

Oliver Stewart
RAIB Recommendation Handling Manager



3 June 2025

Mr Andy Lewis
Deputy Chief Inspector of Rail Accidents

Dear Andy,

RAIB Report: Trap and drag accidents at Archway and Chalk Farm on 18 February 2023 and 20 April 2023

I write to report¹ on the consideration given and action taken in respect of the recommendations addressed to ORR in the above report, published on 27 June 2024.

The annex to this letter provides details of actions taken in response to the recommendations and the status decided by ORR. The status of recommendations 1 & 2 is '**Closed**'. The status of recommendations 3 & 4 is '**Open**'.

ORR will advise RAIB when further information is available regarding actions being taken to address these recommendations.

We will publish this response on the ORR website.

Yours sincerely,

Oliver Stewart

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

Initial consideration by ORR

1. All 4 recommendations were addressed to ORR when the report was published on 27 June 2024.
2. After considering the recommendations ORR passed all 4 recommendations to London Underground Limited asking them to consider and where appropriate act upon them and advise ORR of its conclusions. The consideration given to each recommendation is included below.
3. This annex identifies the correspondence with end implementers on which ORR's decision has been based.

Recommendation 1

The intent of this recommendation is to improve how the risk associated with trap and drag events is understood and controlled.

London Underground Limited should review its processes for managing the risk arising from trap and drag events on the Northern line. The review should include, but not be limited to:

- improving the speed at which accident and incident data, including that from trap and drag events is recorded, reviewed and incorporated in risk management systems (such as LUQRA) and other safety decision making processes
- accurately recording the severity of harm arising from trap and drag accidents
- assessing the validity of the mitigation assigned to existing control measures, such as door obstacle detection systems and train operators identifying passengers trapped in train doors.

Following this review, London Underground Limited should develop a timebound programme to review and update the relevant risk assessments and to identify any additional risk controls which are found to be appropriate.

This recommendation may also apply to other London Underground lines

ORR decision

4. LUL have considered the speed at which accident data including that from trap and drag events is recorded, reviewed and incorporated in risk management systems and concluded the existing protocol of updating of the LUQRA PTI model every three years is an appropriate timescale.
5. LUL has taken steps to improve the accuracy of recording the severity of harm arising from trap and drag accidents. LUL have implemented data quality checks, improved internal review processes and updating systems post-incident if there is a change in severity of an incident.
6. LUL has considered retrofitting door obstacle detection to train fleets that do not currently have it, but concluded the cost would be grossly disproportionate to the

safety benefit. To improve the train operator view of the PTI, LUL has initiated a project to improve the One Person Operated (OPO) monitors.

7. After reviewing the information provided ORR has concluded that, in accordance with the Railways (Accident Investigation and Reporting) Regulations 2005, LUL has:

- Taken the recommendation into consideration; and
- taken action to close it.

Status: Closed.

Information in support of ORR decision

8. On 10 October 2024 London Underground Limited provided the following initial response:

The RAIB recommendation suggested that London Underground (LU) should review its processes arising from trap and drag events on the Northern line, and set out a number of elements which should be considered as part of this review. The action taken on each element of the recommendation is set out below. We have reviewed our processes relating to the risk of trap and drag incidents across the entire LU network, rather than just the Northern line.

Improving the speed at which accident and incident data including that for trap and drag incidents events is recorded, reviewed and incorporated into risk management systems (such as the LU QRA) and other safety decision making processes.

LU has a clear approach to safety decision making, set out in an LU standard (S1521: Safety Decision Making). The LU Quantified Risk Assessment is one of the models/tools used to inform our safety decisions. We also have a robust governance structure in TfL which ensures that appropriate safety decisions can be made at the right time, by the right team – from local teams through to the TfL Executive Committee (ExCo), specifically at our ExCo Safety meeting. This has allowed us to make quick decisions on safety issues, based on incident data and safety risk on a number of issues, including the Platform Train Interface (PTI). While the LU QRA is one of the information sources which informs our decision making, and is a useful tool in making those decisions, it is not the sole input. We have a history of making quick decisions on safety issues based on incident data and risk, including on infrequent events, e.g. the action we have taken to address escalator entrapments, the ban of the carriage of e-scooters on our transport system.

We recognise the importance of maintaining a QRA which allows us to make appropriate and timely safety decisions. The LU QRA is a network-wide, strategic model primarily used to quantify and compare the risk levels associated with different hazardous events. It is not used to monitor risk levels and make safety decisions on a short-term basis or at specific locations. The LU platform train interface (PTI) model, which contains the modelling of the risk of trap and drag events, is the model within the LU QRA which is updated most regularly, as a consequence of the high risk levels associated with the platform train interface. It

was last updated in 2022 and is scheduled to be updated again in 2025. We consider that reviewing and updating this model every three years is an appropriate timescale for incorporation of data into our risk management system.

Accurately recording the severity of harm arising from trap and drag accidents

TfL's injury severity, for serious injuries and accidental fatalities, is aligned to the RIDDOR classification of injuries. The data in our safety reporting system (IE2) is used to quantify safety risk when our risk model (LU QRA) is updated.

There are a number of reasons whereby the severity of an incident may not be accurately recorded; including most usually, that the severity of the incident is not known at the time. On some occasions, TfL is informed about the severity of an incident some time after the incident.

If an injury is classified incorrectly at source (e.g. by the colleague recording the incident on an Electronic Incident Report Form), then our incident reporting system IE2 will also misclassify the severity. To reduce the potential for this, we have implemented data quality checks. SHE Business Partners also review safety performance with the lines that they support. Where TfL has become aware of a change in the severity of the incident post incident (e.g. via the British Transport Police), we update the classification in our incident reporting system.

Assessing the validity of the mitigation assigned to existing control measures, such as door obstacle detection systems and train operators identifying passengers trapped in train doors.

We have considered the suggestions set out in the RAIB recommendation, as set out below.

Door Obstacle Detection Systems

Victoria line 09TS and the rolling stock on the Metropolitan, District, Circle and Hammersmith & City lines (S Stock) have sensitive edge systems which is, in London Underground's view, the most robust engineered detection system. This goes beyond the requirements of the European Standard for Train Door Systems. Sensitive edge generally detects both static objects trapped in doors down to 11-8mm thickness and will also detect thinner objects if dragged and exerting a force on the edge. These features also include ease of removal as the individual doors can partially open to release trapped objects. These improvements will also be implemented on all future new fleet procurements across TfL (i.e. not just on LU).

The new rolling stock on Piccadilly line (24TS) is specified to a similar extent and the door system design is still under review with Siemens (the Original Equipment Manufacturer).

The Jubilee line (96TS), Northern line (95TS), Central line (92TS), Piccadilly line (73TS) and Bakerloo line (72TS) all have interlock detection (i.e. detection of a gap greater than a specific amount between door leaves) on the trains. This offers a lower engineered protection against trap and drag incidents compared to the sensitive edge system noted above. It is worth noting that this

static detection is still better than the minimum requirements of the European Standard for Train Door Systems. The risk of trap and drag incidents is also reduced through the pushback system fitted to all single and half of double door leaf doors. Pushback is a spring system which enables a door to be opened by a set maximum amount (around 115-120mm) whilst the door remains locked. This allows some objects to be removed when trapped in the doors.

Our engineering reviews have identified it is not realistically achievable to retrofit sensitive edge doors to those fleets which don't currently have sensitive edge doors, such as the Northern line, due to the prevalence of pneumatic door operators and the scale of investment required to modify the many thousands of individual doors across those fleets.

We have also considered the fitting of sensitive edges to existing rolling stock that do not have this feature (Northern, Jubilee, Bakerloo, Central and Waterloo & City lines). Given the scale of change required, we do not consider that this is justified on a risk benefit basis. There are over 18,000 door leaves across these fleets so the cost to introduce this feature would run into tens of millions of pounds, therefore it is not financially feasible to pursue this. Our focus instead remains on the other mitigation measures outlined in this letter.

In addition, our new rolling stock that will be introduced on the Piccadilly line and the subsequent variants proposed for the Central, Bakerloo and Waterloo & City lines will all feature asymmetric sensitive edges.

We recognise that improvements to our train door systems will be gradual with the introduction of new rolling stock. Therefore, in the interim our focus is on improving and developing alternative PTI mitigation measures. These are outlined in the TfL Rail PTI Plan. The detail of this plan is outlined in our response to RAIB Recommendation 2 below. A copy of the TfL Rail PTI Plan is also included as Appendix 1 to this letter.



Appendix 1 TfL Rail
Ops PTI Plan October

Train Operators identifying passengers trapped in train doors

As outlined above, many of the technical solutions in place on LU's train doors help a train operator to detect situations where a passenger or their belongings are trapped in train doors. Our safety systems trigger an alert in the train cab which allows the train operator to respond to an incident where a passenger or their belongings have been trapped in a door. In addition to this, we have an ongoing project to improve the One Person Operated (OPO) monitors - which will further improve the train operators view of the PTI. OPO monitors have been upgraded at 30 platforms (between 2020 – 2022) and will be upgraded at a further 54 platforms by July 2026. As part of this work, the OPO monitors on 13 Northern line platforms have been upgraded. In addition, there is a further scope of work for a feasibility study related to OPO system improvements for the Central and Jubilee lines. We can provide further detail on works to improve OPO systems on these lines if you wish.

We believe that we are taking an appropriate approach, on the Northern line and across the TfL network, to door obstacle detection systems on our fleet and in providing train operators with the equipment to help them identify passengers trapped in train doors. We recognise that customer risk at the PTI is LU's most significant customer risk and continue to work to reduce risk in this area. Further details of this work is included in response to Recommendation 2 below.

9. On 27 November 2024 ORR wrote to London Underground Limited as follows:

Bullet 1

It is accepted that the approach to safety decision making and the use of LUQRA is set out in LU standard (S1521: Safety Decision Making). However, with reference to the text 'We also have a robust governance structure in TfL which ensures that appropriate safety decisions can be made at the right time, by the right team – from local teams through to the TfL Executive Committee (ExCo), specifically at our ExCo Safety meeting. This has allowed us to make quick decisions on safety issues, based on incident data and safety risk on a number of issues, including the Platform Train Interface (PTI)', please outline;

- (1) How accident and incident data is incorporated in safety decision making processes on a short-term basis, specifically to include details of timescales (at the right time), and responsibilities (by the right team).
- (2) How the governance structure ensures these arrangements.

Bullet 2

Evidence has been provided to address this part of the recommendation. No further information needed.

Bullet 3

Can you provide the cost benefit analysis that supported the decision made not to retrofit sensitive edge doors to those fleets which don't currently have them. Can you explain in greater detail the safety alert system when a passenger is trapped, e.g. What is the nature of the alert that is triggered?

10. On 17 March 2025 London Underground Limited responded as follows:

TfL regularly reviews incident data to understand trends, which allows us to take action to address changing risks. We have a structured safety governance approach which provides the opportunity for us to review performance and incident data. Each period, the LU Customer Operations leadership team review safety performance at its periodic Performance Meeting. Where issues can be addressed by this team, they are done so, often facilitated by the TfL SHE team. Issues which require escalation can be shared at the periodic TfL Operations SHE & Security meeting for addressing there, or further escalated to the TfL Executive Committee Safety meeting (which takes place every six weeks).

Where an issue is identified which needs action, we will use these meetings to identify the issue and track action. We may set up separate work streams to take the necessary actions to deliver change.

As an example, early in 2023, we identified a small number of incidents where children's shoes were trapped in escalators. We set up a small group to address this – which reported to both the LU Customer Operations team and the TfL Operations Leadership team, as part of our existing safety governance arrangements. In establishing this group, with the support of the TfL Leadership teams, we ensure that there was a clear lead (a Senior SHE Business Partner), and appropriate input from teams across TfL, including Engineering, Customer Experience, Operations). Our initial action was to carry out detailed analysis to ensure that we could identify potential trends and areas of focus. Our analysis showed that these incidents occurred more frequently during school holidays where there are more visitors in London, many of whom are less familiar with London Underground escalators. We knew that other operators had similar incidents, so in March 2023, we held an Escalator Entrapment Workshop with input from TfL colleagues (Engineering, Customer Experience, Operations, SHE), as well as our counterparts from Network Rail, RSSB, MTR, Heathrow Airport, Eurostar and GWR.

This allowed us to identify a number of short, medium and longer term actions. Short term actions included communication with our customers and redeployment of station colleagues in Easter 2023. We have since trialled a trip switch device on an escalator at South Kensington, which immediately stops an escalator in the event of an entrapment. This trial was successful, and we are now in the process of rolling this out to a number of other LU stations. We have also embedded these messages in our customer safety communication, sharing key messages during school holidays. We have also engaged with schools and other parent/guardian networks to communicate this work.

Addressing some of the changing safety trends have complex underlying causes, such as addressing train operator cognitive underload or changing our infrastructure to remove risk. I have provided further detail on the action we are taking to address risks associated with train operation attention and potential distraction below, and we have previously updated the ORR TfL team on the work we are doing to improve our PTI infrastructure. We have shared how we used our Safety Decision Making standard to look at the platform train interface to identify specific locations where the risk, based on engineering assessment and quantified risk assessments, has identified that the risk is tolerable, not as low as reasonably practicable. Where safety interventions require cost benefit analysis, TfL has carried this out to identify appropriate next steps. In autumn 2024, we recognised that our approach to PTI governance could be improved, so set up a TfL PTI Steering Group. This is chaired by the Director of Rail & Sponsored Services, with support from the SHE team. This has provided us with an opportunity to ensure that there is a structured approach to monitoring delivery of our key PTI actions and escalating and addressing any changes in PTI incident trends. A number of PTI groups (across TfL) feed into this Steering Group, and the defined escalation route from the Steering Group is to the TfL Operations SHE & Security meeting, and beyond that to the TfL Executive Committee Safety Group.

Sensitive edge doors

You also requested the cost benefit analysis that supported the decision made not to retrofit sensitive edge doors to those fleets which don't currently have them.

The cost of doing this from an analysis carried out in 2016 has been assessed to still be reasonable, but have been updated based on inflation. The safety benefit figures have been updated based on the last five years' data, but excluding 2020-21 and 2021-22 due to the reduced ridership figures at the time (due to the Covid pandemic) and giving the most conservative safety benefit. These are shown in the table below.

Line	Fatality Weighted Index		Safety Benefit			Estimated Cost
	Total	Per Year	Per Year	Expected Remaining Years	Total	
Bakerloo	0.003	0.0006	£1,385	10	£13,848	£5,584,716
Central	0.1	0.0200	£46,160	10	£461,600	£15,544,075
Jubilee	0.003	0.0006	£1,385	20	£27,696	£10,494,328
Northern	0.008	0.0016	£3,693	20	£73,856	£15,024,215
W&C	None	0.0009 (estimated from LUQRA 2023.01)	£1,986	10	£19,858	£437,652

Value of Preventing a Fatality (VPF) at £2,308,000 as per S1521 A11

Taking into account the fatalities and weighted injuries per year, and the expected remaining lifespan for the respective rolling stock, the estimated cost for retrofitting sensitive edges is consistently greater than three times the safety benefit created from removing dragging risk on each line. This supports a judgement that the cost of the risk reduction measure is grossly disproportionate to the safety benefit achieved when following the safety decision making standard S1521, therefore it supports the current conclusion that the retrofit of sensitive edges is not reasonably practicable.

All new build LU Trains are expected to be fitted with sensitive edges. The 2024TS currently being built for the Piccadilly line is equipped with directional sensitive edge (which can distinguish if a person is inside or outside of the train). This builds on our experience from 2009TS (Victoria line trains) sensitive edge doors.

Safety alert system - dragging

You asked for more detail on the safety alert system when a passenger is trapped and the nature of the alert that is triggered. The alert is different by train type. For the older train stocks, the alert is triggered when an object between 8 and 11mm in diameter are trapped and, as a result, the door interlock will not be made. This 'alerts' the driver that the doors are not properly closed and thus something is stopping them from closing. For our newer train fleets, the train operator can identify which door is not closed. On our older stock, this information is not available to the driver.

The Victoria line stock and rolling stock on the Metropolitan, District, Circle and Hammersmith & City lines have sensitive edge systems. Automatic responses are provided from each door, and this information is displayed to the driver. If an object at least 11mm in diameter is caught in the doors, no "doors closed visual light" in the train cab will be illuminated, so the driver knows that there is potentially something caught in the doors. On these train stocks, train design means that, if it is not

confirmed that the doors are closed, it will not be possible for the train to depart unless the driver operates an appropriate cut out.

Recommendation 2

The intent of this recommendation is to further reduce the risk of a person becoming trapped in train doors and subsequently dragged by a departing train.

London Underground Limited should identify and evaluate options which may further reduce the risk of a passenger becoming trapped and subsequently dragged by a departing train. This should include consideration of options including:

- technology that will detect when thin objects, such as fingers, straps or clothing, become trapped in train doors
- modifying door seals to make it easier for small, trapped objects, such as clothing and straps to be pulled free from closed doors
- using technology to detect when something is being dragged along by the departing train and to generate an appropriate response when this has occurred
- improving the images presented to train operators on in-cab monitors to enable them to identify whether a passenger is potentially trapped in the closed doors by clothing or other small objects

ORR decision

11. LUL have identified and evaluated options for reducing the risk of trap and drag incidents, including modifying door seals. As noted in the response to rec 1, LUL has considered retrofitting sensitive edge door technology to train fleets not currently equipped with it, but concluded the cost would be grossly disproportionate to the safety benefit.

12. Also as noted in response to rec 1, LUL has initiated a project to improve the train operator view of the PTI, by improving the quality of the image provided by the OPO monitors.

13. After reviewing the information provided ORR has concluded that, in accordance with the Railways (Accident Investigation and Reporting) Regulations 2005, LUL has:

- Taken the recommendation into consideration; and
- Has taken action to close it.

Status: Closed.

Information in support of ORR decision

14. On 10 October 2024 London Underground Limited provided the following initial response:

While customer safety risk at the PTI is lower than the PTI risk across the UK rail network, it remains one of the most significant safety risks for TfL. We have a very thorough understanding of the risk on LU where we know that PTI incidents such as falls between the train and the platform, falls onto the track (with no train in the platform) and being caught in the doors and being dragged along the platform are the areas where customers are most likely to be seriously injured. In September 2024, TfL finalised its first TfL Rail Platform Train Interface (PTI) Plan (Appendix 1) which sets out timebound actions to drive improvements which will allow us to reduce risk in this area. The plan specifically considers the risk associated with a person becoming trapped in train doors and subsequently dragged by a departing train. The TfL Rail PTI Plan and recommendation status is reported regularly to the TfL Operations Senior Leadership Team SHE & Security Meeting.

Emma Burton presented the detail of this plan to the ORR TfL team on 2 October 2024. The actions that LU is delivering as part of the TfL Rail PTI Plan include:

- *Engineering Interventions including:*
 - *Platform infrastructure improvements at a number of platforms that have higher numbers of falls between the train and the platform.*
 - *One-Person Operated (OPO) camera replacement programme where oblique and/or obscured views have been identified when platforms are busy.*
- *Innovative Solutions including:*
 - *SMART stations - A programme to use technology to alert station staff to potential a wide range of incidents. A phase 1 proof of concept was completed at one station on the network in 2022. A second trial looking to alert station colleagues specifically of PTI incidents and track trespass is currently being designed.*
 - *PTI artificial intelligence (AI) – exploring the feasibility of using AI analytics and camera vision technology (different to SMART stations) on the LU Network which could alert LU colleagues to a customer in the track environment.*
- *Training & Research including on:*
 - *A programme of work to improve train operator and station colleague awareness of PTI risk.*
 - *A programme of work focused on improving train operator concentration and awareness and managing cognitive underload.*
- *Communicating with customers including:*
 - *Influencing customer behaviours by considering how we can further inform customers about risk at the PTI.*
 - *The detail of the actions set out above are included in the TfL Rail PTI Plan (Appendix 1).*

We recognise that further improvements in technology are likely to provide further opportunities in the future and the importance to maintain up to date knowledge of potential emerging mitigation measures. The TfL Rail PTI Plan will be regularly reviewed to ensure that new and emerging technologies are assessed and implemented, trialled or tested where practical.

In addition to this, the TfL Innovation Team has researched work undertaken by metro organisations across the globe (via a benchmarking group – Community of Metros (CoMET)) on PTI technologies to identify best practice, success stories and lessons learned from other train operating companies. This identified that there are a number of different video analytics, artificial intelligence and SMART CCTV being used to detect track intrusions across a number of metros. The information published on the effectiveness of these and the impact that they have had on safety performance is limited, but TfL will maintain contact with other metros to understand effectiveness as more information emerges.

Recommendation 2 from the RAIB investigation report noted that LU should consider options such as:

- *technology that will detect when thin objects, such as fingers, straps or clothing, become trapped in train doors.*
- *modifying door seals to make it easier for small, trapped objects, such as clothing and straps to be pulled free from closed doors.*
- *using technology to detect when something is being dragged along by the departing train and to generate an appropriate response when this has occurred.*
- *improving the images presented to train operators on in-cab monitors to enable them to identify whether a passenger is potentially trapped in the closed doors by clothing or other small objects.*

TfL's actions relating to these bullet points have been set out in our response to Recommendation 1.

15. On 27 November 2024 ORR wrote to London Underground Limited as follows:

As with rec 1, can you provide the cost benefit analysis that supported the decision made not to retrofit sensitive edge doors to those fleets which don't currently have them.

Can you provide more information to explain what the innovation team is doing to use technology to detect when something is being dragged along by a departing train.

Regarding the size of monitors and quality/clarity of images (bullet 4), please outline how improvements to the One Person Operated (OPO) monitors improves the images presented to train operators, to include reference to the quality, clarity and size of the image.

16. On 17 March 2025 London Underground Limited responded as follows:

TfL PTI New Technologies

During 2025, we will trial technologies to improve customer safety at the PTI in three areas – on the Piccadilly line, on the DLR and on the Central line. We will trial these

technologies in a number of operational environments. This will allow us make recommendations for potential wider deployment. The focus on this work is to address the following risks:

- the risk of someone being hurt when they fall between the train and the platform (hurt immediately, or once the train begins to move)*
- the risk of someone being caught in train doors and being dragged*
- the risks associated with someone accessing the track, either accidentally (i.e. falling) or deliberately going beyond platform end barrier*

The PTI New Technologies Programme Group, which will be chaired by TfL's Director of SHE for TfL Operations, will coordinate work across the three trials. The Group will also establish the evaluation framework (including success criteria) for the trials, and the process for responding to any incidents or issues that occur during the operational trials (considering urgent and non-urgent situations which may arise). Once the trials are up and running, the Programme Group will focus on monitoring and reporting performance against the success criteria, as well as respond to incidents and issues that occur in line with agreements made before beginning the trials.

We are planning to start a trial in July 2025. We are very happy to share details of the programme with the ORR.

One Person Operated (OPO) Monitors

Improvements to OPO have been achieved by adding additional cameras to the platforms and combining these individual images to form the image displayed to the train operator on the in-cab monitor. This means that a person standing on the platform is now closer to the camera producing the image, and as a result will occupy more of the image than they did previously. This is especially relevant to the ends of the platforms where they are furthest away from the camera.

With the important detail of the image (i.e. the person) now taking up more on the monitor (improving the size), the quality and clarity of their image is also improved simply because more TV-lines or pixels are used to produce their image on the monitor, this means that the shape of the person appearing on the monitor is more accurately displayed, improving the quality of the image and making it more likely to be correctly identified as being a person. The presentation of other such detail such as their clothing is also improved, giving enhanced clarity of the person on the platform.

17. On 17 April 2025 ORR wrote to London Underground Limited as follows:

RAIB recommended LUL should identify and evaluate options which may further reduce the risk of a passenger becoming trapped and subsequently dragged by a departing train, including consideration of modifying door seals to make it easier for small, trapped objects, such as clothing and straps to be pulled free from closed doors.

The information so far received does not provide evidence of a review of modification of door seals. The CBA refers to the cost benefit analysis that supported the decision made not to retrofit sensitive edge doors to those fleets which don't currently have them, but it is unclear how LU has considered the option of modifying existing door seals. Can you confirm if the CBA included door seal changes, and if not, if there is a separate door seal CBA?

18. On 16 May 2025 London Underground Limited responded as follows:

You requested further evidence of any review TfL has undertaken on the modification of train door seals rather than on the complete retrofit of sensitive edge doors which was the focus of my previous letter. A number of options for this, and other mechanisms for improving detection of, and response to trapped objects in doors, have previously been considered which are summarised:

Concave-Convex Door Seals

There have been different configurations of LU door edge rubbers on LU train doors which include:

- *Convex-Convex*
- *Concave-Convex*
- *Sensitive edge*

Following a study which considered a wide range of different door seal shapes in the 1990s, all door seals on LU rolling stock were changed to the Concave/Convex design for both existing and new trains. This was to improve the detection of thin rigid objects. Whilst it increased the friction for thin flexible items from 50N to a maximum of 90N (meaning it could be less easy to release a trapped object), a pull through force test on newly-procured seals manages this. The concave-convex seals gave the best compromise between maximising detection and allowing pull out capability of trapped objects.

Pushback Forces and Detection Limits

The current pushback forces are tailored to the door mass and are set as low as they can whilst ensuring doors stay closed under train dynamic conditions. Typically, detection limits for a closed door are between 6 and 12.5mm (depending on the stock). If interlock detection limits were set tighter to detect thinner items, or pushback forces were reduced to make the retrieval of items easier, there would be a corresponding increase in loss of motoring as there would be an increase in trains losing door closed visuals. This would largely be because the doors would be more sensitive to trapped items but also to the effect of customers leaning on train doors (from inside the saloon).

This is a safety concern since it has the potential to cause passenger injury due to falls inside the saloon due to the "jerk" that occurs in these scenarios (as the train motoring is lost). It would also affect service reliability which can cause safety risks through increasing overcrowding on stations and trains. The low number of dragging incidents relative to the large number of customers using our services supports that both the pushback forces and detection limits are set appropriately to balance risk from dragging and risk from a degraded service.

Reduced Friction of Door Edge Seals

A number of factors affect the friction on door edge rubbers over time:

- *Exposure to ozone and contaminants causing the surface of the rubber to breakdown (at a molecular level) which leads to a rougher surface and higher friction.*
- *As rubber seals ages they become harder (stiffer) from cross linking which can lead to a reduced contact area and therefore reduced friction.*
- *As passengers and staff interact with the doors (brushing past seals and retrieving trapped items) this causes wear to the mating faces (faces of the seals which are in contact when the train doors are closed) leading to a polishing effect which reduces friction.*
- *Human interaction with the seals, depositing grease and oils which reduce friction levels.*

The potential for changing our rolling stock door edges to rubber with less friction or modifying the friction through a lubricant (to make it easier to release a trapped object) has also been considered. However, it was determined that this was likely to have an unpredictable and short term impact as the friction will start to be affected by the above factors once the seals are in use.

The benefit of lower friction levels would be most relevant when someone is attempting to pull out a trapped item at close to 90 degrees to the surface of the door. In a dragging scenario, this is not likely to be the case. A tight 'drag angle' increases the force needed for someone to pull away from a train while the train is moving away from them. If the angle is tight or a bulky object is trapped inside (coat toggles, dog leads, a bag etc) and the person cannot free themselves from the object, marginal differences in friction become irrelevant.

It is also likely that a significant number of incidents where items are trapped in train doors are unreported, particularly where there are no associated injuries. We are also unaware of the numbers of customers that self-extract or who are released due to re-stroking of the door (either by train operator intervention, or automatically on those trains suitably equipped).

Based on these factors, it is difficult to quantify the relative value of reducing friction levels further. However, we are reviewing the potential to use train data from our more modern rolling stock to get more accurate data on incident numbers which will feed into any future reviews.

'Light Curtain'

'Light Curtain' type options (for example, infra-red or similar technologies which detect the presence of passengers in the doorway) have also been considered and discounted, as they offer no benefits over sensitive edge for our railway and were considered to be likely to cause disruption to the operation of the service due to normal levels of crowding in the doorway. When the review was undertaken, there was no demonstrated case for their use on any other metro (where doorways are often congested). This congestion would lead to delays in closing the doors to a point where

operating a reliable service would be impacted, leading in turn to potential platform congestion leading to a need to implement station control more frequently. By detecting trapped thin objects before or shortly after train departure, a sensitive edge system reduces dragging risk while allowing a reliable service to operate.

Conclusion

As demonstrated above, we have explored a wide range of options to reduce the risk of entrapment in doors. To date we have concluded that the low-level benefits that these modifications would make, does not justify the case for progressing with them. These decisions followed high level analysis and detailed Cost Benefit Analysis has not been undertaken for any of the options as they have been ruled out on technical and safety grounds.

In our current timetable, LU will run a maximum of 520 trains. Of these, 192 have sensitive edge doors (Victoria, Metropolitan, District, Hammersmith & City and Circle lines). Therefore 37% of our current operating service has this system in place. The introduction of new rolling stock on the Piccadilly line will see this increase to 50% of our services. We continue to ensure that all new rolling stock are equipped with sensitive edge. This remains our long term strategy, as this approach provides the best overall solution to support both operational and safety performance improvement. Nevertheless we remain open to innovation and maintain a dialogue with a wide range of international public transport operators to share information on best practice in this area.

Recommendation 3

The intent of this recommendation is to provide sufficient time for people to be able to alight safely from trains at stations where automatic train operation is in use.

Considering the sequences of events detailed in this investigation along with relevant industry guidance and good practice, including from other railway operators, London Underground Limited should review the current minimum automatic train operation station dwell times to determine if passengers have sufficient time to safely alight or board trains.

Based on this review, London Underground should determine the minimum time needed for train doors to be open and available for use, and the effect which this will have on the associated minimum automatic train operation station dwell times. London Underground Limited should produce a timebound plan and make any appropriate changes to automatic train operation station dwell times on any of its lines using this mode of operation.

ORR decision

19. LUL has undertaken a project to review dwell times for trains at stations where automatic train operation is in use. The project was originally expected to be completed in January 2025, but the remit has since been extended to incorporate

feedback from metro systems in other countries. The review is now planned to be completed in June 2025.

20. After reviewing the information provided ORR has concluded that, in accordance with the Railways (Accident Investigation and Reporting) Regulations 2005, LUL has:

- Taken the recommendation into consideration; and
- Is taking action to close it.

Status: Open.

Information in support of ORR decision

21. On 10 October 2024 London Underground Limited provided the following initial response:

TfL recognises the importance of giving our customers enough time to alight and board trains safely, in particular those customers who may need more time to do this.

We are delivering a project which considers a suitable minimum 'door dwell open time' from a human factors perspective, and how this may be incorporated into future rolling stock (including automated systems). This will consider the minimum time which must lapse between doors opening and doors being permitted to close, to enable safe boarding and alighting for customers behaving predictably under normal conditions. This project will undertake the following:

- 1. Literature Review: this will consider the findings of user trials undertaken at the University College London (UCL) Mock-up Facility to identify train design features that affecting boarding and alighting, a review of the passenger boarding times for High Speed 2, a review of work undertaken regarding customer boarding and alighting times on the Dutch Railway System and the Berlin Public Transport System.*
- 2. Review train operator trained behaviours around train door opening and closing habits (specifically related to dwell times).*
- 3. Undertake observations of typical customer behaviour boarding and alighting trains particularly in relation to Persons of Restricted Mobility, customers travelling with luggage and those travelling with children. This will also consider any further gaps or questions arising from the literature review.*

This project is due to be completed by January 2025. The project report will consider whether a minimum door open time is required on LU lines. Recommendations will be incorporated into the TfL Rail PTI Plan, along with timescales for delivery.

22. On 17 March 2025 London Underground Limited responded as follows:

You asked about our review of minimum ATO dwell times. We had planned to complete this work in January 2025. However, having started the review, this work has been expanded to incorporate feedback from other Metros from across the world via the Community of Metros (CoMET) network. In order to provide sufficient time for responses to be received and any follow meetings to be arranged, we now plan to complete this review in June 2025 but will provide an update on progress to you in May 2025.

Recommendation 4

The intent of this recommendation is to reduce the risk of train operators losing attention and awareness while operating automatic train operation trains.

London Underground should review the environmental, organisational and job factors related to operating trains in automatic train operation mode to understand how underload may affect train operators. This review should specifically consider the effect that underload may have on undertaking safety-critical tasks, such as train despatch, and what improvements may be made to assist train operators in maintaining attention. These improvements should include consideration of how the driving task is designed and the cab environment as well as measures such as individual awareness and training.

ORR decision

23. LUL has conducted three human factors reviews in response to this and other incidents. The recommendations from the reports are being considered by LUL and next steps planned, with an update provided to ORR by the end of June 2025.

24. After reviewing the information provided ORR has concluded that, in accordance with the Railways (Accident Investigation and Reporting) Regulations 2005, LUL has:

- Taken the recommendation into consideration; and
- Is taking action to close it.

Status: Open.

Information in support of ORR decision

25. On 10 October 2024 London Underground Limited provided the following initial response

We recognise that, while automation of train operations has improved safety on the Underground, that automation can lead to cognitive underload for train operators. Led by one of TfL's Human Factors Engineers (the same Human Factors Engineer undertaking the work outlined in the response to RAIB Recommendation 3), we are undertaking a number of activities to address this recommendation which will be completed in January 2025. Recommendations

from the output of this work will be incorporated into the TfL Rail PTI Plan. The detail of the work being undertaken is described below.

Review of the train cab environment

As outlined in recommendation 5 in TfL's Formal Investigation into these incidents, the majority of LU's train stock are fitted with Automatic Train Operation (ATO). In the train cab, the train operator's notifications includes a countdown clock and target point advance (via audible notification). These alert the train operator when it is time to start preparing to close the doors according to the timetabled departure time.

The TfL FIR concluded that there was the possibility these elements may compete for train operators' attention with PTI checks and encourage focus on closing the doors. Therefore, part of our Human Factors project includes a review of the Train Operator Display (TOD) and target point presentation on relevant train stock fitted with ATO, in conjunction with the required PTI checks, available equipment, and other tasks required in the cab. The Human Factors project will consider the possibility of train operators becoming accustomed to the timing of repeated, predictable events (e.g. timing of the target point during normal operations), and the effect this may have on their habitual completion of PTI checks. It will also consider the effect of 'muscle memory' i.e. the effect of a constant practice becoming routine and executed prematurely. Relevant recommendations from the report will be incorporated into the TfL Rail PTI Plan with appropriate timescales for delivery.

Unintentional Errors

In response to recommendation 7 in TfL's Formal Investigation into these incidents, we are evaluating options to reduce the likelihood and severity of inattention blindness and other human error relating to safety critical activity, and where risk controls/safeguards are limited to visual or audible checking, and other self-guided, unchecked behaviours (including review of existing industry/specialist research). A report will be produced detailing the outcomes of the evaluation and risk control options which we will consider for implementation (including equipment and people based-systems and processes). Recommendations will be incorporated into the TfL Rail PTI plan with appropriate timescales for implementation.

Technologies

To complement the Human Factors work outlined above, the LU Customer Operations Team, with support from the TfL Human Factors Engineer, are exploring technology systems utilised by other transport operating companies with a view to assessing feasibility of a trial on London Underground to monitor driver awareness and vigilance. This includes but is not limited to the guardian system operating on TfL Tramlink since 2017 which monitors drivers' eye movement to ensure vigilance & cognitive engagement.

A report led by LU Customer Operations listing the options and recommendations for a feasibility trial will be published in February 2025. Recommendations will be incorporated into the TfL Rail PTI Plan.

Non-Technical Skills (including Cognitive Underload)

As part of our approach to managing the risk of cognitive underload for train operators, the existing LU train operator promotional training includes a 'Staying Focussed' handbook and a cognitive underload video. From October 2024, the train operator Continuous Development Programme (CDP) will also include this information. This will ensure that all train operators have a full understanding on this issue. In addition to this, additional information on shift preparation and fatigue will also be included in LU train operator CDP from October 2024. Copies of these can be provided if necessary.

Whilst we have updated train operator training, we continue to learn from best practice from the national rail network as well as from TfL Formal Investigations, RAIB reports and incident data. We recognise that we could improve safety by integrating non-technical skills into all LU operations training programmes to support a culture where these skills are valued equally alongside technical competencies. Therefore, we have a timebound programme of work underway to update train operator training in line with this. We shared this plan with Emily Gelder (ORR Inspector) on 26 September 2024 and include this in Appendix 2.



Appendix 2
Cognitive Underload

26. On 17 March 2025 London Underground Limited responded as follows:

You asked about our Human Factors review. Three Human Factors Reviews have been undertaken to consider the different aspects of this recommendation including a review of the organisational and job factors related to operating trains in automatic train operation (ATO) to understand how underload may affect train operators.

The three reviews are:

- 1. Stratford Station Customer Fatality – FIR Recommendation 5 - Human Factors Assessment of Train Operator Behaviours in Automatic Train Operation (which covers the impact of human factors on the capability of staff to respond to visual indications and emergency situations, react accordingly, and retain critical information).*
- 2. Passenger Dragging Incidents on the LU Network - FIR Recommendation 5 – Human Factors Assessment (which covers a review of the TOD and target point presentation on relevant train stock fitted with ATO from a Human Factors perspective, in conjunction with the required PTI checks, available equipment, and other tasks required in the cab).*
- 3. Passenger Dragging Incidents in the LU Network – FIR Recommendation 7 – Human Factors Assessment of Train Operator Behaviours in Automatic Train Operation (which covers unintentional errors including inattentive blindness).*

The three reports are included as appendices to this letter. We are currently considering the recommendations made to determine the next steps. There are potential complexities and implications associated with some of these recommendations therefore we will be in a position to update you on them at the end of June 2025.



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Driver Assistive Technology

The Human Factors Review recognised that the described human behaviour characteristics (i.e. cognitive underload, divided attention, etc.) are traits that we are all susceptible to and that, while a greater awareness of this may reduce the likelihood of these traits, awareness cannot remove the risk altogether. Therefore, it has been recommended that technology which could help manage this risk should be reviewed. This work was already underway as outlined in the letter that I sent to you on 9 October 2024. However, work in this area has been re-focused as the same team is currently focusing on our PTI New Technologies Programme which will be trialled this year.

We are reviewing all the recommendations as well as this work together to ensure that the work that we are doing is aligned.

Non Technical Skills Training

We now include Non-Technical Skills (NTS) training in the yearly training for Train Operators (since November 2024). One of the incidents discussed and reflected on in this training is a dragging incident.

To provide an update on our progress against our NTS plan, which we have previously discussed with Emily Gelder, some key highlights are listed below. We would be happy to discuss this in more detail with the ORR if that would be helpful:

1. Engagement with the LU Heads of Professions: 6 TfL RESTRICTED

- We have engaged each profession on the importance and value of NTS.*
- Our NTS mission and useful resources have been shared with the LU Skills Development Trainers and key stakeholders.*

2. Program Integration:

- Work on reviewing NTS reporting in historical train operator Risk Based Training Needs Analysis (RBTNA) is underway, with gradual inclusion in legacy RBTNAs.*
- The Course Catalogue review has uncovered some further gaps and opportunities. These are being addressed.*

3. Trainer Upskilling:

- NTS upskilling for Train Operator trainers was delivered in October 2024.*
- Engagement events with Customer Operations trainers have been held to support NTS delivery with further training planned for March 2025 to complete Trains, Stations, Service Control and Revenue Trainers.*

4. Implementation and Assessment:

- Trainers are implementing NTS delivery and assessment strategies into programs as an overlay of existing materials.
- Flashcards for Train Operators and Service Control colleagues have been created, with their use in training environments to follow once upskill of trainers is completed. This is expected to be completed by April 2025.
- The first Service Control course trialling the refreshed NTS approach was carried out in February 2025. We are reviewing the results, with the next CAB trial to be commence in April 2025.

5. Competency Management System:

- NTS have been included in updated standards for Train Operations published in 2024.
- The launch of an overarching NTS competency management system is to be considered as part of an overarching systems roadmap as part of our overall change programme. This work requires changes to systems in some areas for which work will start in the 25/26 financial year.

6. Verification and Feedback:

- The embedding of NTS in training and assessment is currently being evaluated from the trials complete in Service Control and Trains training with the review of the current trials scheduled by April 2025.

26. On 17 April 2025 ORR wrote to London Underground Limited as follows:

We have a query with content on page 15, Appendix B: Station Arrival & Departure Process (Task Description) of London Underground Passenger Dragging Incidents FIR Recommendation 7 Human Factors (HF) Assessment of Train Operator Behaviours in Automatic Train Operation

- TO/p** In preparation for station departure, monitors the in-cab CCTV for a suitable gap in the boarding and to be able to start door close.
- Train** Sounds the door closing alert (a series of beeps) to advise customers that the doors will start to close.
- Train** Continues to countdown the dwell time showing the remaining time left on the countdown clock.
- TO/p** Continues to monitor the PTI for the status of those boarding to ensure that no one is caught or struggling to get on and to monitor the countdown clock.
- Train** The DCV control lights up when the train recognizes that all doors are closed and door interlocking has been achieved.
- TO/p** Presses the ATO Start control when the DCV has illuminated. ATO Start control must be held for 2 seconds.
- TO/p** Carries out a final check of the PTI to ensure that it is clear and safe to depart.
- TO/p** Continues checking the PTI via the in-cab CCTV and the track ahead as the train departs.

The PTI dispatch instructions to Train Operators in the LU Rule Book (shown below) state that once the door closed visual has been achieved the entire train interface should be checked again. In the Station Arrival & Departure Process in Appendix B it

is not apparent that this key stage is included. Can the process be clarified in the human factors report?

You must:

- check the station starting signal is clear or confirm a valid movement of authority to depart
- check the entire platform train interface
- close the doors and check the doors closed visual
- check the entire platform train interface again.

You must then:

- check that the station starting signal is still clear
- make a final check of the platform train interface
- start your train or confirm a valid movement of authority to depart
- check the in-cab monitors (if working) as your train leaves the platform.

For trains with in-cab monitors which provide a view of the platform after the train has departed, you must continue to monitor the platform train interface until the last carriage has cleared the entire length of the platform.

27. On 16 May 2025 London Underground Limited responded as follows:

You raised a query relating to the PTI dispatch instructions to Train Operators in the LU Rule Book verses the wording used in the Human Factors Report provided as part of my last response. I can confirm that this is an error and the wording should be aligned with the LU Rule Book. The Human Factors report will be updated to reflect this.