



Rail Accident Investigation Branch

Rail Accident Report



**Fatal collision between a tram and a pedestrian,
near Saughton tram stop, Edinburgh
11 September 2018**

Report 09/2019
July 2019

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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Preface

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. 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.

The RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where the RAIB has described a factor as being linked to cause and the term is unqualified, this means that the RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident. However, where the RAIB is less confident about the existence of a factor, or its role in the causation of the accident, the RAIB will qualify its findings by use of words such as 'probable' or 'possible', as appropriate. Where there is more than one potential explanation the RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, words such as 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the event being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of the RAIB, expressed with the sole purpose of improving railway safety.

Information about casualties is based on figures provided to the RAIB from various sources. Considerations of personal privacy may mean that not all of the actual effects of the event are recorded in the report. The RAIB recognises that sudden unexpected events can have both short and long term consequences for the physical and/or mental health of people who were involved, both directly and indirectly, in what happened.

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.

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Fatal collision between a tram and a pedestrian, near Saughton tram stop, Edinburgh 11 September 2018

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Summary

At 12:10 hrs on Tuesday 11 September 2018, a pedestrian who was using a footpath crossing near the Saughton tram stop, was struck and fatally injured by a tram travelling at 53 km/h (33 mph) from Edinburgh city centre towards Edinburgh airport.

The pedestrian was seemingly unaware that the tram was approaching when he walked onto the crossing. The evidence indicates that from the point where he would have had a clear view of the approaching tram, he was not looking out for trams. He may have looked earlier, but would not have had a clear view of approaching trams from the footpath.

The investigation found that although the tram driver had used the tram's bell to sound repeated warnings on the approach to the crossing, this audible warning was not sufficiently loud for it to be heard and acted upon by the pedestrian until it was too late.

The RAIB found that the tram's audible warning devices were not sufficiently loud to provide an effective warning to pedestrians under many operational circumstances. It also found that Edinburgh Trams Limited did not have a process in place for regularly reviewing the risks at its off-street pedestrian crossings.

The RAIB has made four recommendations. One of the recommendations is for Edinburgh Trams Limited to improve the audibility of its trams' warning devices. Another recommendation is for it to identify the risk factors associated with its off-street pedestrian crossings and to develop a process for regularly reviewing the risk control measures. Two further recommendations are made to the Light Rail Safety and Standards Board (LRSSB). One is to improve the current guidance on the audibility of tram warning devices and another is to improve the guidance on the design and layout of tram footpath crossings. The report also identifies a learning point concerning the importance of maintaining records relating to risks that have been identified during project safety assurance processes, and requesting appropriate technical expertise where necessary.

Introduction

Key definitions

- 1 Metric units are used in this report, except when it is normal practice to give highway speeds in imperial units. In such case the equivalent metric value is also given.
- 2 The report contains abbreviations and acronyms. These are explained in Appendix A. Sources of evidence used in the investigation are listed in Appendix B. Urgent safety advice issued by the RAIB during the course of the investigation, is contained in Appendix C.

The accident

Summary of the accident

- 3 At 12:10 hrs on Tuesday 11 September 2018, a pedestrian who was using a footpath crossing near Saughton tram stop (figure 1), was struck and fatally injured by a tram travelling at 53 km/h (33 mph) from Edinburgh city centre towards Edinburgh airport. The pedestrian was crossing the tram lines in a northbound direction, having just finished his morning duties as a bus driver.

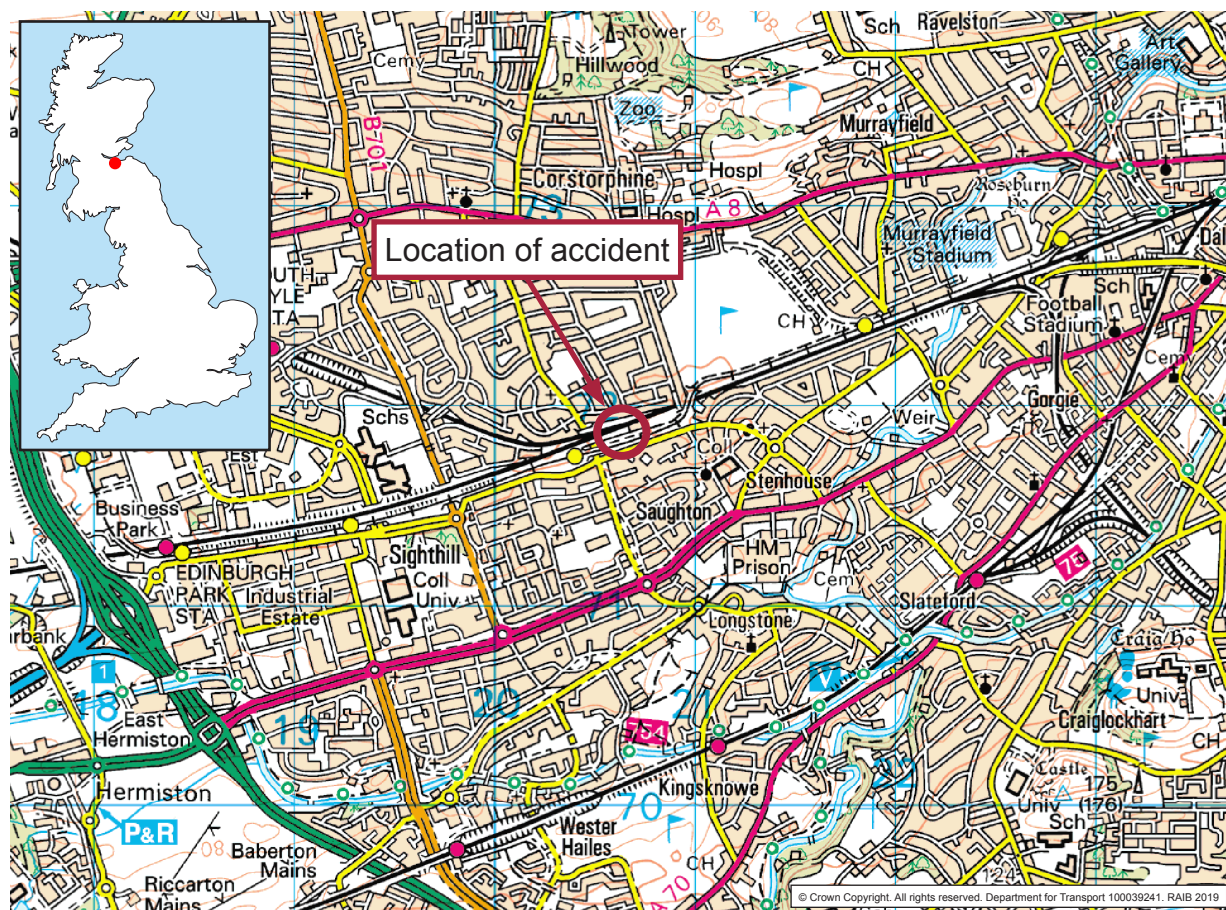


Figure 1: Extract from Ordnance Survey map showing location of accident

Context

Location

- 4 The footpath crossing is located between Balgreen tram stop to the east and Saughton tram stop to the west. It is the most westerly of three crossings on this section of the line and links Stenhouse Drive to the south and Saughton Mains Street to the north (figure 2).

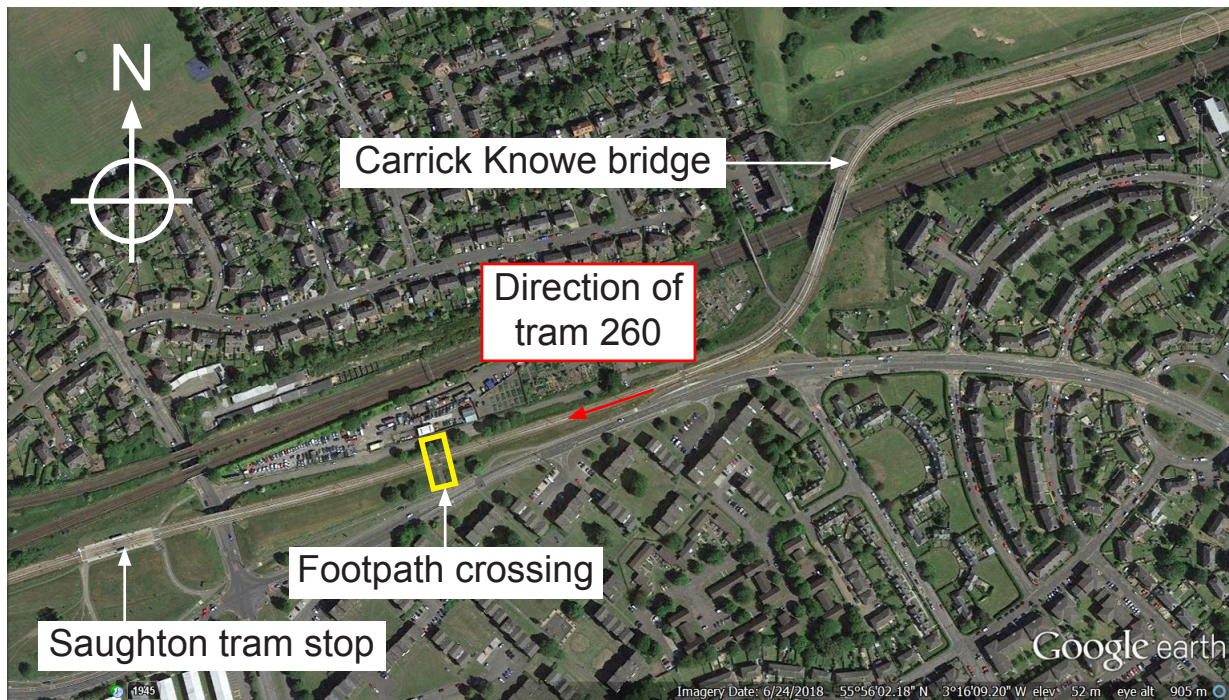


Figure 2: The location of the footpath crossing

- 5 Trams run on two tracks, one for each direction of travel (figure 3). The maximum permitted speed on both tracks at the time of the accident was 70 km/h (44 mph). The crossing is in an off-street section of the tramway and pedestrians must look both ways and judge when it safe to cross. Unlike crossings in the on-street sections of the system, there are no pedestrian light signals.

Organisations involved

- 6 Edinburgh Trams Limited is the operator of the tram system and employs the tram driver. It is referred to in this report as Edinburgh Trams.
- 7 Transport for Edinburgh was created in October 2013. It is the parent company and owner of Edinburgh Trams Ltd and is wholly owned by the City of Edinburgh Council. During the planning and design stages of the tram system, Transport Initiatives Edinburgh Ltd (referred to in this report as Tie Ltd), was set up to manage the tram project. Tie Ltd was a non-profit organisation wholly owned by the council and it was responsible for managing the safety verification process (paragraph 106) until 2008 when the City of Edinburgh Council took over this role directly. This remained the case until May 2014 when Edinburgh Trams Ltd became the duty holder.
- 8 Construcciones y Auxiliar de Ferrocarriles, SA (CAF) is the manufacturer and maintainer of the Edinburgh tram fleet.
- 9 Lothian Buses Limited was the employer of the pedestrian.
- 10 All parties freely co-operated with the investigation.

Tram involved

- 11 The tram involved was number 260, one of 27 trams manufactured by CAF for Edinburgh Trams and delivered before the tram system fully opened in May 2014. All of the trams are of the type known as 'Urbos 2'.



Figure 3: The approach to the footpath crossing looking north

- 12 The trams are fitted with a service brake, an emergency brake and a security brake. The emergency brake, which was used by the driver on the approach to the crossing, applies both the service brake equipment and a magnetic track brake to provide a higher level of retardation than the service brake alone.
- 13 The trams are also fitted with an external electrical sounder at each end to provide audible warnings to pedestrians and vehicles. The sounder is capable of producing two different warnings, commonly known as the 'bell' and the 'horn'. Generally on trams in the UK, the bell is used in on-street sections, and the horn is used in off-street sections and in emergencies.
- 14 The tram was equipped with forward facing closed-circuit television (FFCCTV) and an on-tram data recorder (OTDR). CCTV evidence from Balgreen tram stop shows that the tram's front lights were correctly illuminated prior to the accident.

Staff involved

- 15 The tram driver commenced driver training in September 2016 and passed out as a tram driver in December 2016. Company records indicate that the driver had undergone regular assessments of his competence. The last monitored assessment prior to the accident was on 28 June 2018, and his assessor noted that he had no concerns with his driving.
- 16 Following the accident, the tram driver was breathalysed by the police and his employer screened him for drugs and alcohol. All results were clear.

The pedestrian

- 17 The pedestrian began working for Lothian Buses Limited as a bus driver in July 2018. Following a period of training he began working rostered duties on 5 August 2018.
- 18 On the day of the accident, his morning rostered duty started and finished at a bus stop on Stenhouse Drive, close to the crossing. He had undertaken this rostered duty the previous day and once during the previous week, and it is likely that he had used the crossing on those occasions. He may also have used the footpath crossing on other occasions.

External circumstances

- 19 Local weather records indicate that at the time of the accident, it was mild, dry and partially cloudy. The sun was not in a position where it could have been shining in the pedestrian's eyes.
- 20 Records indicate that there was a gusty wind ranging from 23 mph (37 km/h) to 36 mph (58 km/h) blowing along the tram tracks from a west-south-westerly direction (ie towards the approaching tram). The wind may have affected the ability of the pedestrian to hear the oncoming tram. This is discussed further in paragraph 59.
- 21 Although the wind may have carried some traffic noise from nearby roads, the CCTV evidence indicates that the road traffic was light at the time of the accident.

The sequence of events

Events during the accident

- 22 On the day of the accident, the pedestrian drove from his home and parked his car on Saughton Mains Street. He then walked south over the footpath crossing to begin his first driving duty of the day at 09:56 hrs from Stenhouse Drive. He completed this at 12:07 hrs when he returned his bus to Stenhouse Drive. This was approximately five minutes later than scheduled, because he had experienced problems deploying an accessibility ramp at a previous bus stop.
- 23 Witness evidence and CCTV footage recorded on the bus show that following a brief discussion with the relieving driver, the pedestrian crossed over Stenhouse Drive and walked along the footpath leading to the crossing in the direction of where his car was parked. His next planned rostered duty was at 13:18 hrs from another location involving either a car drive of about five minutes duration, or a walk of about twenty minutes.
- 24 Tram 260 left Balgreen tram stop at around 12:08 hrs heading west towards the airport. Before it reached the section running parallel to Stenhouse Drive, the driver slowed the tram on the approach to the Carrick Knowe bridge (figure 2), which passes over the mainline railway. Shortly after the bridge, as the tram track straightens, the maximum permitted speed increases from 40 km/h (25 mph) to 70 km/h (44 mph). The data recorder indicates that the tram reached a maximum speed of 66 km/h (41 mph) on this stretch of track.
- 25 The driver removed power and applied light service braking when the tram was approximately 73 metres from the crossing (figure 4). Images from the tram's FFCCTV indicate that this is close to the point at which the pedestrian first became visible on the footpath, when he was approximately 6 metres from the nearest rail of the crossing. Prior to this the pedestrian was not visible to the tram driver because of bushes present along the right-hand side of the footpath, and two trees by the southern side of the tramway (paragraph 43).
- 26 When the tram was approximately 53 metres away from the crossing, the driver sounded the warning bell. The OTDR recorded this action as three separate soundings within a period of 1.5 seconds, with the final sounding made when the tram was 26 metres away from the crossing.
- 27 The driver then applied the emergency brake when it became clear that the pedestrian was not responding to the audible warnings. The tram was travelling at around 61 km/h (38 mph) at this time and was 18 metres from the pedestrian (figure 5), who was by then stepping onto the crossing.
- 28 The design of the tram is such that the 'horn' audible warning is automatically sounded when the emergency brake is activated. Once this had occurred, the pedestrian responded to the presence of the tram by attempting to reverse his direction of travel as he reached the centre of the track on which the tram was travelling.
- 29 The tram collided with the pedestrian at a speed of around 53 km/h (33 mph) and stopped around 32 metres beyond the crossing.



Figure 4: Image from the FFCCTV of tram 260 at around 73 metres from the crossing and 4.6 seconds before the collision. The arrow indicates the location from which the pedestrian emerges very shortly afterwards.



Figure 5: Edited image from the FFCCTV of tram 260 at around 18 metres from the crossing and 1.2 seconds before the collision. The rectangle indicates the location of the pedestrian.

Events following the accident

- 30 The tram driver made an emergency phone call to the tram control centre to report the accident, while the ticket services assistant on board the tram phoned for an ambulance. A doctor on board the tram attended to the pedestrian. The police arrived at the scene within 10 minutes followed by an ambulance.
- 31 Tram services were disrupted until 18:06 hrs when normal service was restored.

Key facts and analysis

Background information

- 32 On the Edinburgh tram system, trams are driven in accordance with the 'line of sight' principle. This requires drivers to be prepared to stop before reaching any obstruction by using the service brake in a similar way to road vehicles being driven on the highway. Trams are not required to stop or slow down while approaching crossings unless it is evident to a driver at, or before the service braking distance, that the crossing may still be obstructed when the tram reaches it.
- 33 At the time that the tram system was being designed and constructed, the applicable guidance was 'Railway Safety Publication 2, Guidance on Tramways', November 2006 (RSP2). This was published by the UK's safety regulator for railways and tramways, the Office of Rail Regulation (now known as the Office of Rail and Road (ORR)).
- 34 The crossing is one of five uncontrolled pedestrian crossings on off-street sections in Edinburgh where the maximum permitted speed of trams is 70 km/h (44 mph). An uncontrolled crossing has no pedestrian light signals and requires pedestrians to look for approaching trams and cross only when it is safe to do so. During the design of the tram system, the project team decided the type of crossing to be provided, as well as the choice of pedestrian safety features to be included in the design.

Identification of the immediate cause

35 **The pedestrian moved into the path of the tram as it approached the crossing.**

- 36 The pedestrian walked directly into the path of the tram when it was about 18 metres away. While it cannot be discerned with certainty, evidence from the FFCCTV indicates that he did not look towards the approaching tram in the last seconds before stepping onto the crossing.

Identification of causal factors

- 37 The accident occurred due to a combination of the following two causal factors:
- a) the pedestrian was seemingly unaware of the approaching tram until he was in its path (paragraph 38); and
 - b) the driver was unable to stop the tram before it reached the crossing when it became clear that the pedestrian was going to walk onto the crossing (paragraph 66).

Each of these factors is now considered in turn.

Unawareness of the approaching tram

- 38 **The pedestrian was seemingly unaware of the approaching tram until he was in its path.**
- 39 The action of the pedestrian trying to reverse his direction of travel after he had entered the crossing, probably as a response to hearing the horn when the tram's emergency brake was applied (paragraph 28), suggests that he was previously unaware of the approaching tram.
- 40 This causal factor arose due to a combination of the following:
- i. the pedestrian did not appear to look out for trams during the time the tram was visible, prior to him stepping onto the crossing (paragraph 41); and
 - ii. the tram's bell was not sufficiently audible when it was sounded as a warning (paragraph 55).

Each of these factors is now considered in turn.

Sighting of approaching trams from the footpath

- 41 **The pedestrian did not appear to look out for trams during the time the tram was visible, prior to him stepping onto the crossing.**
- 42 Photographs taken following the accident show that airport bound trams would be visible from the footpath when viewed from distances closer than approximately 6 metres from the nearest running rail of the crossing (figure 6). Images from the FFCCTV of the tram show that the pedestrian became visible when at this distance from the crossing, and the images suggest that the pedestrian did not look, or change his stride beyond this point until just before the collision.



Figure 6: The view to the east from the footpath at 6 metres from the crossing

- 43 It is possible that the pedestrian may have looked for approaching trams while he was still some way away from the crossing as he walked towards it. However, clear views of the tramway to the east from the footpath are interrupted by bushes on the edge of the footpath (figure 7) and two trees adjacent to the track (figure 8).



Figure 7: The view to the east from the footpath at 14 metres from the crossing



Figure 8: The view to the east from the footpath at 8 metres from the crossing

- 44 The bushes and trees also obscured an earlier sighting of the pedestrian by the tram driver. The trees have since been removed (paragraph 137).
- 45 The pedestrian had passed a D4 medical examination¹ required for driving public service vehicles in May 2017. That type of medical examination includes an assessment of both visual acuity and visual field. Although he had previously been diagnosed with a deep cataract in the left eye, this is not thought to be a factor because his vision was adequate for bus driving. Additionally, the CCTV evidence indicates that he did not turn his head towards the approaching tram just before he started crossing the tram lines.
- 46 The medical examination did not include a hearing test. However, the RAIB found no evidence of impaired hearing which might have contributed to the accident, or that he was using a mobile phone, or wearing ear phones, at the time of the accident.

The actions of the pedestrian

- 47 The images from the CCTV fitted to the bus that the pedestrian had just driven, show that as he walked towards the crossing he was possibly removing some items from the bag that he was carrying. This may have been his mobile phone and/or car keys which were found on the ground following the accident. When he was close to the crossing, he swung his bag over his left shoulder. These actions may have distracted him from looking to his right for trams when the approaching tram was visible.
- 48 The RAIB obtained the pedestrian's working records from Lothian Buses Limited. These showed that it was likely that he had used the crossing on previous occasions (paragraph 18). Although it is not known whether he had encountered a tram passing along this section of the line when crossing, it is considered likely.

Fatigue

- 49 Evidence provided to the RAIB by the pedestrian's family indicates that he had been feeling tired prior to the day of the accident, possibly due to his working patterns and the quality of his sleep.
- 50 The RAIB analysed his work patterns based on good practice guidelines in fatigue risk management² published by the ORR. Although this guidance is used in the rail industry, the factors which affect human fatigue identified in the guidance are derived from general guidance applicable to all industries. The public service vehicle sector, uses other guidance³. Application of the ORR guidelines suggests his working patterns may have contributed to his fatigue. In particular, his cumulative working hours exceeded the guideline value of 55 hours in a rolling seven-day period; backwards rotation⁴ of his start times; and having had less than a 12 hour rest period between some of his duties. The ORR guidance states that fatigue can adversely affect both levels of awareness and reaction time.
- 51 Lothian Buses Limited has advised the RAIB that it has also analysed the pedestrian's working hours and that his rostered hours are within the limits stated in the Driver and Vehicles Standards Agency (DVSA) guidance.

¹ <https://www.gov.uk/government/publications/d4-medical-examiner-report-for-a-lorry-or-bus-driving-licence>.

² https://orr.gov.uk/_data/assets/pdf_file/0005/2867/managing_rail_fatigue.pdf.

³ <https://www.gov.uk/guidance/drivers-hours-passenger-vehicles>.

⁴ Backwards rotation is when the start of a shift is earlier than the start of the previous shift on consecutive days.

The layout of the crossing

- 52 The ORR's guidance for tramways, titled 'Pedestrian Safety'⁵, recommends that active and passive guidance measures be considered in the design of pedestrian crossings as necessary, depending upon location. Methods of pedestrian control to be considered include:
- provision and delineation of pedestrian crossings;
 - signage;
 - active deterrents such as barriers, paving, planting, etc; and
 - passive deterrents such as marking the tramway path.
- 53 The safety features at the crossing consisted of two back-to-back 'tramway' signs on each side of it, and an area of tactile paving on the footpath approaches (figure 3).
- 54 The RAIB noted that the tarmac surface on the footpath approach continues over the crossing giving the impression of a continuous path and the tramway rails are not distinctive from the crossing's surface. Other than the tactile paving, there are no other distinctive features, such as ground markings, which would indicate to a pedestrian that they are entering an area of higher risk. Additionally, there are no physical features, such as chicane fencing, to cause pedestrians to change their walking pattern and turn them to face approaching trams on the track closest to them. Such measures are employed at some locations on other tram systems.

The audibility of the tram's warning bell

55 The tram's bell was not sufficiently audible when it was sounded as a warning.

- 56 The RSP2 guidance (paragraph 33) recommends that a tram's audible warning device should produce two levels of sound where trams run both on-street and off-street.
- 57 The quieter of the two levels is to alert people to the tram's presence when running on-street, and this sound should be distinctive compared to warnings given by other road vehicles. The greater sound level is intended for emergencies on-street and when travelling off-street when a warning is required for staff working on the track. It is common practice on tramways in the UK that the quieter level of warning is provided by a bell⁶, and the greater level by a warning horn. However, it was custom and practice that Edinburgh tram drivers used the bell as their preferred method to sound an urgent warning (paragraphs 94 and 95).

⁵ 'Pedestrian Safety', Tramway Technical Guidance Note 2, October 2008.

⁶ The practice is to use a recording of a bell, or whistle, played via an electronic sounder, and not a physical bell.

58 Following the accident, the RAIB commissioned a specialist consultant to carry out acoustic measurements to investigate the audibility of the bell as tram 260 approached the crossing (figure 9). Sound pressure level measurements of the tram's horn were also taken as this is an alternative method of warning provided on the tram, although it was not used on this occasion until the tram was very close to the crossing (paragraph 28). Additionally, measurements were taken of the sound pressure levels of the bell and the horn of another tram which were found to be of a similar level as those of tram 260, when both were measured on level ground in the depot.

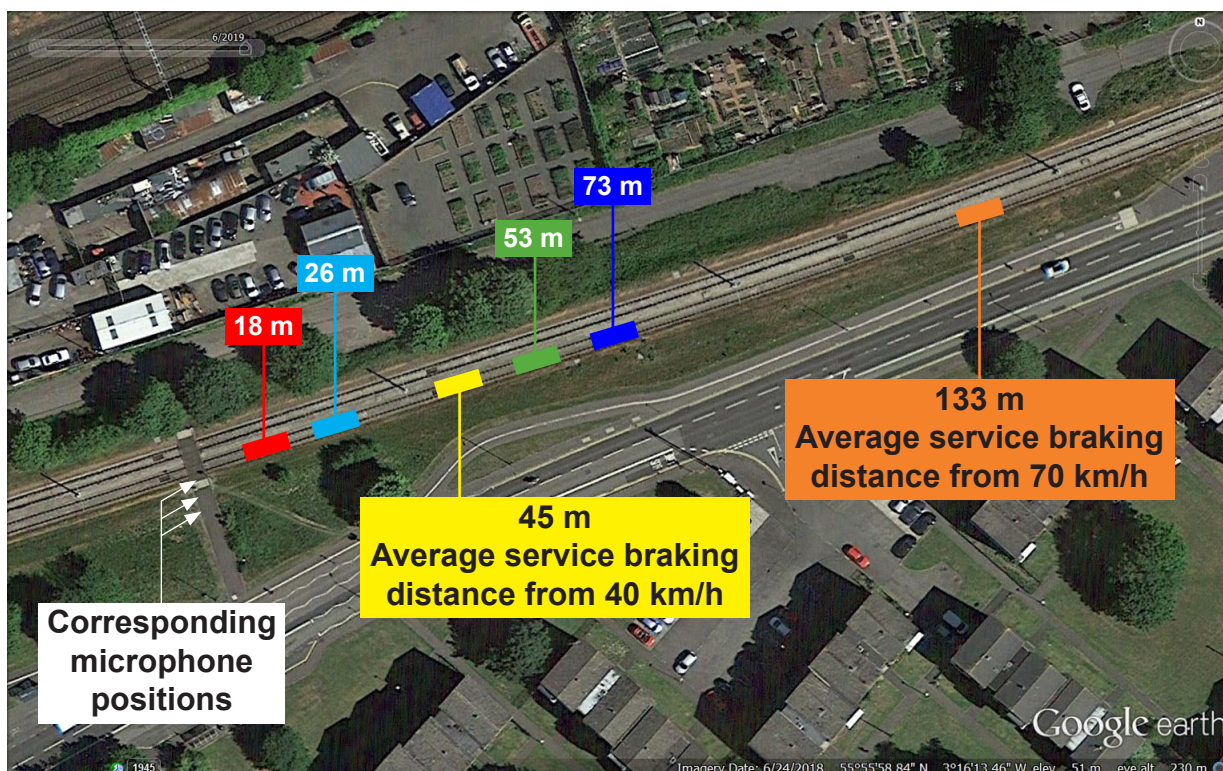


Figure 9: Distances of tram 260 from the crossing during the sound pressure level measurements

59 Some of the measurements were carried out during the night. At the time, the wind was from the same direction as at the time of the accident. However, the wind speed during the measurements was between 3 and 6 mph (5 and 10 km/h), which was significantly lower than the wind speeds on the day of the accident (paragraph 20). There was a low level of background noise as the road traffic was very light. The higher relative effect of the wind at the time of the accident has not been assessed, but since its direction was towards the approaching tram, it may have adversely affected the pedestrian's ability to hear the warning bell, beyond that suggested by these tests.

- 60 The RAIB previously investigated a pedestrian fatality on a Nottingham tram footpath crossing in 2012⁷ (paragraph 125). In that investigation the horn of the tram involved was found to emit a maximum sound pressure level of 107 dB(A)⁸, when measured at a distance of 2 metres. The equivalent measurements of the warning horn of tram 260 was 91.5 dB(A). Sound pressure levels are not a direct measurement of loudness as perceived by the human ear, but it is widely accepted that an increase in sound pressure level of 10 dB is a doubling of perceived loudness⁹. In broad terms this means that the perceived loudness of the horn of tram 260 was significantly less than half of that measured on a Nottingham tram.
- 61 Additionally, following the accident, sound pressure level measurements of the ambient noise were taken from the footpath close to the crossing at the same time of day as that of the accident. It was noted that the road traffic levels at the time of the measurements were similar to those at the time of the accident (paragraph 21). From this a mean background sound pressure level value of 60.5 dB(A) was calculated.
- 62 The bell and horn sound pressure levels relative to the mean background level were calculated from the measurements for the range of distances of the tram from the crossing shown in figure 9. This enabled the audibility of the tram horn and bell to be assessed relative to general background noise. Figure 10 shows a plot of the sound pressure levels of the bell and horn of tram 260 relative to the background level at different distances from the crossing. The mean background level is equivalent to the value of zero on the vertical axis in the figure.
- 63 Research¹⁰ indicates that reliable detection of warning devices is marginal when the sound is between 5 and 15 dB(A) above the background level, and reliably detectable between 15 and 25 dB(A) above it. From figure 10, it can be seen that the sound pressure levels of the bell and horn relative to the background level reached 15 dB(A) when the tram was less than around 20 metres from the crossing. At distances greater than 20 metres, it becomes less likely that a pedestrian will notice the audible warning unless they are actively listening for it. At tramway crossings, unlike at railway footpath crossings, the signs do not advise pedestrians to listen out for trams before crossing.
- 64 The poor audibility of the tram's bell almost certainly explains why the pedestrian did not respond to the sounding of the bell when it was sounded repeatedly on the approach to the crossing (paragraph 26). The pedestrian appears to have responded only when the warning horn was sounded when the tram was close enough for the sound pressure level to achieve an increase of approximately 15 dB(A) above the background level. This was when the emergency brake was applied, and was too late to avoid a collision (paragraph 28).

⁷ Fatal accident at Bayles and Wylies footpath crossing, Bestwood, Nottingham ([RAIB report 19/2013](#)).

⁸ The unit dB(A) is a weighting of the measurement of sound pressure level defined within the International standard IEC 61672:2003. The 'A' indicates the level of weighting to account for the relative loudness perceived by the human ear.

⁹ <http://www.sengpielaudio.com/calculator-loudness.htm>.

¹⁰ Referred to in RSSB/AEATR-PC&E-2004-002 Issue 3 'Audibility of Warning Horns', AEJ Hardy, 2004, and Catchpole, K. & McKeown, D. (2007). A framework for the design of ambulance sirens. *Ergonomics* 50(8), 1287 – 1301.

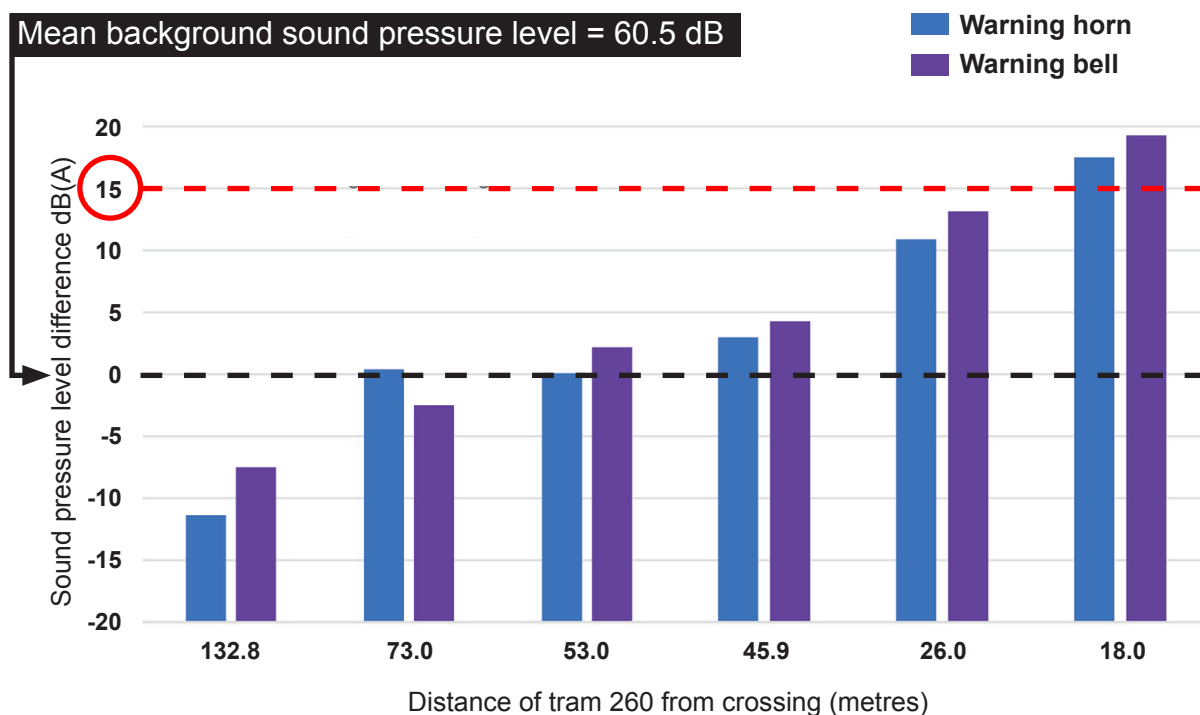


Figure 10: Sound pressure level differences of the bell and horn of tram 260 compared with the mean typical background sound level measured at the crossing, with zero on the y-axis being equivalent to the background sound pressure level of 60.5 dB(A). The red line represents a 15 dB(A) increase over the background level.

65 The test results also indicated that the sound pressure level of the horn is lower than that of the bell. Therefore, had the tram's warning horn been sounded earlier instead of the bell, it is unlikely to have been any more effective as a warning to the pedestrian.

The speed of the tram and its braking distance

66 The driver was unable to stop the tram before it reached the crossing when it became clear that the pedestrian was going to walk onto the crossing.

67 The tram reached a maximum speed of 66 km/h (41 mph) on the approach to the crossing (paragraph 24), which was below the maximum permitted speed of 70 km/h (44 mph).

68 Analysis of the OTDR indicates that the driver responded to seeing the pedestrian approaching the crossing by lightly applying the service brake to reduce the tram's speed from 66 km/h (41 mph) to 61 km/h (38 mph) and sounding the bell repeatedly (paragraphs 25 and 26). When it became clear that the pedestrian was not going to stop, the driver applied the emergency brake (paragraph 27).

69 Police Scotland commissioned independent testing of the tram's service and emergency brakes following the accident. This, and RAIB's analysis of the OTDR, showed that the tram's braking performed as it had been designed to do and was within the specified requirements¹¹.

¹¹ Braking distances specified within European Standard BS EN 13452-1-2003 Railway applications – Braking - Mass transit brake systems, Part 1: Performance requirements.

- 70 The distance in which the tram could stop under full service braking, from the maximum permitted speed on this section of 70 km/h (44 mph), was found to be 133 metres. Had the driver applied full service braking from a distance of 73 metres, when the pedestrian first became visible to him and when travelling at a speed of 66 km/h (41 mph), the tram would not have been able to stop before it reached the crossing.
- 71 The emergency braking distance from 70 km/h (44 mph), measured in the post incident testing, was 54 metres. Although this indicates that the tram could have been stopped before the crossing if the driver had applied the emergency brake when he first saw the pedestrian, it is not practical to drive trams using the emergency brake every time a pedestrian approaches a crossing. The driver correctly made a cautionary service brake application and sounded the audible warning. He applied the emergency brake when it became clear to him that the pedestrian was not going to stop. By the time it was obvious that the pedestrian was not going to stop, the tram was around 18 metres away and was unable to stop even though the emergency brake had been activated. As such, the circumstances of this accident highlight the importance of trams having effective audible warning horns.
- 72 Although the maximum permitted speed on the approach to the crossing was 70 km/h (44 mph), Edinburgh Trams had issued a document to its driver trainers before operations began in 2014 which suggested driving at a speed between 50 to 55 km/h (31 to 34 mph) in this section of the line because of the hazards associated with the three pedestrian crossings close to each other (paragraph 4).
- 73 Edinburgh Trams has told the RAIB that throughout their training and assessments, all drivers are advised to drive within this reduced speed range over this section of line, but it was also permissible to drive above this advised speed if no hazards are visible to the driver.
- 74 The driver stated that he was aware of the 50 to 55 km/h (31 to 34 mph) advisory speed. However, by the time that the tram was accelerating after leaving the bridge, he could see no hazards ahead of the tram and he could not see the pedestrian due to the bushes on the footpath and the trees by the side of the line (paragraph 44). Had the tram been travelling at 50 km/h (31 mph) when he applied the emergency brake at around 18 metres from the crossing, the driver would not have been able to stop the tram before reaching it, although it would have passed over the crossing more slowly. It would also have given the pedestrian more time to react to the tram's approach.

Identification of underlying factors

Crossing risk assessment

- 75 **During both the tramway's design and operation, the risks associated with the crossing's layout, mutual visibility, tram audibility, line speed and braking distance, had not been adequately assessed.**
- 76 The tram lines running parallel to Stenhouse Drive follow the route of the former West Edinburgh Busway which was in use from 2004 to 2009. The footpath leading from Stenhouse Drive was constructed to allow pedestrian access to a bus stop known as Saughton East halt (figure 11). The halt was also accessible from Saughton Mains Street to its north. The crossing was fitted with pedestrian operated traffic lights and there was a 20 mph (32 km/h) maximum speed limit over the crossing. The RAIB has been informed by the ORR that this reduced speed limit, from the general maximum limit of 30 mph (48 km/h), was to reduce the risk of buses becoming unguided as they passed over the crossing.



Figure 11: The Saughton East bus halt and crossing on the former West Edinburgh Busway (Richard Webb [CC BY-SA 2.0 (<https://creativecommons.org/licenses/by-sa/2.0/>)])

- 77 Documents provided to the RAIB indicate that during the design phase, the project designer's recommendation was to keep the footpath for pedestrians to walk between the two roads which it connected. This, and four other crossings in the off-street sections of the system with a maximum permitted tram speed of 70 km/h (44 mph), were to be uncontrolled crossings, meaning there would be no pedestrian lights at these crossings. Apart from the signs and the tactile paving there were to be no additional features at this crossing to warn, or protect pedestrians from trams (paragraph 52).
- 78 The RSP2 guidance stated that fencing or pedestrian guard rails should be provided where necessary, to guide pedestrians to face oncoming trams before they cross the track, although specific situations are not described. Chicane fencing has been used at some locations on other tramways to make pedestrians visually aware that they are entering an area of increased danger, make them alter their walking pattern and turn them to face approaching trams on the nearest track (figure 12).



Figure 12: An example of chicane fencing on a footpath crossing on the Nottingham tram system. The tram in the picture is travelling on the closer of the two tracks from right to left.

- 79 The basis for having no additional safety features at this crossing was that the change from the guided busway to a tramway was considered by the project team not to fundamentally change the risk to crossing users. The reasons given were that both operated over this section on the 'line of sight' principles (ie the bus or tram driver should drive in such a way as to be able stop before reaching a reasonably visible stationary obstruction ahead), the area was well lit and the rails provided a distinct visual marker similar to that provided by the kerb of a road. The independent competent person (ICP) undertaking the safety verification process for the tramway (paragraph 106), did not disagree with the view of the project team.
- 80 In July 2015 the City of Edinburgh Council conducted a Stage 4 Road User Audit of the tram system. This followed the Stage 1 to 3 audits which had been previously conducted at the appropriate phases of design and construction. The Stage 4 audit was required to be undertaken following one year of operation and included a review of all crossings in the off-street sections. The review recognised that the tram rails on the uncontrolled crossings in these sections were not sufficiently visible to warn pedestrians that they were approaching the tramway. A recommendation was made to add an extra pair of the blue and white tramway signs back-to-back with those already in place, and these were subsequently provided (figure 3).
- 81 Although buses and trams are both driven by 'line of sight', there is no evidence that the project considered that a tram generally has an increased braking distance compared to a bus, as the maximum braking rate of a bus is greater than that of a tram. Also it was not considered that at this location, trams were permitted to run at a greater speed over the crossing than buses were previously.
- 82 Uncontrolled crossings rely on both the pedestrian seeing approaching trams and tram drivers seeing pedestrians so that action can be taken. The reduced visibility due to the shrubs beside the footpath, and more particularly the two trees adjacent to the tram lines, compromised their mutual sighting. The trees were planted as part of the landscaping works following construction. Both RSP2 (paragraph 33) and other guidance¹² state that careful consideration should be given to mutual visibility between tram driver and pedestrians.
- 83 There is no evidence that any visits had been made to the crossing since July 2015 to assess pedestrian safety and to review potentially variable factors such as sighting distances, pedestrian usage and tram frequency. Edinburgh Trams did not have a process in place to regularly review the control measures and potential changes in risk of its off-street section crossings. Visits of this type would be expected to detect any changes in visibility of trams by pedestrians and vice versa, and also assess the audibility of tram warnings on the crossing approaches. Guidance on how to carry out crossing risk assessments was available in a UKTram¹³ document 'Segregated Tramway Crossings Guidance', dated 18 July 2010. UKTram has advised the RAIB that this document was published and later withdrawn in June 2019, and it expects it to be replaced by a document produced by the LRSSB (paragraph 135).

¹² Tramway Technical Guidance Note 2, ORR, 2008.

¹³ UKTram is a body representing operators, promoters, manufacturers, contractors and consultants involved in tramways (<https://uktram.com/>).

- 84 The RAIB considers that on crossings over lines where trams are permitted to operate at higher maximum speeds than on on-street sections, and where braking distances are extended, supplementary measures to assist pedestrians in crossing safely should be covered by guidance.

Audibility of tram warnings

85 There was an absence of clear guidance on the audibility requirements for tram warning devices.

- 86 The guidance within RSP2, which CAF stated that it complied with (paragraph 113), stated that a tram should have two levels of audible warnings for on and off-street running (paragraph 57). It stated that the warning device should be loud enough to indicate the approach of a tram without causing injury or undue alarm to those close by. However, it neither recommends any minimum sound pressure levels, nor any factors to be considered when determining a suitable level.
- 87 In June 2010, the ORR published its 'Tramway Technical Guidance Note 6' (TTGN6)¹⁴, which stated 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'. This guidance also made reference to European Directive 70-388-EC¹⁵ for audible warning devices on motor vehicles. This Directive specified the maximum sound pressure level should be at least 93 dB(A) measured at a distance of 7 metres from the front of the vehicle and at between 0.5 and 1.5 metres above level ground. Although the TTGN6 guidance was introduced at the time the trams were being built, there is no evidence that the tram manufacturer was made aware of this additional guidance.
- 88 Measurements following the accident showed that the horn on tram 260 achieved maximum sound pressure levels of 82.4, 88.6 and 90.1 dB(A) at heights of 0.5, 1.0 and 1.5 metres respectively at a distance of 7 metres. The values at all the measured heights were below the minimum specified by the Directive. The Directive was withdrawn in October 2014. The ORR guidance, and that which has since superseded it (paragraph 96), has not been updated to reflect that change.
- 89 The standard for automotive vehicles is UN ECE R28¹⁶. Although there was no requirement for the horn to have been tested to amendment 3 (1995) of this standard, the post-accident testing of the horn of tram 260 was extended to include tests against amendment 3 and amendment 5 (introduced in 2018).
- 90 Amendment 3 (1995) of UN ECE R28 required automotive horns to produce a minimum sound pressure level of 93 dB(A) at a distance of 7 metres from the front of the vehicle. The sound pressure levels from tram 260 were found to be below the minimum requirements stated in this standard (paragraph 88).

¹⁴ https://webarchive.nationalarchives.gov.uk/20150402090855/http://orr.gov.uk/_data/assets/pdf_file/0019/5077/ttgn6-vehicles.pdf.

¹⁵ 70-388-EC 'COUNCIL DIRECTIVE on the approximation of the laws of the Member States relating to audible warning devices for motor vehicles, 27 July 1970' (Not in force since 31 October 2014).

¹⁶ UN ECE R28 'Uniform provisions concerning the approval of audible warning devices and of motor vehicles with regard to their audible signals', Amendment 3 (1995) and Amendment 5 (2018).

- 91 Amendment 5 (2018) of UN ECE R28 specifies levels to be between 87 and 112 dB(A) within the same range of heights as those in Amendment 3 and from a distance of 7 metres in front of the vehicle. The measurements undertaken on tram 260 (paragraph 88) found that although it was compliant with the requirement at the 1 metre and 1.5 metre heights, it was not compliant at the 0.5 metre high measurement position.
- 92 Information provided to RAIB indicates that during the commissioning stage, drivers had reported that people on or around the track were not responding to the warning horn, but were responding to the bell. In March 2013, when the tram system was being commissioned, the City of Edinburgh Council conducted measurements at the tram depot and compared the sound pressure levels of the bell and the warning horn against the horn of a Lothian bus. Some measurements were also taken during an informal test of one of the trams before it was delivered to Edinburgh. The actual test conditions for both of these are not known, but the reported sound pressure level values are similar to those measured by the RAIB following the accident on tram 260, and on one other tram. There is therefore nothing to indicate that tram 260's horn was faulty at the time of the accident.
- 93 Following the measurements in 2013, the City of Edinburgh Council documented that the tram horn was comparable to that of a bus and it was therefore deemed to be 'adequate'. Further documents state that it would be 'hard to argue that the tram horn does not meet the requirements of RSP2'. However, the RAIB has not found any evidence that indicates consideration of the TTGN6 guidance, or that a tram has an increased braking distance compared to that of a bus at a given speed, or that off-street trams generally run faster than on-street buses.
- 94 The RAIB has concluded that the warning horn does not produce a significantly greater sound pressure level than the bell, as intended by RSP2 (figure 10). Additionally, both types of audible warnings fall below the minimum sound pressure levels values given by relevant guidance. The better discernibility of the bell compared with the horn, commented upon by those about the track (paragraph 92) is more likely due to the frequency of its sound rather than its slightly greater sound pressure level.
- 95 The RAIB found that there was no documented instruction to tram drivers on which warning method to use and in which situations. Edinburgh Trams told the RAIB that it was left to tram drivers to decide this using their professional judgement.
- 96 In January 2018 UKTram issued its Tramways Principles and Guidance document¹⁷. This document, although not retrospective, contained similar guidance to that within RSP2 and the TTGN6 document. It referred to the 70-388-EC Directive (paragraph 87), as does TTGN6. It additionally stated that for emergency and off-street use, a horn similar to those on buses or cars would be considered suitable, with a need to be audible from the service braking distance of the tram. However, no sound pressure levels are specified.

¹⁷ Tramway Principles and Guidance, UKTram, First Edition, January 2018.

- 97 The RAIB considers that for a tram audible warning to be effective at crossings, the minimum sound pressure level should take into account the maximum permitted speed of trams, the braking distance, the background sound level and the sighting distance available at each crossing location.

Sharing best practice in the tram industry

98 The modifications to tram horns at West Midlands Metro did not result in a change to the horns on the Edinburgh trams.

- 99 In 2014 CAF began to deliver its Urbos 3 trams to West Midlands Metro¹⁸ to replace the existing fleet supplied by another manufacturer. The then operator specified that the new trams should have a horn capable of producing a sound pressure level of between 105 dB (A) and 118 dB (A), although no test specification or method (distance from the front of the tram, measurement height, etc.) was prescribed by the operator.
- 100 In 2013 CAF produced a specification for these trams which stated that an electronic sounder would provide the bell warning as well as a quieter level of the horn, which was selectable by the driver. Additionally a pair of electrically operated horns, each producing a different tone, were fitted to provide a louder warning level.
- 101 During the introduction of the new trams on the West Midlands Metro system, it was noticed that the warning horn was less discernible than that of the existing trams. The operator commissioned a study which found that the warning horn sound pressure level of the Urbos 3 vehicles was below, or towards the lower end of the range requested, and below the level of the horns on the existing trams. The West Midlands Metro Urbos 3 trams were subsequently modified and an additional pair of horns were added, resulting in four horns and a sounder at each end. Acoustic measurements following the fitment showed that the modification was successful in achieving the sound pressure level that was requested.
- 102 The consultants undertaking the comparative measurements commented that the horn on the older West Midlands Metro trams produced a sound characteristic that was more distinctive than that of the electric horns on the new trams. This was because the horn was pneumatically operated and despite producing a similar sound pressure level, it produced tonal components at certain frequencies which were more discernible and were likely to be perceived as being louder.
- 103 Edinburgh Trams reported to the RAIB that it was unaware that West Midlands Metro Urbos 3 trams had a different specification for the warning horn and that they had been subsequently modified to improve their audibility. CAF, which is also the maintainer of the Edinburgh tram fleet, told the RAIB that the West Midlands Metro horn was a specific customer requirement, whereas there was no such requirement when the trams for Edinburgh were procured. The RAIB has not found any evidence that this safety related information about audible warnings was formally shared between UK tram operators.

¹⁸ West Midlands Metro is the tram system operating between Birmingham and Wolverhampton.

104 Recommendation 1 of the RAIB's report into the overturning of a tram at Sandilands Junction at Croydon on 9 November 2016 ([RAIB report 18/2017](#)) was targeted at improving the management of safety risk in the UK tram industry by enabling more effective UK-wide cooperation. This includes the provision of authoritative and impartial advice and guidance on matters related to safety and disseminating good practice from both the UK and overseas industries (paragraph 134).

The safety verification process

105 The project's safety verification process did not robustly capture and manage the issue of tram warning audibility.

106 The safety assurance process used in the Edinburgh tram project was known as 'safety verification'. This was a requirement of the 'Railways and Other Guided Transport Systems (Safety) Regulations', 2006, known as the 'ROGS' regulations. These replaced the earlier Railways and Other Transport Systems (Approval of Works, Plant and Equipment) Regulations 1994. Under the earlier regulations a new tramway required approval from the ORR as the safety authority. Under the ROGS regulations, it was a requirement that tramway operators establish a safety management system, and that from 2008 new works and equipment were assured under the safety verification process.

107 The safety verification process is expected to identify potential errors, or failures, in safety critical areas such as the specification and selection of appropriate standards and the design, construction and testing of systems. This is to enable those responsible for the project to take the appropriate preventative, or remedial action, to minimise the risks prior to bringing the equipment, in this case trams, into use.

108 To ensure that risks are identified and controlled, the process is led by an independent competent person, or ICP (this role is known as the 'competent person' under the ROGS regulations). The role of an ICP is to establish, through audit and inspection, that the design meets relevant standards, or has necessary derogations, and that it is 'safe', as far as is reasonably practicable. The ICP's role also includes checking that the system has been properly constructed, installed and tested, and that operational procedures and maintenance arrangements are in place. Since the ICP's role is purely one of verification, the risks are owned and retained by the duty holder, in this case the City of Edinburgh Council until May 2014; then Edinburgh Trams Limited. The ICP for the Edinburgh tram project was appointed in 2007 and acted in this role until 2014.

109 The change in the regulations led to the role of the ORR being limited to checking that projects under ROGS had a documented safety verification system, and that a competent person had been appointed to undertake this task. This was achieved by regular meetings and audits. The ORR has told the RAIB that at no stage was it asked about, or involved in decisions relating to the tram audible warnings, or the crossing design.

- 110 One of the key processes in safety management is the identification of hazards, so that the associated risks can be assessed and controlled. The management of hazards is generally achieved by the use of a hazard log which is a formal system to record hazards that have been identified, assess their possible outcomes, and record ways in which the risk can be reduced or eliminated. It is common that hazards are assigned to an 'owner' who is best able to mitigate any arising risk.
- 111 In 2006, during the planning and design stages of the project, a specification had been created for the trams on behalf of Tie Ltd (who initially was the client for the project until late 2011) and who, at that time, was responsible for the project's safety management system and safety verification. The tram's audible warning device had been identified at the specification stage as one of the safety systems, along with the braking and 'passenger emergency' systems. A hazard log was created, and from 2008 until the tram system became operational in May 2014, it was part of the safety verification activities, which by then was the responsibility of the City of Edinburgh Council.
- 112 The potential of a pedestrian being struck by a tram had been identified at the start of the hazard review process, with one of the possible causes stated as an inadequate tram warning bell or horn. This hazard was recorded in the hazard log and the management of the issue was assigned to CAF as the tram designer.
- 113 In 2009 CAF submitted a document to Tie Ltd showing the compliance of the tram design against the clauses within the RSP2 document. Against the clauses relating to the bell and the horn (paragraph 57), CAF stated that it was compliant with the requirement to produce two levels of warning and referred to the manufacturer's data sheet for the electronic sounder. This stated that it had a nominal maximum sound power level of 110 dB. However, sound power level is not the same as sound pressure level (for reference 110 dB of sound power is approximately equal to 82 dB of sound pressure at 7 metres and 89 dB at 3 metres in free space). The data sheet did not show compliance to any standards relating to sound pressure levels for audible warning devices.
- 114 The ICP reviewed this document and requested further information on the type of audible warning device. A representative of Tie Ltd responded that both a 'bell' and a 'horn' were provided and this was expected to be similar to the trams on the Nottingham tram system. It was agreed that the audible warnings would be reviewed during the testing phase of the tram.
- 115 In December 2009 and March 2010, the ICP inspected the trams, including when they were being tested before being delivered to Edinburgh. In the March and April 2010 period reports sent to Tie Ltd, the ICP reported that the bell and horn functioned adequately, but that compliance with the specified volumes and frequencies was still to be confirmed.
- 116 In April 2010 there was a meeting of the project's safety group which included Tie Ltd and its contractors. The ICP raised the issue of the audible warning devices and the minutes of this meeting recorded that Tie Ltd would ask CAF how this was being closed out. The minutes also state that Tie Ltd would ask one of its team, who was a professional tram driver, to pay attention to this issue when he next visited the tram at the test track.

- 117 The subsequent ICP report at the end of April made no mention of this issue. The RAIB did not find the outcome of the actions that were recorded on the safety group's minutes.
- 118 In November 2010 CAF submitted a design assurance statement to Tie Ltd which included a response to the comments raised by the ICP relating to volumes and frequencies. The response stated that there were no specified volumes and frequencies in the customer's specification and that there were no known standards against which the bell and the horn could be assessed (this was incorrect by June 2010, paragraph 87). CAF stated that the bell and horn on the Edinburgh trams were the same as it had supplied to other tram systems (not in the UK) and therefore had proven service performance.
- 119 The version of the hazard log provided to the RAIB by Edinburgh Trams shows that the hazard of a pedestrian being struck by a tram was 'closed' at the design stage. The mitigations against this hazard included the statements that the tram is driven line of sight, the tram is fitted with emergency braking and exterior lights, and it has a warning bell.
- 120 Although the ICP raised the issue relating to the audible warnings and reported this to the project's safety group, who then passed it on to CAF, it was not formally recorded on the system being used by the project team to monitor and track other safety related issues. Although there were no numerical sound pressure levels specified by RSP2, by 2010 there was such guidance given within TTGN6 (paragraph 87). There is no evidence that the project's safety group or the ICP, sought or requested expert advice, or considered practice from the other established UK tram operators to establish that the trams' audible warnings were sufficiently effective.

Previous occurrences of a similar character

- 121 The RAIB investigated a fatal collision between a tram and a pedestrian on the Nottingham tram system which occurred at Bayles and Wylies footpath crossing on 28 November 2012 ([RAIB report 19/2013](#)). The accident occurred on a segregated section of tram line, where access to the track either side of the crossing was restricted by fencing. Some of the recommendations made are relevant to this accident (paragraph 125).

Summary of conclusions

Immediate cause

122 The pedestrian moved into the path of the tram as it approached the crossing (paragraph 35).

Causal factors

123 The causal factors were:

- a) The pedestrian was seemingly unaware of the approaching tram until he was in its path (paragraph 38). This causal factor arose due to a combination of the following:
 - i. The pedestrian did not appear to look out for trams during the time the tram was visible, prior to him stepping onto the crossing (paragraph 41, no recommendation); and
 - ii. The tram's bell was not sufficiently audible when it was sounded as a warning (paragraph 55, **Recommendation 1**).
- b) The driver was unable to stop the tram before it reached the crossing when it became clear that the pedestrian was going to walk onto the crossing (paragraph 66).

Underlying factors

124 The underlying factors were:

- a) During both the tramway's design and operation, the risks associated with the crossing's layout, mutual visibility, tram audibility, line speed and braking distance, had not been adequately assessed (paragraph 75, **Recommendations 2 and 4**);
- b) There was an absence of clear guidance on the audibility requirements for tram warning devices (paragraph 85, **Recommendation 3**);
- c) The modifications to tram horns at West Midland Metro did not result in a change to the horns on the Edinburgh trams (paragraph 98, no recommendation. See paragraph 134); and
- d) The project's safety verification process did not robustly capture and manage the issue of tram warning audibility (paragraph 105, **Learning point 1**).

Previous RAIB recommendations relevant to this investigation

125 The following recommendations, which were made by the RAIB as a result of its previous investigations, have relevance to this investigation.

[Fatal accident at Bayles and Wylies footpath crossing, Bestwood, Nottingham, 28 November 2012, RAIB report 19/2013](#)

126 Recommendation 1 was as follows:

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.

127 On 29 June 2016, ORR reported to the RAIB that recommendation 1 had been implemented by the operators of the six tramways operating at the time of the RAIB's publication of the report. This did not include Edinburgh Trams which was not in the scope of the RAIB at the time that the report was published¹⁹. The ORR reported to the RAIB that it made Edinburgh Trams aware of recommendation 1, but it did not require a reply. However, it should be noted that the driver of tram 260 at Saughton operated the bell in a series of three short warnings (paragraph 26).

128 Recommendation 2 was as follows:

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.

129 On 24 October 2013 the ORR made Edinburgh Trams aware of the RAIB investigation report and recommendation 2, and asked it to consider what, if any changes should be adopted, but it did not require a reply. Edinburgh Trams was unable to tell the RAIB what actions it took following notification of this recommendation.

¹⁹ Edinburgh Trams came into the scope of the RAIB on 26 May 2015.

130 On 17 June 2016, ORR reported to the RAIB that recommendation 2 had been implemented by the operators of the six tramways operating at the time of the RAIB's publication of the report. It reported that the six tram operators had reviewed their crossings in the light of the RSSB's project and some had made 'modest improvements'.

131 Recommendation 3 was as follows:

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.

132 On 18 September 2014, ORR reported to the RAIB that it had reviewed its existing guidance on tramways and found that it provided adequate guidance. It had agreed that this guidance would be transferred to UKTram whom the ORR expected would review it and to bring it into line with best practice. This responsibility was formalised with UKTram in 2015 via a memorandum of understanding. The RAIB expressed its concerns in its [2014 Annual Report](#) that the actions taken were insufficient to address the risks identified in the investigation.

133 UKTram issued its Tramways Principles and Guidance document in January 2018. This document contained no additional guidance on the issue of crossing design over that contained within RSP2.

[Accident at Sandilands junction, Croydon, 9 November 2016, RAIB report 18/2017, Recommendation 1](#)

134 The above recommendation addresses one of the factors identified in this investigation (paragraph 98). So as to avoid duplication, it is not remade in this report. However, this recommendation and an account of its current status, is shown below. Recommendation 1 was as follows:

The intent of this recommendation is to improve the management of safety risk in the UK tram industry by enabling more effective UK-wide cooperation.

ORR should work with the UK tram industry to develop a body to enable more effective UK-wide cooperation on matters related to safety, and the development of common standards and good practice guidance.

As a minimum, the purpose and aims of this body should be to:

- i. provide a forum for the discussion of common safety issues and the exchange of experience;
- ii. the provision of authoritative and impartial advice and guidance on matters related to safety;

- iii. managing the development of safety related design and operational standards, and their subsequent maintenance;
- iv. participation in the development of industry standards and guidance by international bodies;
- v. sponsoring and project management of the research and development needed to inform the above;
- vi. gathering data, monitoring and reporting on the industry's safety performance (including comparisons of safety performance on different tramways);
- vii. providing suitable guidance on effective safety management, including guidance applicable to public highways;
- viii. working with tramways to help plan industry safety improvement; and
- ix. disseminating good practice from both the UK and overseas industries.

The body should be suitably constituted and funded to enable the effective delivery of the above functions. It should be structured so that ORR promotes, encourages and supports its operation.

- 135 On 5 April 2019 the ORR informed the RAIB that the tramway sector has established a safety and standards body known as the 'Light Rail Safety and Standards Board' (LRSSB). The LRSSB, which is part funded by the Department of Transport, is a subsidiary company of UKTram, with a separate governing body from the main UKTram Board, an independent chair and a board comprising of industry representatives. The ORR has in place formal arrangements to monitor the work of LRSSB.
- 136 The ORR has reported to the RAIB that it considers the role and remit of the LRSSB is capable of enabling more effective UK-wide cooperation on safety matters, and achieving effective implementation of the matters raised in Recommendation 1 of the RAIB's Sandilands report.

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

- 137 Edinburgh Trams has told the RAIB that in December 2018 it had, in conjunction with the City of Edinburgh Council, removed the vegetation which was restricting the clear view of the tram lines to the east of the footpath approach to the crossing.
- 138 On 14 February 2019 the RAIB issued urgent safety advice to Edinburgh Trams with respect of the sound pressure levels of its warning horn (Appendix C). It noted that:
- both the bell and the warning horn are not sufficiently discernible above the level of background noise at this footpath crossing to indicate the approach of a tram at a full service braking distance from the crossing at line speed (as is stated in the current tramway guidance); and
 - the warning horn produces a lower sound pressure level than the bell and can therefore be regarded as quieter.
- 139 The RAIB advised that Edinburgh Trams increase the sound pressure level of the warning horn fitted to its trams and that in the meantime, it should consider measures to mitigate risks at locations where audible warnings may be required. In particular, consideration should be given to the appropriateness of the current warning horn or bell as a method of warning to pedestrians using footpath crossings over off-street track sections with high line speeds.
- 140 On 26 February 2019 Edinburgh Trams informed the ORR that it had:
- begun work with CAF to increase the sound pressure level of the tram horns;
 - issued an urgent operating notice to its drivers to use both the bell and the horn as a warning when the bell alone is not getting the desired response, and
 - implemented four temporary speed restrictions (TSRs) of a maximum speed of 40 km/h (25 mph) in both directions, covering seven of its footpath crossings where the maximum permitted speed had previously been 70 km/h (44 mph), including the five unprotected crossings.
- 141 Edinburgh Trams has told the RAIB that on 27 February 2019 it held a hazard review, in conjunction with the City of Edinburgh Council, of its uncontrolled pedestrian crossings and generated a list of risk mitigation options. On 22 April 2019 it completed the implementation of some of the options at the crossings. This included the use of ground markings and the installation of timber 'knee rails' (a low fence) either side of the footpath where it intersects the tramway, in order to improve the demarcation of the crossings to pedestrians. On 3 July 2019, Edinburgh Trams informed the RAIB that both parties had agreed a delivery programme to implement additional control measures to all of its off-street pedestrian/cycle crossings.

142 On July 2019, Edinburgh Trams informed the RAIB that:

- a. it had modified the horns on all but one of its trams;
- b. was working on a solution to make the horns pulse automatically in response to recommendation 1 of the RAIB report into the tram accident at Bayles and Wylies footpath crossing (paragraph 126);
- c. had undertaken background sound measurements on all of its off-street pedestrian/cycle crossings; and
- d. had updated its training materials regarding the correct use of the tram audible warnings.

143 On 8 May 2019 the RAIB wrote to Lothian Buses Limited to inform it that the hours worked and the pattern of the pedestrian's bus driving duties may have contributed to him becoming fatigued, and that this in turn may have adversely affected his awareness and reaction time when approaching the crossing (paragraph 50). A copy of this letter was also sent to the Traffic Commissioner for Scotland.

Recommendations and learning point

Recommendations

144 The following recommendations are made²⁰:

- 1 *The intent of this recommendation is to improve the audible warnings provided to pedestrians by trams in Edinburgh (paragraph 55).*

Edinburgh Trams Limited should:

- a) increase the audibility of its tram warning horns so that they provide effective warning of approaching trams to pedestrians, in particular at foot crossings on off-street sections of its network. The warning horns should be clearly discernible above the background noise at relevant locations and take into consideration sighting distances and line speeds; and
- b) develop, document, brief and train instructions in which situations it expects its drivers to use the horn as an audible warning.

This recommendation may apply to other UK tram operators.

- 2 *The intent of this recommendation is to improve the safety of pedestrian crossings on off-street sections where trams run at relatively high speeds (paragraph 75).*

Edinburgh Trams Limited should:

- a) undertake risk assessments of all of its pedestrian crossings on off-street sections and identify any necessary control measures. The assessment should include consideration of the crossing layout, sighting distances, line speed, tram braking distances and the audibility of the tram warning horns. Control measures for consideration should include the following safety features:
 - improved demarcation of the crossing; and
 - barriers, chicanes, or similar, to turn pedestrians' direction of travel, just before crossing, to face oncoming trams on the nearest track.

²⁰ 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 and Road (ORR) 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.gov.uk/raib.

b) develop and implement a procedure for monitoring that the control measures identified remain valid.

- 3 *The intent of this recommendation is to establish improved industry guidance for the audibility of warning horns and bells fitted to current and future UK trams (paragraph 85).*

The Light Rail Safety and Standards Board (LRSSB) should develop the guidance for audible warnings devices on both current and future UK trams, so that they provide effective warning of approaching trams. The guidance should define a process so that each tram operator can establish appropriate sound pressure levels and frequencies for warnings that are clearly discernible above background noise and which take into consideration sighting distances, tram braking characteristics and line speeds.

- 4 *The intent of this recommendation is to improve current industry guidance for pedestrian level crossings on UK tram systems, by including lessons from this accident and previous similar accidents (paragraph 75).*

The Light Rail Safety Standards Board (LRSSB) should update and improve the current industry guidance for the design, layout and management of off-street pedestrian level crossings on UK tram systems contained in 'Tramway Principles and Guidance', January 2018. The new guidance should consider lessons from this and previous similar tramway accidents. It should as a minimum include guidance on routine risk assessments of crossings, taking into account sighting distances, line speed, tram braking characteristics and the audibility of warning horns.

Learning point

145 The RAIB has identified the following key learning point²¹:

- 1 For those responsible for the safety verification of new tram or railway systems, this investigation highlights the importance of maintaining a robust log of safety related issues during the project and ensuring each issue is managed and assured as closed out by persons with the appropriate technical expertise (paragraph 105).

²¹ 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

Appendices

Appendix A - Glossary of abbreviations and acronyms

CAF	Construcciones y Auxiliar de Ferrocarriles, SA
FFCCTV	Forward facing closed-circuit television
ICP	Independent competent person
LRSSB	Light Rail Safety and Standards Board
ORR	Office of Rail and Road
OTDR	On-tram data recorder
ROGS	Railways and Other Guided Transport Systems (Safety) Regulations, 2006
RSP2	Railway Safety Publication 2
TTGN	Tramway Technical Guidance Note

Appendix B - Investigation details

The RAIB used the following sources of evidence in this investigation:

- information provided by witnesses;
- information taken from the on-tram data recorder (OTDR);
- closed-circuit television (CCTV) recordings taken from the tram and a bus on the nearby road;
- site photographs and measurements;
- weather reports and observations at the site;
- documents provided by parties involved in the tram system;
- medical records;
- work records provided by Lothian Buses Limited;
- a report on the tram's braking tests commissioned by Police Scotland;
- an expert acoustic report commissioned by the RAIB; and
- a review of previous RAIB investigations that had relevance to this accident.

Appendix C - Urgent Safety Advice

Urgent safety advice 01/2019: Warning horns on Edinburgh trams

Published 14 February 2019

1. Safety issue

The warning horn on the Edinburgh tram fleet does not provide a sound pressure level in line with current industry guidance. Furthermore, it does not generate a greater sound pressure level than the tram bell.

2. Safety advice

Edinburgh Trams Limited is advised to increase the sound pressure level of the warning horn fitted to its trams. In the meantime, it should consider measures to mitigate risks at locations where audible warnings may be required. In particular, consideration should be given to the appropriateness of the current warning horn or bell as a method of warning to pedestrians using footpath crossings over off-street track sections with high line speeds.

3. Issued to:

- Edinburgh Trams Limited

4. Background

At about 12:10 hrs on 11 September 2018, a pedestrian who was using a footpath crossing located between Balgreen and Saughton tram stops, was struck and fatally injured by an outbound tram travelling from Edinburgh city centre towards Edinburgh Airport. The crossing, over two tram tracks on an off-street section, provides a pathway between Stenhouse Drive and Saughton Mains Street.

The tram driver had observed the pedestrian approaching the crossing and, in response, applied the service brake to reduce the tram's speed as well as sounding repeated warnings using the tram's bell. The pedestrian did not respond to these audible warnings and continued onto the crossing. Although the driver then operated the emergency brake (which automatically activated the warning horn) before arriving at the crossing, the tram was too close to be able to stop before reaching it. The tram's speed at the time of the collision was approximately 50 km/h, and the maximum line speed in this section is 70 km/h.

Since this accident, the RAIB has conducted acoustic measurements of both the bells and the warning horns fitted to the tram involved in this accident and on one other Edinburgh tram. Tests from 7 metres (the distance stated in the 70-388-EC specification, referred to by current tramway guidance) in a flat, open area over ballast, found that the arithmetic means of the sound pressure levels from nine tests of the warning horns were approximately 86 dB(A) and 85 dB(A) on the two trams tested. 70-388-EC specifies a level equal to, or greater than 93 dB(A) under these conditions. For context, it is generally recognised that a reduction of 10 dB is approximately equivalent to a halving in loudness as perceived by the human ear.

Sound pressure level measurements were also recorded for both trams in this location from a distance of 2 metres to compare sound pressure levels of the bells and the warning horns. It was found that the average sound pressure level of the bell was 95 dB(A) and the warning horn was 89 dB(A).

Further acoustic measurements were conducted with the incident tram at different distances on the approach to the footpath crossing. The sound pressure levels of both the tram's bell and warning horn were recorded from the footpath crossing for each distance, together with the typical background noise measured at the crossing at the same time of day as that of the accident, but on a different day.

These measurements indicate that:

1. Both the bell and the warning horn are not sufficiently discernible above the level of background noise at this footpath crossing to indicate the approach of a tram at a full service braking distance from the crossing at line speed (as is stated in the current tramway guidance).
2. The warning horn produces a lower sound pressure level than the bell and can therefore be regarded as quieter.

The RAIB are aware that at the time that the trams were procured and commissioned there were no specified numeric requirements for the sound pressure levels for tram audible warning devices. However, guidance existed at the time of procurement, and continues to exist, which states that there should be two levels of audible warnings; the lesser level for on-street use, and the greater for off-street sections and emergencies. It is common practice on tramways in the UK that the former is provided by a bell, and the latter by a warning horn.

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