



**DESIGN PACKAGE C146  
CUSTOM HOUSE STATION**

**RIBA Stage F Legion Modelling Report**

**Document Number: C146-ATK-Z-XMO-CR145-00003**

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Learning Legacy Document

# 1 Passenger Movement Strategy Report

## 1.1 Introduction

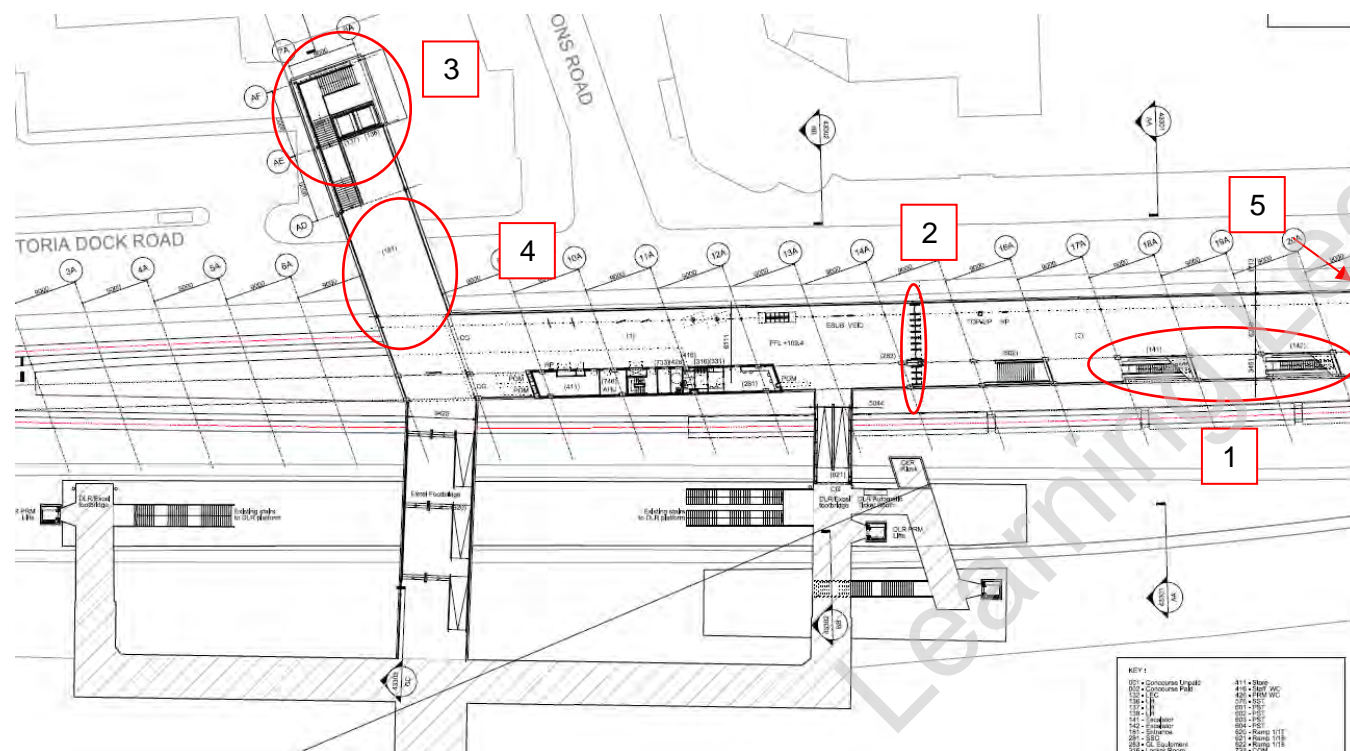
The Atkins/Arup Design Team has been appointed under contract C146 to develop the design of Custom House station from the existing SD3 Station Design to RIBA Stage F. The design is presently being developed at RIBA Stage F, following the implementation of a number of value engineering opportunities which have been instructed following the completion of RIBA Stage E.

This report provides analysis of the Legion modelling undertaken to assess these design changes. This modelling is a continuation of the work undertaken at RIBA Stage E.

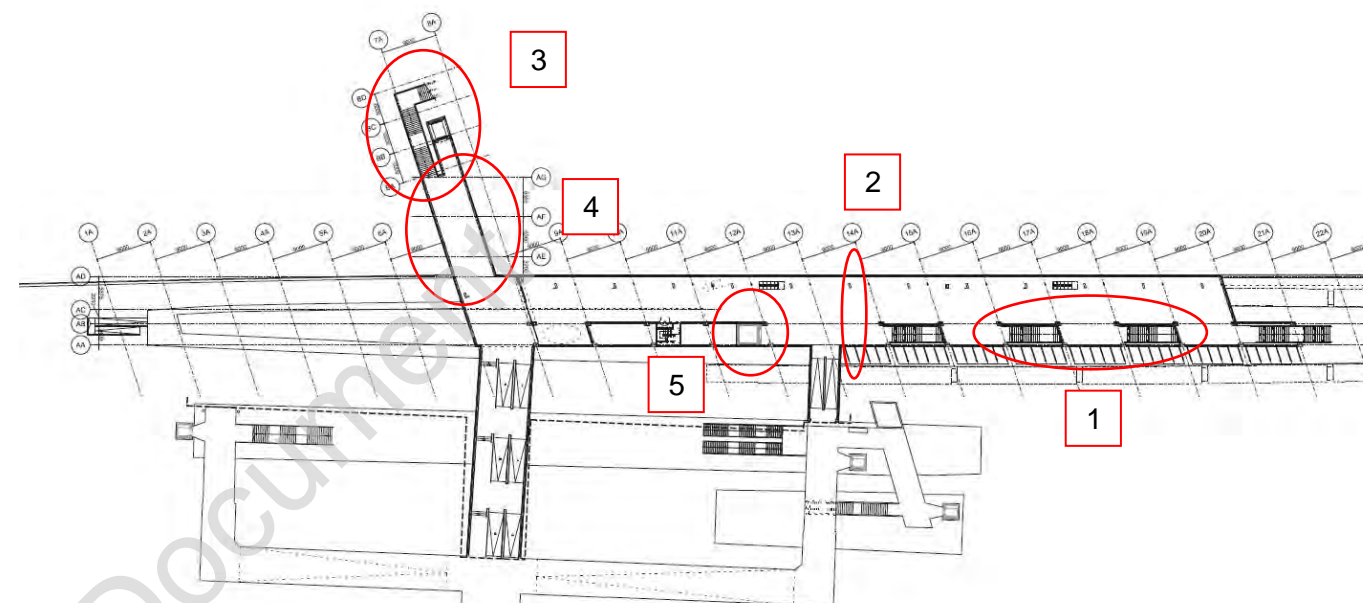
## 1.2 Design Changes from Stage E

The current Stage F Design including the value engineering opportunities has several major differences when compared to the Stage E design. The key differences between the Stage E and Stage F designs which have an effect on pedestrian movement are outlined below and shown in **Figure 1** and **Figure 2**.

**Figure 1: Stage E AADT Design (Concourse Level)**



**Figure 2: Stage F AADT Design (Concourse Level)**



### 1.2.1 Escalator Removal (1)

As part of the value engineering exercise it has been proposed to remove the two escalators from the Crossrail concourse and replace them with additional banks of stairs. The concourse now has four banks of stairs connecting the concourse and platform.

### 1.2.2 Gateline Removal (2)

C146 has been instructed to remove the gateline from Custom House station. Subsequently a number of validators have been included in the design to enable passengers to swipe in/out of the network. Six validators have been provided as requested by RfL, two each at the ExCeL bridge, station entrance and DLR interchange. The removal of the gateline has enabled the staircases to be moved further to the west to minimise the length of the concourse and subsequently passenger walk times.

### 1.2.3 Station Entrance (3)

One of the value engineering opportunities identified is the removal of one of the lifts at the station entrance. The lift is not required from a passenger flow perspective and management strategies will be employed if the remaining lift is out of service. Due to the removal of this lift the bridge over Victoria Dock Road has been reduced in width (4).

### 1.2.4 Relocation of Crossrail Passenger Lift (5)

Due to a reduction in the size of the station accommodation, it is now possible to move the Crossrail station passenger lift to the end of the accommodation block, to the west of the eastern link. This position is much preferred to the original lift location at the eastern extent of the concourse, which was above the centre of the platform island. The lift is now located above the western end of the platform island which provides considerable journey time savings and significantly shorter walk distances for PRMs (up to 200m shorter distance).

### 1.3 Scenarios Modelled and Passenger Demand

Following the completion of the RIBA Stage E Modelling report, C146 was instructed to adopt revised demand and assumptions, as detailed in report C146-ATK-Z-XMO-CR145-00004. A summary of the key changes is included below.

The original requirement to model 2016, 2016 + 20% and 2016 + 35% (2076) has been replaced by a requirement to model 2026 and 2026 + 28% (2076). A revised demand forecast for these years has been constructed by Crossrail from the latest version of Railplan, with the 28% increase applied uniformly across the station demand.

The demand used during the current RIBA Stage E 2016 AM Base modelling is included below in **Table 1**, whilst the Demand provided as part of the Impact Assessment for the 2026 AM Base is included in **Table 2**.

**Table 1: 2016, 3 hour AM Peak Demand (07:00 – 10:00)**

CHHB5051107A	STATION ENTRANCE (R.V. ROAD)	NORTH LONDON LINE	CROSSRAIL (EB)	CROSSRAIL (WB)	DLR	TOTAL
STATION ENTRANCE (ROYAL VICTORIA ROAD)	-	-	100	1800	250	2150
NORTH LONDON LINE	-	-	-	-	-	0
CROSSRAIL (EB)	200	-	-	-	200	400
CROSSRAIL (WB)	150	-	-	-	450	600
DLR	100	-	800	5000	-	5900
<b>TOTAL</b>	<b>450</b>	<b>0</b>	<b>900</b>	<b>6800</b>	<b>900</b>	<b>9050</b>

**Table 2: Revised Passenger Demand for 2026 AM Peak (07:00 – 10:00)**

CH199RuAM	STATION ENTRANCE (VICTORIA DOCK RD)	CROSSRAIL (EB)	CROSSRAIL (WB)	DLR (EB)	DLR (WB)	TOTAL
STATION ENTRANCE (VICTORIA DOCK RD)	-	100	2000	0	200	2300
CROSSRAIL (EB)	550	-	-	850	150	1550
CROSSRAIL (WB)	150	-	-	250	100	500
DLR (EB)	150	400	350	-	-	900
DLR (WB)	0	400	3350	-	-	3750
<b>TOTAL</b>	<b>850</b>	<b>900</b>	<b>5700</b>	<b>1100</b>	<b>450</b>	<b>9000</b>

Overall the AM Peak has a comparable number of passengers in the revised demand scenario, 9,000 compared to 9,050 in the previous demand.

The predominant change is the shift of destination for interchange passengers. In the 2016 matrix, 7,700 passengers were moving to the Crossrail platforms, 5,800 of these from DLR. In the 2026 matrix only 6,600 are heading to Crossrail, down around 15%, while the remaining passengers are now alighting Crossrail trains and heading to DLR (roughly two thirds) and the station entrances (roughly one third).

This changes the nature of the station, as previously the flow was unanimously tidal in nature, with 85% of all passengers heading to Crossrail. This number has now dropped to 73% with an increased opposing flow around the DLR Eastern link and Crossrail stairs (increase from 1,000 to 2,050 alighting Crossrail trains).

The demand is transposed for the PM peak (16:00 – 19:00).

The event demand scenario modelled at Stages D and E has been repeated at Stage F, with the event demand (alighting passengers) applied to the PM 2026 model.

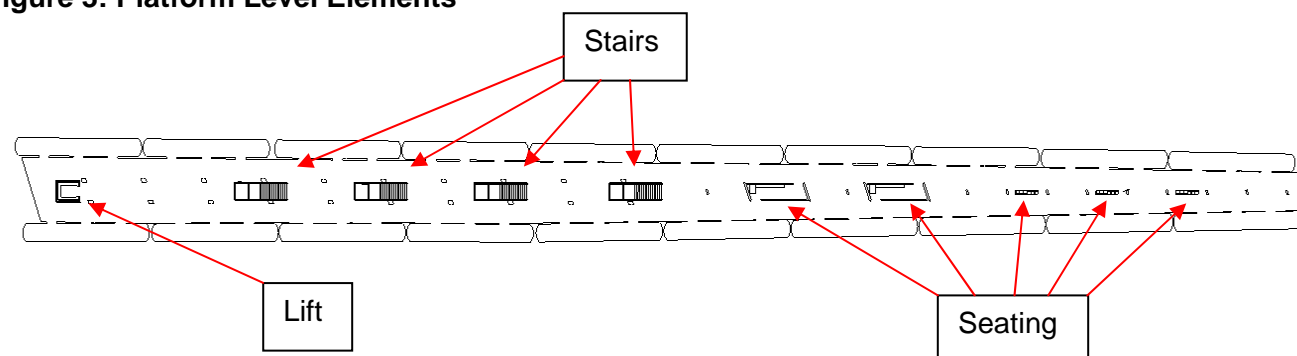
### 1.4 Modelled Layout

The Stage E Legion models were updated with the following CAD drawings received from C146 Custom House Station design team (October 2010):

- Concourse Level (Drawing: C146-ATK-A-DDA-CR145\_a-42104 rev P06.1 and C146-ATK-A-DDA-CR145\_a-42105rev PO5.1); and
- Platform Level (Drawing: C146-ATK-A-DDA-CR145\_a-42100 rev P06.1 and C146-ATK-A-DDA-CR145\_a-42101rev PO5.1).

Figure 3 outlines the platform level layout of vertical elements and seating.

Figure 3: Platform Level Elements



### 1.5 Modelling Assumptions

The inputs and modelling assumptions remain consistent with the Stage E modelling with the exception of updates instructed by Crossrail, as outlined in C146-ATK-Z-XMO-CR145-00004, alongside changes required following the design development. Key changes to the model include:

- Following the removal of the escalators, alighting passengers on the Crossrail platforms are now routed to the nearest set of stairs. Passengers boarding Crossrail trains (excluding PRMs) are assumed to all use the first set of stairs to the platforms (worst-case scenario);
- Following the removal of the gateline, all passengers entering the station from street are assumed to stop at a ticket validator. Passengers interchanging from DLR are not assumed to use a validator as they will already have swiped in at the start of their journey (as agreed with Crossrail); and
- The Crossrail platform boarding has been reverted to the original SD3 profile which was based upon an end loaded platform from the western end. This is deemed more appropriate for the current station design given the new stair position and the 100% assumption using the western stair.

#### 1.5.1 Train frequencies

The length of Crossrail trains and frequency of all the train services used in this study are tabulated in Table 3.

Table 3: Length and Frequency of Trains

Description	2026	2026 + 28%	2026 + Event
Length of Crossrail Trains	10 Car	10 Car	10 Car
<b>Train Frequency (trains per hour)</b>			
Crossrail (EB & WB)	12	12	12
DLR (EB & WB)	12	17.5	27

### 1.6 Legion Modelling Outputs

All the areas of the Crossrail station were assessed for queuing, stairway and walkway Fruin Levels of Service.

Cumulative Mean Density (CMD) plots based on Fruin's Levels of Service for walkways for the peak 15 minutes within the peak hour have been provided for each scenario. Where appropriate, this is backed up with queuing level of service plots.

#### 1.6.1 Levels of service (LoS)

Level of Service (LoS) is used in pedestrian planning to indicate densities of pedestrians per square metre and hence classify pedestrians' experience in terms of freedom of movement and comfort.

LoS A represents free-flow conditions whilst LoS F indicates a very congested situation associated with the breakdown in flow conditions with many stoppages (Pedestrian Planning and Design, John J. Fruin, 1987). Figure 4 below shows the Walkways LoS A to F commonly used in pedestrian planning.

Figure 4: Fruin Levels of Service (LOS) - Walkways

### Level of Service (LoS) - Fruin standards for walkways

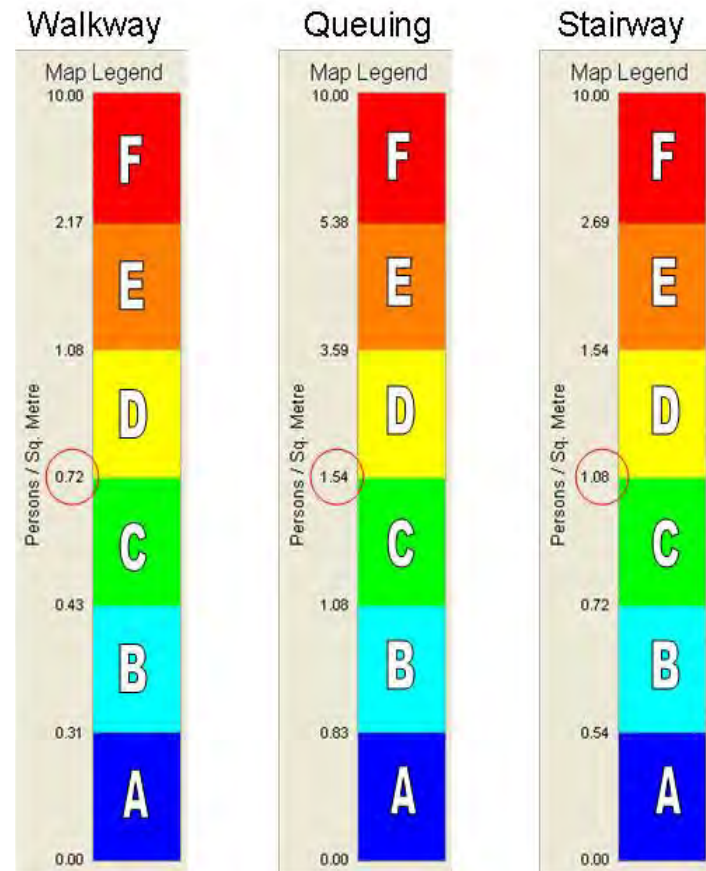
<b>A</b>	Normal walking speed can be freely selected & slower pedestrians can be easily overtaken. Crossing conflicts can be easily avoided.	
<b>B</b>	Sufficient space is available to select normal walking and to bypass other pedestrians in primarily one-directional flows. Where there are reverse-direction or crossing movements, minor conflicts will occur.	
<b>C</b>	Restricted ability to select normal walking speed & freely pass others. High probability of conflict where crossing movements & counter-flows exist. Conflict avoidance requires frequent adjustment of walking speed & direction. Flow is reasonably fluid, however considerable friction & interaction between pedestrians is likely to occur.	
<b>D</b>	Restricted walking speed; overtaking slower pedestrians is difficult. Counter-flows & crossing movements severely restricted. Some probability of reaching critical density causing temporary stoppages.	
<b>E</b>	Walking speed & passing ability is restricted for all pedestrians. Forward movement is possible only by shuffling. Counter-flows & crossing movements extremely difficult. Flow volumes approach limit of walking capacity.	
<b>F</b>	Severely restricted walking speed; frequent unavoidable contact with others; reverse or cross movements are virtually impossible. Pedestrian flow is sporadic & unstable.	

Source: Pedestrian Planning and Design, John J. Fruin, 1987

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The key for Fruin LoS for Walkways, Queuing and Stairways is shown in **Figure 5**. The areas of the station where passengers are willing to tolerate higher levels of service due to the nature of activity (queuing) are analysed using Fruin Queuing LoS.

**Figure 5: Fruin Levels of Service (LOS)**



meet this level of service over the busiest 15 minute period of operation. This shall be demonstrated through the use of Legion Average Level of Service plots.

Similarly, in other locations where a mix of queuing and walking take place, a common sense approach should be adopted in the interpretation of Fruin results, relying heavily on the observed performance of the space in question during simulation".

**Table 4: LU's - SPSG Planning Criteria and Levels of Service**

Station Area	Normal Operation	LoS	Quantitative Measure
Ticket Hall / Open Concourses	Queuing	LoS B	1.0m <sup>2</sup> per person
Queuing for Ticket Hall facilities	Queuing	LoS C	0.8m <sup>2</sup> per person
Passageways:			
One-way	Walkway	LoS D	50 passengers /minute/metre width
Two-way	Walkway	LoS C	40 passengers /minute/metre width
Stairways			
One-way	Stairway	LoS D	35 passengers /minute/metre width
Two-way	Stairway	LoS C	28 passengers /minute/metre width
Platforms	Queuing	LoS C	0.8m <sup>2</sup> per person

(Source: SPSG, LUL, November 2005)

### 1.6.2 CRL Acceptance Criteria for Legion Modelling

**Table 4** below shows London Underground (LU)'s Level of Service measures to apply to the four categories of station operation in the station areas listed.

Crossrail's Pedestrian Modelling Standard, **Station Planning: Platforms, CR-STD-305, V6**, states that, "Under normal operation, platforms must be sized to offer a minimum Fruin Level of Service C at the busiest part of the platform. The platform must be sized:

- to provide both waiting areas/accumulation areas
- to provide circulation areas for passengers

The Platform Accumulation Area should be sized to perform at a maximum average density of 1.54 people per square metre. The Platform Circulation Area should be sized to a maximum average density of 0.72 people per square metre. Both the Accumulation Area and the Circulation Area are to be added together to determine the required platform width. It is acknowledged that Fruin Level of Service C performance standard may not be met for short periods of time. However it is required that platforms

## 1.7 Results

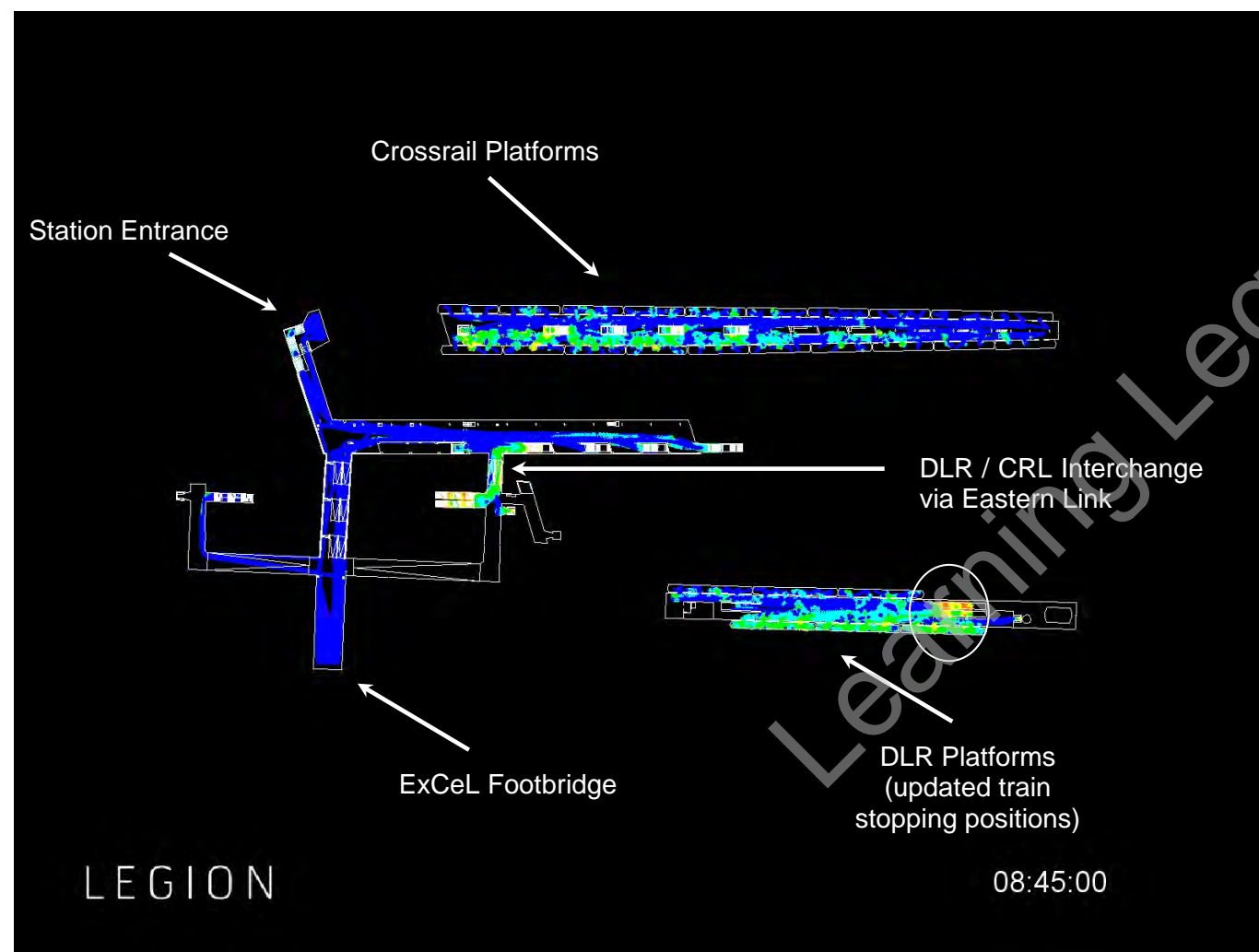
The Results of the Legion modelling for Custom House station are included below. The following plots are Cumulative Mean Density plots using Walkways levels of service unless stated.

### 1.7.1 AM Peak (07:00 – 10:00)

#### 1.7.1.1 2026 (Base)

Figure 6 highlights the density for the 08:30 – 08:45 period in the 2026 Base model.

Figure 6: Cumulative Mean Density Plot, 08:30 - 08:45, 2026 Base

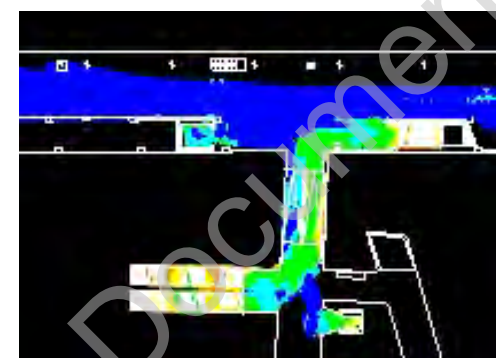


Overall the station operates satisfactorily in the AM Base model. The Crossrail westbound (WB) platform is a mixture of LoS B & C through the western and central sections of the platform and tailing off to LoS A at the eastern end of the platform. The eastbound (EB) platform is LoS A across its whole length.

The DLR platforms are predominantly LoS B/C and a small area of LoS D is beginning to form at the base of the DLR eastern stair (circled on Figure 6). This is due to passengers movements being focussed at the bottom of the stairs and is only for a short duration.

The concourse, station entrance and ExCeL footbridge operate at LoS A. The eastern link between DLR and Crossrail is a mixture of LoS B/C and this LoS is maintained to the top of the western Crossrail stairs, as highlighted in Figure 7

Figure 7: Cumulative Mean Density Plot, 08:30 - 08:45, 2026 Base – CRL/DLR Eastern Link

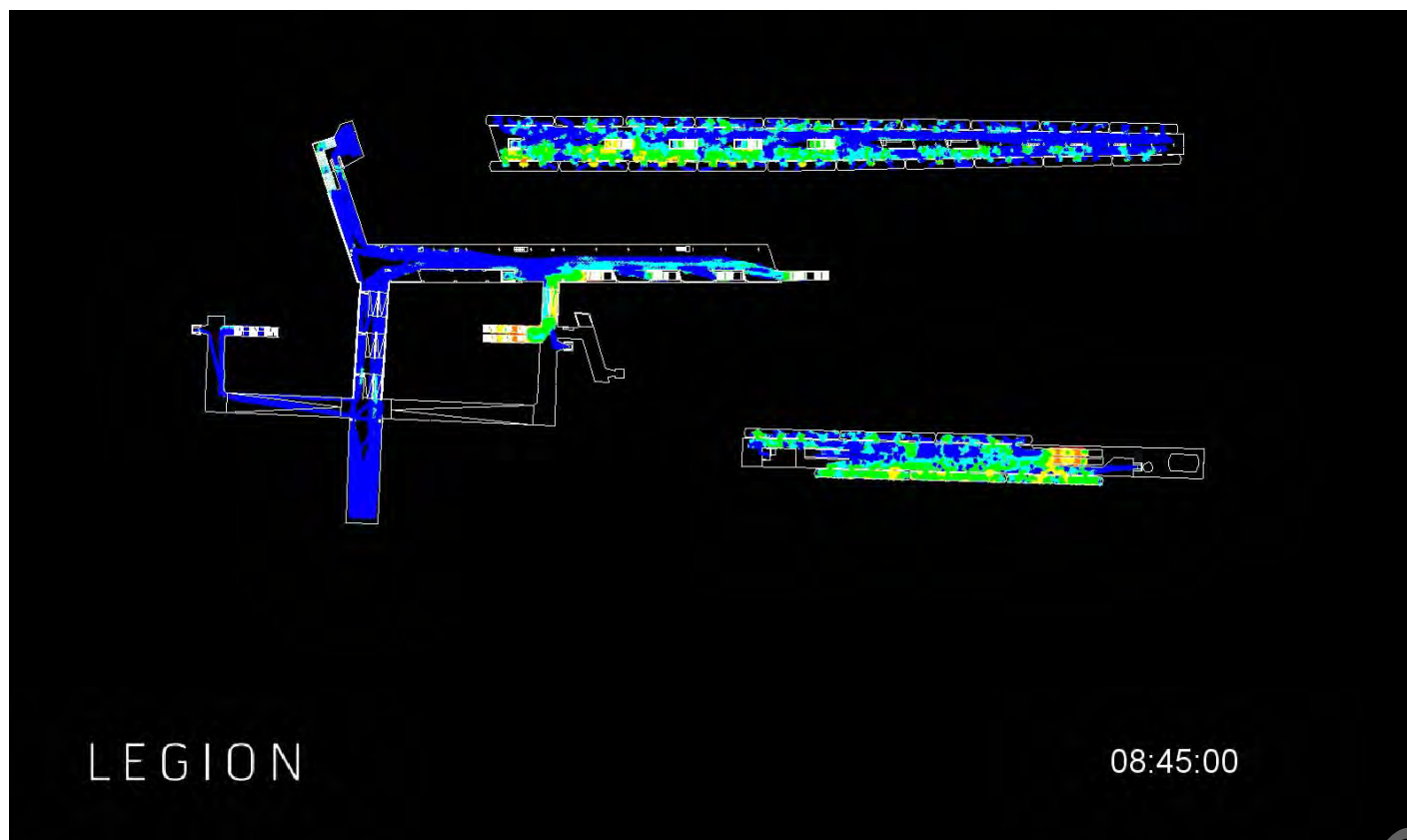


#### 1.7.1.2 2026 + 28% (2076)

Figure 8 highlights the density for the 08:30 – 08:45 period in the 2026 Base + 28% model.



**Figure 8: Cumulative Mean Density Plot, 08:30 - 08:45, 2026 Base + 28%**



The station operates in a similar pattern to the 2026 Base, with higher densities occurring in some areas of the station. The Crossrail concourse, station entrance and ExCeL footbridge remain at LoS A.

The DLR platforms are showing an increased amount of LoS C, mainly on the westbound platform, with a slightly increased area of LoS D at the base of the DLR eastern stairs.

The Crossrail/DLR eastern link is showing a mixture of LoS B and D, although on average the link operates at LoS C. The connecting passageway to the top of the DLR stairs and the top of the Crossrail stairs are also operating at LoS C.

The Crossrail westbound platform has increased LoS C, although the eastern end of the platform and the eastbound platform are still predominantly LoS A.

#### 1.7.1.3 AM Summary

Overall the AM Peak operates satisfactorily.

- Small areas of congestion on the DLR platform eastern stairs are not sustained and additional capacity is available in the form of the western stairs;
- The Crossrail concourse operates predominantly at LoS A, with LoS B and C at the top of the western stairs to the Crossrail platforms;

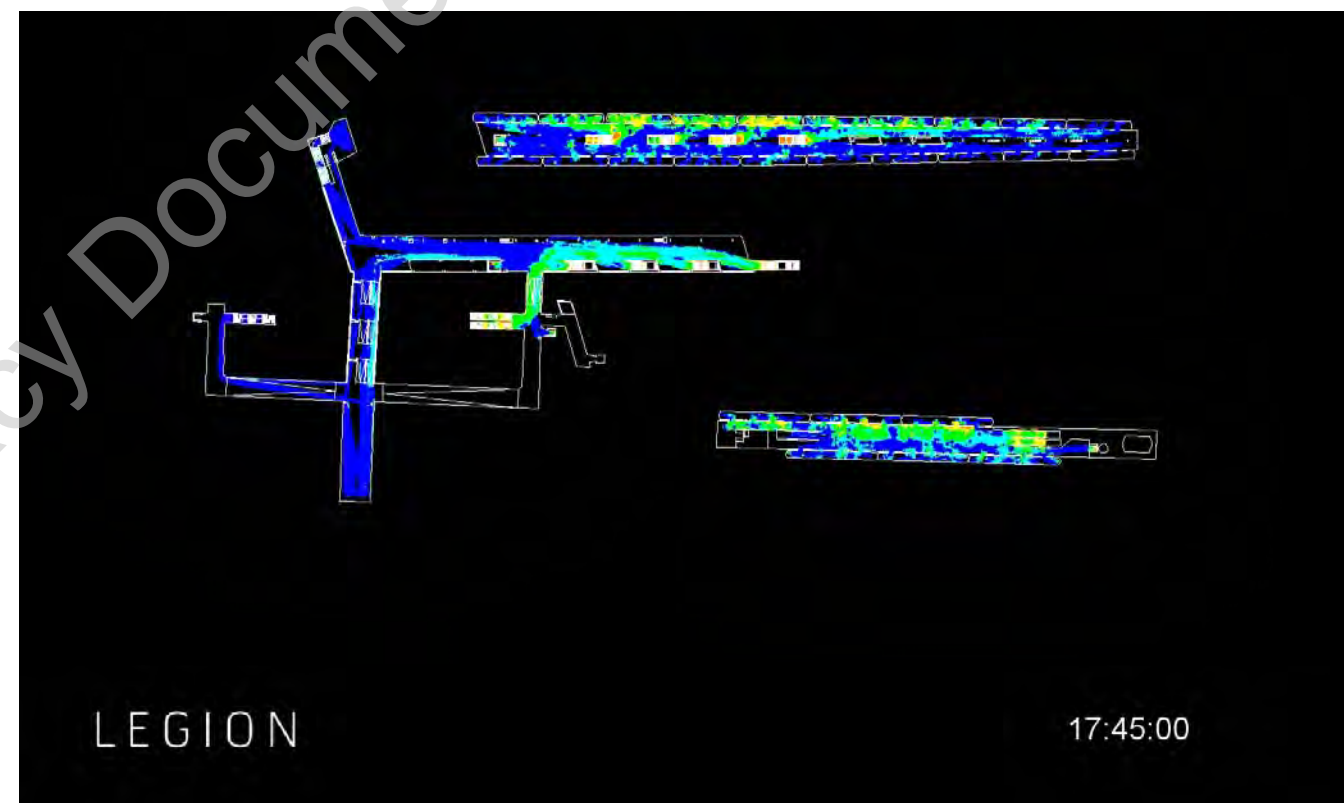
- The Crossrail WB platform is mainly LoS C, with small areas of LoS D experienced near some doors in the busiest section of the platform;
- The DLR eastern link-bridge is at LoS C; and
- The station entrance is at LoS A.

#### 1.7.2 PM Peak (16:00 – 19:00)

##### 1.7.2.1 2026 (Base)

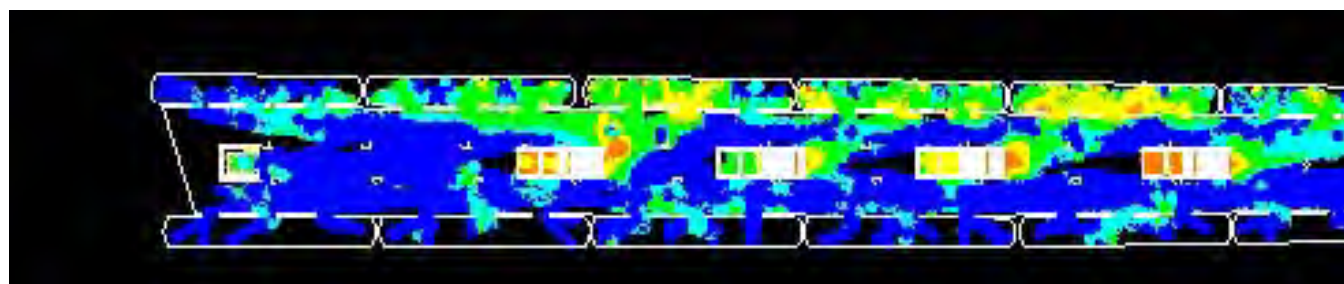
**Figure 9** highlights the density for the 17:30 – 17:45 period in the 2026 Base model.

**Figure 9: Cumulative Mean Density Plot, 17:30 - 17:45, 2026 Base**



**Figure 9** highlights areas of LoS D/E on the Crossrail platforms, as shown more clearly in **Figure 10**. These areas are located at the base of the stair cases and are caused by crowding of alighting passengers as they head to the Crossrail concourse. Aside from these areas, which are localised and not sustained for long periods, the remainder of the Crossrail platforms average LoS A/B.

**Figure 10: Cumulative Mean Density Plot, 17:30 - 17:45, 2026 Base – Crossrail Platforms**



110      1,715      906      1,178      2,686

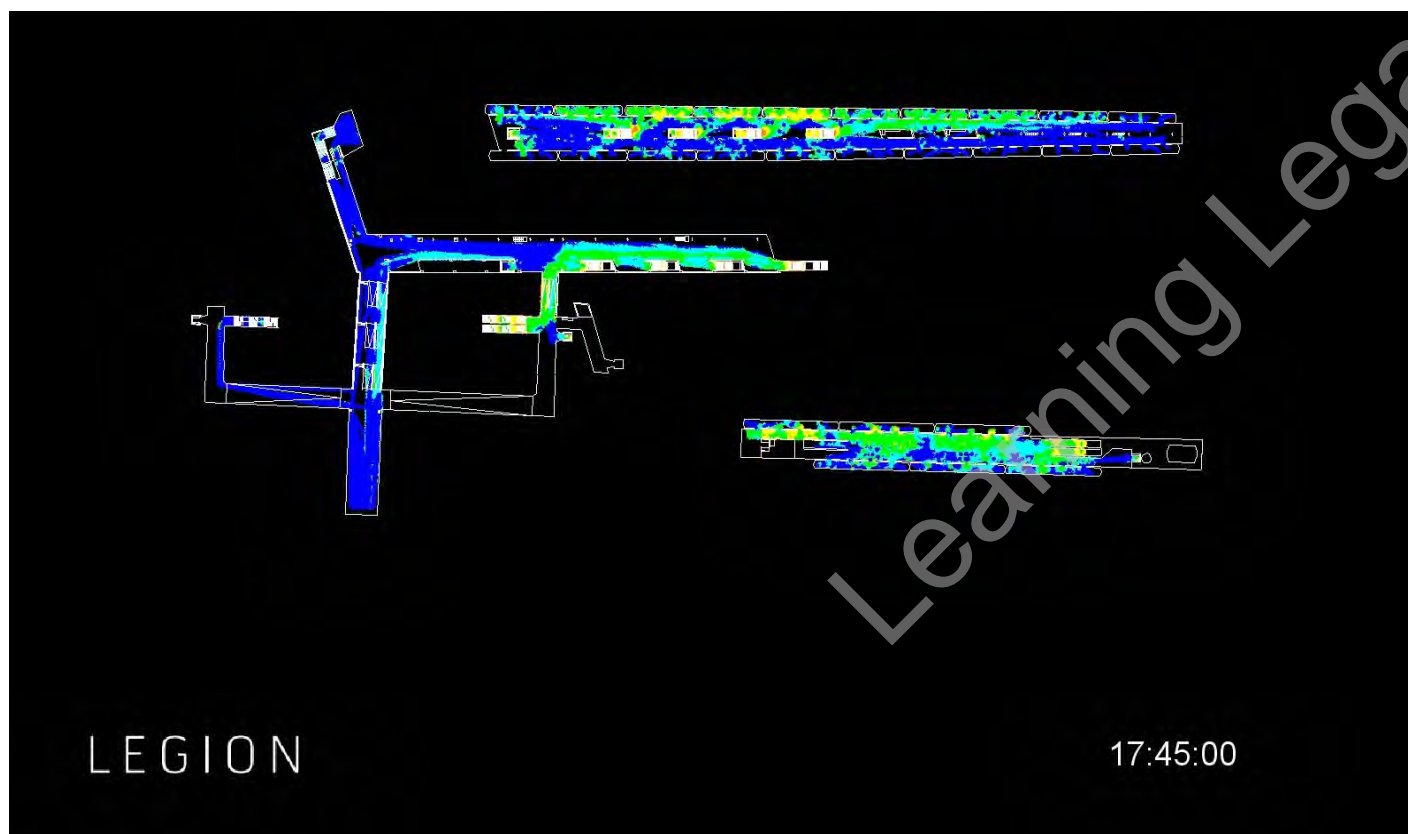
Passengers using each element: The area around the stairs is at LoS B/C, while the western end of the concourse, the station entrance and ExCeL bridge are mostly LoS A. The DLR Eastern link is also at LoS B/C.

The DLR eastbound platform is predominantly at LoS C, while the westbound platform is at LoS A/B, with a small area of LoS C at the narrow end of the platform adjacent to the eastern stairs.

1.7.2.2 2026 + 28% (2076)

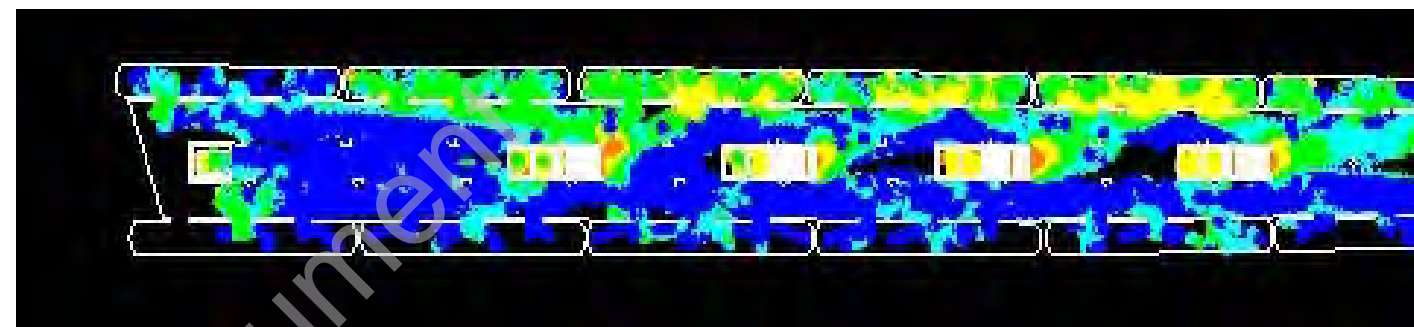
Figure 11 highlights the density for the 17:30 – 17:45 period in the 2026 Base + 28% model.

**Figure 11: Cumulative Mean Density Plot, 17:30 - 17:45, 2026 Base + 28%**



The densities for the 2076 model are broadly similar to those in the 2026 model. The Crossrail platforms show the same areas of LoS D/E, as highlighted in Figure 12. The Crossrail concourse has slightly more LoS C, as do the DLR platforms. The western end of the eastbound DLR platform is also showing some LoS D, as this end is constrained in width by the location of the lift. Overall this platform averages LoS C which is considered satisfactory.

**Figure 12: Cumulative Mean Density Plot, 17:30 - 17:45, 2026 Base + 28% – Crossrail Platforms**



1.7.2.3 PM Summary

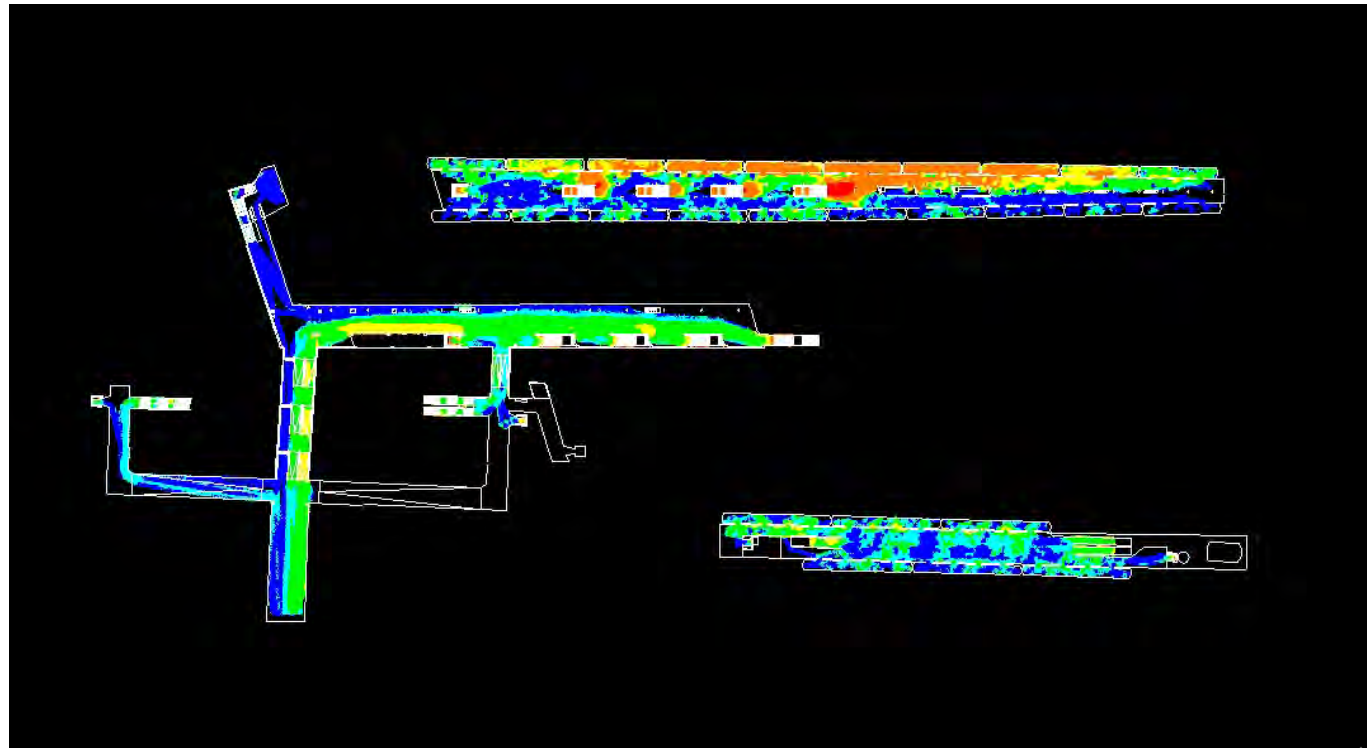
Overall the PM Peak operates satisfactorily.

- The Crossrail platform westbound platform is primarily LoS A, while the eastbound platform is at LoS B/C. There are small areas of LoS D/E at the stair boarding areas;
- The Crossrail concourse operates predominantly at LoS A at the western end, with LoS B/C at the eastern end around the top of the Crossrail stairs;
- The DLR Eastern link-bridge is at LoS C; and
- The station entrance is at LoS A.

1.7.3 PM Event scenario (2026 Base + Event Demand)

Figure 13 highlights the density for the 17:30 – 17:45 period in the 2026 Base + event model

Figure 13: Cumulative Mean Density Plot, 17:30 - 17:45, 2026 Base + Event



The PM event scenario shows a high level of density on much of the Crossrail platform, with LoS C throughout the majority of the remainder of the station. Figure 13 is a CMD for the fifteen minutes between 17:30 and 17:45 and is typical for most of the 90-minute event arrival period.

The main area of congestion is at platform level, which has a large area of LoS E and smaller areas of LoS F around the stair boarding areas, particularly at the eastern stair. This stair picks up the majority of people from the end 4-5 cars of the Crossrail train, although a condition is built into the model to spread these people to the second stair if it is empty. Despite the high densities seen, the platform is still comfortably able to clear within the train headway.

The main Crossrail concourse and link bridge to ExCeL are at LoS C. There is a small area of LoS D as entities pass the station accommodation and turn left from the Crossrail concourse onto the ExCeL bridge. In practice this would not happen as people would utilise the full width of the bridge, thereby maintaining the blanket LoS C. The ramps on the ExCeL bridge also show LoS D as entities slow down to pass over them.

Figure 15 to Figure 17 highlight the time spent at Level of Service D, E and F for the peak 15 minutes.

These figures use the following colour scale, ranging from 0 – 12 minutes:

Figure 14: Colour-Scale for Level of Service D – F Plots

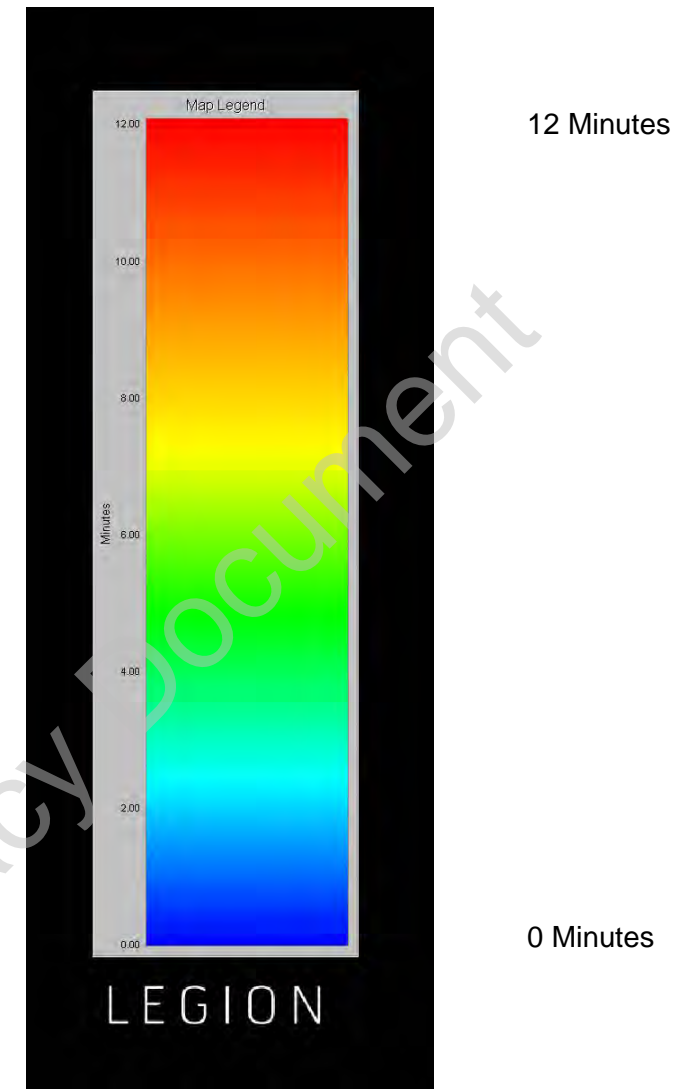


Figure 15: Time spent at Level of Service D, 17:30 - 17:45, 2026 + Event Demand

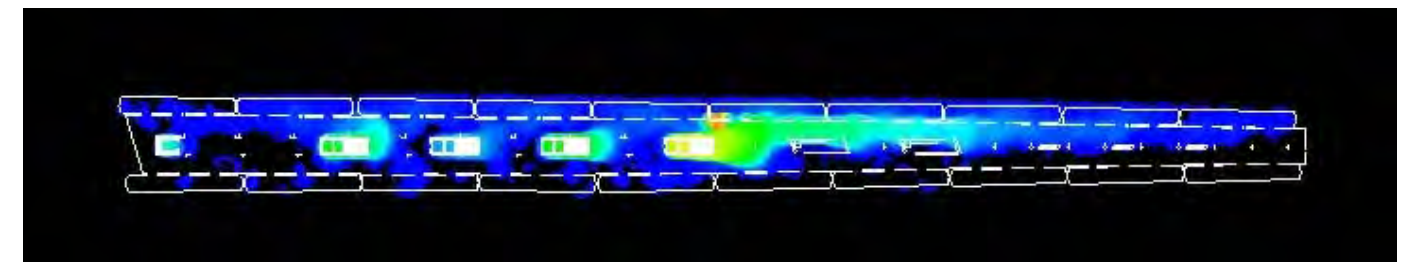


Figure 16: Time spent at Level of Service E, 17:30 - 17:45, 2026 + Event Demand

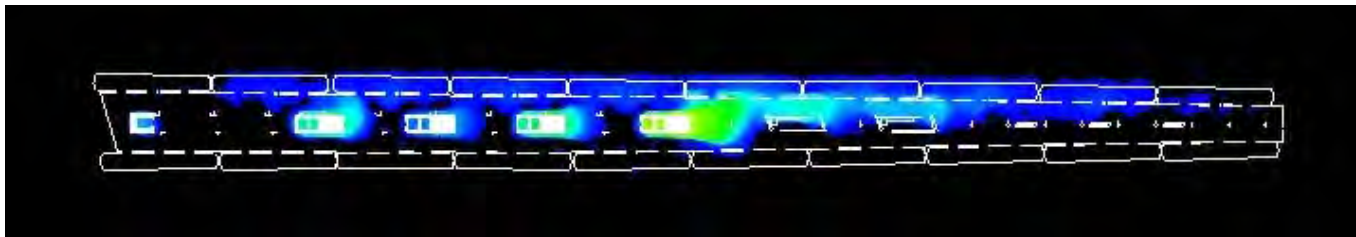


Figure 17: Time spent at Level of Service F, 17:30 - 17:45, 2026 + Event Demand

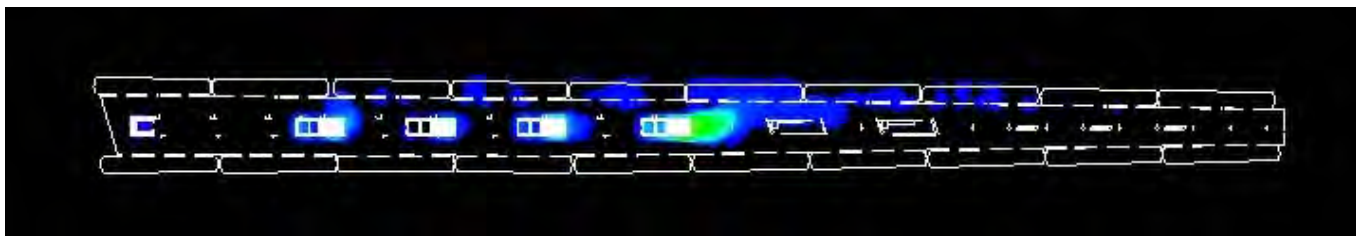


Figure 15 to Figure 17 show that the whole of the Crossrail EB platforms experiences LoS D at some point across the whole fifteen minute period. At the ends of the platform this is only for up to one minute in each fifteen minute period, but the busy section in the middle of the platform experiences LoS D for up to seven or eight minutes. This area is also at LoS F for around six of these minutes in the peak 15 minutes.

Despite these areas of high densities, the platform is able to clear comfortably with a train headway.

#### 1.7.4 PRM Analysis

As seen at Stages D and E, the Stage F modelling indicates that there are no concerns around access for People with Restricted Mobility (PRMs) within the station. There is appropriate step-free access in the form of lifts at the station entrance, as well as on Crossrail and DLR platforms. The repositioning of the Crossrail PRM lift to the end of the station accommodation block has also decreased PRM walk distances and subsequently journey times.

## 1.8 Conclusions

### 1.8.1 AM

Overall the AM Peak operates satisfactorily.

- Small areas of congestion on the DLR platform eastern stairs are not sustained and additional capacity is available in the form of the western stairs;
- The Crossrail concourse operates predominantly at LoS A, with LoS B and C at the top of the western stairs to the Crossrail platforms;
- The Crossrail WB platform is mainly LoS C, with small areas of LoS D experienced near some doors in the busiest section of the platform;
- The DLR eastern link-bridge is at LoS C; and
- The station entrance is at LoS A.

### 1.8.2 PM

Overall the PM Peak operates satisfactorily.

- The Crossrail platform westbound platform is primarily LoS A, while the eastbound platform is at LoS B/C. There are small areas of LoS D/E at the stair boarding areas;
- The Crossrail concourse operates predominantly at LoS A at the western end, with LoS B/C at the eastern end around the top of the Crossrail stairs;
- The DLR Eastern link-bridge is at LoS C; and
- The station entrance is at LoS A.

### 1.8.3 PM + Event

The Event scenario operates satisfactorily.

- Areas of LoS F are seen on the Crossrail platforms at the Base of stairs;
- The platforms are able to clear comfortably within the train headway; and
- The Crossrail concourse and DLR/ExCeL bridges are predominantly at LoS C.

## 1.9 Recommendations

Following the pedestrian modelling outlined in this report, all three time periods modelled are considered to operate satisfactorily from a pedestrian flow perspective and there are no recommendations to alter the design.

### 1.10 Reference Documents

- C146 Stage D Legion Modelling Report - C146-ATK-Z-XMO-CR145-00001
- C146 Stage E Legion Modelling Report - C146-ATK-Z-XMO-CR145-00002
- C146 Impact Assessment for Revised Demand - C146-ATK-Z-XMO-CR145-00004
- CPFR v4.1
- Custom House Modelling Methodology Report (CRL1-XRL-T1-RGN-CR145-00003)
- SD3 Legion Modelling Report (CR-SD-CUH-X-RT-00011)
- Crossrail's Pedestrian Modelling Guidelines (CR/QMS/OPS/GN/0010)
- Crossrail's Pedestrian Modelling Standard, Station Planning: Platforms (CR-STD-305, V6)
- Custom House Planning Freeze Report (C146-ATK-A-LRG-CR145-00001)
- Western Link Design Opportunity (C146-ATK-A-RGN-CR145-00002)
- LUL Standard 1-371 – Station Planning