- 73 Measurements taken by the RAIB's specialist consultant indicated that the light on the Network Rail side of the crossing (paragraph 29 and figure 8) was sufficiently bright as to cause visual discomfort and *disability glare* which could reduce the visual performance of anyone approaching from the west side of the crossing. This could affect their ability to visually identify the approach of a tram. Such effects were likely to be brief¹⁴, lasting less than a second for a young person, but of possible significance to anyone who just happened to glance quickly along the tramway as they passed through the chicane.

¹² A not-for-profit company owned and funded by major stakeholders in the railway industry, and which provides support and facilitation for a wide range of cross-industry activities. The company is registered as 'Rail Safety and Standards Board', but trades as 'RSSB' (see www.rssb.co.uk).

¹³ The Department of Transport: Road Safety Research Report No.60, Review of the 'Looked but failed to see' accident causation factor.

¹⁴ Schieber, S. 'Age and Glare Recovery Time for Low-Contrast Stimuli', Department of Psychology, University of South Dakota, SD 57069.



Figure 8: The light on the Network Rail side of the crossing

- 74 The *brightness* of the light also had a second effect, known as veiling glare, in which objects in a person's peripheral vision could be more difficult to see. This could have reduced the possibility of the young person seeing the movement of the approaching tram in her peripheral vision as she approached and started to cross the tram track. This would be of likely significance if the young person had not looked before crossing (paragraph 71).
- 75 When Network Rail fitted the light following the double fatality on 22 November 2008, their objective was to improve pedestrian safety by illuminating the crossings of both infrastructures. It was not identified that the light's brightness could be a source of glare potentially affecting the visual performance of pedestrians approaching the crossing from its west side.

Discounted factors

The operation of tram 211

- 76 The RAIB considers that the tram driver's actions, including application of the emergency brake, were in accordance with NTL's procedures and training.
- 77 The OTDR showed that the tram driver did not exceed the 80 km/h permissible speed limit up to and over Bayles and Wylies footpath crossing before he started braking in response to seeing the young person starting to cross.

- 78 When the tram left the stop at Moor Bridge, about 50 seconds before the young person left the chicane to the west of the crossing, the driver switched the headlights to full beam, as required by NTL's operational instructions.
- 79 Although trams are driven on line of sight (paragraph 16), pedestrians crossing the tramway were required to take sufficient care that they had enough time to cross before any tram running at normal speed arrived at the crossing. Trams are not required to stop, or slow down, while approaching crossings unless it is evident to a driver at or before service braking distance that the crossing will still be blocked when the tram arrives at it.
- 80 The tram driver sounded the horn as soon as the first three girls in the group passed through the chicane onto the crossing and continued sounding it until they were clear. He immediately re-sounded the horn when the young person started walking towards the tram track, when the tram was about 30 metres away from the crossing.
- 81 In both cases, the driver would have had a reasonable expectation that the horn would have alerted those crossing to the tram's presence. Tram drivers are used to pedestrians walking across the path of trams, particularly in areas of street running. Once it was clear that the young person was not responding to the horn, the driver applied the service brake followed about a second later by the emergency brake. By this time, it was too late to prevent the accident occurring.

The visual conspicuity of the tram

- 82 There is no standard that specifically applies to tram headlights and the only relevant standard found was a manufacturing standard for the type of headlamp fitted to the Nottingham trams rather than a performance requirements specification¹⁵. The RAIB commissioned a specialist consultant to carry out optical tests to compare the headlights with this standard and to assess the visual conspicuity of the tram as it approached Bayles and Wylies crossing.
- 83 The *luminous intensity* of each headlight on the full beam setting (the setting of the headlights as the tram approached the crossing – paragraph 30) did not comply with standard UN ECE R20. Both headlamps were also found to be slightly misaligned downwards and outwards. The results are in table 1. The colour of the headlights was found to be compliant with the standard.

Tram 211 leading end at the time of the accident	Test angle	Angles at which peak values of luminous intensity occurred
	0.0° horizontal 0.0° vertical	Between 0.7° and 1.9° off-axis
Specification (UN ECE R20)	48 -240 lux	N/A
Left-hand ¹⁶ driving beam	28.1 lux	36.4 lux
Right-hand driving beam	22.0 lux	35.1 lux

Table 1: Luminous intensities of tram 211 'B' end head lamps from 25 metres away

¹⁵ UN ECE R20 (1979), 'Uniform provisions concerning the approval of motor vehicle headlamps emitting an asymmetrical passing beam or a driving beam or both and equipped with halogen filament lamps (H4 lamps)'.

¹⁶ In direction of travel.

- 84 The key factors for the conspicuity of an approaching tram at the crossing are the colour and brightness of its headlights and the adverse effects caused by the brightness of the crossing light (paragraphs 73 to 75). Besides the tram headlights, other influences adding to the conspicuity of the tram are the other lights showing on the front (paragraph 19) and the reflected component of the front-end lights from the surfaces of the rails.
- 85 Although the tram headlights were found not to comply with the relevant standard, the RAIB has concluded from its own observations that the approaching tram would have been clearly visible from the crossing chicane from the point at which it left the tram stop at Moor Bridge. Figure 9 shows tram 211 approaching the crossing from Moor Bridge while about 200 metres from the crossing and the amount of light cast by the light on the Network Rail side of the crossing (paragraph 73).



Figure 9: Tram 211 approaching Bayles and Wylies crossing from Moor Bridge

- 86 The evidence from the FFCCTV and OTDR is that the first group of girls entered the crossing from the chicane when the tram was around 100 metres away (paragraph 38). Figure 10¹⁷ shows tram 211 at 100 metres from the crossing when it was dark.
- 87 The young person entered the crossing when the tram was around 60 metres from the crossing (paragraph 39). Figure 11 shows tram 211 at 60 metres from the crossing when it was dark.

¹⁷ In adjusting the exposure to take account of the tram headlights shown in figures 10 and 11, the camera has not properly represented the amount of background lighting from the light at the crossing as shown in figure 9.



Figure 10: The appearance of tram 211 at a distance of 100 metres from the crossing



Figure 11: The appearance of tram 211 at a distance of 60 metres from the crossing

NTL's risk assessment of Bayles and Wylies footpath crossing

- 88 NTL has a procedure under which its activities must be risk assessed and had applied it to Bayles and Wylies crossing. The risk assessment in place at the time of the accident was dated 3 January 2012 and assessed the risk, based on its severity and probability, of each hazard present using a one to five scale rating.
- 89 With the control measures in place, the level of risk of a collision with a pedestrian had been judged to be acceptable. The control measures were the training of tram drivers, the design of the tramway system, the method of operation, tram audible warnings and headlights, the central refuge, tramway warning signs, chicane fencing and 12-weekly track inspections.
- 90 The risk assessment did not identify any particular factors, such as the adjacent Network Rail crossing, or note any areas for improvement such as the design of the chicane.
- 91 NTL's process of risk assessment is highly unlikely to have challenged the suitability of the design of the tramway crossing because it was built to conform to the ORR's guidance on tramways (paragraph 33). It was accepted by *HM Railway Inspectorate* before the tramway opened for service.

Previous occurrences of a similar character

- 92 NTL has not logged any incidents of near misses at Bayles and Wylies crossing, although there have been incidents of vandalism where tram windows have been broken (and train windows on the adjacent Network Rail line).
- 93 Since the tramway opened in 2004 and before 28 November 2012¹⁸, the following accidents have occurred at Bayles and Wylies crossing:
- 16 June 2004: a pedestrian riding a bicycle was struck and injured by a southbound tram while using the crossing over the tramway. This accident was not investigated by the RAIB because it occurred before it became operational¹⁹.
 - 22 November 2008: a woman and child were struck and fatally injured by a southbound train on the Network Rail side of the crossing. The RAIB investigated this accident (covered in more detail in paragraphs 99 to 103).
 - 28 September 2009: a fatality occurred on the Network Rail side of the crossing when a person walked into the path of a southbound train. This was reported to be as a result of a deliberate act.

¹⁸ On 9 February 2013, a fatality occurred on the Network Rail side of the crossing when a person walked into the path of a southbound train. This was reported to be as a result of a deliberate act.

¹⁹ The RAIB became operational on 17 October 2005.

Summary of conclusions

Immediate cause

- 94 The young person moved into the path of the tram as it approached Bayles and Wylies crossing (**paragraph 44**).

Causal factors

- 95 The young person not responding to the sound of the horn of the approaching tram was causal to the accident (**paragraph 50, Recommendation 1**).

Possible factors leading to this are:

- i. the horn was sounded continuously starting from a distance at which it would have been unlikely to have been audible (**paragraphs 59 to 61**); and/or
 - ii. the young person believed the horn was being sounded by another vehicle in the area (**paragraph 62**).
- 96 It is possible that the young person did not look towards the approaching tram when she was at the crossing chicane (**paragraph 63**).
- Possible factors leading to this, which may have acted singularly or in combination are:
- i. the young person may have been distracted (**paragraph 65**); and
 - ii. the design of the crossing resulting in a weak chicane and no clear demarcation of the crossing boundary (**paragraphs 66 to 70, Recommendations 2 and 3**).
- 97 It is also possible that the young person looked in the direction of Moor Bridge tram stop but did not see the tram (**paragraph 71, Recommendation 4**).
- The possible factor leading to this is:
- i. the glare from the light provided to illuminate the crossing if the young person looked at it momentarily (**paragraphs 73 to 75, Recommendation 4**).
- 98 Although there is no direct evidence, it can not be ruled out that the young person saw and/or heard the tram approaching and thought incorrectly that she had time to cross safely, or that it would stop or slow down.

Previous RAIB recommendations relevant to this investigation

- 99 The RAIB investigated the accident on the Network Rail side of Bayles and Wylies crossing on 22 November 2008 in which two people were killed (report 32/2009). Two recommendations were made that may be relevant to the circumstances of the accident on 28 November 2012.
- 100 Recommendation 2 stated that Network Rail and Nottinghamshire County Council should jointly assess the lighting of Bayles and Wylies level crossing and if necessary alter it so that it is adequate for pedestrians to clearly see where they are walking when crossing the line. The rationale was to ensure that the crossing surface was adequately illuminated for use during darkness and led to the erection of the light to illuminate the crossing (paragraphs 73 to 75).
- 101 Recommendation 3 stated that Network Rail, together with NET²⁰, should re-assess Bayles and Wylies crossing and establish if the installation of additional protective measures, such as a *miniature warning light* (MWL) system, are required. In response Network Rail straightened the alignment of the crossing across the railway but concluded that it was not practicable to fit MWLs because they would have to be interfaced with tram services, which would be difficult to achieve technically. NTL agreed with Network Rail's conclusions and took no separate action.
- 102 The actions of the parties to whom recommendations 2 and 3 were made have been assessed as adequate by the Office of Rail Regulation²¹.
- 103 Before the accident on 28 November 2012, Network Rail was already developing a scheme for a footbridge as part of a national initiative to replace identified high risk footpath crossings with bridges.

²⁰ Nottingham Express Transit, the public name for the Nottingham tram system.

²¹ The Office of Rail Regulation has a duty under regulation 12(2) of the Railways (Accident Investigation and Reporting) Regulations 2005 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.

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

- 104 Following the accident on 28 November 2012, Network Rail obtained an emergency closure order for the crossing pending the construction of a footbridge over both Network Rail's and NTL's infrastructure. This has obviated the need for the RAIB to make any recommendations relating to the improvement of the crossing.

Recommendations

105 The following recommendations are made²²:

- 1 *The intent of this recommendation is that a review is carried out to determine the most effective means of warning persons who may be in the path of a tram.*

Where not currently the case, tram operators should review whether it is practicable and appropriate for a series of short, urgent, danger warnings, or other audible warning, to be sounded when there is a person on or close to the line who does not appear to be responding to a tram's approach. The review should take account of the human factors implications such as the method of operating the warning. Instructions to drivers should be updated accordingly and briefed as necessary (paragraph 95).

- 2 *The intent of this recommendation is to improve the safety of pedestrian crossings crossed by tramways on segregated lines and where trams run at relatively high speed.*

Tram operators should review the marking of the boundary of pedestrian crossings crossed by segregated tramways where trams run at relatively high speeds. The review should assess the effectiveness of the means of demarcation in the following respects:

- indicating that a pedestrian is entering into a higher risk area; and
- prompting pedestrians to look for approaching trams.

Where appropriate, the review, which should also take account of the emerging findings of RSSB's research project T984, should include identification of proposals to improve the effectiveness of the means of demarcation. Improvements that are appropriate and practicable should be implemented (paragraph 96).

continued

²² Those identified in the recommendations, have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail Regulation to enable it to carry out its duties under regulation 12(2) to:

- (a) ensure that recommendations are duly considered and where appropriate acted upon; and
- (b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 200 to 203) can be found on RAIB's website www.raib.gov.uk.

- 3 *The intent of this recommendation is that the ORR's guidance on tramways be amended so that it gives guidance to tramway operators on the design of pedestrian crossings crossed by segregated tramways where trams run at relatively high speeds.*

The Office of Rail Regulation should, in conjunction with the UK tramway industry, ensure that its current guidance to tram operators on pedestrian crossings crossed by segregated tramways where trams run at relatively high speeds is reviewed and amended as necessary. The review should include consideration of the following factors:

- the means of indicating that a pedestrian is entering into an area of higher risk; and
- the means of prompting pedestrians to look for approaching trams (paragraph 96).

- 4 *The intent of this recommendation is for Network Rail and tram operators to issue guidance to their staff and contractors on the best way to illuminate pedestrian crossings while minimising any visual impairment of pedestrians when looking out for approaching trains/trams.*

Network Rail and tram operators should provide guidance to their staff or other third party on the best means to illuminate pedestrian crossings, when necessary, taking into account the following factors:

- sufficient illumination of the crossing surface to enable pedestrians to see it;
- the possible impact on the visual capabilities of pedestrians using the crossing, in particular with respect to glare affecting their ability to detect approaching trains/trams; and
- relevant findings from RSSB research project T984 (paragraph 98).

Appendices

Appendix A - Glossary of abbreviations and acronyms

FFCCTV	Forward Facing Closed-Circuit Television
MWL	Miniature Warning Lights
NTL	Nottingham Trams Limited
ORR	Office of Rail Regulation
OTDR	On-Tram Data Recorder

Appendix B - Glossary of terms

Brightness	How much luminous power an observer will detect while looking at a surface from which light is being emitted. It may be classed in a range from very dim to very bright, or glaring.
Conspicuity	A subjective term which relates to how easy it is for an object to capture the attention of an observer.
dB(A)	A commonly used unit of measurement for measuring the loudness of sound weighted to simulate the frequency response of human hearing. Because it requires about a tenfold increase in power for a sound to register twice as loud in the human ear, a logarithmic scale is used for comparing sound intensity. This means that each increase of 10 dB(A) corresponds to a tenfold increase in intensity and a doubling of loudness.
Disability glare	Glare is the visual consequence of viewing light sources of significant brightness. It may be classed in a range from discomfort glare to disability glare, where disability glare affects the observer's visual perception.
Emergency closure order	An order issued by a local authority that closes a public footpath on the grounds that it is dangerous for use by the public.
Frequency	The number of occurrences of a repeating event per unit time.
HM Railway Inspectorate	The railway and tramway safety regulator for Great Britain between 1990 and 2006, when it became part of the Office of Rail Regulation.
Luminous intensity	The amount of light emitted by a point light source in an infinitesimal cone divided by the angle of the cone. Normally measured in candelas, it can be converted to lux by dividing by 625.
Lux	A measurement of the amount of light per unit area falling onto a surface.
Miniature warning lights	Small red and green lights mounted on a board adjacent to a crossing and operated by the passage of trains. Also called miniature stop lights.
Office of Rail Regulation	The safety regulator for the railways of Great Britain.
Sound pressure level	A logarithmic measure of the effective sound pressure of a sound relative to a reference value. It is measured in decibels (dB) above a standard reference level.
Warning time	The shortest time for trams to travel from the point at which they become visible to arriving at the crossing as seen by a pedestrian located at the place where they make a decision whether or not it is safe to cross the tramway.

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