Oliver Stewart
RAIB Recommendation Handling Manager
T: 020 7282 3864
M: 07710069402
E-mail oliver.stewart@orr.gov.uk

6 August 2020

Mr Andrew Hall
Deputy Chief Inspector of Rail Accidents
Cullen House
Berkshire Copse Rd
Aldershot
Hampshire GU11 2HP

Dear Andrew,

RAIB Report: Overturning of a tram at Sandilands junction, Croydon, 9 November 2016

I write to provide an update[1] on the action taken in respect of recommendation 4 addressed to ORR in the above report, published on 7 December 2017.

The annex to this letter provides details of the action taken regarding the recommendation. The status of recommendation 4 is **'Implemented'** for London Trams/Tram Operations Ltd.

We will publish this response on the ORR website on 7 August 2020.

Yours sincerely,

Oliver Stewart

[1] In accordance with Regulation 12(2)(b) of the Railways (Accident Investigation and Reporting) Regulations 2005

Recommendation 4

The intent of this recommendation is to reduce the likelihood of serious accidents due to tram drivers becoming inattentive because of fatigue or other effects. Existing tram systems relying on drivers applying forces to driving controls (driver safety devices) do not necessarily detect an inattentive driver. Implementation of this recommendation may be assisted by work in this area already underway by Croydon tramway organisations.

UK tram operators, owners and infrastructure managers should work together to research and evaluate systems capable of reliably detecting driver attention state and initiating appropriate automatic responses if a low level of alertness is identified. Such responses might include an alarm to alert the tram driver and/or the application of the tram brakes. The research and evaluation should include considering use of in-cab CCTV to facilitate the investigation of incidents.

If found to be effective, a time-bound plan should be developed for such devices to be introduced onto UK tramway.

ORR decision

1. To tackle driver fatigue and inattentiveness, LT and TOL have installed the Guardian system. The system works by initiating two responses if a low level of alertness is identified; an audible alarm to the driver followed by a vibration of the seat. The Guardian system therefore satisfies the part of the recommendation concerning initiating an appropriate automatic response and the sounding of an alarm.

2. Guardian is not linked to the tram braking system. LT and TOL considered integrating the Guardian system with the brakes of its trams, but following extensive work and the advice of the manufacturer, concluded that it was not possible.

3. TOL use data from the Guardian system to further develop safety improvement activities. These include fatigue and distraction hotspot maps which have been incorporated into driver training and competence development activities. Analysis provided by TOL shows a 52% reduction in driver error hazard braking activity and a 44% reduction in the number of micro-sleep and drowsiness events recorded between April 2018 to January 2020.

4. TOL do not rely solely on the Guardian system to manage fatigue and inattentiveness of the driver and have 3 other main systems that form part of their system of control measures: Physical Prevention Of Overspeed (PPOS), iTram and improved, active signage.

5. PPOS will stop a tram and prevent it overturning at risk assessed high risk locations. At other locations around the network LT/TOL are relying on Guardian, iTram and other infrastructure improvements (e.g. signage, chevrons, etc.) to mitigate the risk of over speeding.

6. iTram is a non-safety critical system which enhances day to day operational safety by providing continual real time speed monitoring and over-speed advice to

drivers via in-cab driver alerts if the permanent speed restriction is exceeded by 3kph. iTram is capable of providing hazard alerts to drivers in real time.

7. TOL have produced data which has been provided to ORR to demonstrate the effectiveness of Guardian on catching inattentiveness incidents and can show that there have been no safety related incidents following a Guardian activation. TOL have also invested heavily in improving their fatigue management system to further decrease inattentiveness incidents.

8. The system approach taken by TOL/LT has addressed the issue of driver inattentiveness and therefore met the requirements of the recommendation by providing a solution that continually monitors and detects tram speed and driver alertness and initiating an appropriate automatic brake response where the risk of a serious accident is judged to be high as a result of those conditions.

9. See Annex C for a more detailed review of the measures taken by TOL/LT.

10. After reviewing the information provided ORR has concluded that, in accordance with the Railways (Accident Investigation and Reporting) Regulations 2005, TOL/LT have:

- taken the recommendation into consideration; and
- has taken action to implement it

Status: Implemented.

Previously reported to RAIB

11. On 3 March 2020 ORR reported the following:

TOL/LT TOL have fitted the ‘Guardian’ eye closure detection system to their tram fleet that detects driver inattentiveness and provides an alert. It is not linked to the tram brake system. On 26/02/2020 TOL provided a copy of their risk assessment which concluded that, when taking into account the *physical prevention of over speed controls (rec 3)*, the risk of driver inattentiveness was reduced as low as reasonably practicable. ORR is considering this additional information and will provide an update in April 2020.

Previously reported to RAIB

Recommendation 4

The intent of this recommendation is to reduce the likelihood of serious accidents due to tram drivers becoming inattentive because of fatigue or other effects. Existing tram systems relying on drivers applying forces to driving controls (driver safety devices) do not necessarily detect an inattentive driver. Implementation of this recommendation may be assisted by work in this area already underway by Croydon tramway organisations.

UK tram operators, owners and infrastructure managers should work together to research and evaluate systems capable of reliably detecting driver attention state and initiating appropriate automatic responses if a low level of alertness is identified. Such responses might include an alarm to alert the tram driver and/or the application of the tram brakes. The research and evaluation should include considering use of in-cab CCTV to facilitate the investigation of incidents.

If found to be effective, a time-bound plan should be developed for such devices to be introduced onto UK tramway.

1. On 9 December 2019 Tram Operations Ltd provided the following update:

The Guardian System was installed by London Trams on their tram fleet in October 2017 and is operating effectively.

Research carried out by Ian Rowe Associates Limited (IRAL) on behalf of UKTram has identified that no single system currently exists that is capable of fully addressing the requirements of recommendation 4 (by alerting the driver and automatically initiating a brake application if a low level of alertness is identified).

The Guardian System reliably alerts the driver when a low level of alertness is identified; in order to adequately address this recommendation, London Trams have overlaid the proven functionality of this system with Physical Prevention of Overspeed technology and iTram (which provides continual GPS based speed monitoring and driver alerts when the permanent speed restriction has been exceeded).

Evaluation and assessment of this approach using Common Safety Method principles has been undertaken; findings of this assessment support a claim that the risk of a serious accident occurring due to tram driver inattention has been reduced to so far as reasonably practicable (SFARP) levels.

Status: Implementation on-going - TOL have fitted the 'Guardian' eye closure detection system to their tram fleet that detects driver inattentiveness and provides an alert. It is not linked to the tram brake system. On 26/02/2020 TOL provided a copy of their risk assessment which concluded that, when taking into account the physical prevention of over speed controls (rec 3), the risk of driver inattentiveness was reduced

as low as reasonably practicable. ORR is considering this additional information and will provide an update in April 2020.

2. On 3 January 2020 London Trams provided the following update:

As per our previous updates, this recommendation was implemented on London trams using available technology [Guardian System] in October 2017. This system is designed to detect driver inattentiveness and provide an alert, but does not apply the brakes, as suggested as an option in the recommendation.

Research carried out by Ian Rowe Associates Limited (IRAL) on behalf of UKTram has identified that no single system currently exists that is capable of fully addressing the requirements of recommendation 4 (by alerting the driver and automatically initiating a brake application if a low level of alertness is identified).

The Guardian System reliably alerts the driver when a low level of alertness is identified; in order to adequately address this recommendation, London Trams have overlaid the proven functionality of this system with Physical Prevention of Overspeed technology (see above) and iTram (which provides continual GPS based speed monitoring and driver alerts when the permanent speed restriction has been exceeded).

Evaluation and assessment of this approach using Common Safety Method principles has been undertaken and is about to be finalised; findings of this assessment will, we believe, support a claim that the risk of a serious accident occurring due to tram driver inattention has been reduced to so far as reasonably practicable (SFARP) levels.

Status: Implementation on-going - As per TOL response.

Analysis of LT/TOL's responses for recommendation 4

The Recommendation

Recommendation 4: UK tram operators, owners and infrastructure managers should work together to research and evaluate systems capable of reliably detecting driver attention state and initiating appropriate automatic responses if a low level of alertness is identified. Such responses might include an alarm to alert the tram driver and/or the application of the tram brakes. The research and evaluation should include considering use of in-cab CCTV to facilitate the investigation of incidents.

UK tram operators, owners and infrastructure managers should work together to research and evaluate systems capable of reliably detecting driver attention state and initiating appropriate automatic responses if a low level of alertness is identified. Such responses might include an alarm to alert the tram driver and/or the application of the tram brakes. The research and evaluation should include considering use of in-cab CCTV to facilitate the investigation of incidents.

If found to be effective, a time-bound plan should be developed for such devices to be introduced onto UK tramways

Background

TOL and London Trams have provided several updates relating to this recommendation since the publication of the RAIB recommendations. Initially, UK Tram commissioned Ian Rowe Associates Limited (IRAL) to identify and review the availability of technology capable of satisfying the requirements of Recommendation 4. Research findings published by UK Tram in April 2019, indicated that no single system currently exists. These findings concurred with the preliminary research carried out by London Trams (LT) in the immediate aftermath of Sandilands.

Measures taken by LT/TOL to implement Recommendation 4

Guardian

LT and TOL have installed the Guardian system. This tackles driver fatigue and driver inattentiveness. The Guardian system is not linked to the tram braking system. It works by initiating two responses if a low level of alertness is identified, an audible alarm to the driver followed by a vibration of the seat.

LT and TOL considered the integration of the Guardian system with the brakes of its trams but following extensive work concluded this was not possible. Linking the Guardian System to the tram brakes was ruled out in January 2018 on the advice of Seeing Machines. This then started TfL's global search for a suitable complimentary system. The main reasons for this conclusion were:

- The original tram manufacturers were consulted but considered integration of a new technical system with the existing traction brake packages would require homologation of that complete integrated system. The Guardian System does not have a Safety Integrity Level (SIL) rating therefore certification of any new system would prove impossible.
- There were issues around the operational suitability of linking the Guardian system to the brakes in city centre running areas. There are a number of situations where Guardian

provides enhanced attention alerts that do not warrant a brake application. TOL/LT believe that the operational risk of the tram brake automatically applying - for example as a result of the system not being able to differentiate between perceived inattention and a driver correctly applying a defensive driving approach that requires prolonged attention from the forward facing direction; outweighs the safety benefit, when applied in every similar situation.

TOL/LT believe that the use of Guardian supports their claim that they have done all that is reasonably practicable in relation to reducing the likelihood of hazardous events due to driver inattentiveness occurring that could lead to a serious accident (they have provided data to back up this assertion which is at Appendix A). Additionally, TOL have been able to confirm that there have been no safety related incidents following an activation of the Guardian system.

The Guardian system also produces a wealth of management information reports. These range from immediate alerts that go almost immediately to TOL (via a data processing centre in Arizona, USA) and for which there is a TOL procedure (SM0068 – see Appendix B), through to system management information. TOL have explained they have used this information to inform their safety improvement activities. Fatigue and distraction hotspot maps have been developed and incorporated in driver training and competence development activities. Data-led work diagrams have been created to address the root causes of driver inattention.

As a result of these activities TOL confirm that they have seen a 52% reduction in driver error hazard braking activity (the greatest contributor to passenger harm on their network) and a 44% reduction in the number of micro-sleep and drowsiness events recorded between April 2018 to January 2020.

TOL are also able to pull out information related to repeat activations of the Guardian system by drivers. Their analysis shows that in the period April 2018 to Feb 2019 the Guardian System recorded 382 fatigue events. 13 drivers were recorded as having a repeat event in their shift and 130 drivers were recorded as having a single event. In the period April 2019 to Jan 2020 (following introduction of data-led work diagrams) this number reduced to 167 fatigue events. Only 6 drivers experienced a repeat event in their shift and 76 drivers had a single event.

Appendix C contains the graphical output of TOL's analysis of the Guardian system management data discussed above.

This information demonstrates that TOL are able, through the Guardian system, to reliably detect driver attention state and the data indicates the way TOL have used the system and the data it generates has led to a substantial reduction in fatigue and inattentiveness events. Those that do occur are appropriately managed through their performance procedures and there have been no safety related incidents following a Guardian alert to date.

The Guardian system thereby satisfies the part of the recommendation concerning initiating an appropriate automatic response and the sounding of an alarm. Whilst it does not apply the brakes it does include seat vibration and as the recommendation states braking is and/or the Guardian system meets the requirements of the recommendation.

Other Control Measures to Tackle Driver Inattentiveness

TOL do not rely solely on the Guardian system to manage fatigue and inattentiveness of the driver. They have 3 other main systems that form part of their system of control measures.

Physical Prevention of Over Speed (PPOS)

LT and TOL have led the tram industry in the UK by installing a system called PPOS at high-risk locations on their network to further reduce the risk of a tram overturning due to driver inattentiveness. These locations have been identified following a suitable and sufficient risk assessment which has been provided to ORR. The assessments and associated correspondence can be found at Appendix D.

PPOS is a system that demands an automatic maximum service brake application under specific circumstances at 13 identified high-risk locations by interrupting the on-tram safety monitoring circuits. If a tram passes over an RFID beacon at more than 5 kph or 10% (whichever is greater) over the permissible speed, the on-tram PPOS component interrupts the tram safety monitoring circuit and demands a maximum service brake application.

There is a clear management process in place to deal with any PPOS activations.

iTram

iTram is a non-safety critical system which enhances day to day operational safety by providing continual real time speed monitoring and over-speed advice to drivers via in-cab driver alerts if the permanent speed restriction is exceeded by 3kph.

iTram is capable of providing hazard alerts to drivers in real time. TOL did examine this feature but discounted it as there was a real danger of driver's attention being diverted from the tramway and looking for oncoming hazards to the iTram display itself.

Line Speed and Orientation Signage

To supplement and enhance the above controls LT have additional safeguards in the form of tram activated speed signage, directional chevrons, cats-eye indicators, warning boards, high visibility yellow borders fitted to critical speed signs and standard tramway speed signs.

Summary of Control Measures and Conclusion

LT/TOL have focused their efforts on control measures to prevent trams from overturning in the first place and the PPOS system concentrates solely on this. This has been complemented by the Guardian system and the additional measures identified above to mitigate other hazardous events that have the potential to eventuate such as vehicle or pedestrian collision.

Whilst these other controls do not stop a tram automatically, they do provide automatic alerts to both drivers and in some circumstances the TOL control room. This is in line with the wording of the recommendation itself which does not require all controls to automatically stop the tram in the event of driver inattentiveness.

The tram industry operates on line of sight driving principles. Tram drivers are required to operate their tram at a speed that allows them to stop in a distance that they can see to be clear ahead. There is no and never has been a legal requirement to stop a tram in the event of any and all driver inattentiveness. Tram drivers operate to highway principles and conflict points are managed accordingly.

LT/TOL have taken the decision that the “reasonably practicable” boundary in relation to driver inattentiveness and the control measures needed to tackle it has shifted since the Sandilands accident.

This has led them to install PPOS – the first system of its kind to be used on UK tram infrastructure. This will stop a tram and prevent it overturning at risk assessed high risk locations. At other locations around the network LT/TOL are relying on the other controls – Guardian, iTram and other infrastructure improvements (e.g. signage, chevrons, etc.) to mitigate the risk. They have produced data which has been provided to ORR to demonstrate the effectiveness of Guardian on catching inattentiveness incidents and can show that there have been no safety related incidents following a Guardian activation. TOL have also invested heavily in improving their fatigue management system to further decrease inattentiveness incidents.

The system approach taken by TOL/LT in relation to recommendation 4 has meant that TOL/LT have robustly tackled the issue of driver inattentiveness and have concluded, rightly in my opinion, that this combined approach fully addresses the requirements of Recommendation 4 by providing a solution that continually monitors and detects tram speed and driver alertness, initiating an appropriate automatic brake response where the risk of a serious accident is judged to be high as a result of those conditions.

Consequently I would support moving TOL/LT from “implementation ongoing” to the status of “implemented” based on the information above.

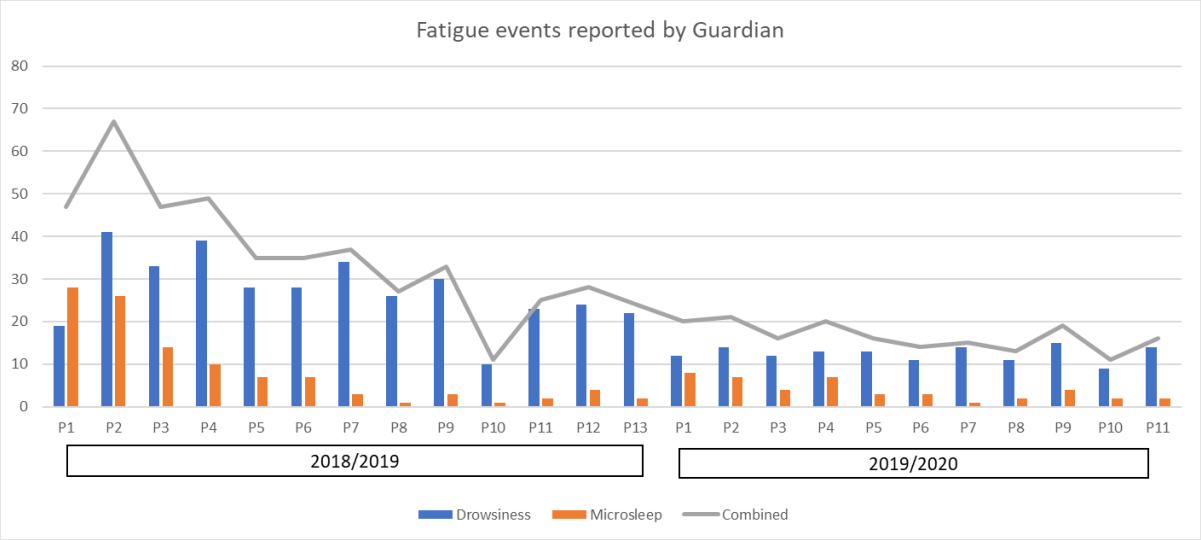
APPENDIX A - Hazardous Event List and Assessment of Safety Control Level

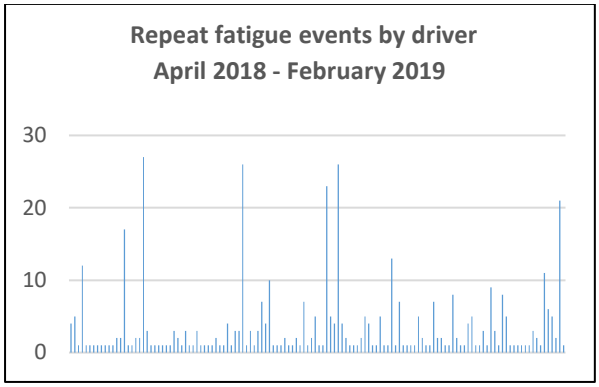
Hazardous Event Type	Frequency (events per year)	Level of Harm (FWI per year)
HE110: Tram/Tram collision (SPAS at junctions or single line)	0.055	0.008
HE120: Tram/Tram collision (No SPAS)	0.2	0.008
HE121: Tram/Tram collision in depot	0.066	0.0005
HE122: Tram/Tram collision in maintenance shed	0.2	0.0001
HE140: Buffer stop collision	1.0	0.026
HE151: Tram derailment in depot (low speed)	1.0	0.0005
HE152: Tram derailment and stays in swept path (mainline)	0.333	0.001
HE153: Tram derailment and leaves swept path (mainline)	0.1	0.026
HE154: Tram overturns	0.008	0.0972
HE160: Tram/Vehicle collision (Highway Code violation at a highway crossing)	3.65	0.263
HE170: Tram/Vehicle collisions (On street section)	11.3	0.067
HE190: Mobile Maintenance Plant in Collision with Tram	0.04	0.002
HE210: Tram/MOP collision (at tramstop or associated crossings)	2.96	0.189
HE220: Tram/MOP collision (on street section)	4.59	0.137
HE230: Tram/MOP collision (off street track)	0.74	0.055
HE240: Tram/MOP collision on crossing	1.185	0.204

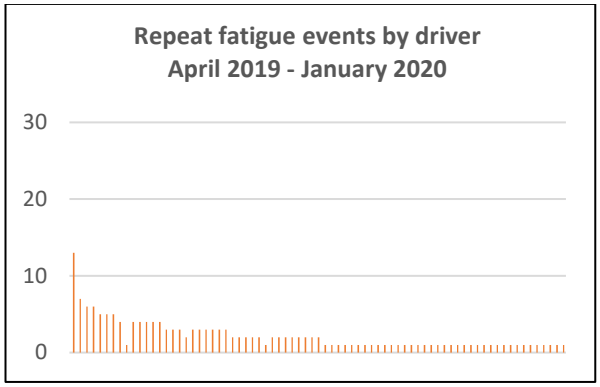
APPENDIX B – GUARDIAN PROCEDURE

Guardian
Procedure Version 1

APPENDIX C – Graphical representation of Guardian management data







APPENDIX D – PPOS correspondence and risk assessment

Fw Risk Assessment to Supp