Door closure warning sounds on the Docklands Light Railway

Report on the modelling and live trials of 1, 2 and 3-second door closure warning sounds

MAYOR OF LONDON

TRANSPORT FOR LONDON

EVERY JOURNEY MATTERS

Door closure warning sounds on the Docklands Light Railway

Report on the modelling and live trials of 1, 2 and 3-second door closure warning sounds

MAYOR OF LONDON

TRANSPORT FOR LONDON

EVERY JOURNEY MATTERS

Table of contents

1. Executive summary 4
2. Glossary of acronyms and abbreviations 5
3. Introduction 5
3.1 RVAR requirements and exemptions 5
3.2 Purpose of this document 6
3.3 Key features of the DLR operation 6
4. Trial approach and methodology 7
4.1 Technical constraints to testing 7
4.1.1 Vehicles 8
4.1.2 Timetable compiler 8
4.2 Approach 8
5. Three-second door warning sound (model and live trial) 9
5.1 Developing the 3-second model 9
5.1.1 Outputs of the 3-second model (AM peak weekday service) 10
5.1.2 Outputs of the 3-second model (off-peak and weekend service) 11
5.2 The 3-second trial 11
5.2.1 Validating the model 12
5.2.1.1 Impact on journey times 12
5.2.1.2 Impact on vehicle requirements 13
5.2.1.3 Impact on staff requirements 13
5.2.1.4 Validation conclusions 13
5.2.2 Passenger feedback 13
5.2.3 PTI observations 14
5.2.4 PSA feedback 15
5.3 Summary 16
6. Two-second door warning sound (model) 17
7. One-second door warning sound (model and live trial) 17
7.1 Developing the 1-second model 17
7.2 The 1-second trial 18
7.2.1 Impact on journey times 18
7.2.2 Impact on overall performance 19
7.2.3 Platform observations and CCTV 21

7.2.4 PSA feedback 22
7.3 Summary 22
8. Modelling the effects of extended headways 23
8.1 Impact on journey times 23
8.2 Impact on capacity 24
9. Accessibility 25
10. Conclusions 26

Appendices 27

1. Executive summary

The Rail Vehicle Accessibility Regulations 2010 (RVAR) were introduced to provide equal access to rail users with disabilities or accessibility needs. Sections 3(3) and 3(5)(b) of RVAR state that “each passenger doorway in the side of a rail vehicle must be fitted with an audible warning device”, which must emit a warning sound “commencing not less than 3 seconds before the door starts to close”.

On the Docklands Light Railway (DLR), the warning sound is linked to the illumination of the door control device, which, under section 4(2) of RVAR, must also cease at least 3 seconds before the doors begin to close.

Currently, the DLR is non-compliant with the requirements listed above. No sound is emitted before the doors start to close, only *as* they start to do so. This has been the case since the railway was first opened in 1987.

For the purposes of this report, the term ‘warning sound’ shall refer to the sound which is required to be emitted before the doors start to close (and, for simplicity, the related visual warning). That is, the DLR does not currently operate with a warning sound, but is required to do so under RVAR.

Docklands Light Railway Limited (DLRL) was required by the Department for Transport (DfT) to conduct trials to assess the impact on safety, accessibility and operations of inserting a door closure warning sound with a duration of 3 seconds.

DLRL’s experience indicated that it would be virtually impossible to introduce the required 3-second door warning sound whilst maintaining current levels of service – a service which is designed to meet passenger demand within the constraints of vehicle availability and the present railway infrastructure.

To test the hypothesis that a 3-second warning sound could not be accommodated into the timetable, DLRL and its franchisee operator, Keolis Amey Docklands (KAD), modelled the impact of the 3-second warning sound using an operational simulator before conducting a live trial during a weekend with a partial network closure.

As well as validating the model, the live trial was used to assess the impact of the 3-second warning sound on passenger safety and accessibility. The methodology used included a passenger questionnaire, platform observations, and feedback from on-board Passenger Service Agents (PSAs).

The modelling and live trial exercises were then repeated with a 1-second warning sound, again utilising a weekend with a partial network closure. A model was also created to assess the effects of a 2-second door warning sound.

The models, which were validated by the trials, highlighted significant operational issues with inserting a door warning sound of any duration. The increased journey times would require more vehicles in service to maintain the current service levels, which would in turn increase staffing requirements and reduce access to vehicles for maintenance.

Another option would be to run a reduced service without increasing the vehicle requirement. However, this would lead to a reduction in capacity across the network. The DLR is already a crowded network and with passenger demand expected to rise

further due to the redevelopment of several parts of East London, any loss in capacity may cause significant overcrowding.

The evidence from the trials also highlighted an increased safety risk at the Platform-Train Interface (PTI). During both the 1 and 3-second trials, the number of passengers who were trapped in or struck by closing doors rose significantly. Feedback from staff indicated that they felt the increase in such incidents was a result of their reduced control over the door control procedure.

This report therefore supports an application for exemption from RVAR sections 3(3), 3(5) and 4(2). However, DLRL recognises the need for continued engagement with accessibility groups to ensure the DLR meets the accessibility needs of all passengers.

2. Glossary of acronyms and abbreviations

ADC	All Doors Closed
COD	Close Other Doors
DCP	Door Control Panel
DfT	Department for Transport
DLR	Docklands Light Railway
DLRL	Docklands Light Railway Limited
KAD	Keolis Amey Docklands
LEDP	Lead Emergency Driving Position
OPSIM	Operational Simulator
PSA	Passenger Service Agent
PTI	Platform Train Interface
RTD	Ready to Depart
RVAR	Rail Vehicle Accessibility (non-interoperable rail system) Regulations

3. Introduction

3.1 RVAR requirements and exemptions

The DfT requires DLRL to assess the safety, accessibility and operational impacts of introducing a 3-second door closure delay (with warning sound) to the DLR network. This is to comply with the Rail Vehicle Accessibility Regulations 2010 (RVAR), which ensure equal access to rail vehicles for passengers with disabilities.

Under its current exemption, DLRL must:

- On or before 15 October 2018, confirm to the Secretary of State that DLRL has begun to conduct a trial to assess the impact on passenger safety,

accessibility and service reliability of complying with paragraphs 3(3), 3(5) and 4(2) in relation to the B2007 vehicles;

- On or before 31 March 2019, confirm to the Secretary of State that DLRL has completed an evaluation of the trial's outcomes and report on those findings; and,
- On or before 31 March 2019, submit a further exemption application, or confirm that DLRL will not be submitting a further exemption application.

With respect to the first requirement, DLRL confirmed the commencement of the trials in a separate letter (our ref: 00424), which was accepted by the DfT.

This document reports on the outcomes of the trials and will support an exemption application, as per the second and third requirements.

3.2 Purpose of this document

The purpose of this document is to report on DLRL's evaluation of the effects of adopting a door closure warning sound. More specifically, this document outlines:

- The approach and methodology used for modelling the effects of 1, 2 and 3-second door warning sounds using an Operational Simulator (OPSIM);
- The results – in particular the impact on safety and operations – of the live trials conducted with 1 and 3-second door warning sounds;
- The outcomes of DLRL's engagement with Real, a local accessibility user group; and
- DLRL's conclusions.

3.3 Key features of the DLR operation

The DLR is an automatic, driverless, passenger railway. The network comprises six routes which link the City of London (to the west) with the Isle of Dogs and Lewisham (to the south), Stratford (to the north via two routes), Beckton (to the east) and Woolwich Arsenal (to the south east).

Approximately 380,000 passengers are carried on the DLR each weekday with a current high of 500,896, achieved during the London Olympics 2012. The current high outside of the Olympics is 434,983, achieved when there was significant disruption on the Jubilee Line in April 2016.

With the exception of four sub-surface stations, the stations on the DLR are unstaffed.

The operation of DLR trains is different to those of London Underground. In normal operation, DLR trains run automatically between stations. Passenger-operated door buttons are enabled automatically when a train correctly docks at a station, allowing

passengers to open the doors for boarding and alighting. A Passenger Service Agent (PSA) travels on every train and is responsible for closing the doors so the train can safely depart the station, as well as carrying out various passenger care duties and driving the train from the Lead Emergency Driving Position (LEDP) when it is not possible to operate the train in automatic mode.

The PSA becomes aware the train is ready to depart when the 'Ready to Depart' (RTD) chime sounds. This marks the point at which the signalling system is ready for the train to depart (after the scheduled dwell, or a shorter, 'minimum dwell' if the train is late running).

After hearing the RTD chime, the PSA is able to close the doors. The primary means of doing so is carried out from a Door Control Panel (DCP), located adjacent to each passenger door. When working from a DCP, the PSA is able to close all the other doors on the train while keeping the door local to the DCP open, allowing the PSA to continue monitoring the platform-train interface (PTI). PSAs are trained to only close the doors when it is safe to do so, i.e. when the PTI is clear. This is a safety critical activity.

Once the other doors are closed, the PSA can then close the local door. When all doors are detected by the train systems as correctly closed, the train can depart in automatic mode.

Currently, the DLR operates without a door warning sound. This means the passenger doors begin to close immediately after the PSA initiates door closure by pressing the Close Other Doors (COD) button on their control panel. A door closure warning sound is emitted throughout (but not before) the closing cycle and the illumination of the passenger door control devices is extinguished.

There are currently 149 vehicles in the DLR fleet; this is comprised of 55 B2007 vehicles and 94 B92 vehicles. The vehicles run in formations of either two or three 'cars', however the two types of vehicles are incompatible with each other for passenger service (i.e. B92s can only be coupled to other B92s). Each formation is then allocated to a 'circuit' and assigned an origin and destination, which the train will run between until programmed to do something else. For instance, Bank<>Lewisham services run on a Bank-Lewisham-Bank circuit.

The service pattern on the DLR has been developed to provide the optimum balance between vehicle availability and capacity, infrastructure constraints, and passenger travel demand and levels of crowding. Within these constraints, the DLR maintains headways which are delivered by the operator, Keolis Amey Docklands (KAD).

4. Trial approach and methodology

4.1 Technical constraints to testing

In developing the approach to modelling and trialling door warning sounds of various lengths, the technical constraints described in sections 4.1.1 and 4.1.2 had to be taken into account.

4.1.1 Vehicles

The two vehicle fleets operating on the DLR have doors that are mechanically very different.

The B2007 vehicle doors are electrically driven, meaning the door closure timing process (including warning sound durations) is software controlled. Therefore, no physical modification to the doors is necessary to change the door warning sound length; however, each individual door requires new software to be uploaded in order to make any timing changes.

By contrast, the doors on the B92 fleet are pneumatically driven. To introduce a change to the door closure timing would require a new component (an electro-mechanical, configurable, timer relay) to be installed at each doorway, which is highly intrusive work. Each set of doors would then need to be revisited in order to switch the delay timer to the required number of seconds.

To revisit each door and change the warning sound timing is a significantly longer exercise on the B92 fleet than with the software change on the B2007s. With the resources currently available, it is estimated that it would take 3-4 weeks (once the new relays have been installed) to make a change to the door warning sound on the B92 fleet.

4.1.2 Timetable compiler

The timetable compiler used by KAD can only compile to the nearest whole second, and cannot model fractions of seconds. This constrains the modelling scenarios and the testing of various door closure durations since only whole second intervals can be used.

In addition, the timer relay which would be introduced on the B92 fleet is only configurable to half second intervals.

4.2 Approach

The DfT required a trial of a 3-second door warning sound (as required under RVAR) before they were prepared to consider an exemption. DLRL had intended to carry out a full fleet trial involving both vehicle fleets, to assess the impact of a 3-second door warning sound. However, the working hypothesis of both DLRL and its operator, KAD, was that the 3-second door warning sound (which would add 3 seconds of extra dwell time per platform served) could not be accommodated in the operational timetable without causing significant disruption to services and passengers.

Disruption on the DLR, particularly during the morning and evening peaks, can quickly result in overcrowding on an already busy network. This can be severe at some stations, and requires KAD, at short notice, to mobilise crowd control staff at

key stations. The knock-on impact of DLR disruption on neighbouring service providers can also be significant, and vice versa.

If a full fleet trial of a 3-second door warning sound had taken place and the predicted disruption occurred, these safety risks would have remained in day-to-day operations until KAD were able to remove the 3-second warning sound from every door on every vehicle. As noted, this is not a quick task, with the implication that this could result in weeks of disruption and an ongoing, increased safety risk.

As a result, a new approach was developed jointly between DLRL and KAD, in discussion with the DfT, with the aim of testing the working hypothesis. This was comprised of the following:

- Modelling a timetable with a 3-second door warning sound and reviewing its outputs.
- Conducting a live trial (using only the B2007 fleet) to validate the model and assess the impacts in terms of safety, operations and accessibility of introducing a 3-second door warning sound.
- Modelling both 2-second and 1-second door warning sounds and reviewing their outputs.
- Conducting a further live trial with a 1-second door warning sound, again using only the B2007 fleet.

In consultation with the DfT, it was agreed that the trials would use the B2007 fleet only, due to the difficulties with changing the warning sound duration on the B92s as outlined in section 4.1.1. It was also not desirable to run the B2007s, with a 3-second warning sound, alongside the B92s, which would have had no warning sound. This may have caused confusion for customers, with implications for safety, and would have complicated the analysis of the trial. In order to keep the two fleets separate, the trials were carried out during weekend closures, where the vehicle requirements could be met by the 55 available B2007s.

5. Three-second door warning sound (model and live trial)

5.1 Developing the 3-second model

The model for a service including a 3-second door warning sound focuses on the morning peak timetable, when the service intensity and passenger demand is at its greatest, the capacity of the infrastructure is at its most stretched, and the number of vehicles in service is at its highest.

Particular infrastructure challenges include the single line sections on the north route (through Bow Church to Pudding Mill Lane, and then from Pudding Mill Lane to Stratford), junctions in the central area (i.e. the axis of Poplar, West India Quay and Canary Wharf), crossovers and terminal platform occupancy. These route

complexities, and their location on the network, are depicted in Appendix A. As described in section 3.3, the timetable and headways are optimised to deliver a safe and reliable service whilst accounting for each of these factors.

131 of the 149 vehicles are currently required for the AM peak. However, a number of vehicles are always out of service for routine maintenance, heavy maintenance, reactive repair, or DLRL project work such as vehicle upgrades. With the ageing B92 fleet, it can be a challenge to meet the daily AM peak vehicle requirements, and this is monitored closely by the DLRL and KAD management teams.

Although other periods of the day would also be impacted, the AM peak was the focus for the modelling for the reasons described above.

The timetable was modelled using a 3-second door warning sound whilst maintaining the current service frequencies. In this scenario the headways needed to remain intact to maintain current service levels and avoid overcrowding. The scenario was modelled on KAD's OPSIM.

5.1.1 Outputs of the 3-second model (AM peak weekday service)

The model shows that the impact of a 3-second door closure delay is significant on some routes while others have a greater ability to absorb the time. Key outputs of the model are listed below:

- Due to the single line sections on the north route, northbound trains would have to wait at Pudding Mill Lane for outbound Stratford trains. Consequently, the dwell times at Stratford and Canary Wharf would drop to 30 seconds (from 4 minutes 18 seconds currently). This significantly impacts operational resilience and the ability to recover the service after failures and disruption.

- The impacts on the Stratford<>Canary Wharf route could be mitigated by extending the route to Crossharbour and reversing trains in the headshunt (in the same way as carried out at Bank). However, this leaves no time for out-of-service procedures. The longer run would also require four additional 2-car trains.

- There is a lack of terminal capacity at Lewisham, which, when combined with the north route's single line restrictions, means that terminal dwells are reduced at Lewisham on the Bank<>Lewisham and Stratford<>Lewisham routes. As a result, extra vehicles would be required on both routes.

- The impact on the Tower Gateway<>Beckton services is similar to the Bank<>Lewisham services; the terminal dwell is reduced to the extent that an additional circuit is required, with an additional 3-car train needed to deliver this.

- Notwithstanding the above, the Bank<>Woolwich Arsenal and Stratford International<>Woolwich Arsenal routes are able to absorb the increased

running time from the terminal dwells with little risk to the reliability of the railway.

Overall, the model showed that the introduction of a 3-second door warning sound across the network would have the following effects:

- Morning peak vehicle requirements would rise from 131 vehicles to 143 vehicles to maintain the current headways. To provide two spare 3-car trains, the entire DLR fleet of 149 vehicles would be required every weekday.
- A total of 40 extra PSAs per day would be required to operate the extra vehicles.
- Journey times would increase by up to 19% on some routes.
- Operational resilience would be severely impacted.

5.1.2 Outputs of the 3-second model (off-peak and weekend service)

The off-peak model shows that 4 additional circuits (comprising 11 vehicles) would be required to deliver the existing service levels. The weekend service would also require 5 additional circuits and between 11-13 vehicles. Under both models, the morning run-out (where trains are taken out of the depot and into service) and evening run-in would be impacted, with all of the additional vehicles having to be squeezed into the already congested service launch.

The overall increased fleet requirement would also increase the number of trains needing to be launched prior to 05:30 and run-in after 00:30, giving maintenance teams a reduced time window in which they would have access to vehicles. This would also reduce the engineering hours available to undertake reparative work on railway infrastructure.

5.2 The 3-second trial

Conducting a live trial using only the B2007 fleet (not mixed with the B92 fleet) required utilising a part-closure of the network. The B2007 fleet was chosen due to the ease of changing the door warning sound duration, compared to the B92 fleet. The closure which best suited the requirements was over the weekend of 21st and 22nd July 2018, when the south route from Canary Wharf to Lewisham was open.

This leg was chosen because the route includes the Lewisham terminus, which the model showed was a key pinch point in the infrastructure, and Cutty Sark station, where large numbers of tourists would be accessing the DLR.

The outcomes of the trial were compared to the following weekend, 28th and 29th July 2018, which was used as a control weekend. Services operated as usual (i.e. without a door warning sound) on this weekend.

The purpose of the trial was to:

1. Review the operational service to validate the 3-second door warning sound model described in sections 5.1.1 and 5.1.2.

2. Assess the impact of the door warning sound on safety and accessibility by:

    a. conducting a passenger questionnaire to gather insights into DLR users' experiences of the 3-second door warning sound

    b. observing customer behaviour on platforms and tracking PTI incidents before and after the trial

    c. asking PSAs for feedback on the impact of the 3-second door warning sound at the end of their shifts

5.2.1 Validating the model

As outlined in section 5.1.1, the model indicated that several issues would arise if the 3-second warning sound were to be added to all vehicles. Journey times would increase on all services, meaning additional vehicles – and staff – would be required to maintain current headways. The first aim of the trial was to prove that, based on a timetable that included a 3-second door warning sound, these model outputs would exist in reality.

5.2.1.1 Impact on journey times

The model's output on increased journey times is built around an additional 3 seconds being introduced at every platform served. Over the Stratford>Lewisham route of 19 stations, journey times were modelled to increase by a whole minute (19 stations served x 3 seconds = 57 seconds. Canary Wharf has a platform either side of the train, so the door closure procedure needs to be done twice, adding an additional 3 seconds to the assumed dwell).

The trial weekend was used to test whether this assumption was correct. Over the trial and control weekends, 599 platform departures were analysed across five of the key stations on the route, during three different time periods, to compare the impact. The average dwell time results are shown in figure 1:

	Average dwell time	Notes
21/22 July (trial)	21.63 seconds	With 3 second warning sound
28/29 July (control)	18.65 seconds	With no warning sound
Difference	2.98 seconds	Within 0.1 of expected 3 seconds

Figure 1: Average dwell times on 3-second trial and control weekends

The trial therefore validated the increase in journey time assumptions used within the network-wide modelling of the 3-second warning sound. Platform occupancy increased at every station by an average of approximately 3 seconds, increasing the end-to-end journey time of every train.

5.2.1.2 Impact on vehicle requirements

Over the trial weekend, as each train took longer to complete its circuit, an additional train (consisting of 3 vehicles) was required in order to maintain the 5-minute service frequency. This extra vehicle was an output of the OPSIM exercise on the trial weekend timetable. The trial therefore validated the model output regarding increased vehicle requirements.

5.2.1.3 Impact on staff requirements

Every train running requires a PSA to be aboard to operate the train and provide customer service and revenue checks. With additional trains running, more PSAs are required and over the trial weekend, even with only 1 additional train, an additional 3 PSAs were required to run the service. The trial weekend thus validates the model's assumption that additional trains would require more staff.

5.2.1.4 Validation conclusions

Based on the trial weekend, the core issues raised by the network-wide 3-second warning sound model are validated. As the model predicted, journey times increased, more vehicles were required and more PSAs were required. In turn, this also validates the hypothesis that the morning peak timetable would not be deliverable with a 3-second door warning sound, due to the current infrastructure and fleet restrictions.

5.2.2 Passenger feedback

A passenger survey questionnaire was undertaken, similar to that used by London Underground's door warning sound trial on the Victoria Line. However, there were some differences to take account of the DLR operation, such as the current lack of door warning sound and the presence of the RTD chime. The survey aimed to answer the following questions:

- Did DLR passengers realise the difference between the RTD chime and the 3-second door warning sound, and if so, what was their reaction to the warning sound?

- How did passengers behave in response to the different noises emanating from the trains?
- Did passengers feel safer with a longer door warning sound?
- Did passengers want the door warning sound duration to increase?
- Did the answers to the above questions differ depending on whether the passenger considered themselves to have a disability?

In total, 901 questionnaire responses were collected over the trial and control weekends. Most respondents were regular DLR users: although it was a weekend survey, the data showed that 66% of those surveyed used the DLR more than three days a week, and almost 45% used the DLR five days a week.

Only 26 respondents identified as having a disability (756 didn't consider themselves to have a disability and 119 chose not to answer this question). Unfortunately, due to the small number of people who declared a disability, it is not possible to draw many concrete conclusions about the impact of the warning sound on disabled users.

An important question asked was whether those surveyed could tell the difference between the RTD chime and the door warning sound. 92% understood the meaning of the RTD chime, i.e. that the train is ready to depart and the doors will shortly be closing. Although the number of respondents who identified as having a disability was very small, almost all of this group could also identify the RTD chime.

When asked about how they act upon hearing the RTD chime, 25% of those who could identify the RTD chime said they would quicken their pace, whilst 18% said they would wait for the next train as they knew they would not make it. This indicates that users were able to make a judgement and change their behaviour accordingly. The RTD chime gave forewarning that the doors would soon be closing.

30% of respondents believed they would feel safer with an increased door warning sound. Of those that identified as disabled, this percentage increased to 50%, although it should be re-emphasised that the number of those identifying as disabled was very small. However, when asked if they would accept an increase in journey times to accommodate the increased door warning sound, 75% of all questioned, and 70% of those who identified as disabled, said they would prefer journey times to stay as they are currently, with no warning sound. This demonstrates that end-to-end journey time is a key priority for most DLR users.

5.2.3 PTI observations

A team of observers was positioned at key platforms throughout the trial and control weekends to assess any effects of the warning sound on passenger behaviour. Observers were positioned at the following stations: Cutty Sark, Heron Quays, Mudchute, Lewisham, Crossharbour and Greenwich.

Their observations included the following:

- Broadly similar numbers of passengers were observed to rush for trains on both the non-trial weekend (373 people) and the trial weekend (357 people). This indicates that passengers will rush irrespective of the presence and duration of a door warning sound.

- On the control weekend there were zero incidents observed in which passengers were trapped in or caught by doors. By comparison, there were 16 such incidents on the trial weekend, at Cutty Sark, Mudchute, Heron Quays and Lewisham.

The CCTV images in figure 2 (below) from one particular entrapment at Cutty Sark station helps to illustrate what was observed:

- The PSA begins the door closure sequence (i.e. the 3-second door closure warning sound begins)

- From the direction of the escalator, a man and woman are seen to be walking towards the train. Because of the layout of the station, they are not seen by the PSA until they appear almost at the doors.

- The passengers approach the train, continuing to walk whilst the closure warning sound sounds. It should be noted that they do not appear to be rushing; nevertheless they still try to board.

- The PSA sees the passengers and re-enables the doors before the two people board the train, but cannot stop the doors closing. The door control device illuminates, but the doors continue to close.

- The man gets onto the train; however, his bag and the woman are caught in the doors.

- The woman self releases, the doors close and the train gains its All Doors Closed (ADC) status.

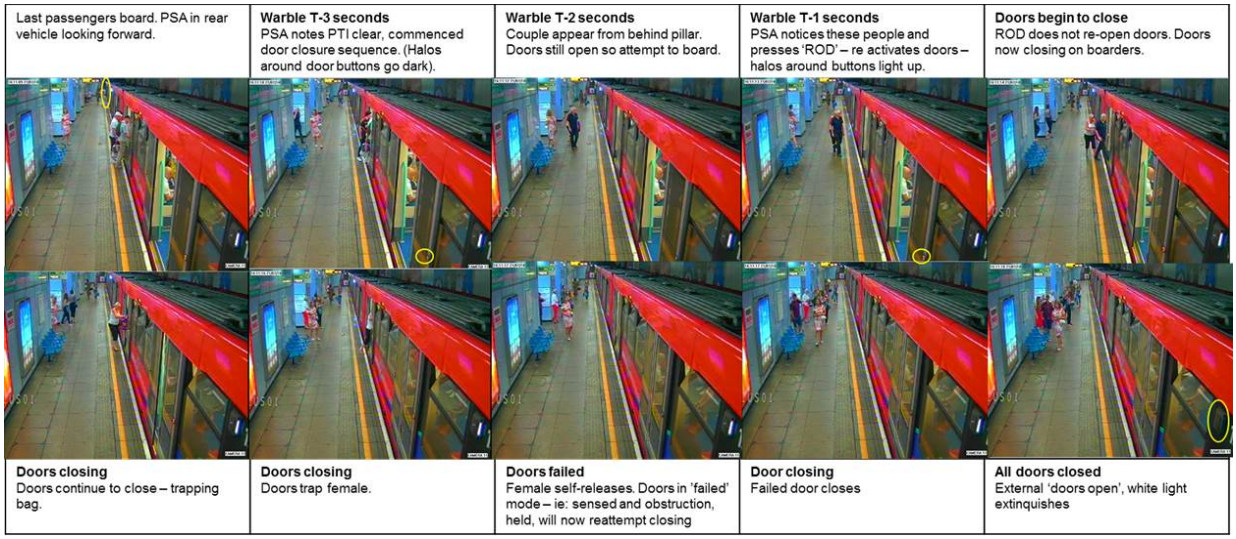


Figure 2: CCTV of door entrapment incident at Cutty Sark during 3-second door warning sound trial

5.2.4 PSA feedback

The 45 PSAs involved in the trial were asked to provide formal feedback at the end of each shift.

The feedback showed that PSAs felt the 3-second door closure warning sound gave them less control at the PTI than with the current arrangements.

In normal circumstances, when carrying out the door closure procedure without a warning sound, the PSAs felt in control of the dispatch procedure because the doors reacted immediately to their pressing of COD once they had checked the PTI was clear.

However, the warning sound added a 3-second period during which the clear status of the PTI could change, with passengers arriving onto the platform and attempting to board the train even after the PSA has initiated the door closure cycle. Many DLR station layouts have staircases and escalators very close to platforms, meaning the status of the PTI can change quite quickly; it is possible for passengers to arrive at the platform, hear the warning sound, see the doors are still open and attempt to board the train all within the 3-second warning sound period. Once the PSA has pressed COD and the 3-second warning sound starts, they cannot prevent the doors closing; the risk of passengers being trapped in doors is therefore increased.

The increased likelihood of door trappings was noted as a safety concern by several PSAs. One comment received was:

> *"People hear the warning sound and run. They also do this on the RTD chime. The difference now is that they have more time to obstruct the doors. I now have to wait until platform is completely clear before closing the door."*

Such comments would appear to support the results of the platform observations, which recorded significantly more door incidents on the trial weekend compared to the control weekend. As the PSA above notes, not only does this impact passenger safety, but it also causes delays as a) door obstructions mean the train will not achieve ADC and so cannot depart until the obstruction is removed and b) the PSA has to spend more time checking the entire platform (in addition to the PTI) before closing the doors at each station.

The need to conduct more thorough platform checks, looking in both directions for the entirety of the 3-second period, caused some PSAs to comment that they felt increasingly fatigued as their shift went on. Stress also became a factor due to the increased concentration levels required.

5.3 Summary

The modelling work done to test the effects of a 3-second door warning sound showed that it would not be feasible to add a warning sound of this duration into the current operational timetable. Doing so would cause significant disruption, longer journey times, and increased and unsustainable vehicle and staffing requirements.

The trial validated the assumption used in the model that the warning sound would add 3 seconds to the dwell time at each platform. As this assumption was validated, it follows that the effects listed in the paragraph above would indeed occur were the 3-second warning sound to be introduced into the existing timetable.

Of greater concern, however, is the safety impact (in terms of passengers' changing behaviour) of the 3-second warning sound. This could not have been predicted on the OPSIM, but the results of the trial were clear: the warning sound gave PSAs a reduced level of control over the door closure procedure, which led to a rise in door incidents.

6. Two-second door warning sound (model)

To assess the effects of inserting a 2-second door warning sound, it was decided that a modelling process would be sufficient. Live trials were conducted and analysed for the 3-second and 1-second warning sounds (detailed in sections 5 and 7 respectively) and it was predicted that the results of a 2-second trial would fall somewhere in between.

With this in mind, and given the significant financial and operational costs attached to preparing the vehicles and running live trials, it was concluded (in consultation with the DfT) that there would be no additional value in conducting a live 2-second trial.

Due to the infrastructure and vehicle availability constraints described in section 5, the 2-second warning sound model produced many of the same outcomes as the 3-second warning sound model. These outcomes would have impacted operations to a slightly lesser extent than with the 3-second warning sound, but there remained significant operational issues.

Under the 2-second model, journey times would have increased by up to 18% on some routes and, to maintain the current headways, 142 vehicles would be required (including two 3-car spares). At present, vehicle availability generally ranges from between 131-137 on a daily basis. Even if the operator was consistently able to reach the upper end of this bracket, this would not be sufficient for a full service.

The increased number of vehicles being used would also require additional staff and an increased maintenance regime, which would invoke time, resource and cost constraints. Furthermore, the enhanced fleet utilisation would increase the likelihood of a vehicle failure in traffic, and the increased use of terminal capacity would leave fewer places that a failed train could be taken to clear the line without causing further disruption.

Therefore, for the same reasons as with the 3-second warning sound, introducing a 2-second warning sound whilst maintaining the current headways is still an unworkable and unsustainable option.

As no live trial was conducted for the 2-second warning sound, it was not possible to look at the safety impact in terms of the number of PTI incidents, although it is assumed that these results would lie somewhere between those of the 3-second and 1-second warning sound trials, detailed in sections 5 and 7 respectively.

7. One-second door warning sound (model and live trial)

7.1 Developing the 1-second model

As with the 2 and 3-second warning sound modelling work described in the sections above, the first approach to assessing the impact of a 1-second warning sound was to create a model in which the current service patterns were operated with an additional 1 second per platform.

Due to the previously noted infrastructure constraints, the outcomes were very similar – if slightly less impactful - due to the reduced warning sound duration compared to the previous models. Journey times increased by an average of 1-2%, although Bank<>Lewisham services were extended by almost 10%. The vehicle requirement rose to 134 for the morning peak, which would again require additional staff and associated costs. Based on current vehicle availability, this is a more achievable figure than in the 3 and 2-second models. As with the previous models, however, a tighter timetable would make dealing with incidents and asset failures more difficult.

7.2 The 1-second trial

A 1-second door warning sound trial was conducted on the weekend of 29th and 30th September 2018. Unlike the 3-second trial earlier in the year, the timetable for the weekend was not altered to accommodate the 1-second warning sound. This different approach was used in order to see if the current service pattern would be able to absorb the additional 1 second per platform and still run a reliable service.

The dates of the trial were selected due to the railway having a part closure from Poplar and West India Quay to Bank and Tower Gateway. The trial was conducted on the north and south legs of the railway (between Stratford and Lewisham). This section was chosen for a number of reasons; it is one of the busiest sections on the railway, it can be operated in isolation from all other services, and it includes the single line section between Bow Church and Stratford, which was identified as problematic during the 3-second trial.

As discussed in section 4.2, a full fleet trial was not conducted due to the significant time and cost implications of installing new relays on the B92 vehicles. For this trial, 39 of the 55 B2007 vehicles were fitted with the 1-second warning sound.

The intention of the trial was to ascertain whether the additional time introduced by the 1-second warning sound could be absorbed within the current timetable and journey times. The safety impact of the 1-second warning sound was also analysed via platform observations and PSA feedback, as with the previous 3-second trial.

The analysis looked at the two days of the trial separately as they were very different in terms of passenger loadings. On the Saturday, higher passenger numbers and a category A event (50,000 people attending a football match at the London Stadium) meant that the day was close to replicating the conditions of a busy weekday service. By comparison, the Sunday was a quiet day on the railway, with a 53% decrease in passenger numbers from the Saturday.

7.2.1 Impact on journey times

All 712 journeys over the weekend were analysed to measure the impact of the 1-second warning sound on journey times. The expected late running of the services would be 19 seconds per journey, as there are 19 platforms serviced on Stratford<>Lewisham services.

This would not present a major issue, were it not for the single line restriction between Bow Church and Stratford. The single line entails that late running of any Stratford-bound service will delay the southbound service leaving Stratford. Even though recovery dwells are built into the journey, the late running of services leads to tight reversals at termini, which exacerbates the impact of any other late running services or incidents on the network.

The analysis of the weekend's journey times is summarised in the table below:

Saturday 29th September 2018				
Journey	Number of Journeys	Scheduled Journey Time	Average Journey Time	Difference
Lewisham to Stratford	196	00:28:32	00:29:41	00:01:09
Stratford to Lewisham	197	00:28:03	00:28:35	00:00:32
Sunday 30th September 2018				
Journey	Number of journeys	Scheduled Journey Time	Average Journey Time	Difference
Lewisham to Stratford	159	00:28:32	00:29:05	00:00:33
Stratford to Lewisham	160	00:28:03	00:28:10	00:00:07

Figure 3: Journey times during 1-second door warning sound trial

On the Saturday, the average journey time was 69 seconds greater than scheduled for Lewisham to Stratford services, and 32 seconds greater for Stratford to Lewisham services. Both of these increases are far greater than the theoretically expected 19 seconds per journey, giving a clear indication that, due to the effects of the single line section, the current schedule could not absorb the 1-second warning sound on a network-wide basis.

The average journey times on Sunday increased by 33 seconds from Lewisham to Stratford and 7 seconds in the opposite direction. Although these increases were not as dramatic as on the Saturday, the additional time is still significant, particularly in the northbound direction. The reason for the smaller increases compared to Saturday is that passenger numbers on Sundays are by far the lowest throughout a regular week, meaning that PSAs are able to close the doors much quicker at each station and maintain their journey times.

7.2.2 Impact on overall performance

The primary two performance metrics for the DLR are ‘departures’ and ‘journey times’, both of which are measured on a daily basis. The departures score indicates the percentage of the day’s trains which fully completed their scheduled journey, whilst the journey times measure relates to the number of trains which completed their journey within the target journey time for that route.

Over the weekend of the 1-second trial, the performance scores were generally good. However, there were a few service-affecting delays on the Saturday, and the impact of these was exacerbated by the effects of the 1-second door warning sound. In total, 4 departure losses and 2 journey time losses were allocated to the trial.

The impact of the warning sound on performance would likely have been more significant were it not for the large number of manual interventions which were made by staff in the control centre. Data shows that, over the 1-second trial weekend, the controllers manually intervened with the service on significantly more occasions than would have been necessary on a regular service weekend. These included instances where controllers held trains at stations (as shown in Figure 4) or manually departed trains in order to keep services running on time (Figure 5).

Figures 4 and 5 show the number of occasions on which these two forms of manual intervention were made by control centre staff during different weekend closures throughout the year. The Saturdays of the 3-second trial (21/07/18) and the 1-second trial (29/09/18) are shown, along with four other Saturdays on which the network was partially closed. Of these, Saturday 17/11/18 can be regarded as anomalous as the service was affected by a signalling issue at Canning Town, which required more manual intervention than usual from control centre staff.

On the Saturday of the 1-second trial, a significantly higher amount of both of these forms of manual intervention was required than would be expected on a usual service day (unlike the 1-second trial, the 3-second trial ran with a specially-amended timetable, and so did not require such an large amount of manual intervention).

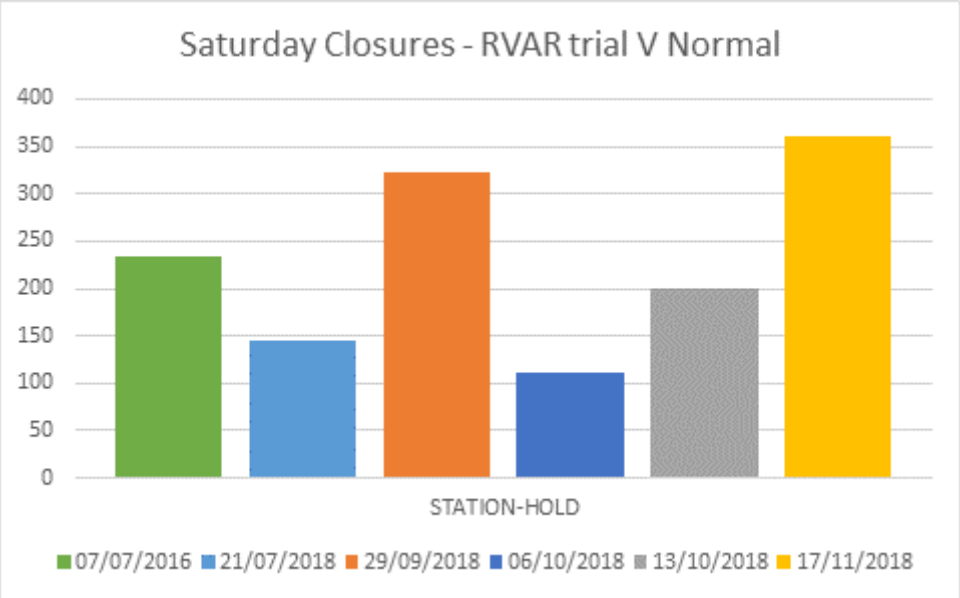


Figure 4: Manual intervention (Station Holds) data for 2018 closures

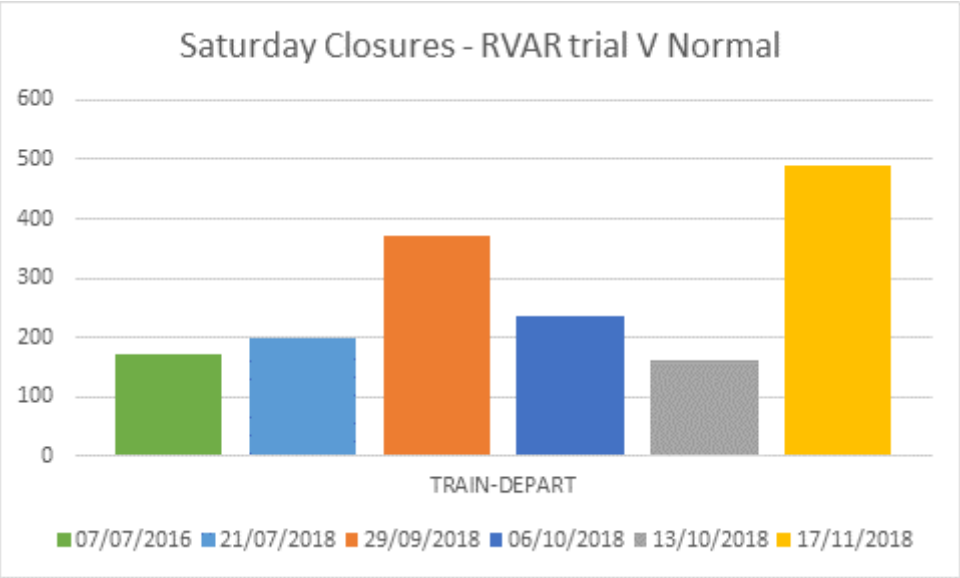


Figure 5: Manual intervention (Train Departs) data for 2018 closures

The DLR is an automatic railway and increasing the necessity for such manual interventions represents a human factors issue.

A previous independent review of manual interventions in the DLR control centre concluded that “the need for manual intervention can be cognitively demanding”. The report found that controllers are able to deal with such increased workload for short periods of time, for example during service disruption or incident management, but that a sustained period during which manual intervention is required can lead to “cognitive overload”.

It would therefore be undesirable to increase the need for manual intervention in normal operational circumstances, as this may impact the controllers’ ability to respond to incidents on the network. In turn, this could have an adverse effect on the railway’s performance and, although the automatic system provides protection against serious incidents such as collisions, there is the potential for other incidents to occur.

7.2.3 Platform observations and CCTV

As with the 3-second trial, members of KAD staff were positioned on platforms to observe customers’ behaviour whilst boarding trains. Observations were made at platforms between Canary Wharf and Lewisham only, to enable direct comparison between the trial weekend and the control weekend (Stratford<>Lewisham services do not run on a regular weekend).

The observations particularly focused on the numbers of people running for trains and getting struck by or stuck in the doors. In total, 84 hours of observations were made across 7 platforms. The findings are summarised below:

28th & 29th July (regular weekend service – control weekend)	
Passengers running for the train	373
Passengers struck by/stuck in closing doors	0
29th & 30th September (1-second door warning sound trial weekend)	
Passengers running for the train	449
Passengers struck by/stuck in closing doors	12

Figure 6: Results of 1-second trial platform observations

The results show a 20.4% increase in passengers running for the train on the 1-second trial weekend compared to the weekend of 28/29 July, used as a control comparator. There were also 12 door incidents, compared to none on the control weekend. This is perhaps due to the reduced amount of control the PSA has over the door closure process, as reflected in the PSA feedback in section 7.6.

7.2.4 PSA feedback

A questionnaire was distributed to 31 PSAs working on the weekend of the 1-second trial, to gather feedback on the impact of the warning sound. The full questionnaire is included as Appendix B.

The majority of PSAs said they had not noticed any effects of the 1-second warning sound on safety or passenger behaviour. However, amongst those who had, the feedback was similar to that received after the 3-second trial, the main theme being the reduction in control over the door closure procedure. Some example comments are listed below:

> *"[It was] difficult to anticipate passengers' movements from COD and doors closing"*
>
> *"Less control with added delay. After COD is pressed the delay allows passengers to still try and board"*

As was the case in the previous trial, the warning sound introduced a short period of time in which the status of the PTI could change. Passengers could arrive at the PTI and attempt to board the train after the PSA had initiated the door closure cycle, increasing the risk of door entrapments.

7.3 Summary

Unlike the 3-second trial, where the timetable was adjusted to accommodate the door warning sound, the timetable for the 1-second trial was left unchanged to test whether it could absorb the additional time.

Good performance scores were achieved by the operator over the weekend of the trial, but this was mainly because it was a largely quiet weekend with few other service-affecting incidents on the railway. There were some performance losses

attributed to the trial, and there may have been more were it not for a significant level of manual intervention by Control Centre staff.

It should also be emphasised that the trial was carried out on an isolated section of the railway; if the 1-second warning sound were rolled out across the network, the journey time increases would have caused greater disruption.

In terms of safety, there were similar concerns to those raised in the 3-second trial. There was a dual risk identified as passenger behaviour change (increased rushing to board trains) combined with PSAs' reduced control over the door closure procedure, causing a significant increase in the number of door incidents observed.

8. Modelling the effects of extended headways

Given the numerous operational issues with inserting a door warning sound of any duration, as outlined in sections 5, 6 and 7, an alternative method of operating with a warning sound was also modelled. For these scenarios, headways (the scheduled gaps between trains on each route) were extended slightly. This meant a less frequent service was operated, but the problems of unsustainable vehicle and staffing requirements were mitigated.

The headway extensions are detailed in figure 7:

Current headways	Headways in 3-second model	Headways in 2-second model	Headways in 1-second model
8 minutes	8 mins 30 seconds	8 mins 10 seconds	8 mins 6 seconds
4 minutes	4 mins 15 seconds	4 mins 5 seconds	4 mins 3 seconds

Figure 7: Service frequencies for extended headway warning sound models

The outputs of these models are discussed below.

8.1 Impact on journey times

With the headways extended as described above, the journey times still increased on each route due to the additional time introduced by the warning sound and the operational infrastructure constraints outlined in section 5.1.

Under the 3-second door warning sound model with extended headways, the journey times increased by up to 5.5%. The journey time increases with the corresponding 2-second warning sound model were slightly lower, with a maximum increase of 3.4%.

The increases are not as large as in the earlier models (where the headways were not changed), but are significant nonetheless.

8.2 Impact on capacity

Perhaps more significantly, the models also showed that running a service with extended headways to accommodate the door warning sound would lead to an overall loss of capacity. As fewer trains would be able to run per hour, the DLR would be able to carry fewer passengers. The changes to overall network capacity resulting from the extended headway models are shown below:

Route	Current hourly capacity (AM peak service)	Capacity with 3-second warning sound and extended headways	Capacity with 2-second warning sound and extended headways	Capacity with 1-second warning sound and extended headways
Stratford<>Lewisham	3300	3106 (-5.88%)	3233 (-2.04%)	3259 (-1.23%)
Bank<>Lewisham	9900	9318 (-5.88%)	9698 (-2.04%)	9798 (-1.23%)
Stratford<>Canary Wharf	3300	3106 (-5.88%)	3233 (-2.04%)	3259 (-1.23%)
Tower Gateway<>Beckton	4950	4659 (-5.88%)	4849 (-2.04%)	4889 (-1.23%)
Bank<>Woolwich Arsenal	4950	4659 (-5.88%)	4849 (-2.04%)	4889 (-1.23%)
Stratford Int'l <>Woolwich Arsenal	3300	3106 (-5.88%)	3233 (-2.04%)	3259 (-1.23%)

Figure 8: Impact of extended headway warning sound models on route capacity

As figure 8 shows, introducing a door warning sound – and easing the headways to accommodate it – will cause a reduction in network capacity. A 3-second door warning sound would lead to a reduction in capacity of almost 6% on every route.

The immediate impact of any reduction in capacity would likely be a rise in crowding on trains and at stations, as fewer services would be available for passengers. During peak periods, the DLR is already 'severely crowded' (3-4 pax/m^2) on the airport route and 'heavily crowded' (2-3 pax/m^2) on parts of the north and south legs.

Furthermore, London, and in particular the area covered by the DLR, is predicted to experience continued growth over the coming decades. London is growing at a faster rate than any other region of the United Kingdom, with its population predicted to reach 9.5 million by 2026[1]. The London Borough of Tower Hamlets, which includes 17 DLR stations, is the fastest growing local authority in the country in terms of population, and the Royal Borough of Greenwich, which covers a further 5 DLR stations, is also in the top ten.

[1] Office for National Statistics (2018) 'Subnational population projections for England: 2016-based'. https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/subnationalpopulationprojectionsforengland/2016based Date viewed: 04/12/2018

There is a large amount of development ongoing in East London in particular, as shown in Appendix C. Particular areas of development include the Isle of Dogs, where regeneration is forecasted to provide 20,000 additional homes and 65,000 jobs, and Silvertown (14,000 homes, 24,000 jobs). With this predicted influx of people to the areas served by the DLR, it is likely that DLR passenger numbers will continue to increase.

In order to meet this forecasted increase in demand, DLRL are in the process of procuring 43 new higher-capacity trains, which will be brought into service from the mid-2020s and will eventually replace the ageing B92 fleet. The opening of the Elizabeth Line (Crossrail) in the next few years may also help to alleviate crowding, particularly on services from Woolwich Arsenal.

However, given the existing concerns around overcrowding on the network, and the scale of the predicted growth of many parts of East London, any reduction in the current capacity due to operating with a door warning sound and extended headways is undesirable, and presents a significant potential safety issue.

9. Accessibility

Although the DLR is a completely step-free network, it is recognised that some passengers may require additional assistance to complete their journeys. This includes people with mobility and visual impairments, as well as a range of other user groups including school parties and families with young children. A PSA is present on every train and will always check the PTI before closing the doors. PSAs are trained to look out for user groups such as those mentioned above and allow them extra time to board and alight if necessary.

Unfortunately, very few respondents to the trial feedback surveys disclosed a disability, and it is therefore difficult to draw any firm conclusions about the impact a door warning sound would have on users with additional accessibility needs.

To date, however, DLRL's engagement with local accessibility groups has shown that the door warning sound is not a significant issue or priority for disabled users. The issue has been discussed with representatives from Real, an organisation which works to improve opportunities for disabled people in the London Borough of Tower Hamlets. As part of its 'Local Voices' project, Real continually monitors feedback from the local community on accessibility issues on the DLR. The group reported that they have not received any feedback from any member regarding door warning sounds, or the lack thereof, and as such do not perceive this as a barrier to the railway being accessible. Moreover, they recognise the operational and safety issues that introducing a warning sound may cause.

Therefore, DLRL believes that the lack of a door warning sound does not negatively impact passengers with disabilities. However, DLRL is committed to continued engagement with such user groups to monitor any developments surrounding this and other accessibility-related issues.

10. Conclusions

Following the extensive work undertaken to test the effects of the 3-second door warning sound required under RVAR, and also those of 1 and 2-second door warning sounds, DLRL and KAD conclude that introducing a warning sound is neither desirable (due to its adverse effects on passenger safety) nor operationally viable.

As this report has shown, the introduction of a door warning sound of any length would cause significant operational issues. The additional time per platform would increase journey times, with the potential for knock-on operational effects including unsustainable vehicle requirements, increased staffing requirements, reduced access to vehicles for maintenance, and a reduction in customer satisfaction.

If an alternative approach were taken, whereby service frequencies were extended in order to maintain the current vehicle requirement, this would result in an overall loss of capacity across the network. This is not a desirable option as it may lead to unsafe levels of overcrowding on an already busy system.

Under either approach, the direct impact of the warning sound on passenger safety is a major concern. Although not identified conclusively in our trials, there is the possibility that a warning sound would encourage passengers to rush to board trains, increasing the likelihood of door trappings. Evidence of this ‘hustle effect’ was found in London Underground’s warning sound trial, which collected data from a much longer period of time and so gained more conclusive results.

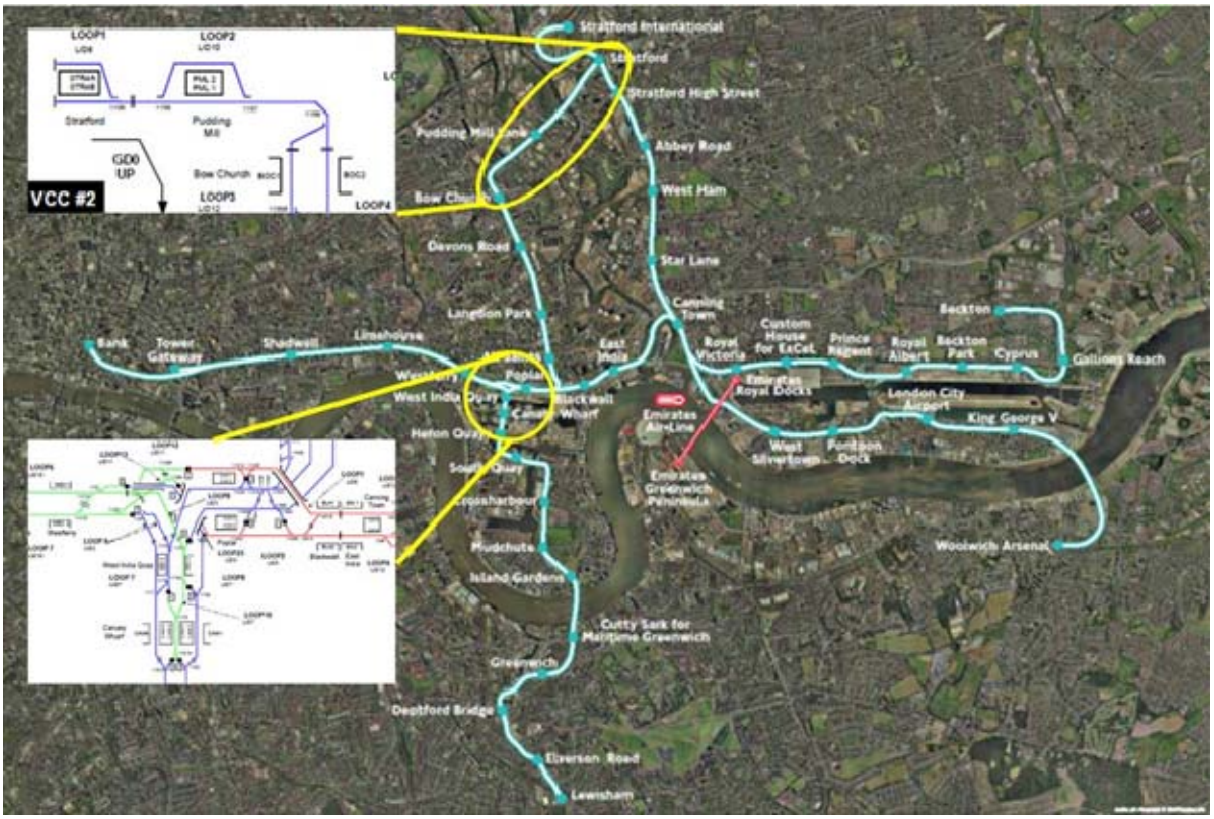
A further safety concern is the change to the door closure procedure that a warning sound would cause. Currently the PSA has control over this procedure, with the doors responding immediately once they press COD, having checked that the PTI is clear. A door warning sound would introduce a period of time after the PSA has initiated the closure cycle in which passengers may attempt to board. There is a clear risk, as demonstrated by the results of the trial, of customers being struck by or trapped in the doors.

DLRL is due to introduce 43 new vehicles into passenger service by the mid-2020s, which will have the functionality for the duration of the door warning sound to be altered much more easily. However, given the operational and safety impacts of a door warning sound outlined in this report, derogation should also be sought for this future fleet.

The evidence therefore supports an application for permanent exemption from sections 3(3), 3(5) and 4(2) of RVAR for all current and future vehicles used in passenger service on the DLR.

Appendices

Appendix A: Map of DLR network showing key route complexities and infrastructure constraints



Appendix B: PSA questionnaire on warning sound trials

Q1. Did the extended door warning sound improve passenger behaviour when boarding or alighting the train?

Q2. What impact did the door warning sound have on passengers rushing to board the train?

Q3. What effect do you think the increased warning sound and door closing time had on carrying out the door procedure safely?

Q4. Did you change the way you normally operate in response to the door warning sound extension?

Q5. Did you change the way you normally operate in response to the door warning sound extension?

Q6. Did the door warning sound work correctly for the duration of your duty?

Q7. Did you encounter any issues due to the increased time to close other doors?

Q8. Did you receive any feedback from passengers about the door warning sound?

Q9. Did you notice and specific examples of rushing or passenger behaviour?

Q10. Do you have any other comments or suggestions about the door warning sound extension?

Appendix C: Predicted future development in East London