Crossrail

Package C136 - Farringdon Station

Pedestrian Modelling Report

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1 Introduction

1.1 Scope

This document reports on the pedestrian modelling study undertaken to assess the operational performance of the Crossrail Station at Farringdon.

The chapters herein examine the modelling inputs and assumptions, the results for both morning and evening peak periods, and explain the conclusions and recommendations from the study. A further study examining station breakpoint (in light of the high forecast Thameslink usage) has also been undertaken.

The assessment has been undertaken using Legion Studio, and progresses Legion model files (LGMs) developed through stages RIBA D and E design.

This document is an updated version of the original report (submitted October 2010) and takes into account comments made by London Underground in their audit and review. These comments are summarised in Section 2.

1.2 Approach

The assessment of the RIBA E design at Farringdon Station has been undertaken using the Legion Studio pedestrian simulation software.

Legion modelling can be used to predict crowd behaviour and determine likely levels of pedestrian congestion in peak passenger flow conditions in a range of operation scenarios. It takes account of how individuals interact with each other and the obstacles within their physical environment.

Visually, the pedestrian model is based on precise architectural plans of the venue, with each individual, or entity, represented by a coloured circle whose size, speed, choices and preferences are based on algorithms empirically researched and calibrated.

1.3 Assessment Methodology

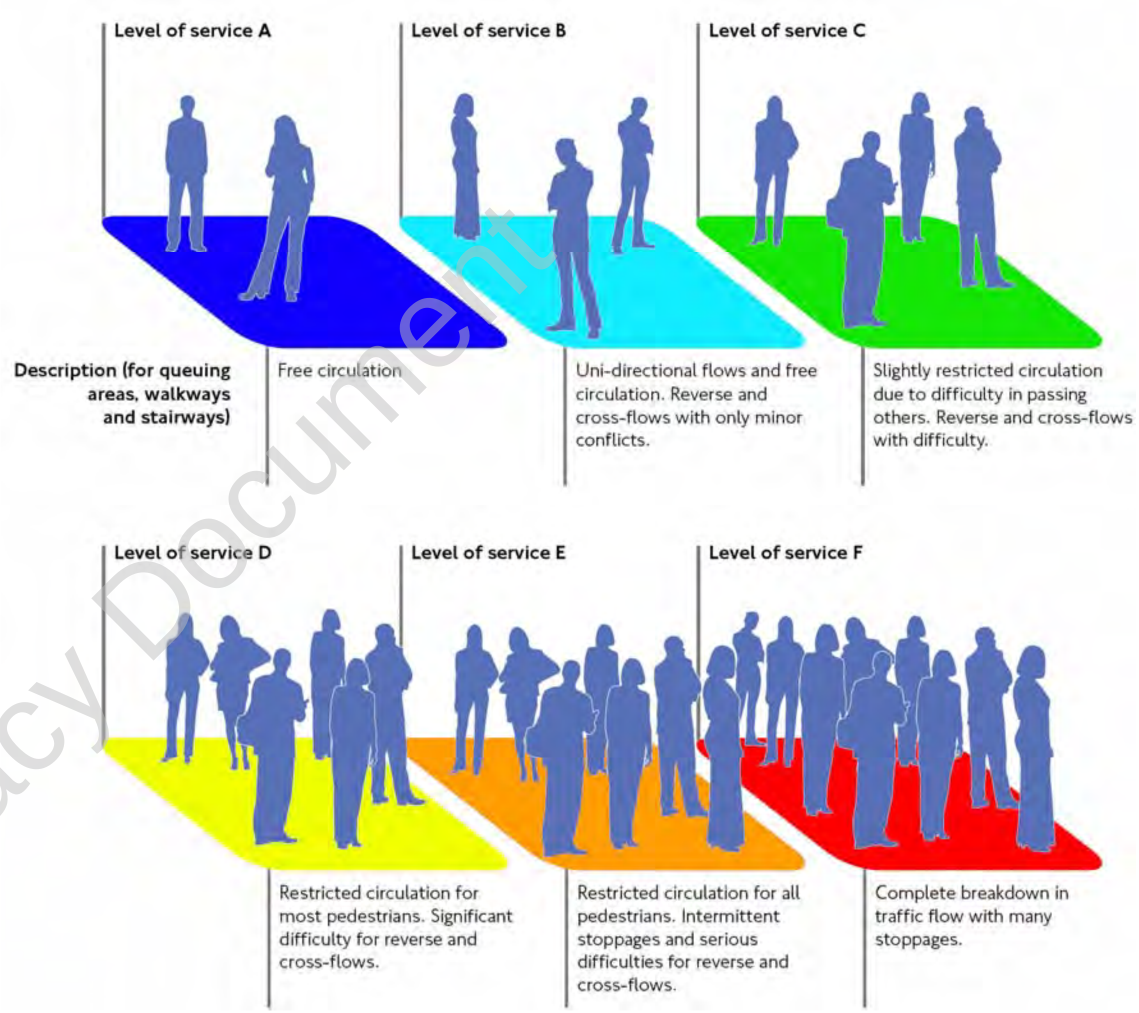
Results for the modelling are presented in a number of different ways.

Cumulative Mean Density (CMD) for Walkways – these reflect Levels of Service (from A to F) for areas where pedestrians circulate. They show the average density of an area of the station whenever it is occupied, though it should be noted that non-occupancy does not decay the average.

Cumulative Mean Density (CMD) for Queuing - these reflect the Levels of Service (again from A to F) for areas where pedestrians dwell or are normally delayed. They show the average density of an area of the station whenever it is occupied. Front edges of platforms should be assessed in the context of these maps (where pedestrians wait at Platform Edge Doors). As noted above, zero occupancy does not decay the average results recorded in these maps.

Both Walkways and Queuing maps (above) are coloured corresponding to the Level of Service (LOS) thresholds. These are shown in Figure 1.1 below – an image derived from the LOS description in London Underground's Station Planning Standards and Guidelines document (November 2005).

Figure 1.1 Levels of Service



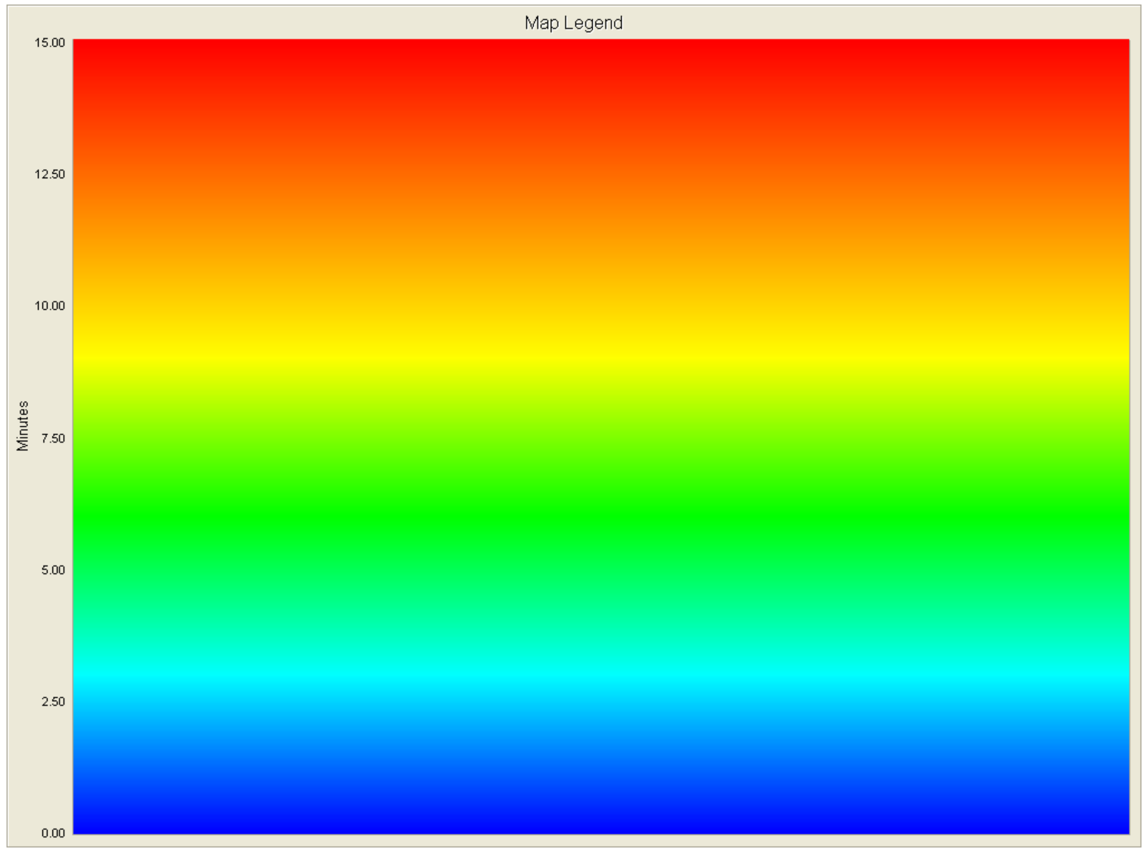
Cumulative High Density (CHD) – unlike mean density mapping, a high density map focuses on how sustained utilisation above or below a pre-set limit is. Accordingly, results from these maps illustrate time and not density. Confusingly, they do use the same colour range (blue to red).

A typical measure for assessing station performance is the provision of 0.8sqm per person within the venue. This is typically a comfortable environment expected of a busy, but efficiently performing station (0.8sqm per person roughly equates to the LOS C - LOS D boundary).

High Density maps therefore allow a model to be interrogated for the duration during which conditions are below 0.8sqm per person. Any area coloured in a CHD map therefore breaches the 0.8sqm measure, with the actual colour itself illustrating the duration of time spent above this.

Results for both CMD and CHD are presented in 15minute periods in this document. As the recognised standard output for Legion modelling CMD maps are shown in Sections 4 and 5. CHD maps are presented separately in Appendix A to avoid misreading and confusion with the Level of Service plots. For consistency and ease of comparison, a fixed CHD time/colour range has been set-up. This is shown in Figure 1.2 below (and repeated in Appendix A), and should be used as the legend for all maps of this type.

Figure 1.2 Cumulative High Density Time/Colour Range



Through a combination of CMD and CHD both the average (occupied) congested conditions and the sustained nature of any congestion above a specified minimum can be ascertained.

In addition to the mapped results, graphs are shown illustrating performance in each model scenario. These include:

- Platform clearance – showing clearance of passengers off platforms between service headways. Where the downward trend of a clearance graph meets the upward curve of the next train arrival onto platform, then the latent demand between headway can be seen;
- Escalator flow rate – showing utilisation/demand for escalators and their theoretical operating capacity;

A commentary on the results follows the maps and graphs for each respective peak period and/or scenario.

1.4 Assessment Scenarios

Central case modelling assesses the normal peak operations of the station on a typical day in the 2026 demand scenario.

In addition, further scenarios examine operational flexibility against the worst-case 2026+28% demand scenario. Congestion-free performance is not expected at this level of passenger demand; however, space proofing should consider likely performance at this furthest forecast.

The four scenarios reported on in this document are therefore:

- 07h00-10h00, 2026 operation
- 16h00-19h00, 2026 operation
- 07h00-10h00, 2026+28% operation
- 16h00-19h00, 2026+28% operation

Escalator failure performance is considered in light of previous modelling undertaken, but has not been simulated or analysed again with the amended post-audit models.

2 London Underground Audit

2.1 Issues Log

The following issues were highlight by LU and have been addressed in the modelling presented in this report.

None of the issues raised in the log were deemed to significantly alter the results or conclusions drawn from the modelling, and none were identified as shortcomings in the modelling undertaken.

The original issues log is presented in more detail in LU letter reference G22-614, dated 02/03/2011.

REF	ISSUE	ACTION
FAR1	Platform width is 4.9m not 4.5m. CAD is based on wall to wall width, not headroom derived floor space.	CAD altered to show 4.5m floor space.
FAR2	Cordon present in both 2026 and 2026+28% modelling.	This has been removed in 2026 modelling. For the reasons explained in Sections 3.3 and 3.4 this cannot be removed in 2026+28% models.
FAR3	Lift logic not in line with LU Modelling Best Practice Guide.	Lift cycle timings have not been altered, for reason explained in Section 3.2 below.
FAR4	WAG and Manual gate inconsistency.	All wider gates renamed as WAG with appropriate delay depending on unidirectional or bidirectional nature.
FAR5	Modelled CRL EB stopping position and provided boarding profile are inconsistent.	C136 have modelled CRL EB trains modelled stopping nearer the western escalators, not the head-wall, to best suit the vast majority of passengers heading west. CRL WB boarding profile used for CRL EB.
FAR6	Ticket purchasing not modelled.	C136 are not required to model ticket buying. Density mapping results demonstrate very low flow in this area, with more than sufficient space to accommodate ticket buying queues. No action required.
FAR7	Crowding at top of western CRL escalator.	This occurs for a short period at the absolute peak in the busiest +28% demand scenario. A 4th escalator here is not feasible for a number of reasons. No action required.

FAR8	LU not able to confirm trains per hour pattern from model file.	Explained to LU at post audit meeting, with no action required.
FAR9	LU unaware that the previous bank of 4 escalators changed to 3 plus a stair.	Design progression between RIBA D and E, and value engineering exercised identified an over-provision leading up to the Integrated Ticket Hall. No action required.
FAR10	Cancelled train logic	CRL internal modelling team are working on an internal paper to explain their logic. C136 modelling includes cancelled train as per CRL instruction. No action required.
FAR11	Lindsey Street gateline different to previous LU understanding of scheme design	C136 to update model cover sheet. No modelling action required.
FAR12	Thameslink platform dwell different to expected.	TL dwell based on original TL model (pre merge of TL and CRL models). No action required.
FAR13	Modelling approach varies across the whole model.	Result of merging inherited CRL with TL and LU station models. No action required.

3 Inputs

3.1 Demand

Previous pedestrian modelling for the Farringdon Crossrail station has used a 2016+35% forecast for space proofing and design purposes. Revised forecasts have now been issued for a 2026+28% forecast. It should be noted that both forecasts represent an approximate 2076 level of demand, and that the revision has been made to account for economic, social and infrastructure changes since the original forecast.

Crossrail requirements are for the station to operate at 2026+28% level, but they do not expect stations to operate congestion-free at this level (CPFR states “cope”) – it is the worst case demand forecast representing an approximate 2076 demand year.

Models and results for both 2026 and 2026+28% are reported on.

3.2 Assumptions

The revised demand forecasts have been issued to each Framework Design Consultant (FDC) by Crossrail with a number of inputs, assumptions and parameters that are to be strictly adhered to. These set-out a significant number of fundamental elements within the modelling, and therefore dictate performance to an extent. A summary of the required inputs is listed below:

- Overall station use by origin and destination (for example the 2026 and 2026+28% matrices)
- Train frequency and service types for all platforms (LU, Thameslink and Crossrail)
- Routing split between adits for boarding/alighting flows
- Proportional use of platform waiting areas from both western and eastern ends
- Boarding and alighting profiles for all platforms
- Constraint of boarding movements, where applicable
- Dwell time logic
- Time profile broken down into 15minute periods
- Alighting demand assigned to each 15minute period
- Boarding types by destination for each platform
- Peak time cancelled train assumption

Lifts in the modelling fall into two categories at Farringdon: two-level and three-level. Lift cycles are modelled running at the same speed (between floors) and spend the same amount of time at each floor.

For several reasons, more detailed modelling of lift operations is not deemed worthy:

- PRM numbers and usage of lifts (certainly 65 years into the future) is arbitrary and not something that can be robustly predicted;
- In the busiest scenario (+28%) there are just over 600 Passengers of Reduced Mobility (PRMs) in the 3hour peak. Not all of these would need to, or desire to, use lifts, but should they need to then there are six separate lift cores within the model (Lindsey Street to CRL, Ticket Hall to LU SB, Ticket Hall to LU NB, Ticket Hall to Ticket Hall to TL NB, Ticket Hall to TL SB and CRL x 2).
- Lift occupancy in the +28% scenario peaks at about 4 people (for the busiest Ticket Hall to CRL lifts) – even at this low level of occupancy, there are no lift related congestion concerns in any of the modelling.

Where escalators and stairs provide vertical circulation on the same route (i.e. ticket hall to TL platform level) passengers will always use escalators in both directions, unless the capacity of 100 passengers per escalator per minute is breached. Then, and only then, will they re-route to stairs for as long as the capacity is exceeded.

3.3 Forecast Comparison and Impact Assessment

In terms of **overall** station demand, the 2026+28% matrix totals change very little from the previous forecast. Three hour matrix totals are shown in Table 3.1 below.

Table 3.1 Three-Hour Passenger Demand, By Peak/Forecast.

Peak Period	2026+28%	2016+35%	Change
AM (07h00-10h00)	79,680	82,620	- 3.69%
PM (16h00-19h00)	77,696	76,950	+ 0.96%

In overall pedestrian flow, the morning peak (07h00-10h00) decreases by nearly 4%, whilst the evening peak shows an increase by nearly 1%.

However, within these 3hour total flows, **specific** origin-destination pairs vary more significantly and have proved problematic.

Of primary interest are flows to/from Crossrail. These are summarised below in Table 3.2, showing morning and evening peak flows.

Table 3.2 Three-Hour Total Crossrail Passenger Demand, By Peak/Forecast

07h00-10h00	2026+28%	2016+35%	Change
From CRL (alight)	18,240	26,798	- 32%
To CRL (board)	11,712	7,628	+ 54%

16h00-19h00	2026+28%	2016+35%	Change
From CRL (alight)	13,568	10,530	+ 29%
To CRL (board)	17,280	20,655	- 16%

The dominant flows in each peak are alighters during the AM peak and boarders during the PM peak – both of these flows decrease.

Static assessment has been undertaken to ascertain the impact of these flows on the Crossrail station prior to Legion modelling. In no case was an increase on the provision set-out in Stage D required. The only significant change is the 54% increase in boarding flows during the morning peak. This certainly increases the pressure on the downward vertical circulation capacity at the western end of the station (see results section below), but it does not strictly increase the requirement beyond the 1 downward escalator (though it pushes the requirement close to the upper capacity of 1 escalator). Alighting flows reduce and are therefore accommodated with 2 upward escalators in the highest demand scenario.

At the Eastern end of the station, passenger demand is very low, meaning that upward/downward flows are comfortably accommodated by the 2 escalators and a considerable transfer of passengers could likely be accommodated.

Flows to and from the London Underground platforms do not change significantly, generally showing a decrease where a change is seen.

However of much more significance are the considerable changes to the Thameslink passenger demand. Flows to and from Thameslink platforms are summarised in Table 3.3 below.

Table 3.3 Three-Hour Total Thameslink Passenger Demand, By Peak/Forecast

07h00-10h00	2026+28%	2016+35%	Change
From TL (alight)	46,144	35,235	+ 31%
To TL (board)	6,784	5,670	+ 20%

16h00-19h00	2026+28%	2016+35%	Change
From TL (alight)	7,808	7,290	+ 7%
To TL (board)	38,272	35,775	+ 7%

The Legion modelling of Farringdon station is a full station model. As such it incorporates both LU and Thameslink platforms. As explained in Section 3.4 below, the latter is a cause for concern and has been problematic to simulate, resulting in the creation of cordon (Crossrail only) models.

3.4 Repeatability

The 2026+28% demand forecasts a considerable increase in passengers using Thameslink services. Although not part of the FDC remit (and therefore not explicitly assessed in this study), it would appear that the quantum of demand now forecast to use Thameslink services exceeds the actual capacity of the platform areas. For sure the forecast assessed herein represents considerable increases on the space proofing level of demand Thameslink themselves have used.

As a direct result of this, the whole station complex model (LU+TL+CRL+Ticket Halls) regularly fails to simulate due to severe congestion and blockages on the Thameslink platforms.

Cordon models – assessing ALL Crossrail impacted elements of the station, and using ALL demand associated to these areas – have therefore been developed and used to report on the RIBA E design of the Crossrail station.

These cordon models ensure a level of repeatability expected for effective and reliable simulation modelling of the Farringdon Crossrail station at full 2026+28% demand. Models at 2026 demand level simulate full station operations.

4 Results – 2026 Demand

Please refer to Figure 1.1 for the Fruin Level of Service threshold boundaries and performance levels.

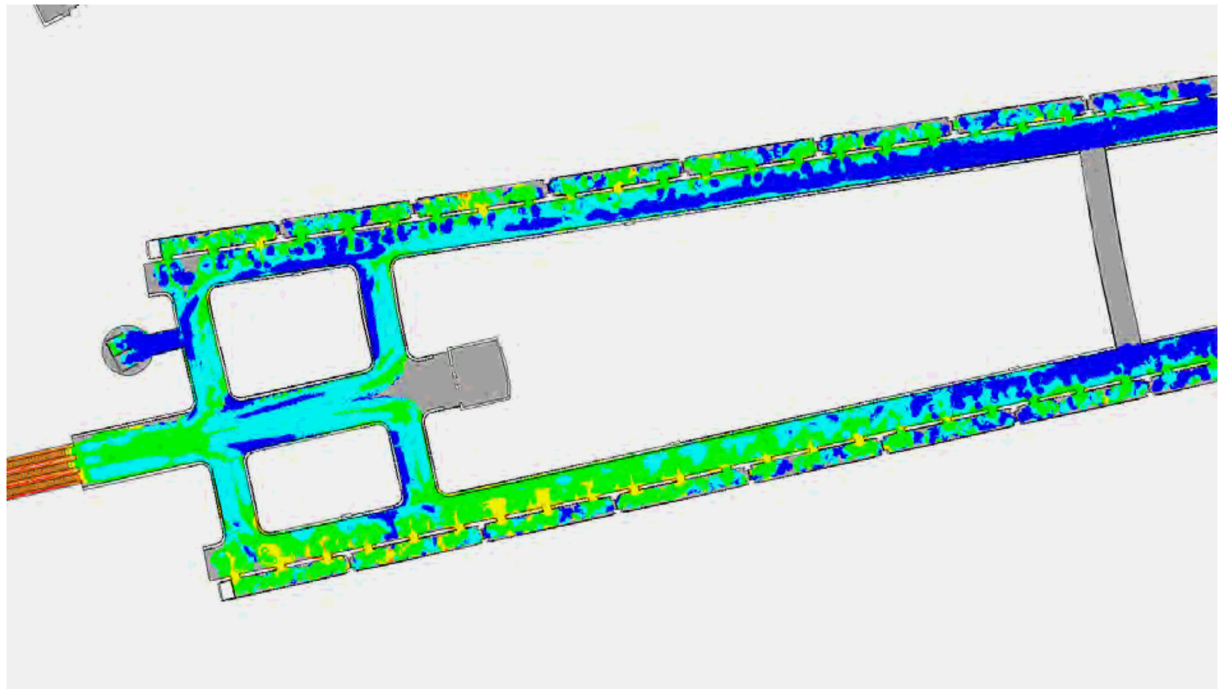
LUL and Thameslink results are shown [with a following commentary] in Appendix B.

4.1 2026 AM Peak Modelling, 07h00-10h00

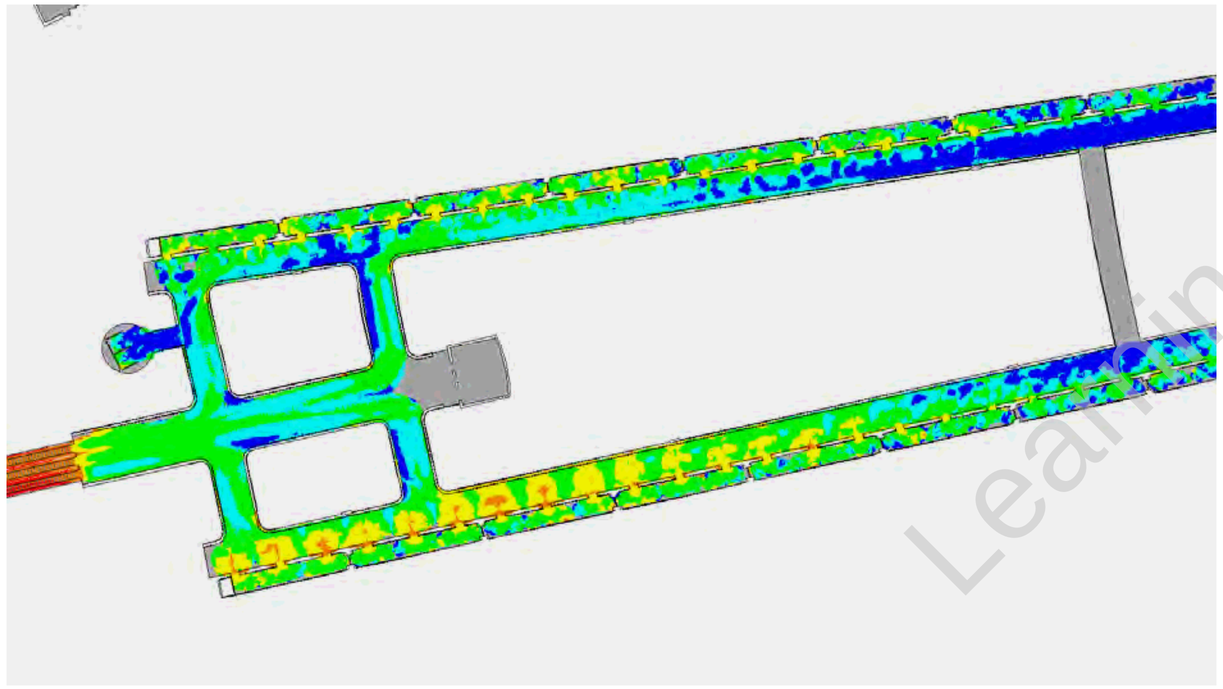
Results here are shown for Crossrail sections of the station: West and East ends and for the Integrated Ticket Hall.

A commentary on the results follows the images and graphs.

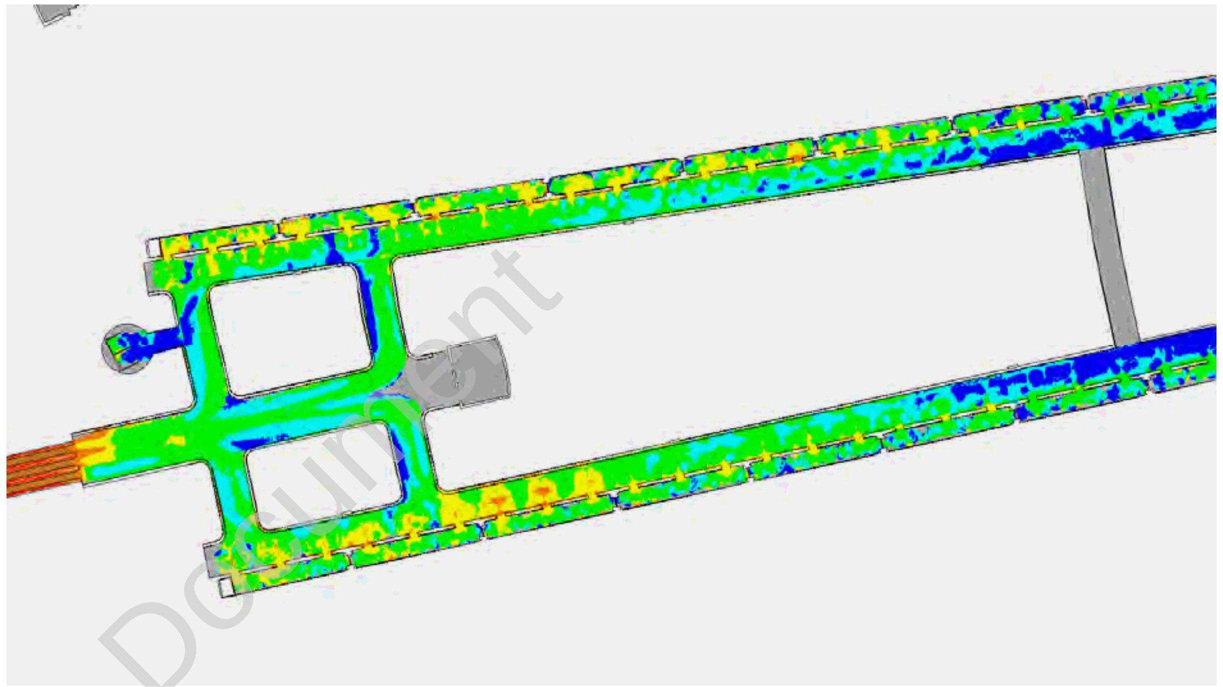
4.1.1 08h19-08h34, Mean Density (Walkways) WEST



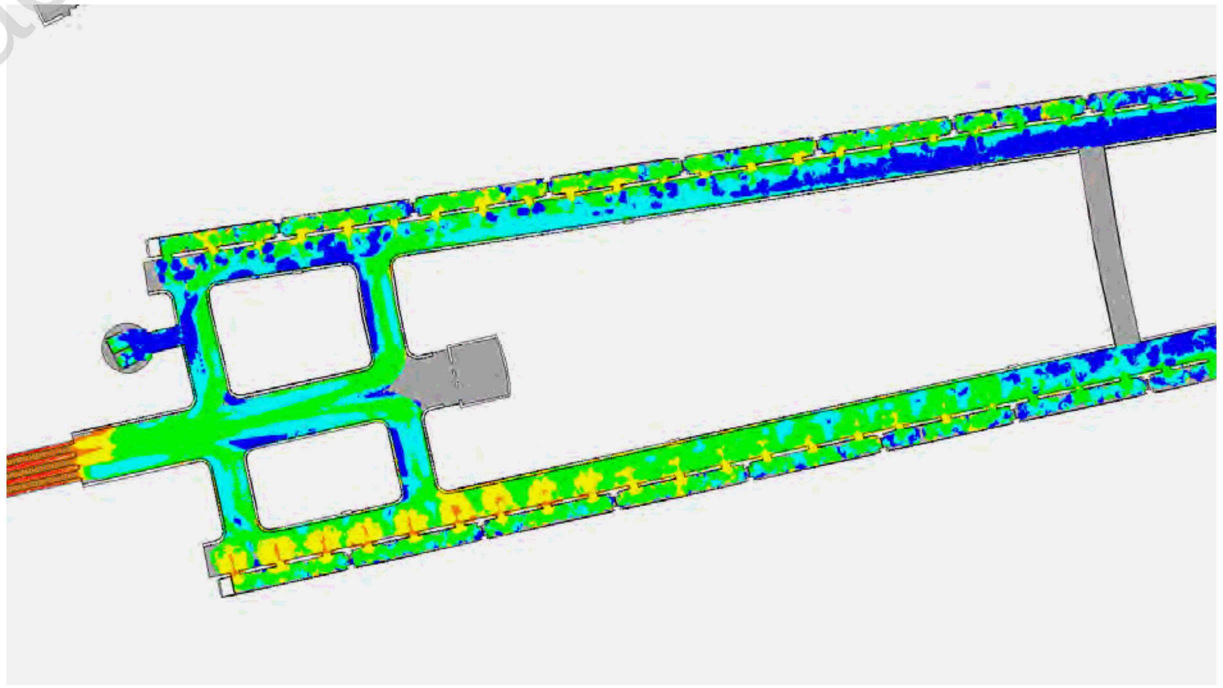
4.1.2 08h34-08h49, Mean Density (Walkways) WEST



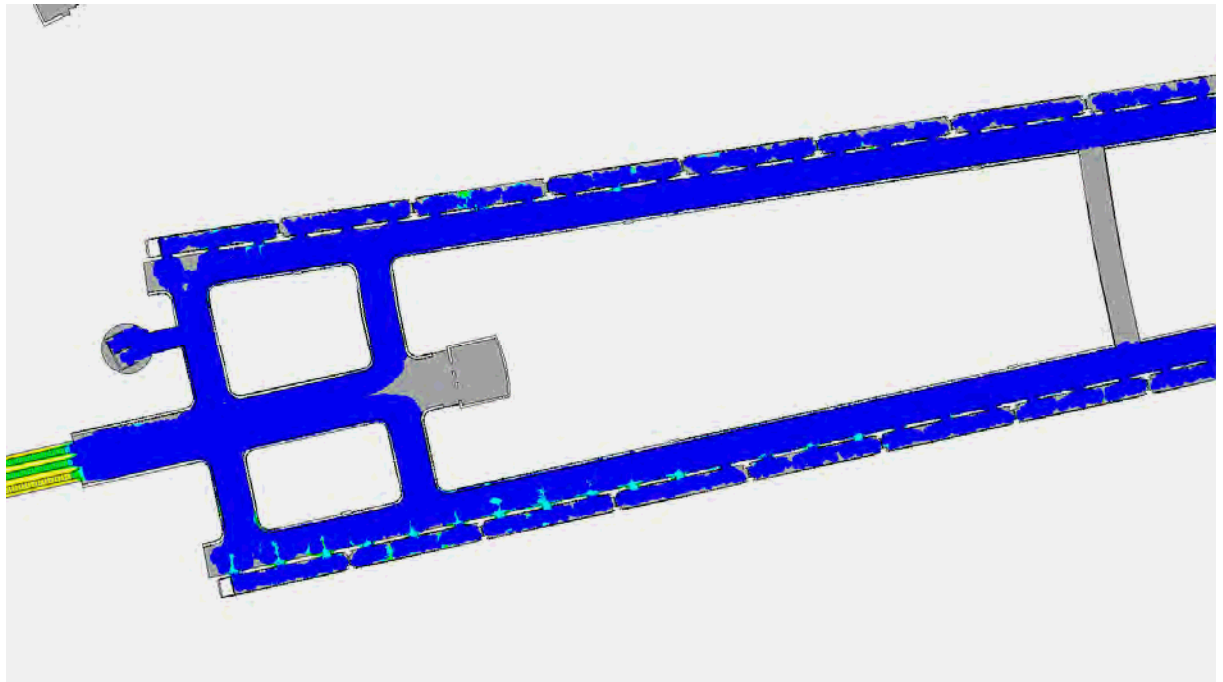
4.1.3 08h49-09h04, Mean Density (Walkways) WEST



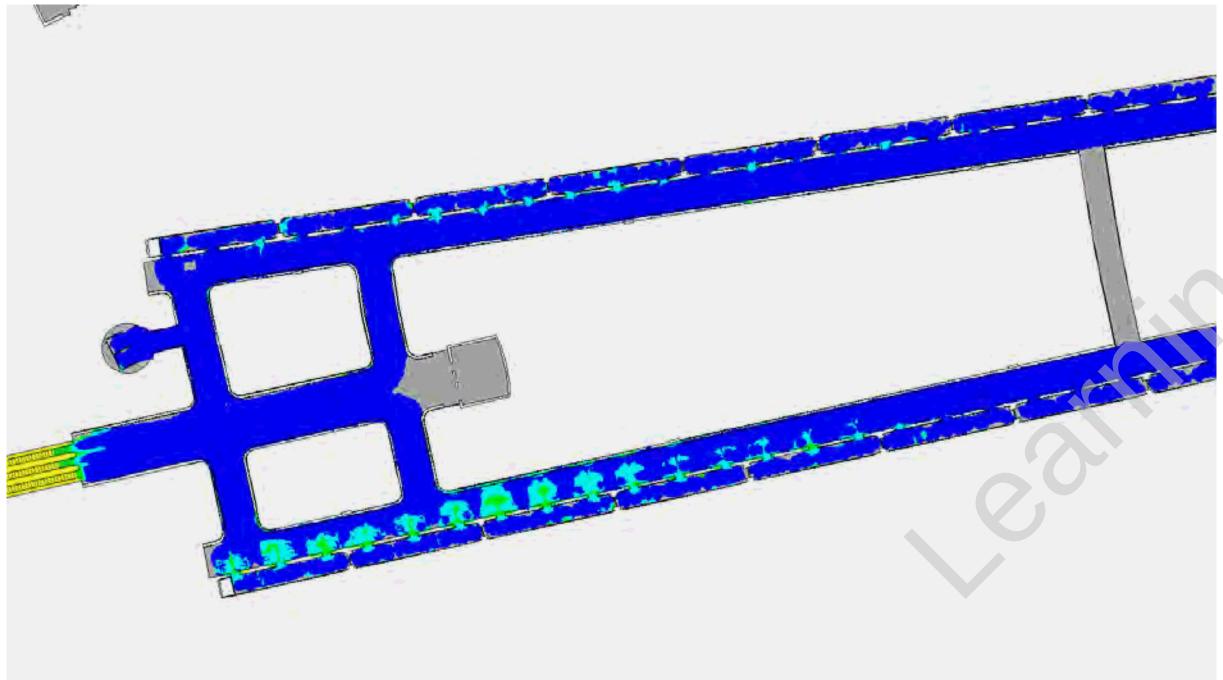
4.1.4 09h04-09h19, Mean Density (Walkways) WEST



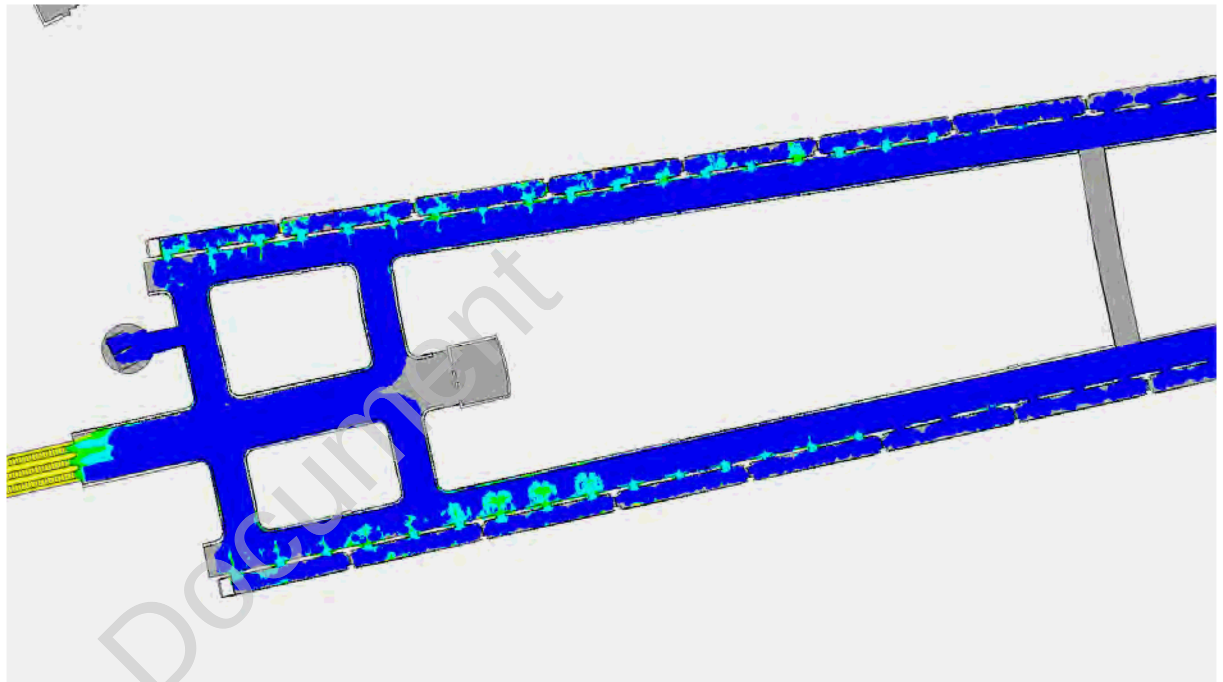
4.1.5 08h19-08h34, Mean Density (Queuing) WEST



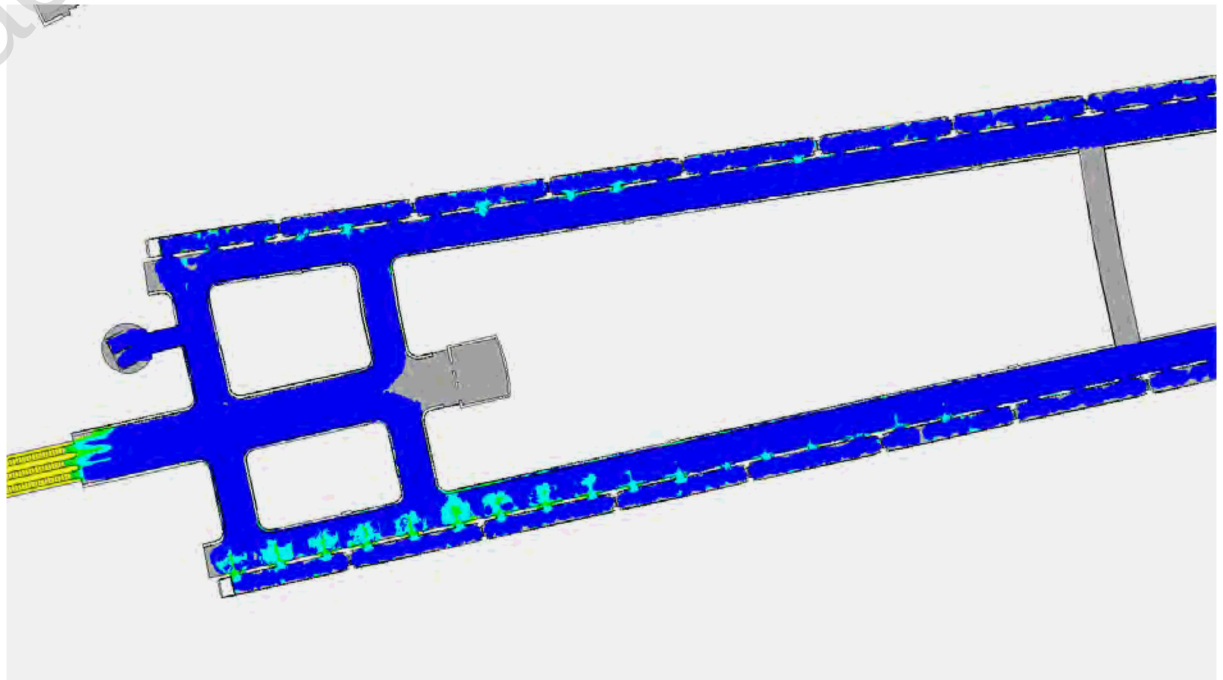
4.1.6 08h34-08h49, Mean Density (Queuing) WEST



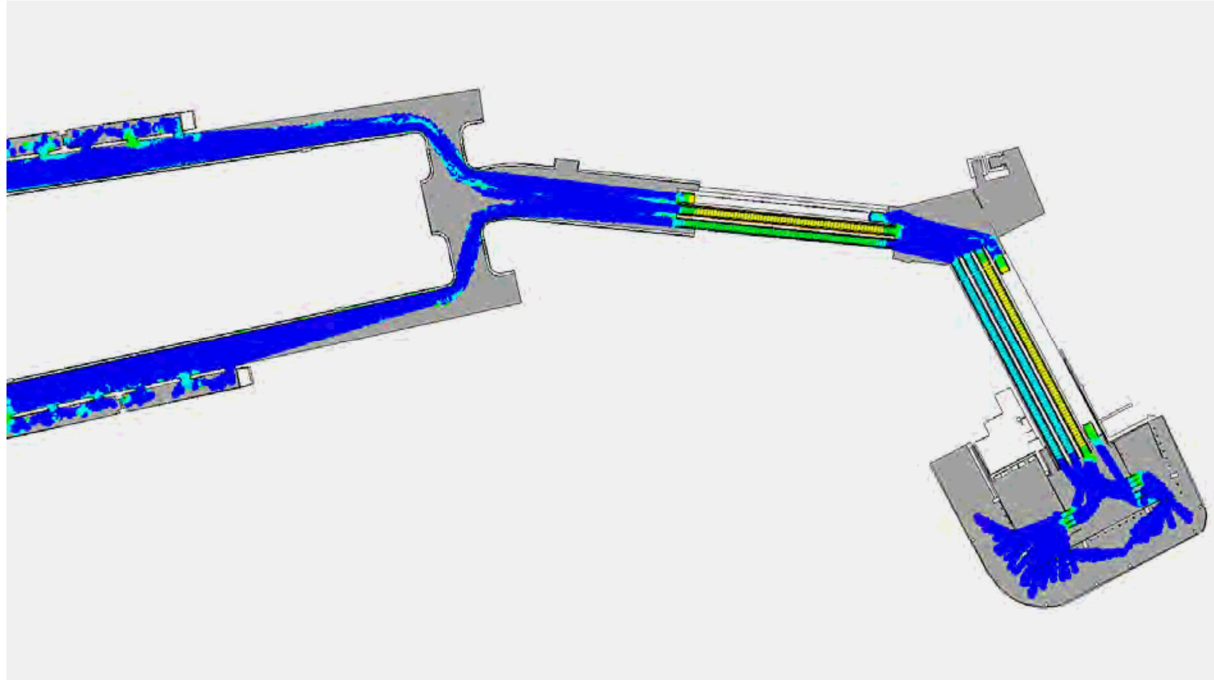
4.1.7 08h49-09h04, Mean Density (Queuing) WEST



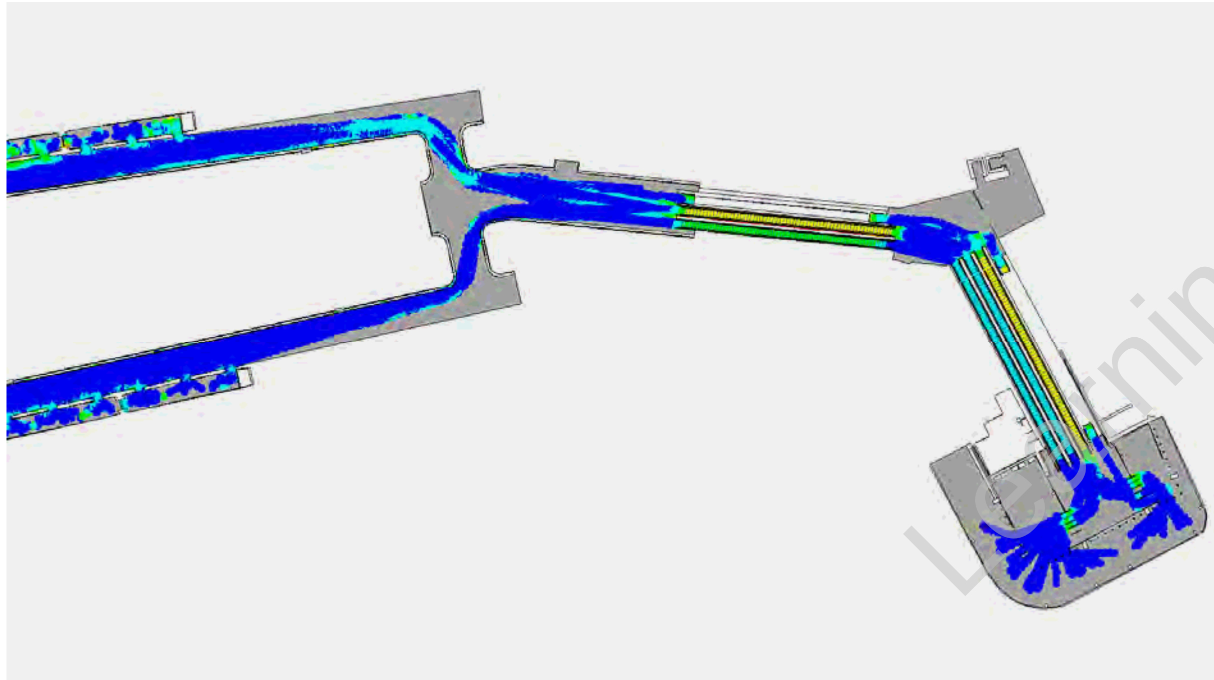
4.1.8 09h04-09h19, Mean Density (Queuing) WEST



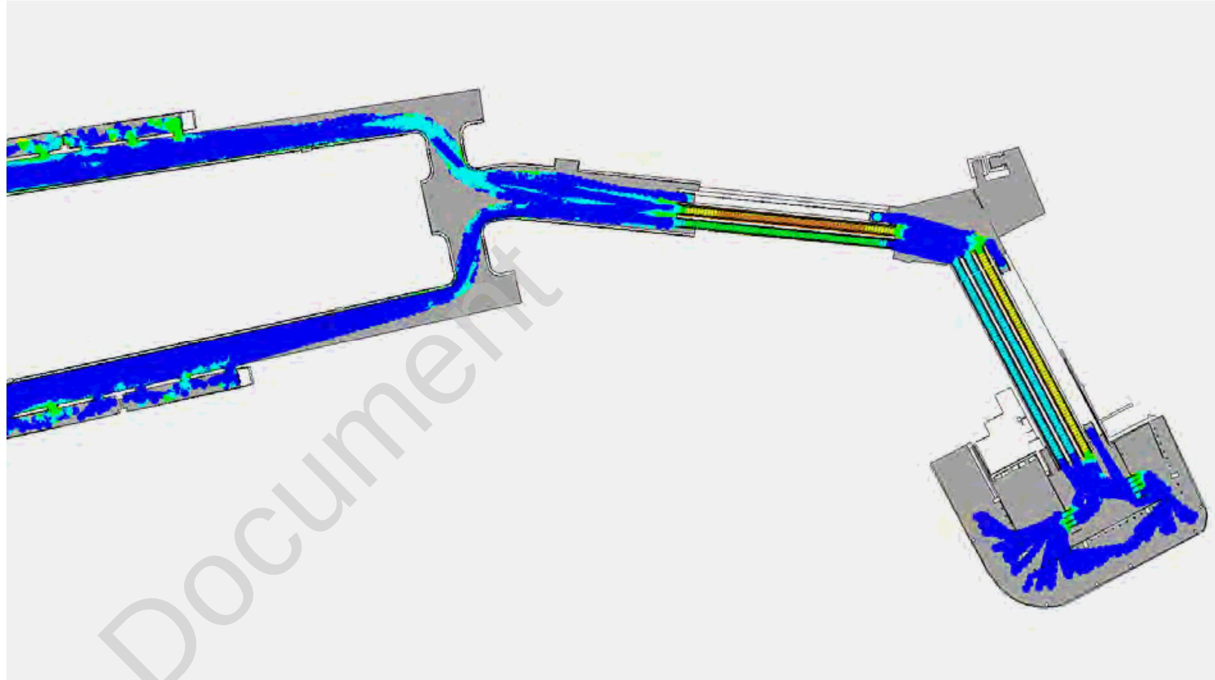
4.1.9 08h19-08h34, Mean Density (Walkways) EAST



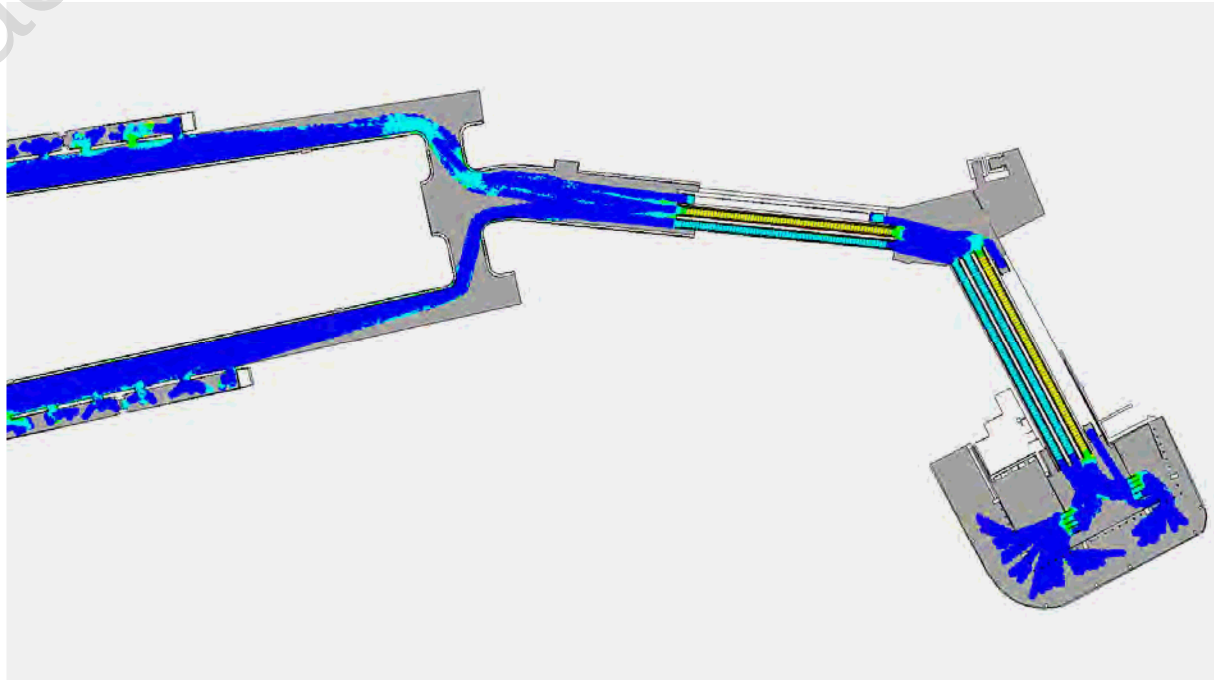
4.1.10 08h34-08h49, Mean Density (Walkways) EAST



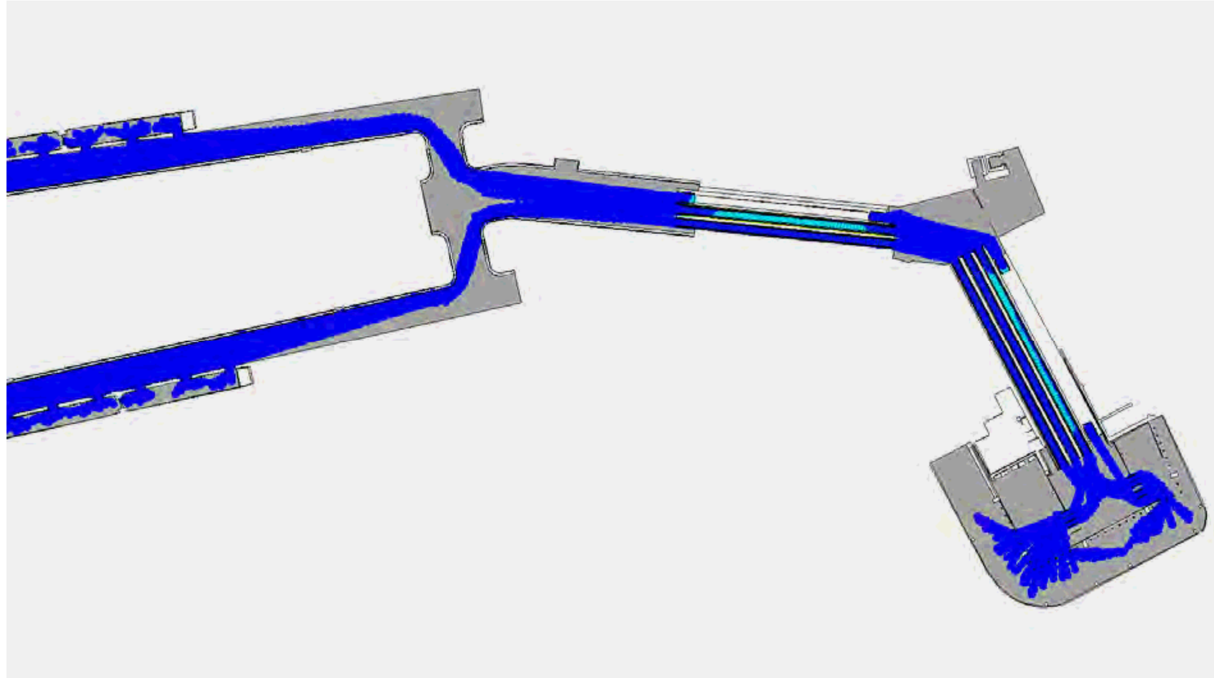
4.1.11 08h49-09h04, Mean Density (Walkways) EAST



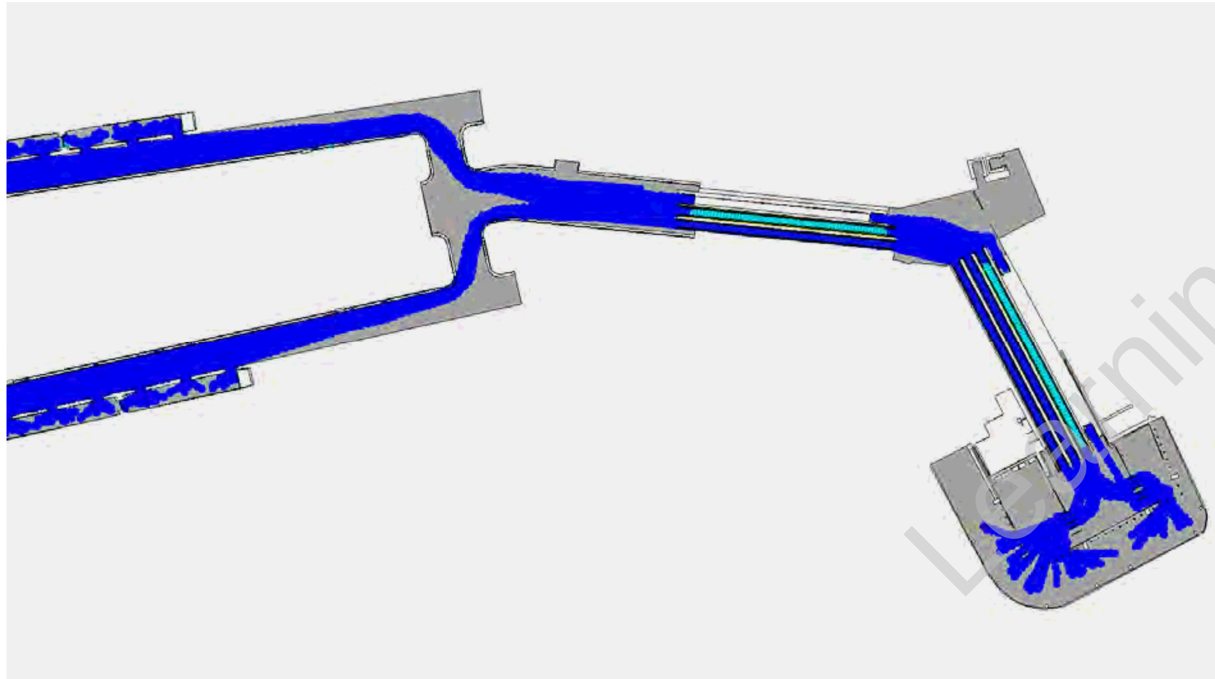
4.1.12 09h04-09h19, Mean Density (Walkways) EAST



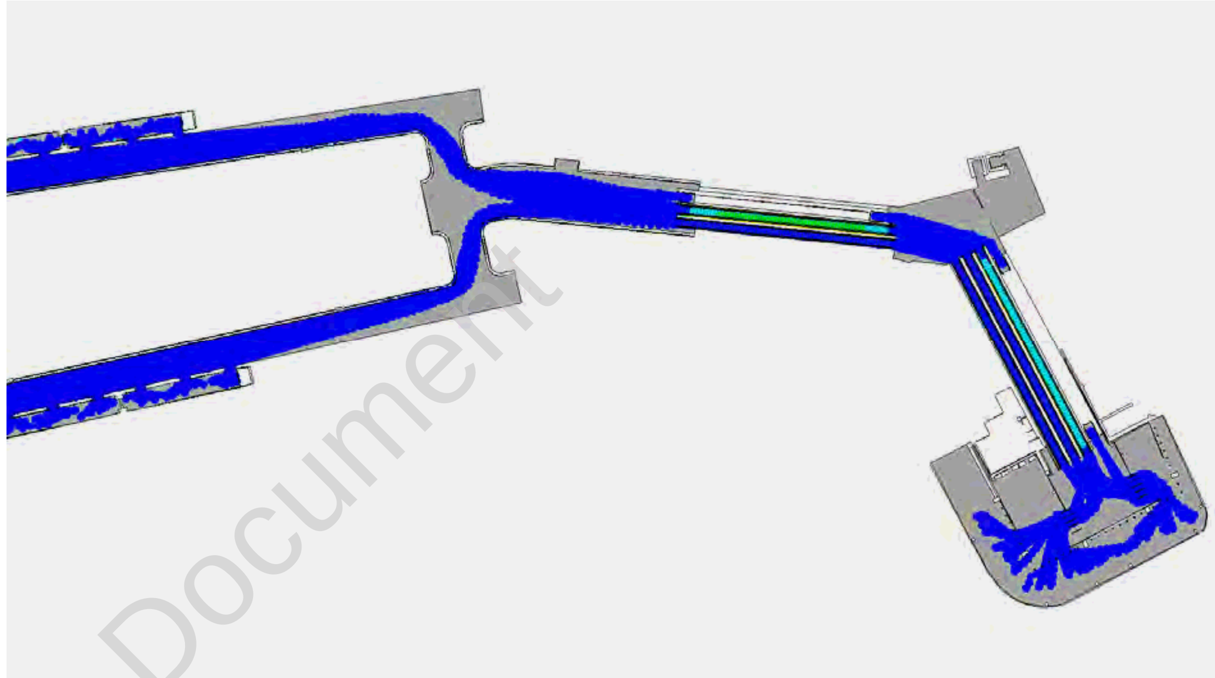
4.1.13 08h19-08h34, Mean Density (Queuing) EAST



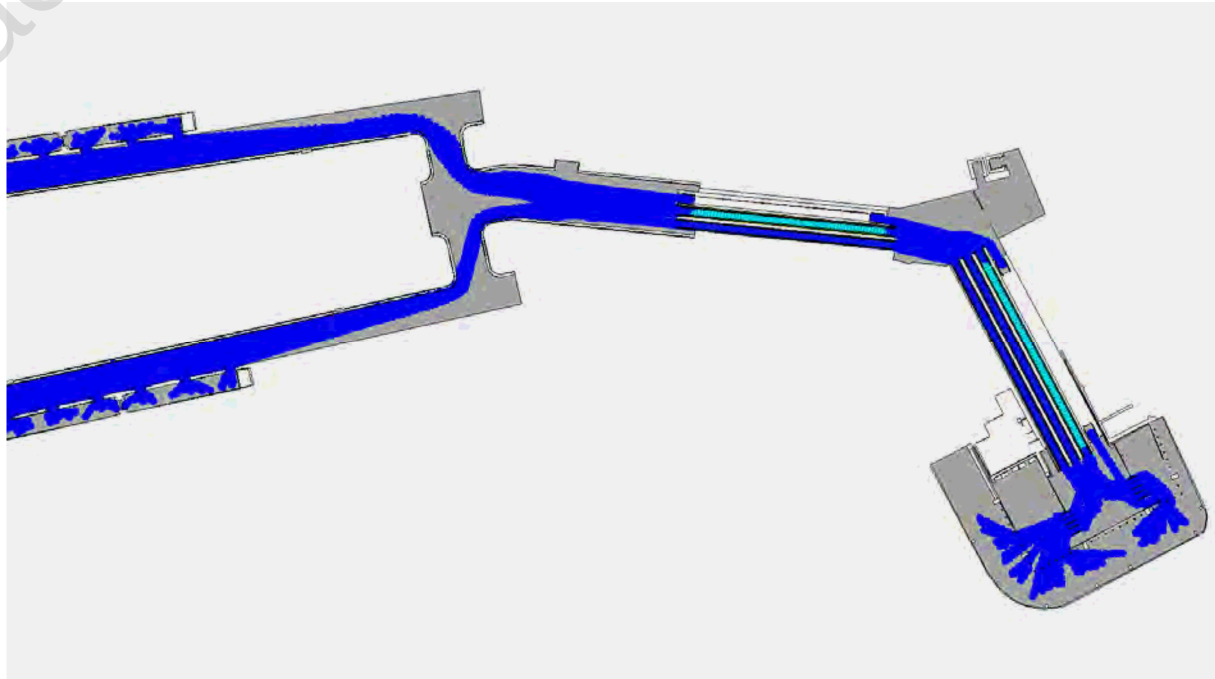
4.1.14 08h34-08h49, Mean Density (Queuing) EAST



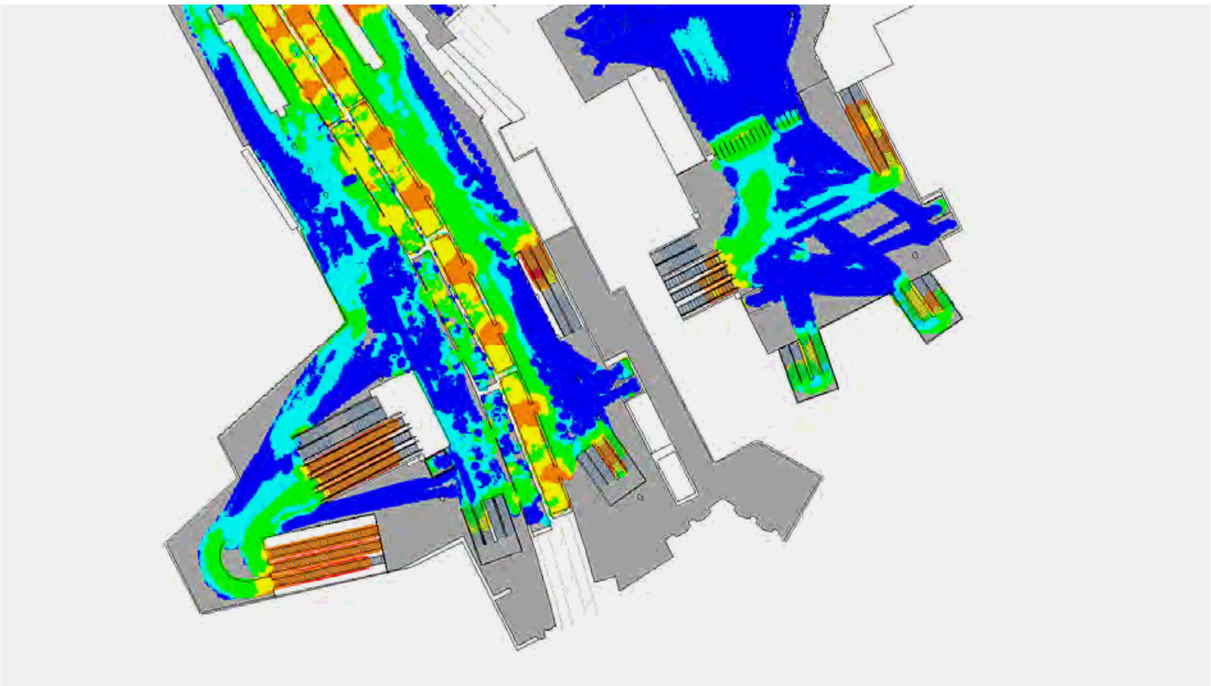
4.1.15 08h49-09h04, Mean Density (Queuing) EAST



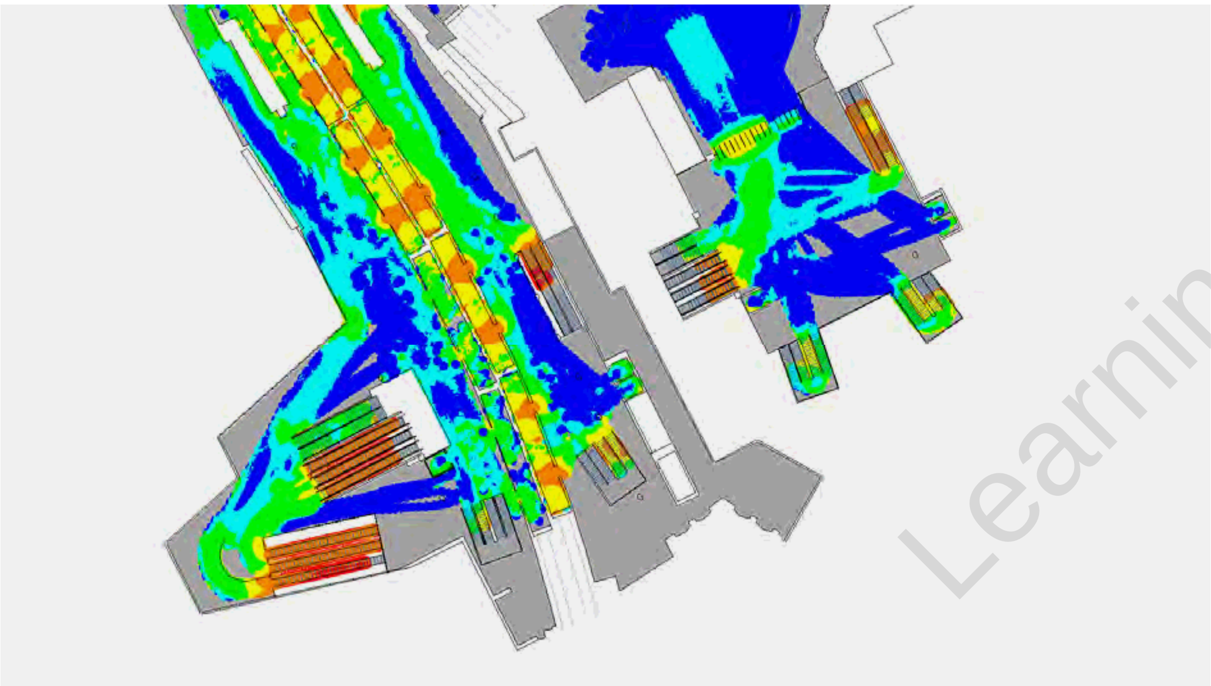
4.1.16 09h04-09h19, Mean Density (Queuing) EAST



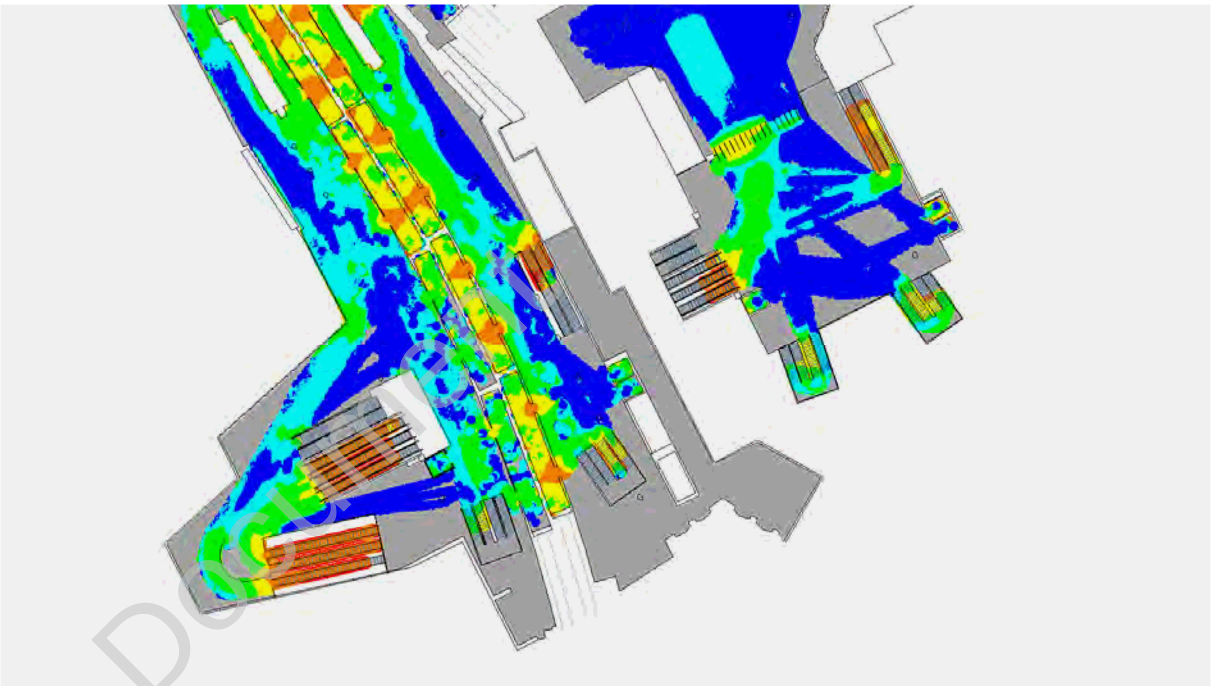
4.1.17 08h19-08h34, Mean Density (Walkways) TICKET HALL



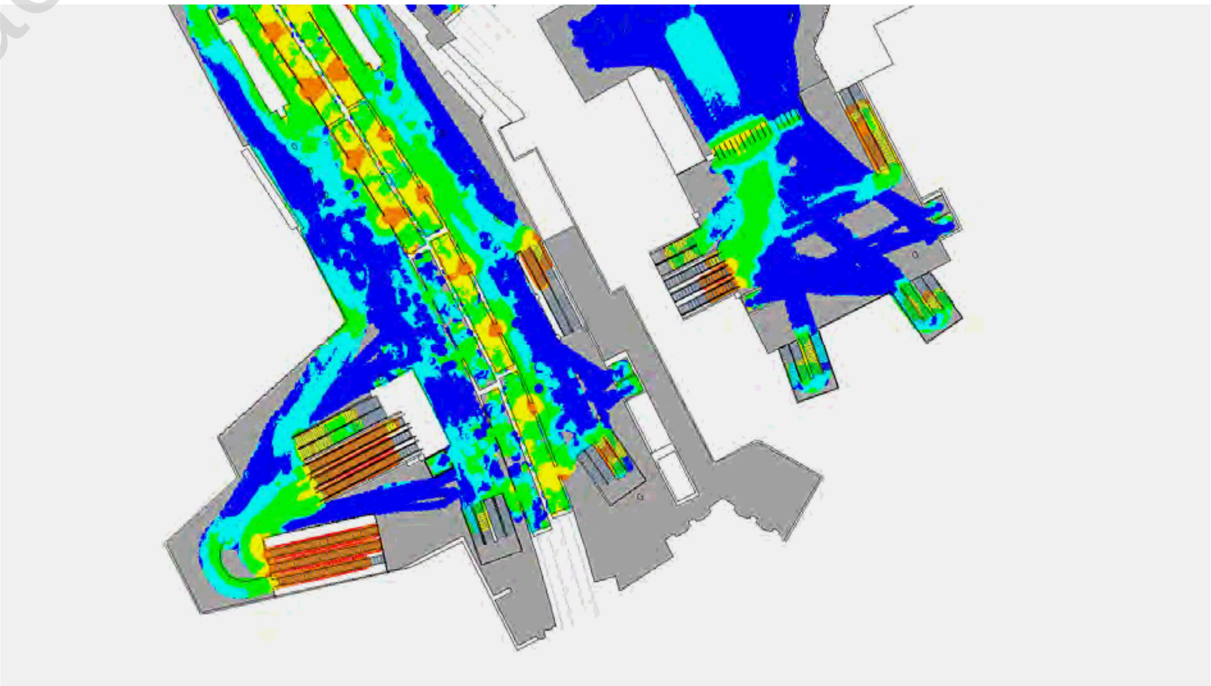
4.1.18 08h34-08h49, Mean Density (Walkways) TICKET HALL



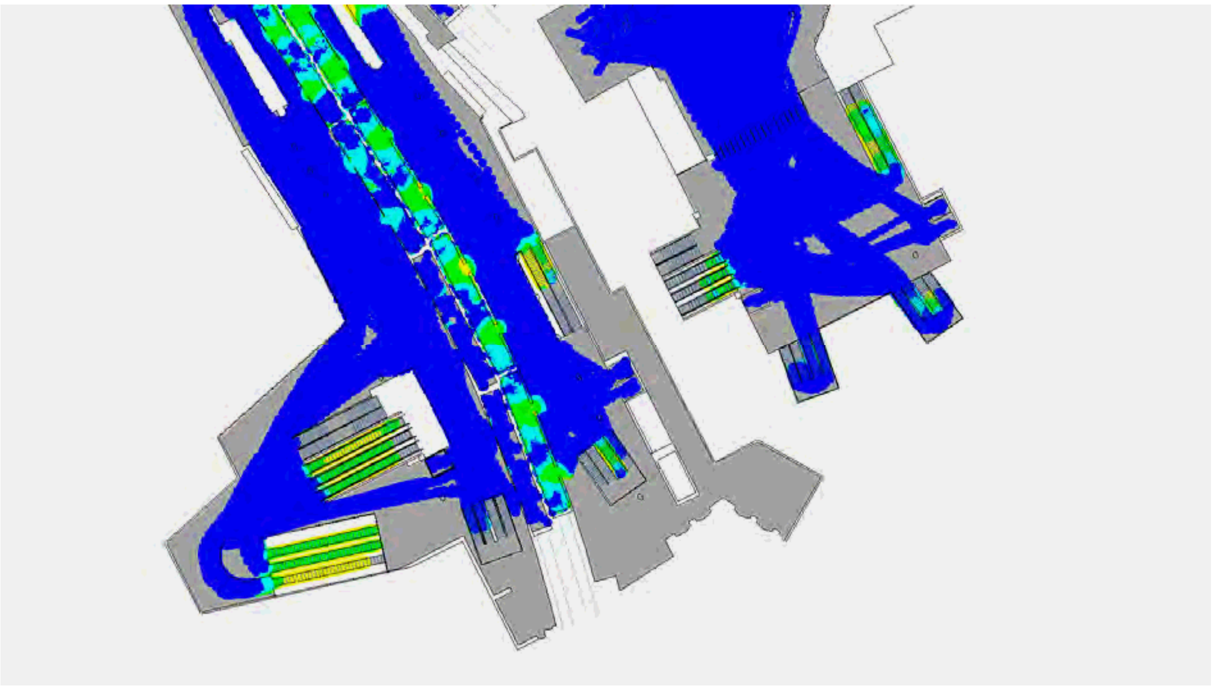
4.1.19 08h49-09h04, Mean Density (Walkways) TICKET HALL



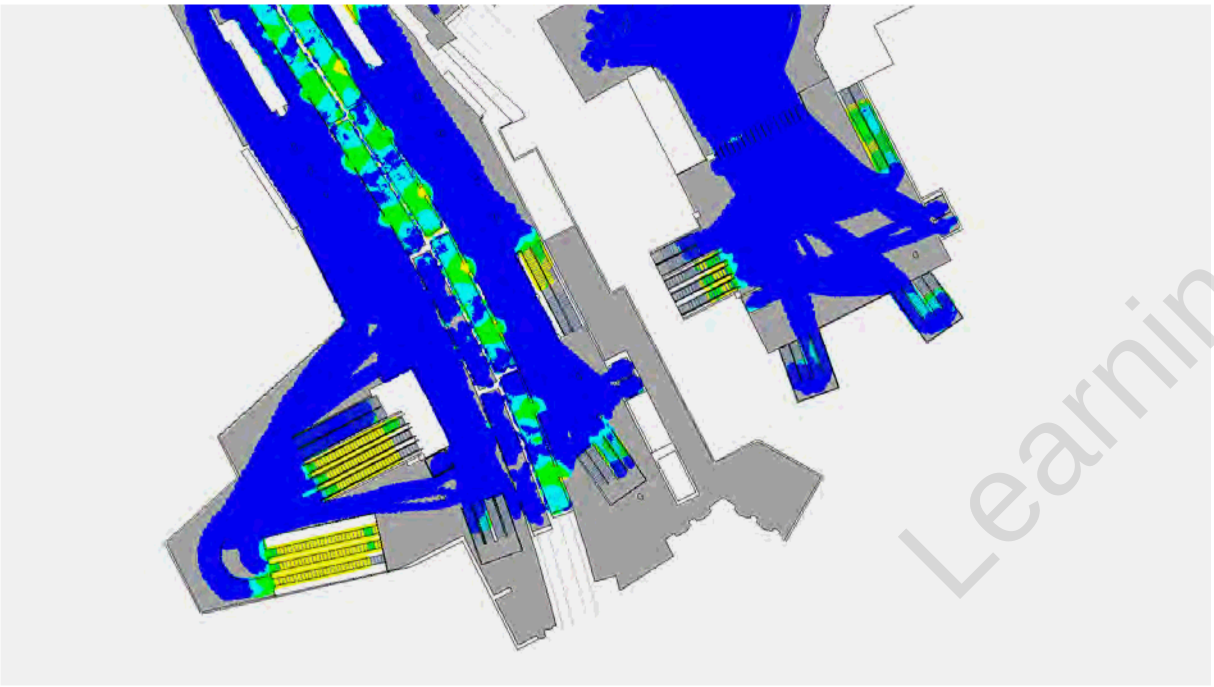
4.1.20 09h04-09h19, Mean Density (Walkways) TICKET HALL



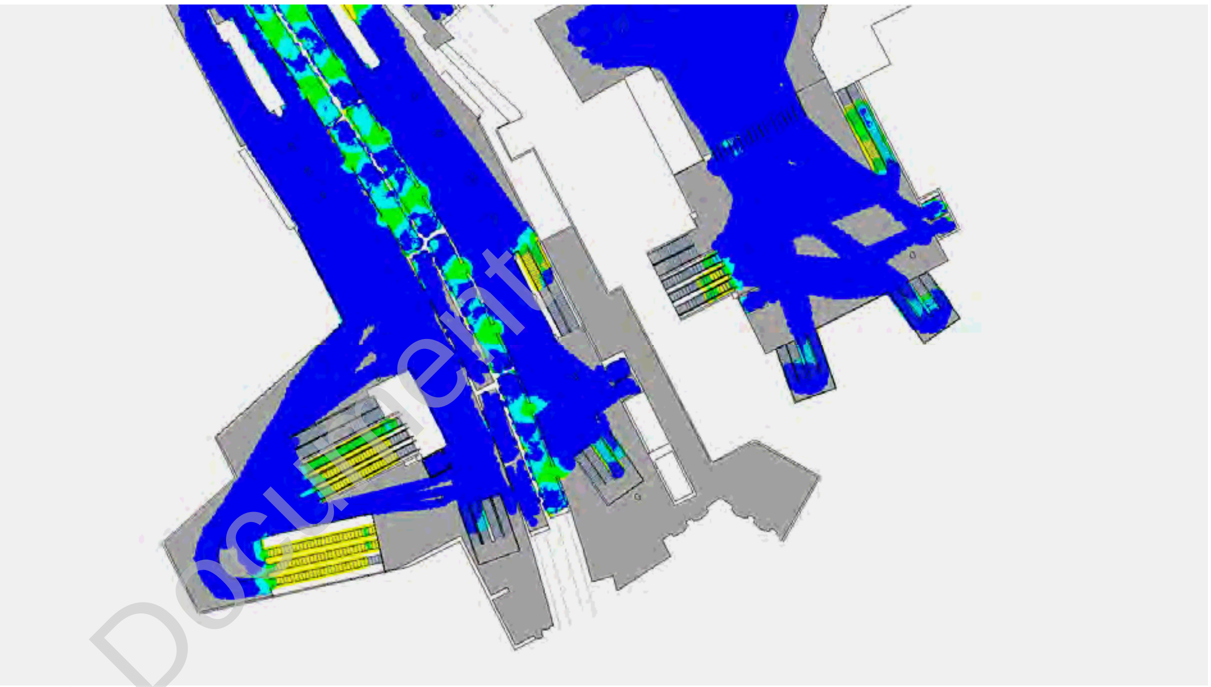
4.1.21 08h19-08h34, Mean Density (Queuing) TICKET HALL



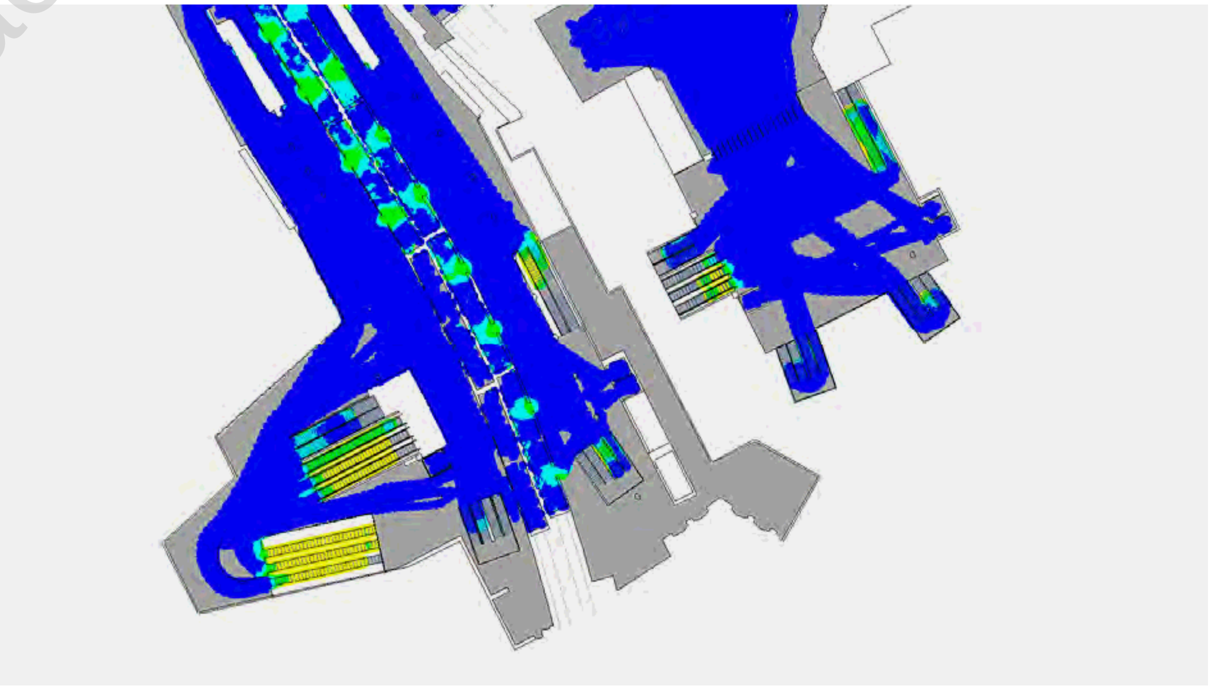
4.1.22 08h34-08h49, Mean Density (Queuing) TICKET HALL



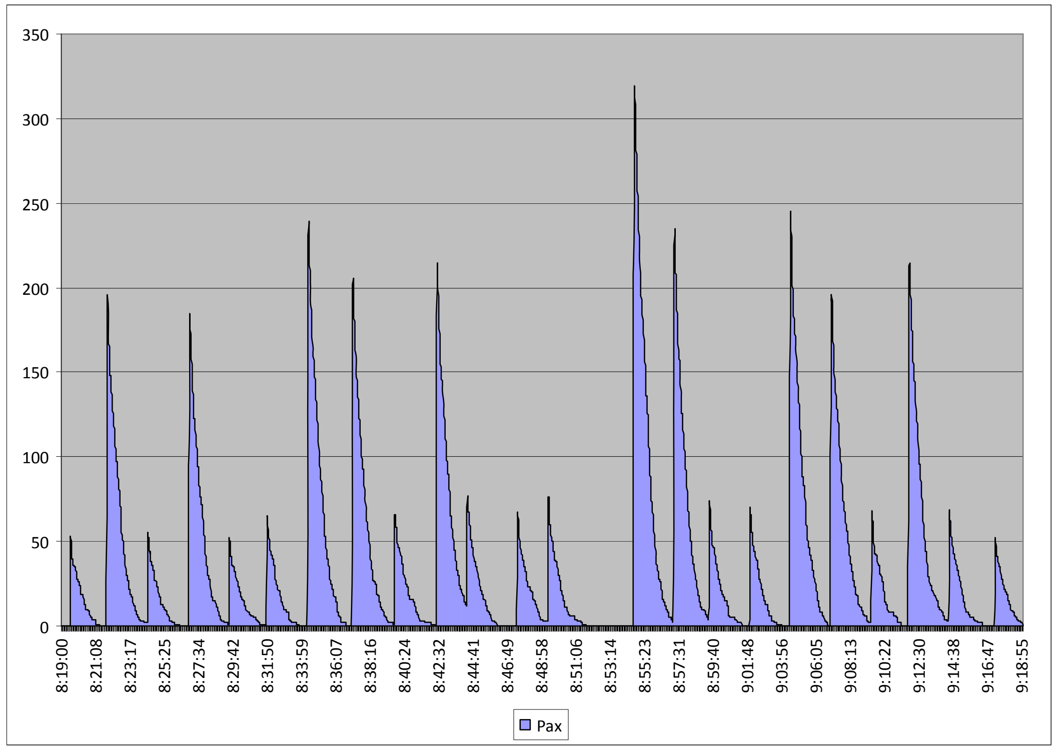
4.1.23 08h49-09h04, Mean Density (Queuing) TICKET HALL



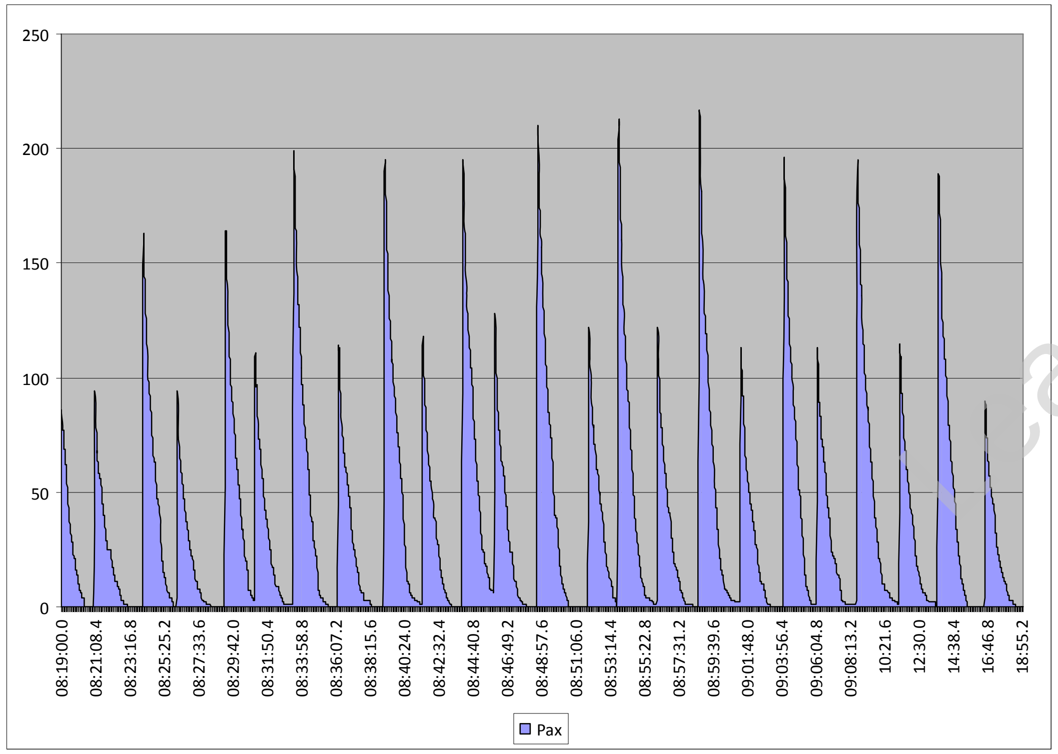
4.1.24 09h04-09h19, Mean Density (Queuing) TICKET HALL



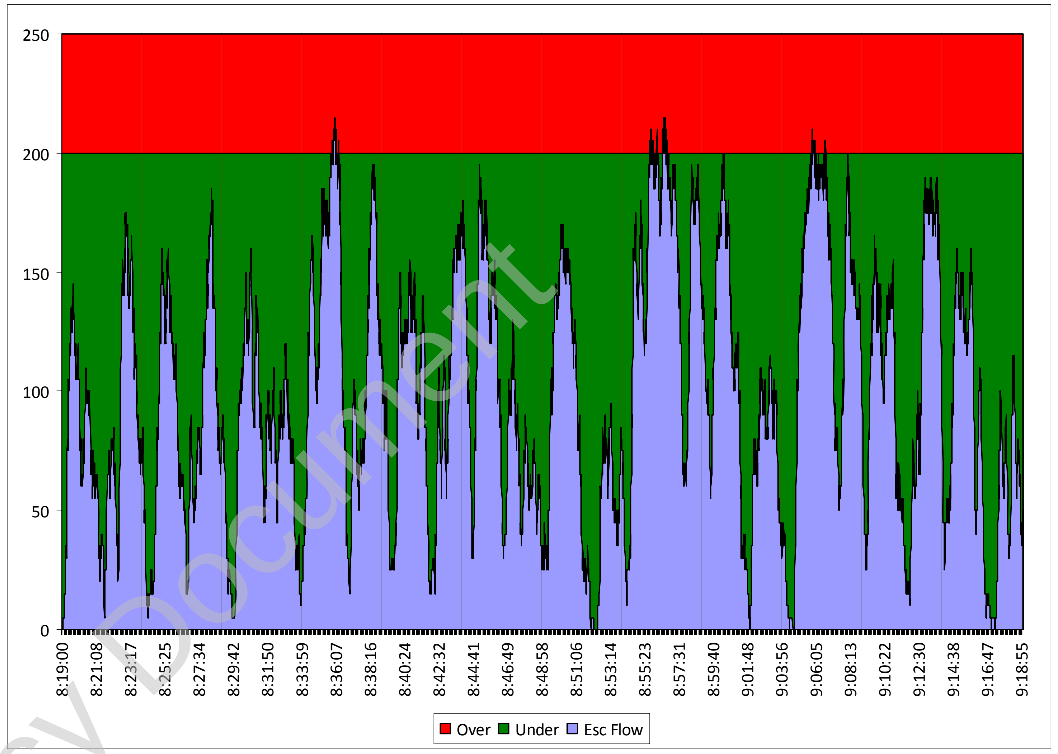
4.1.25 08h19-09h19, Platform Clearance CRL Eastbound



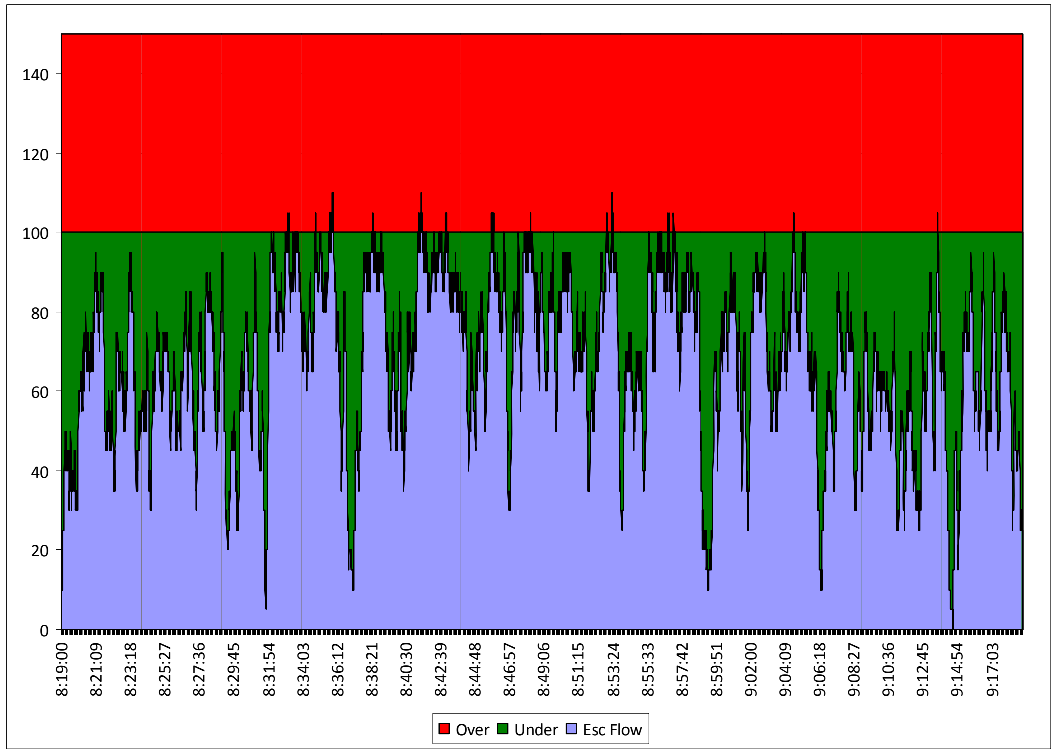
4.1.26 08h19-09h19, Platform Clearance CRL Westbound



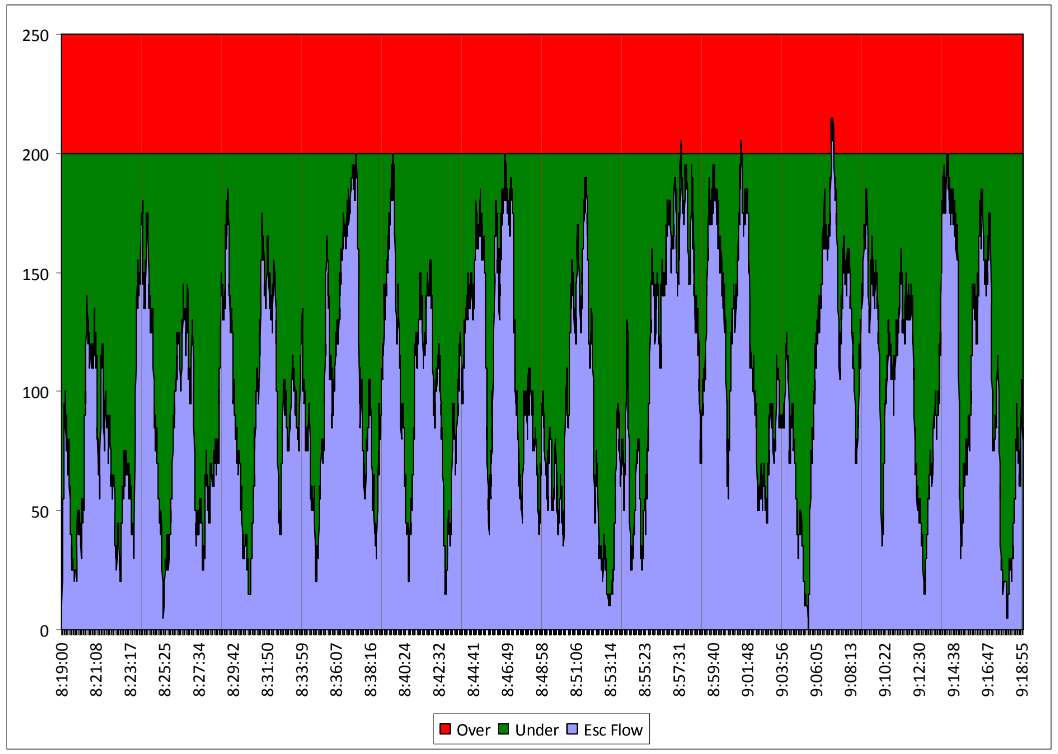
4.1.27 08h19-09h19, Upward Escalator Flow Rate



4.1.28 08h19-09h19, Downward Escalator Flow Rate



4.1.29 08h19-09h19, Escalator Flow toward Integrated Ticket Hall



4.2 2026 AM Peak Commentary

The Crossrail station and platforms operate without circulatory problems or congestion throughout the 08h19-09h19 peak period. Free-flow conditions remain throughout the hour.

Although higher levels of services are shown in the walkways mapping towards the front edge of platforms (noticeably on westbound) these areas represent dwell zones where passenger wait at PEDs between train headways (a CRL input requirement) and thus do not utilise any more than about half of the platform area. These areas of higher density should be viewed in the context of the Queuing mapping, which show nothing more severe than an acceptable Level of Service C (green) throughout the peak hour.

The highest LOS values are shown in both Walkways and Queuing maps towards the western end of the platforms. The boarding-by-car proportions are heavily weighted towards the front Westbound carriages (and rear Eastbound), resulting in the sliding scale of crowding to the east. The boarding proportions used in the modelling are a prescribed input from Crossrail Central, and do not account for passengers choosing to migrate away from comparatively denser areas. In any event, the western crowding is not severe at all; it does not restrict movement to and from the platforms in any way, and should demand increase then considerable spare capacity is available further to the east.

Circulatory areas all operate at (or below) a compliant LOS C, and at no point is movement in any direction to and from platforms impeded. It should be noted that the density results for platform circulatory areas are distorted to an extent by the concentration of waiting passengers near the PEDs, which results in the [walkway] LOS D/E “spots” facing each carriage door.

The “run-on” to the Western escalators shows LOS C in queuing maps, suggesting passengers are not delayed as they move upwards.

At the East end of the station the low passenger demand results in virtual free-flow conditions at all time and no areas of congestion concern. The bank of two escalators at the Eastern end provides more than sufficient capacity to process the board/alight flows.

The platform clearance graphs reflect the unimpeded circulatory conditions at Crossrail platform level. Clearance between headways is achieved for virtually all train arrivals at both westbound and eastbound platforms throughout the peak hour. On the few occasions this is not achieved (EB and WB trains in the period immediately before 09h00) only a small number of alighters remain on platform areas (maximum of about 10). This is a function of the headway gap at 24 TPH (actual arrival times are random within this frequency constraint) and the lengthy walk-distances, rather than a platform or adit capacity issue.

Escalator flow rates for the upward escalators (total of 2) at the western end show that they approach the theoretical vertical circulation capacity of 200 on a small number of occasions (100 passengers per minute per escalator is the typical operating capacity), but drop off significantly between headways.

The escalators peak in flow rate with each alighting surge. Indeed in the middle of the peak hour with the highest alighting loads they briefly exceed a flow rate of 200 passengers per minute (i.e. two escalators) on the arrival of heavily loaded concurrent/small headway services. These are not sustained flows and result in a no discernable delay at the base of the escalators (see the LOS queuing maps for the West end of platforms).

In the downward direction a single escalator operates at, or just below, capacity (100 per minute) for brief periods during the peak hour. This aligns with the findings from the static assessment which showed that the increased number of boarders in the morning peak (in the new forecast) pushes the requirement nearer to the upper capacity of 1 escalator than the old forecast did – but not beyond. Sustained utilisation of this single downward escalator does not lead to any congestion at the top of the Western escalators (at Thameslink platform level) – and the queuing maps for this area do not show anything greater than a LOS C (green) on the escalator run-on.

Circulatory areas of the Integrated Ticket Hall operate without sustained congestion – the 3 escalators plus stair provide sufficient capacity to process both Thameslink Northbound and Crossrail related demand, whilst the gateline area shows little congestion in either Walkways or Queuing maps. Figure 4.1.29 illustrates the flow rate up the 2 escalators towards the ticket hall. When the trend line breaches the red area, passengers may consider using the stairs – as this graph shows the stairs are significantly underutilised in the 2026 demand models, with only 14 passenger in the peak 3 hours (07h00-10h00) ascending by the stair.

The Eastern Ticket Hall operates without congestion throughout the peak hour. Passenger flows here are low and do not place any strain on the escalator or gating provision at the Eastern end of the station.

No mitigating measures would be required to operate the station during 2026 AM peak.

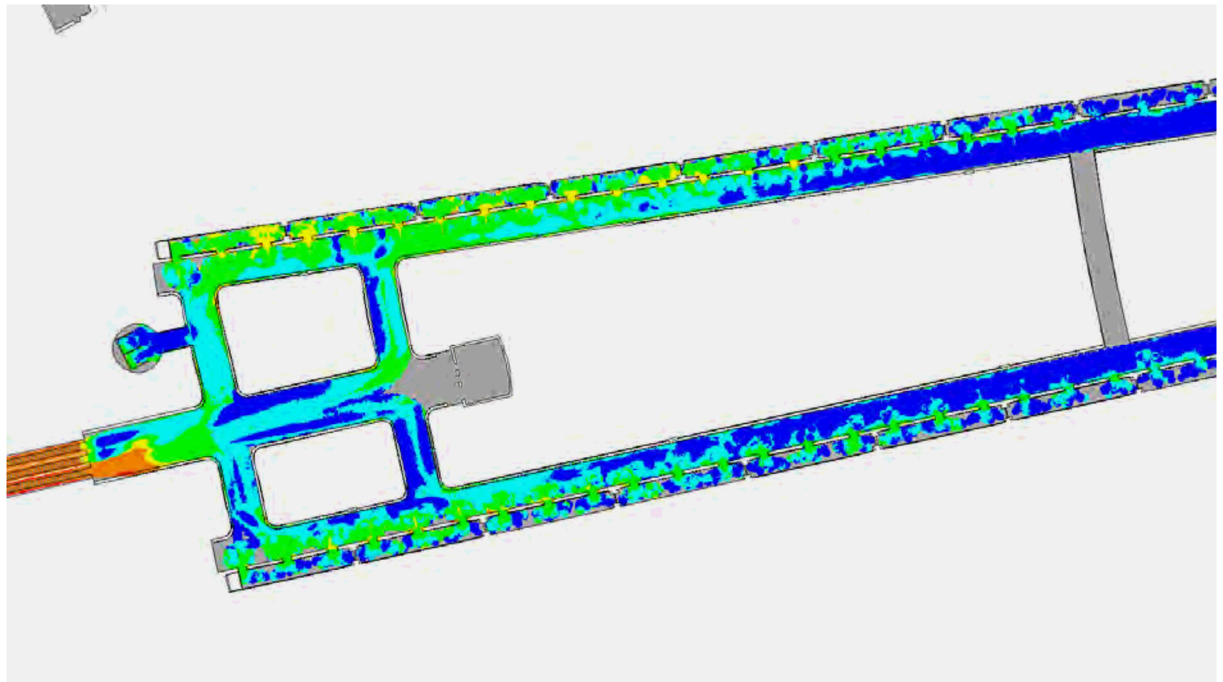
Graphical outputs for the London Underground and Thameslink platforms (and a brief commentary on results) are shown in Appendix B, Section 10.1.

4.3 2026 PM Peak Modelling, 16h00-19h00

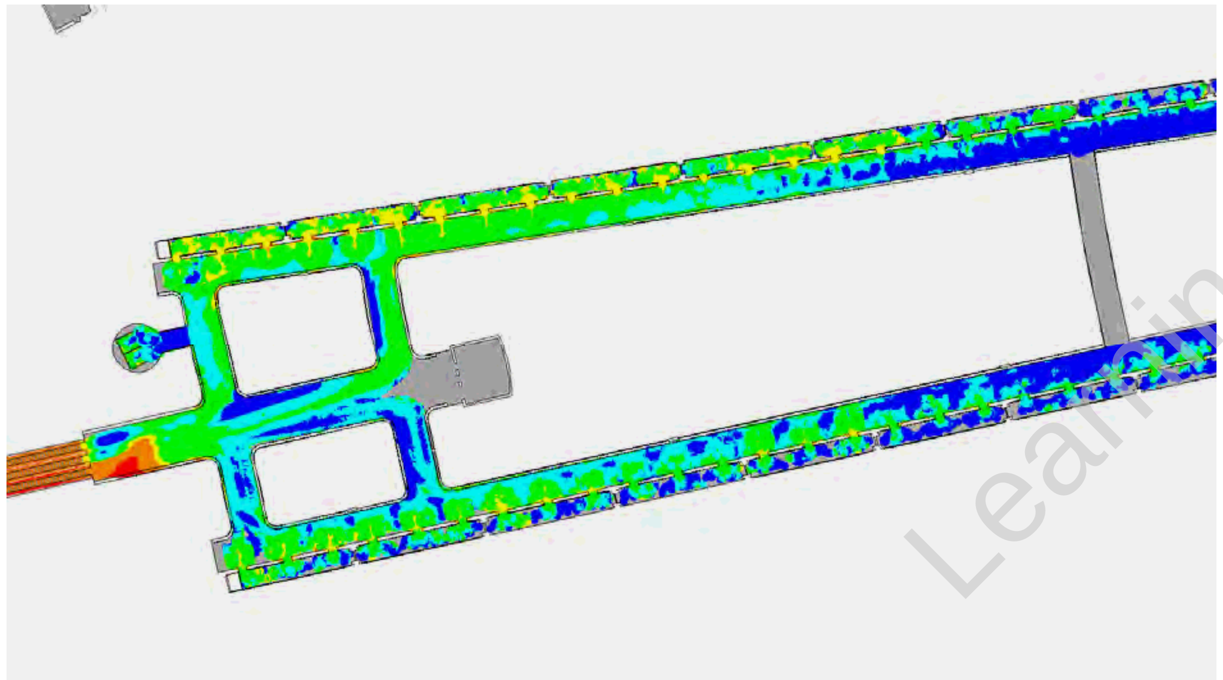
Results are shown for West and East ends of the station, and for the Integrated Ticket Hall.

A commentary on the results follows the images and graphs.

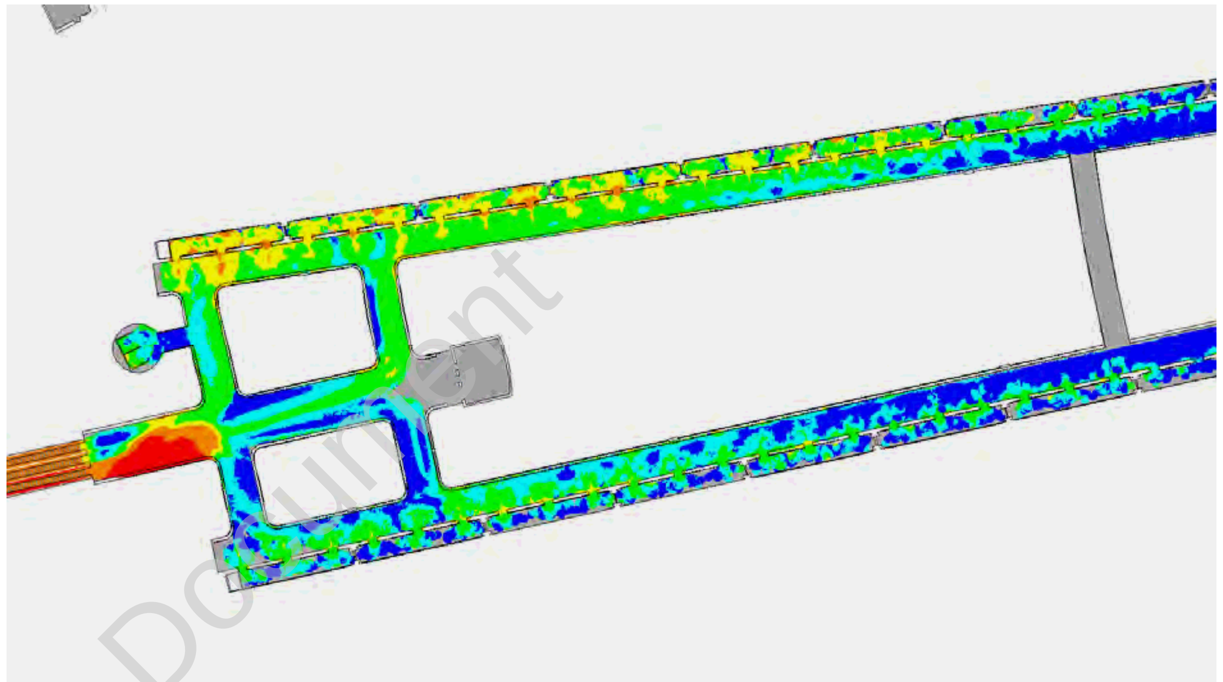
4.3.1 17h18-17h33, Mean Density (Walkways) WEST



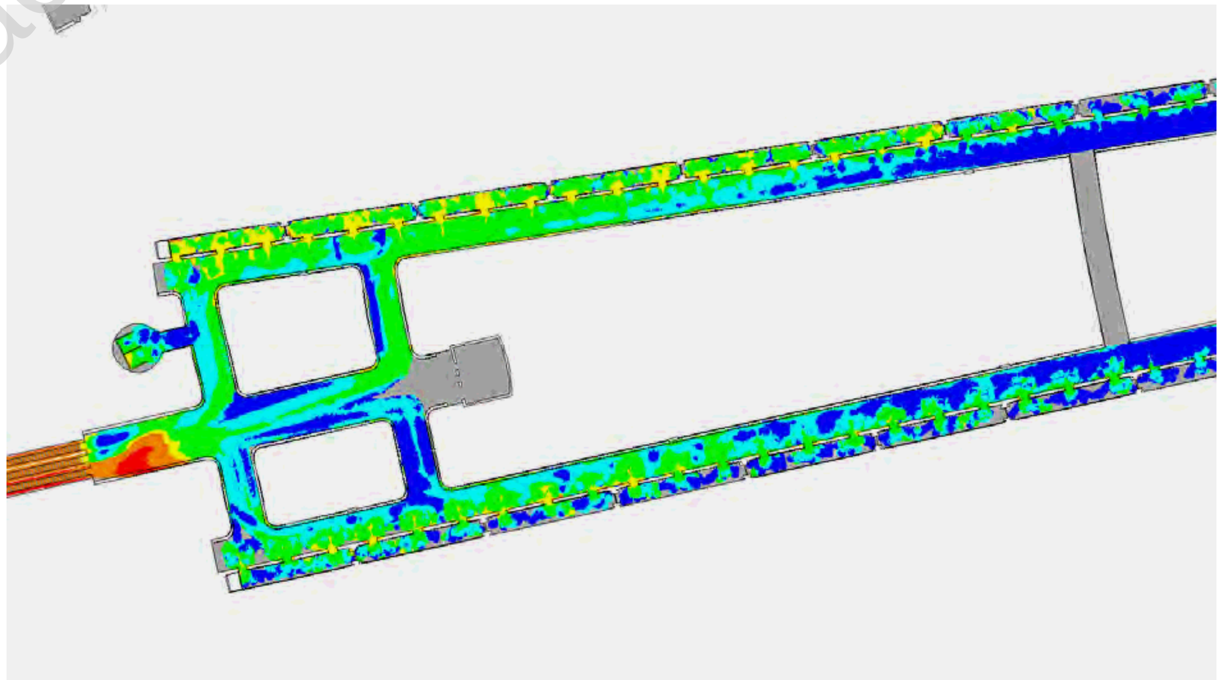
4.3.2 17h33-17h48, Mean Density (Walkways) WEST



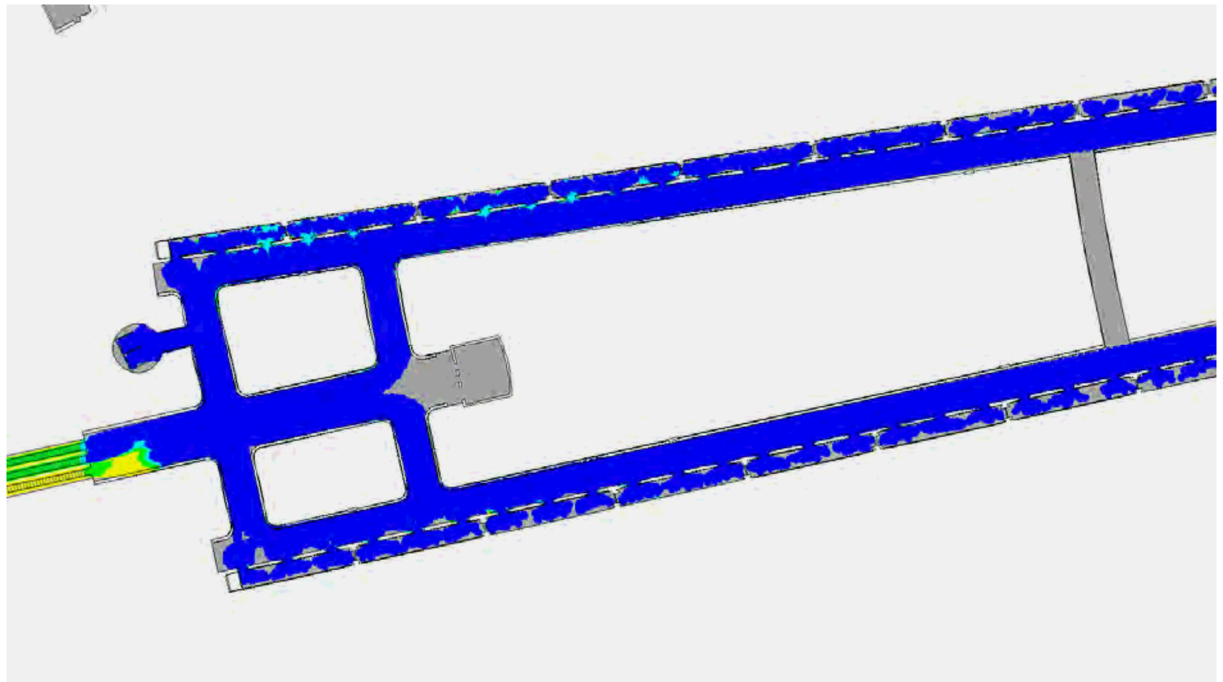
4.3.3 17h48-18h03, Mean Density (Walkways) WEST



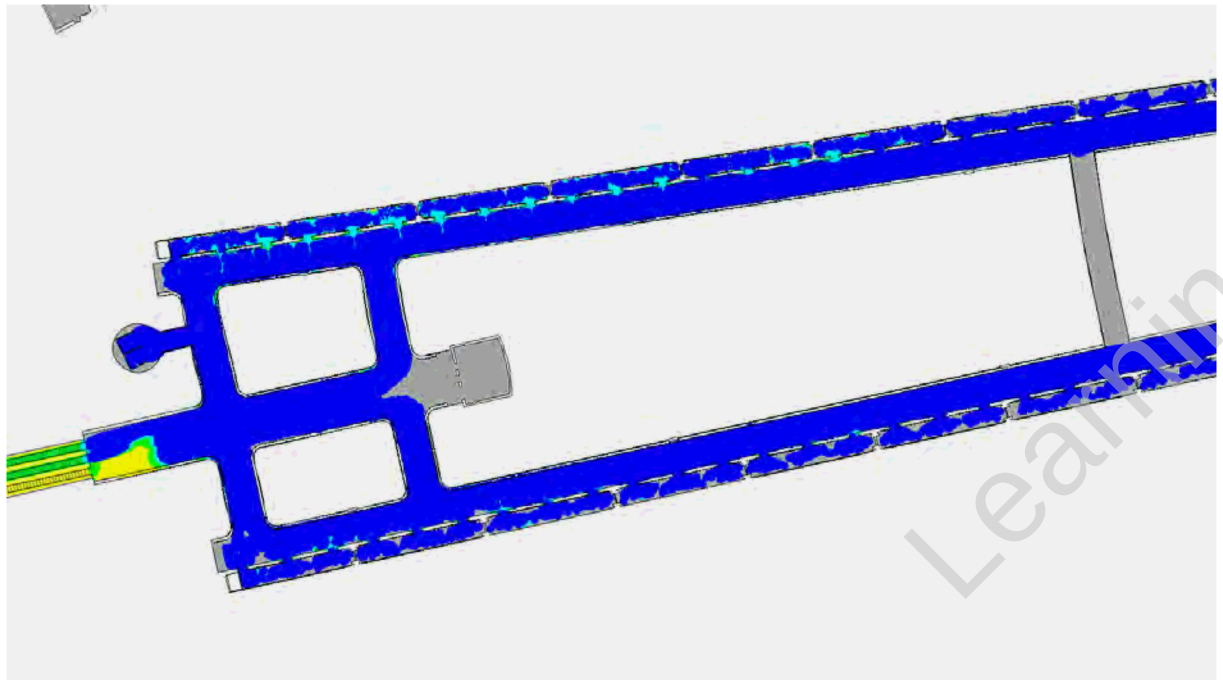
4.3.4 18h03-18h18, Mean Density (Walkways) WEST



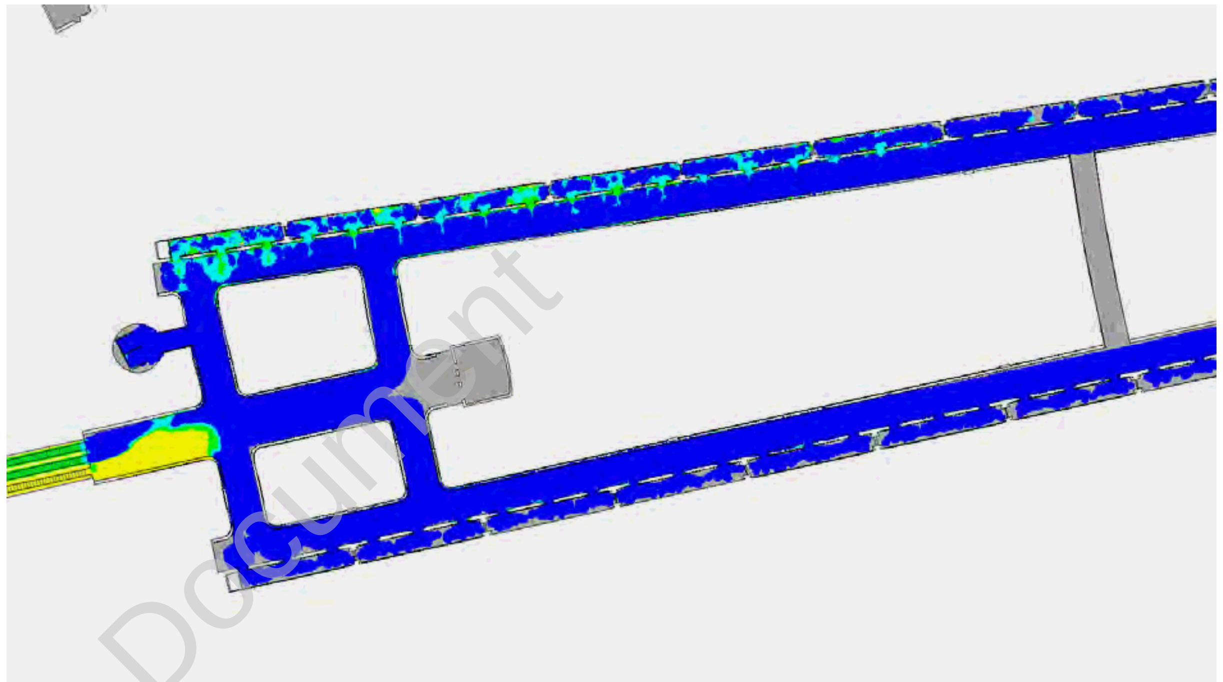
4.3.5 17h18-17h33, Mean Density (Queuing) WEST



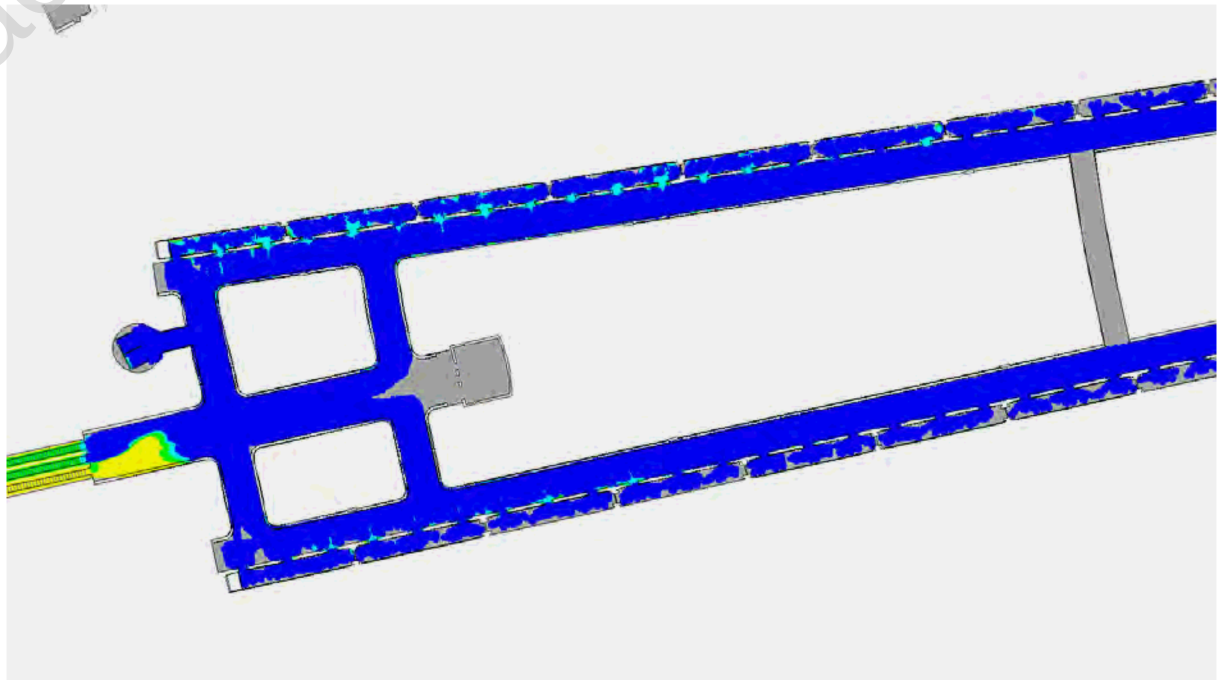
4.3.6 17h33-17h48, Mean Density (Queuing) WEST



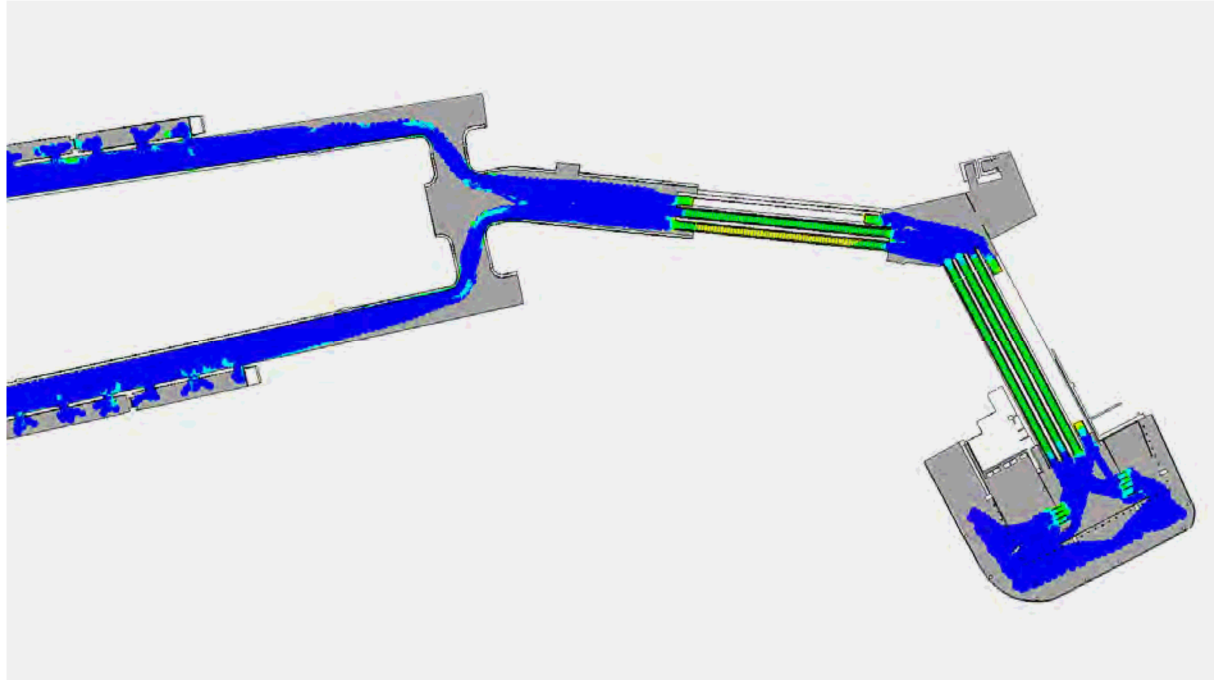
4.3.7 17h48-18h03, Mean Density (Queuing) WEST



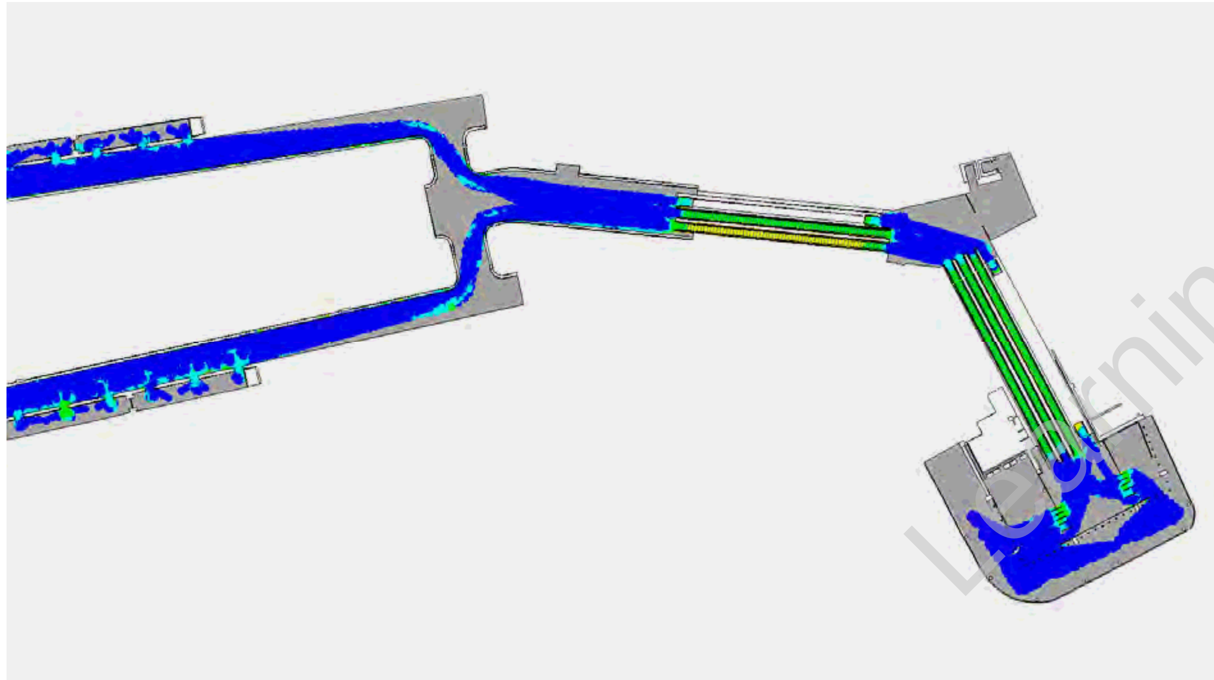
4.3.8 18h03-18h18, Mean Density (Queuing) WEST



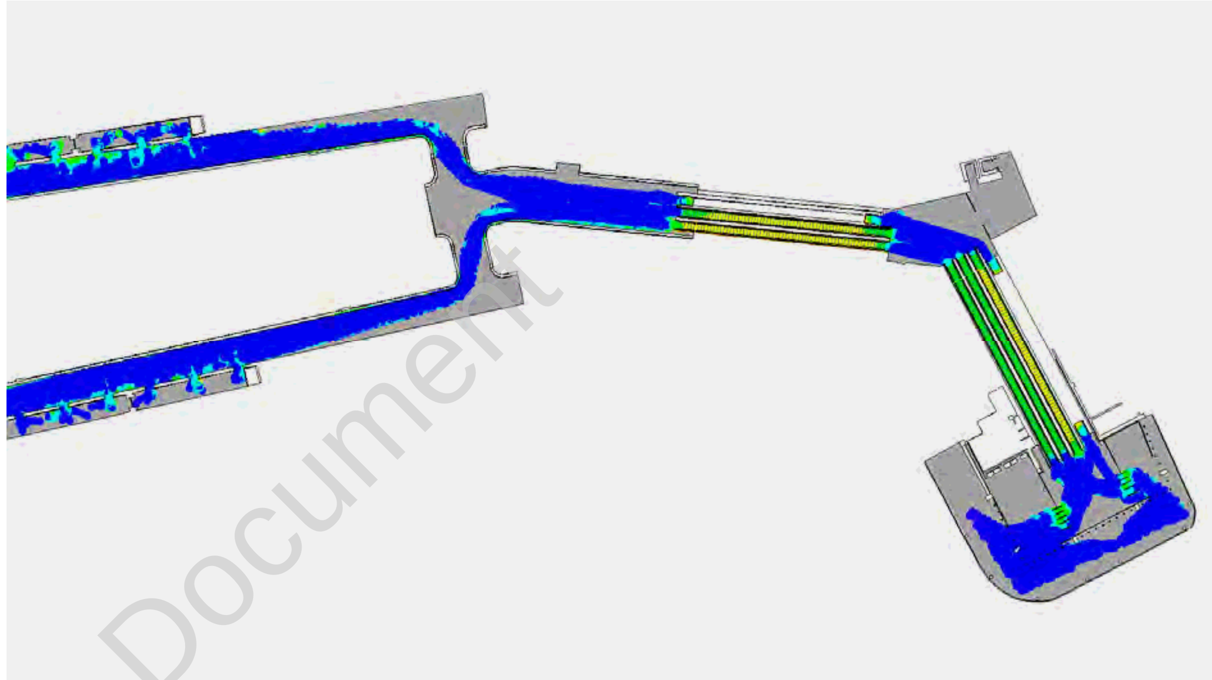
4.3.9 17h18-17h33, Mean Density (Walkways) EAST



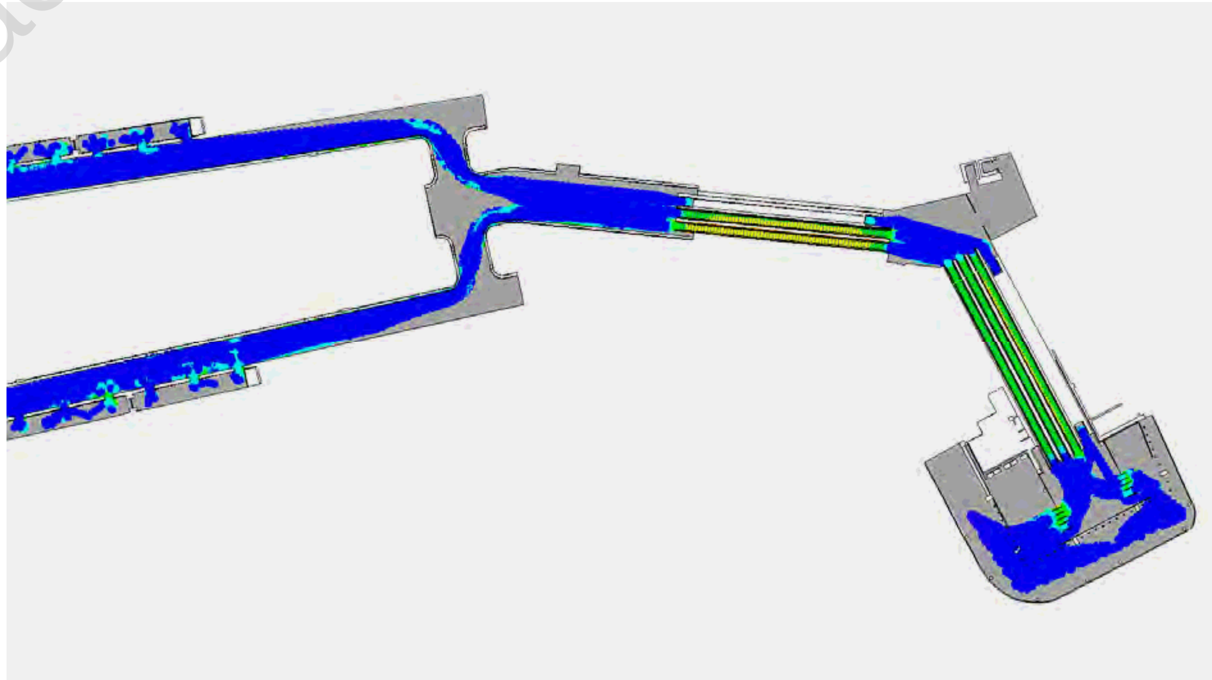
4.3.10 17h33-17h48, Mean Density (Walkways) EAST



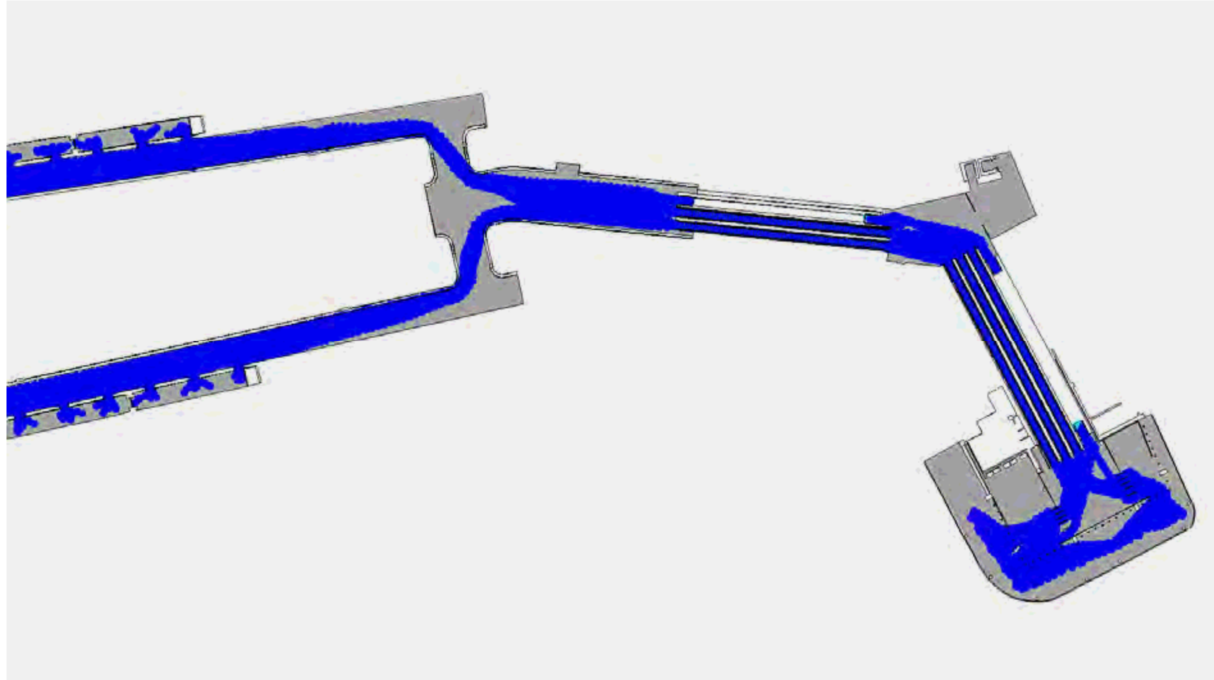
4.3.11 17h48-18h03, Mean Density (Walkways) EAST



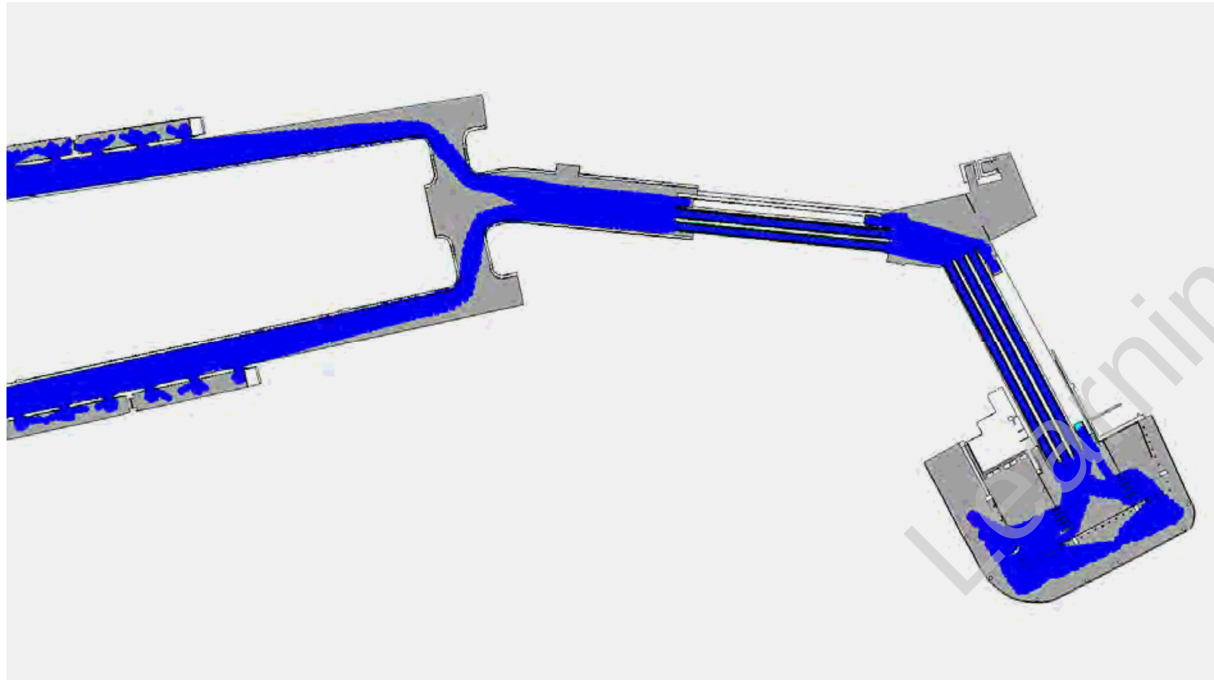
4.3.12 18h03-18h18, Mean Density (Walkways) EAST



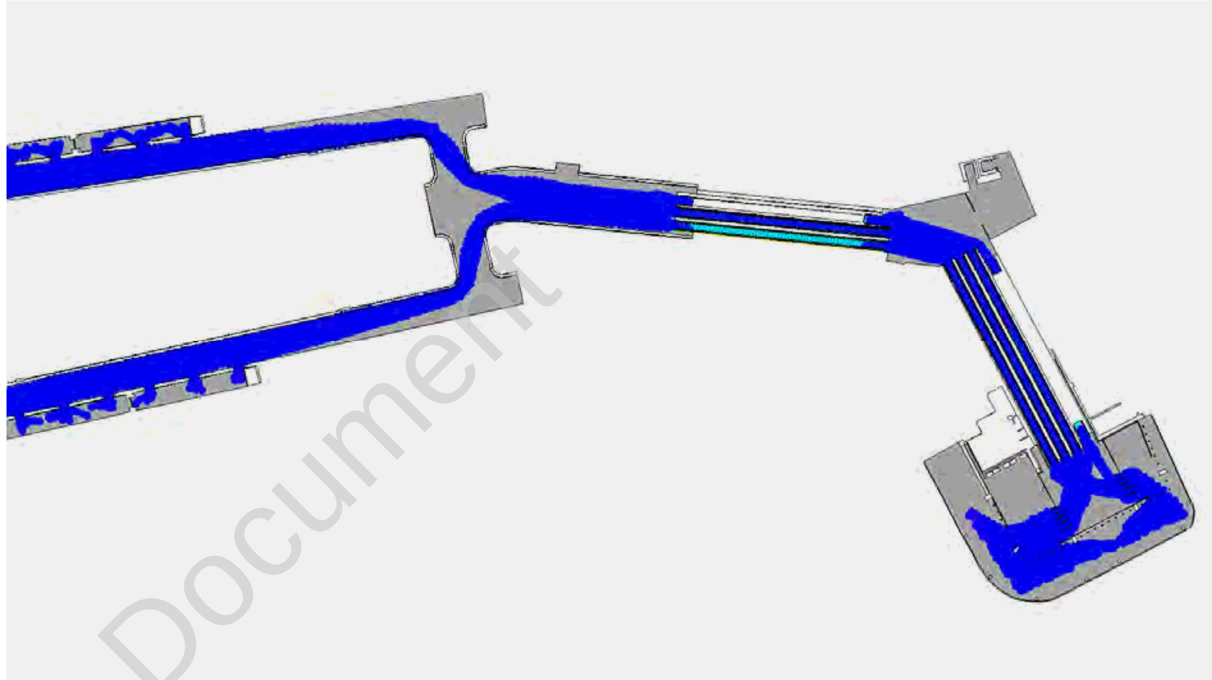
4.3.13 17h18-17h33, Mean Density (Queuing) EAST



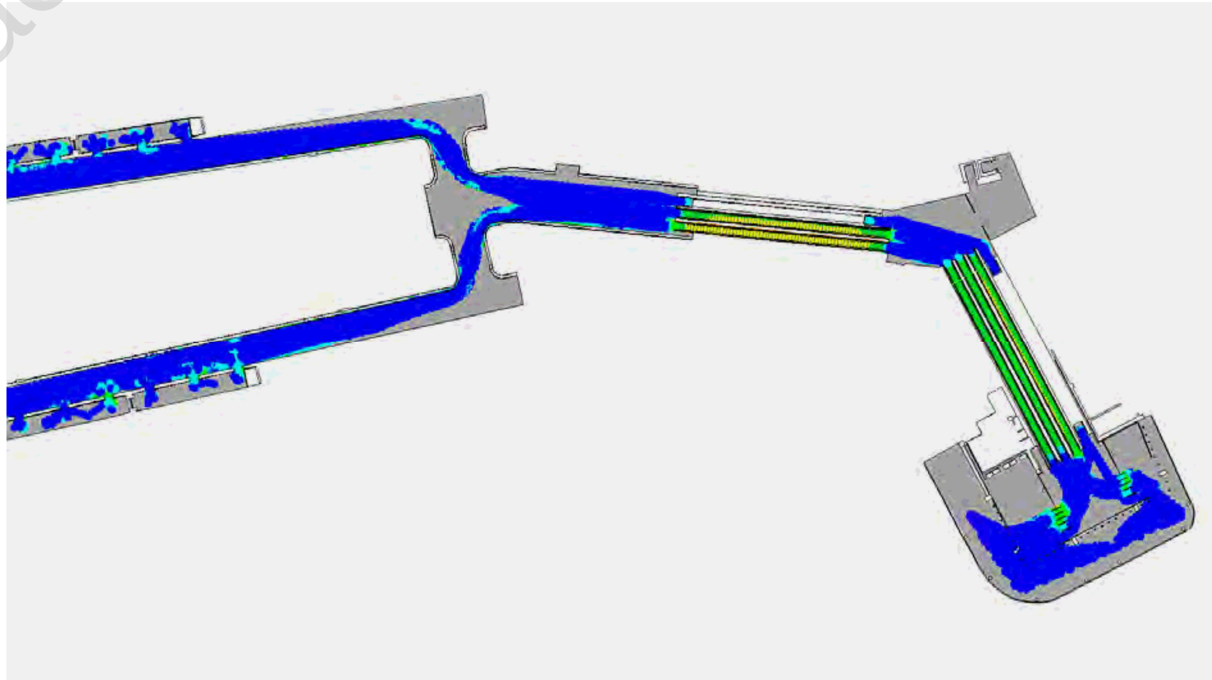
4.3.14 17h33-17h48, Mean Density (Queuing) EAST



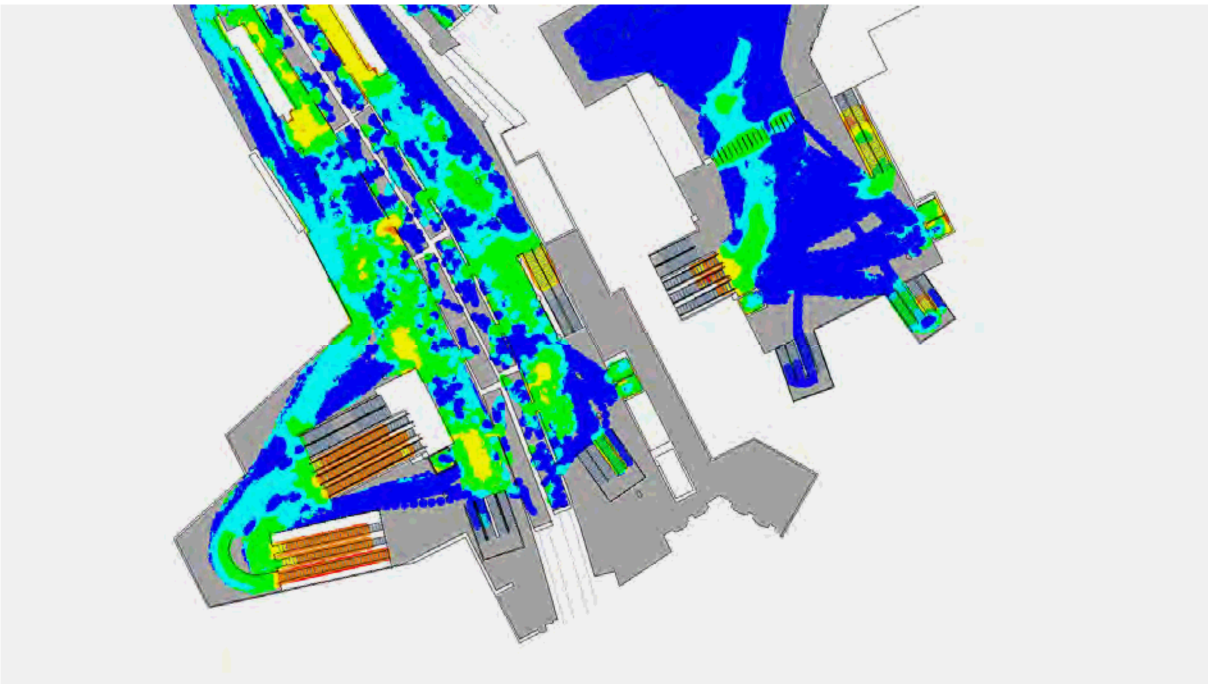
4.3.15 17h48-18h03, Mean Density (Queuing) EAST



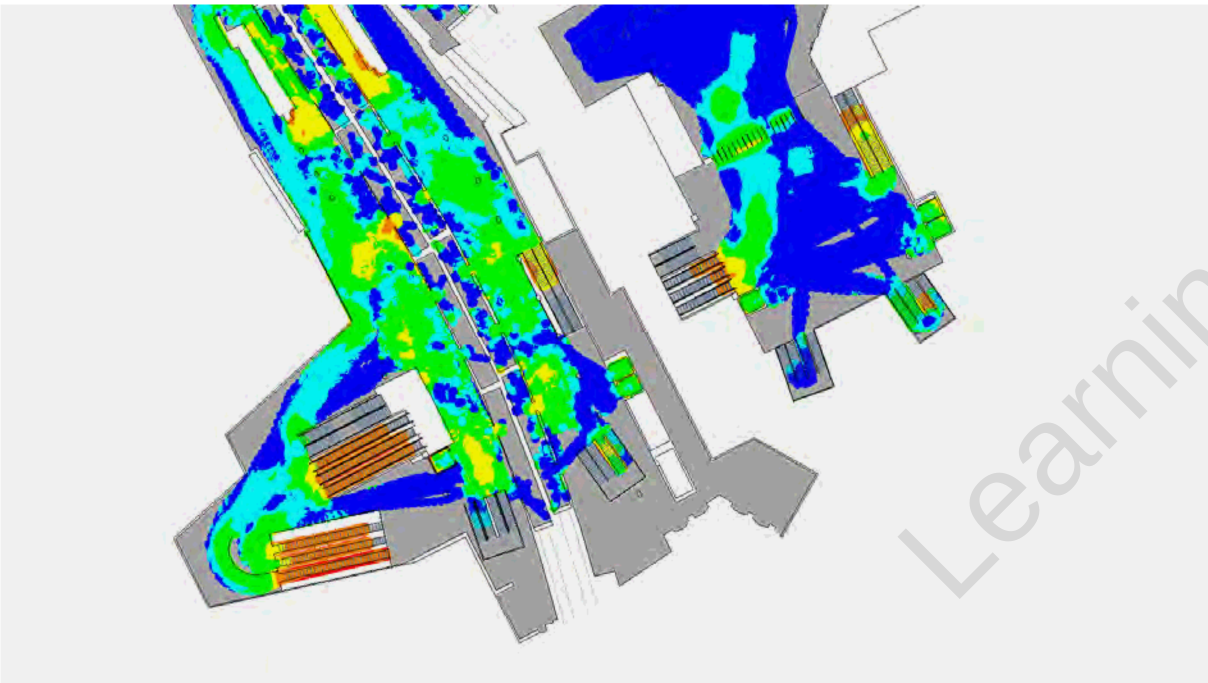
4.3.16 18h03-18h18, Mean Density (Queuing) EAST



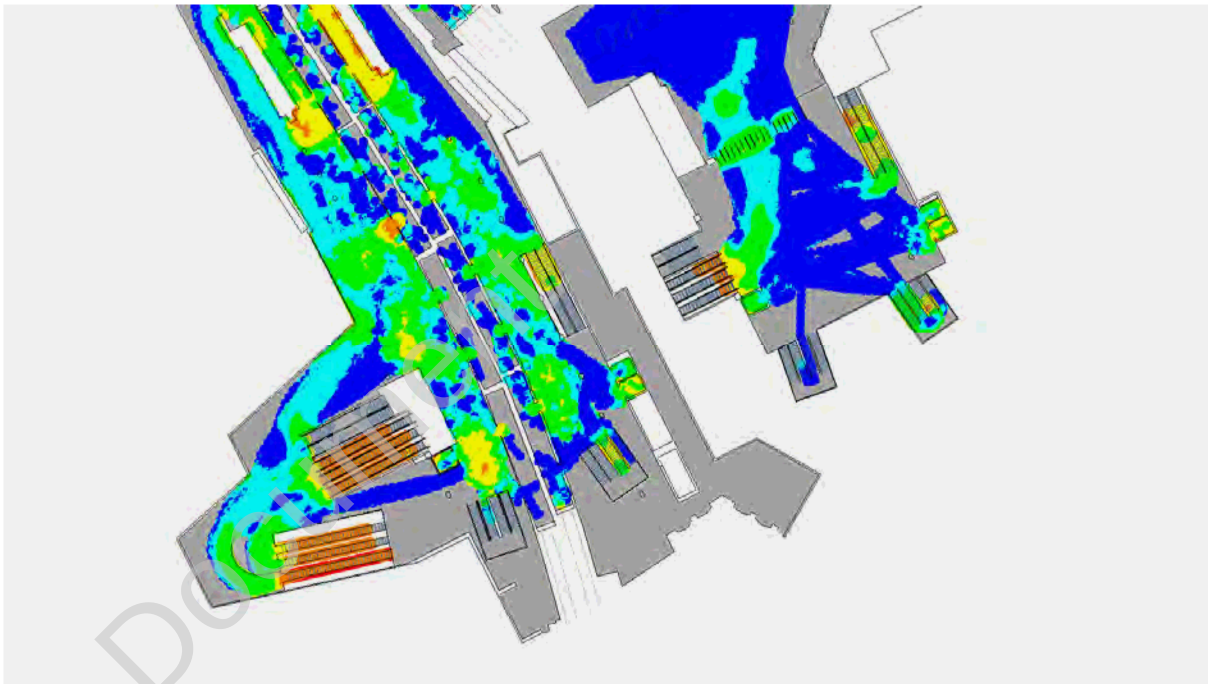
4.3.17 17h18-17h33, Mean Density (Walkways) TICKET HALL



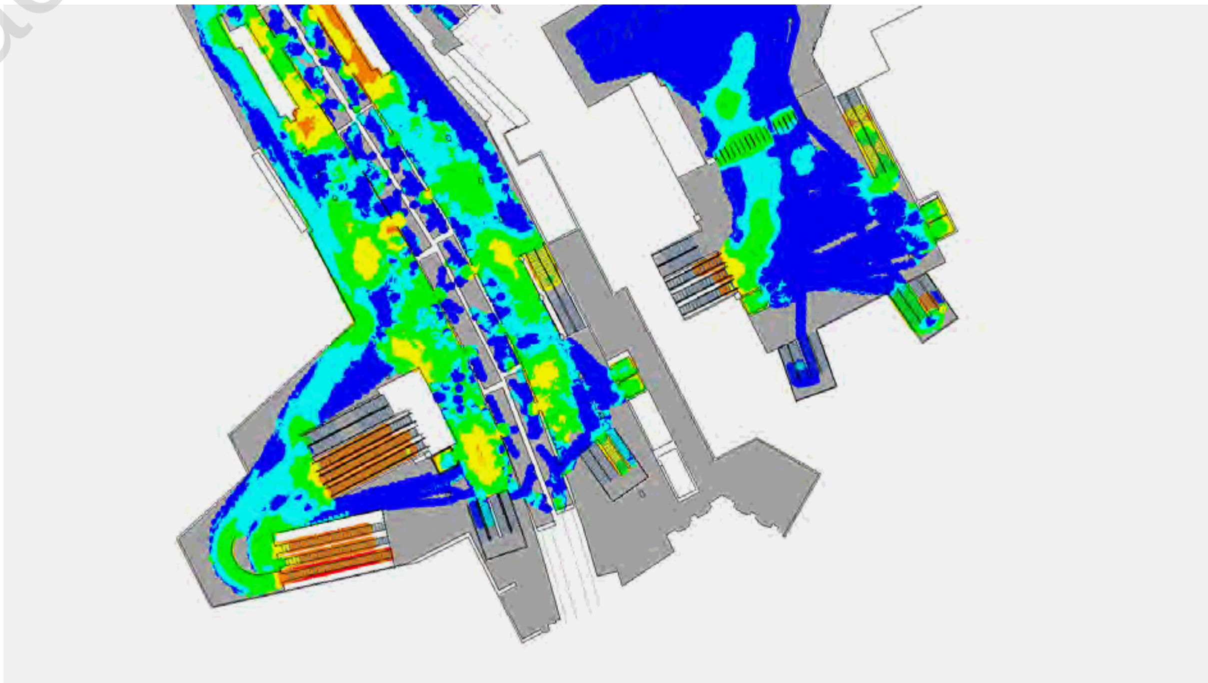
4.3.18 17h33-17h48, Mean Density (Walkways) TICKET HALL



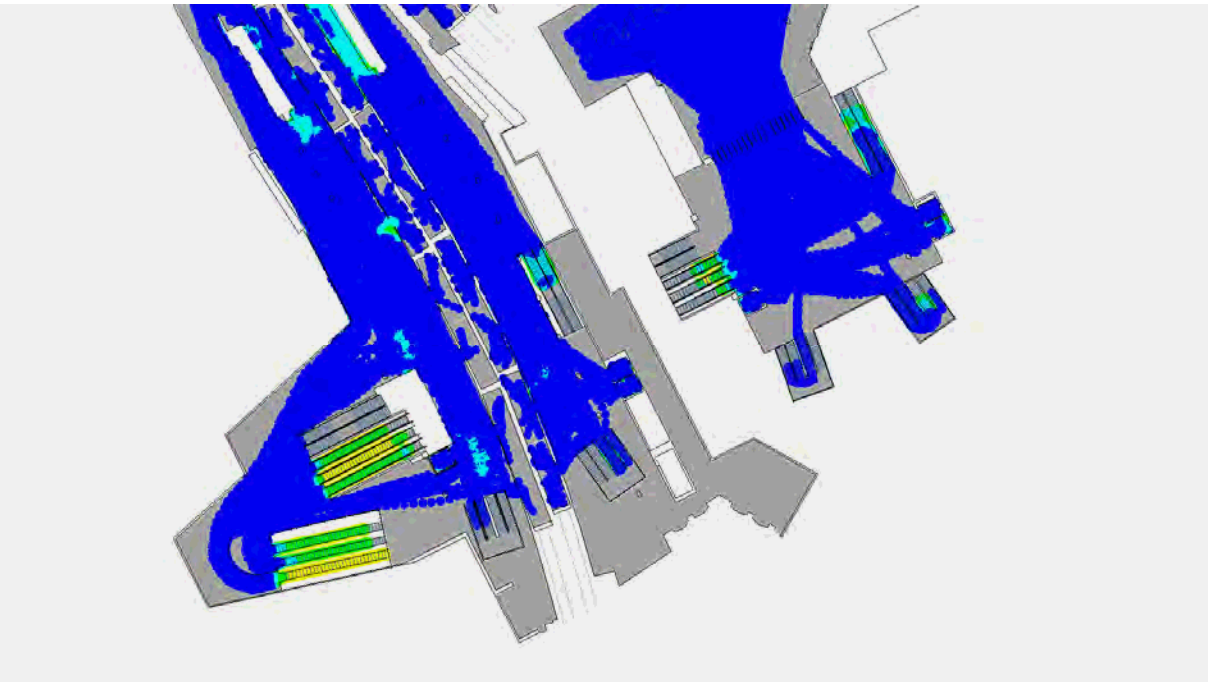
4.3.19 17h48-18h03, Mean Density (Walkways) TICKET HALL



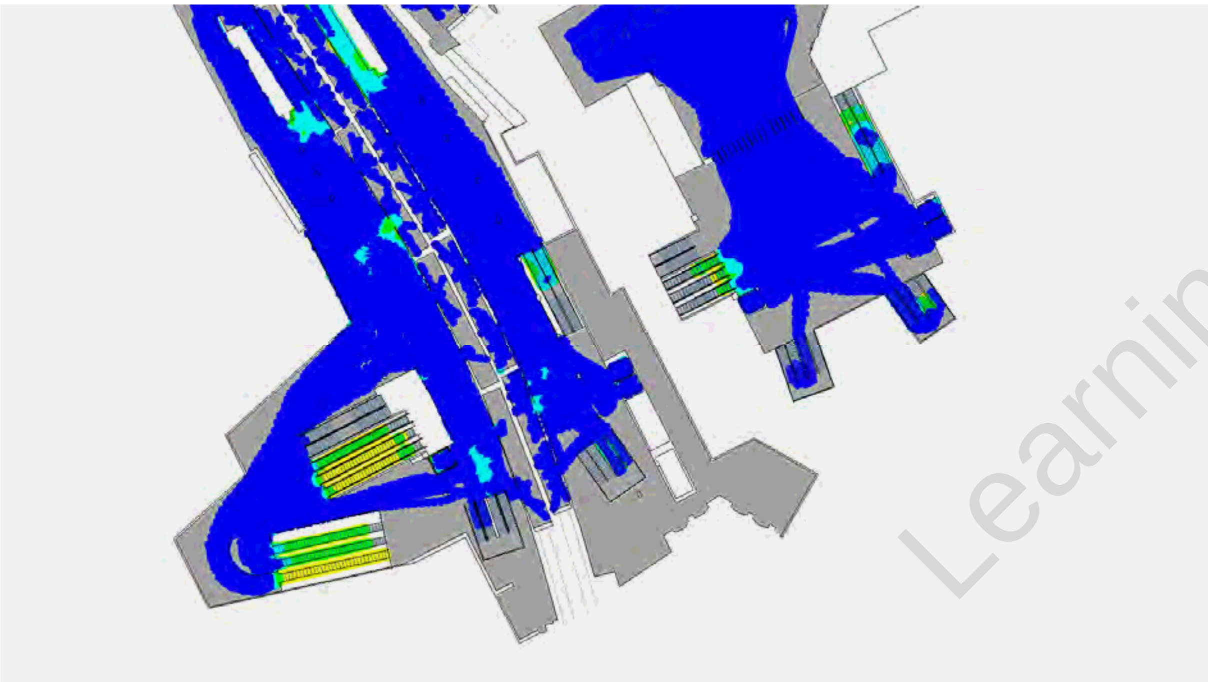
4.3.20 18h03-18h18, Mean Density (Walkways) TICKET HALL



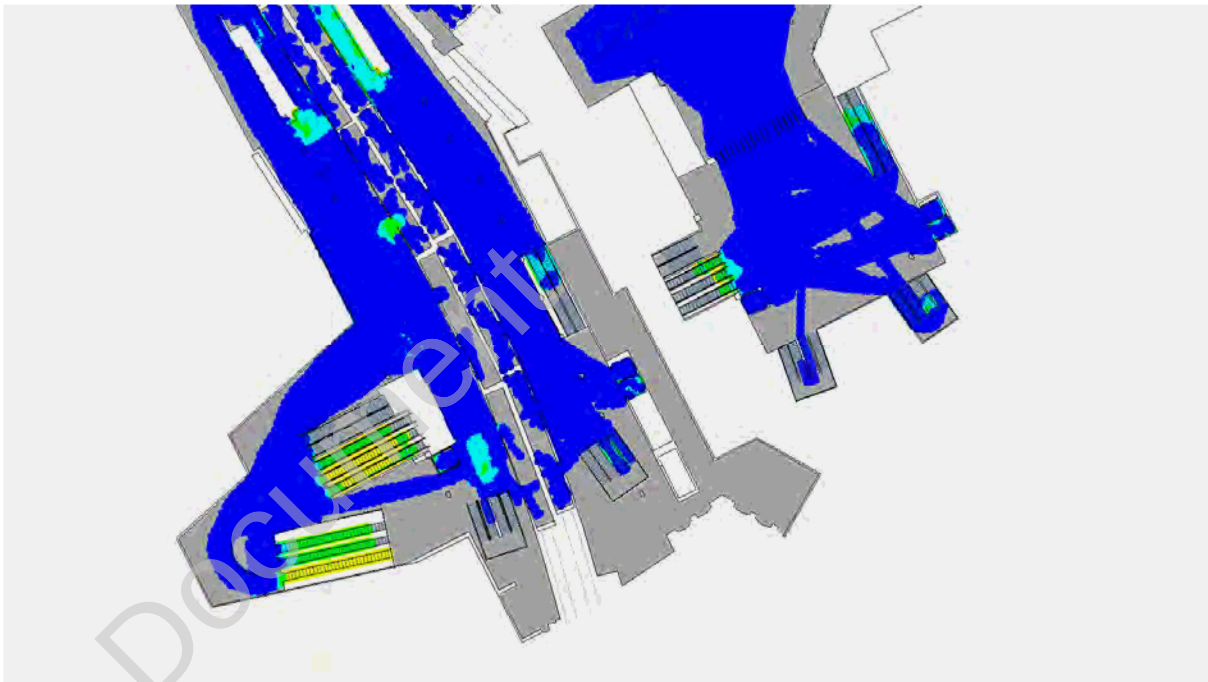
4.3.21 17h18-17h33, Mean Density (Queuing) TICKET HALL



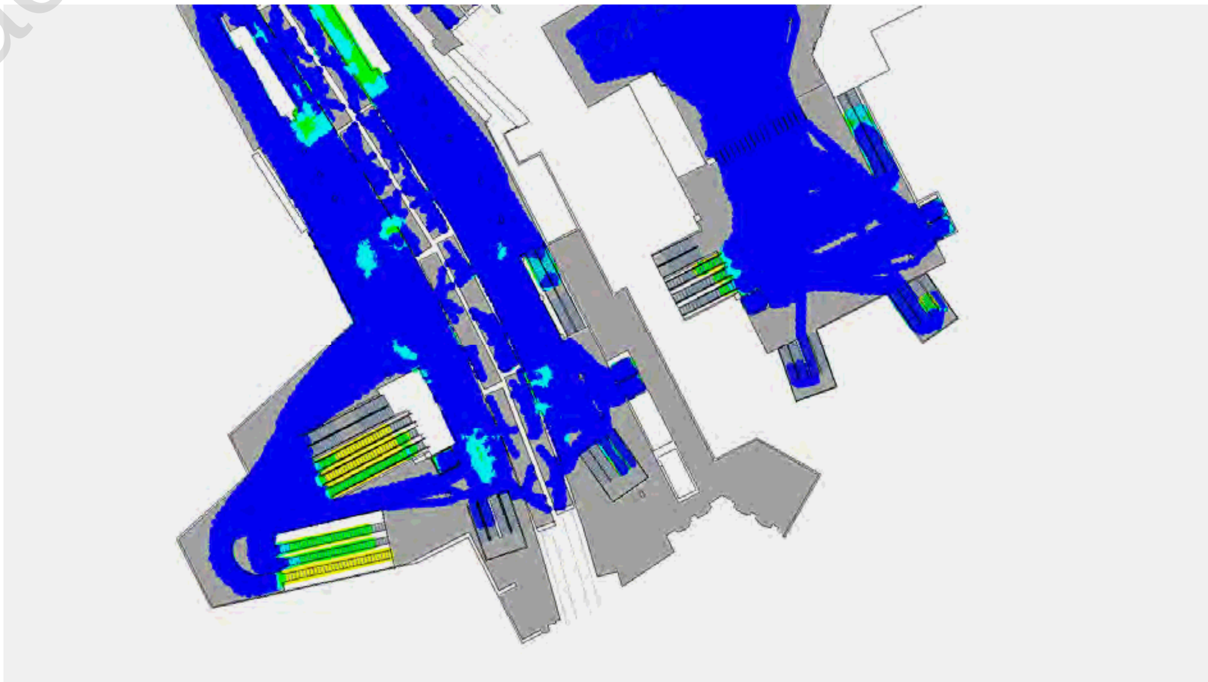
4.3.22 17h33-17h48, Mean Density (Queuing) TICKET HALL



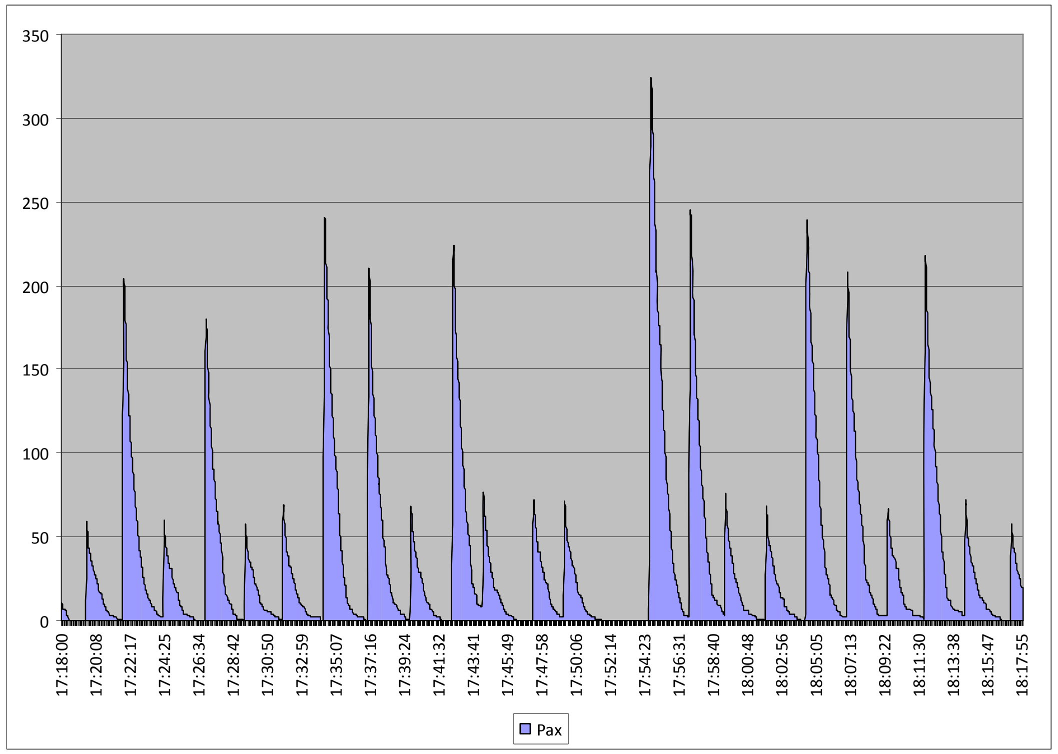
4.3.23 17h48-18h03, Mean Density (Queuing) TICKET HALL



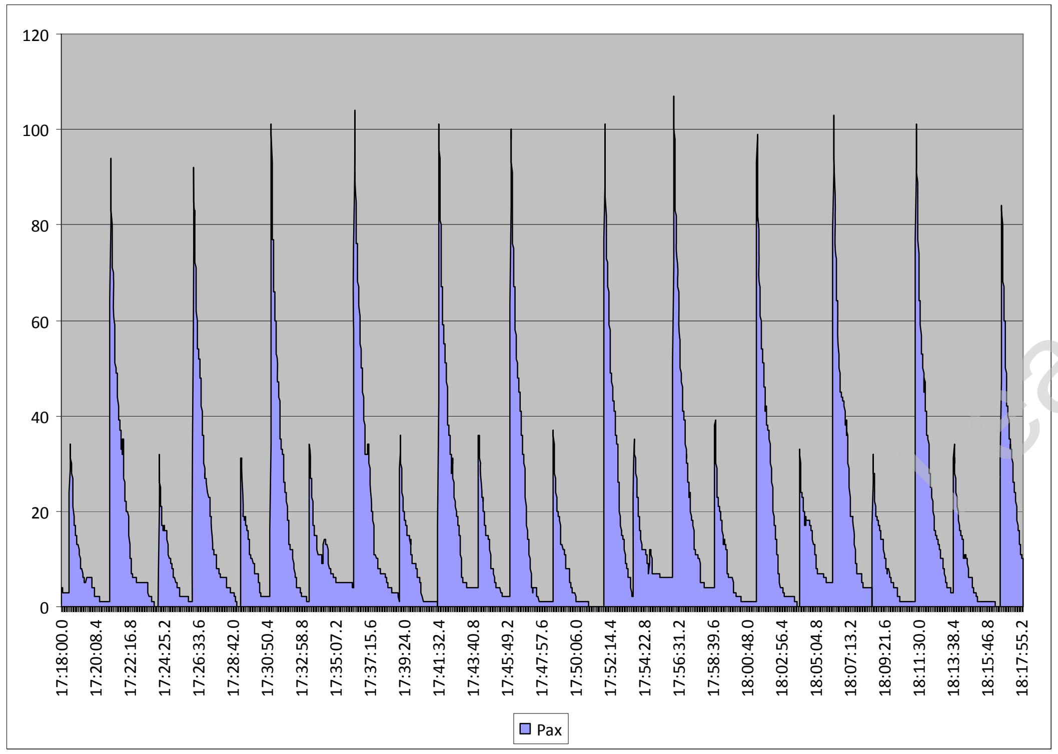
4.3.24 18h03-18h18, Mean Density (Queuing) TICKET HALL



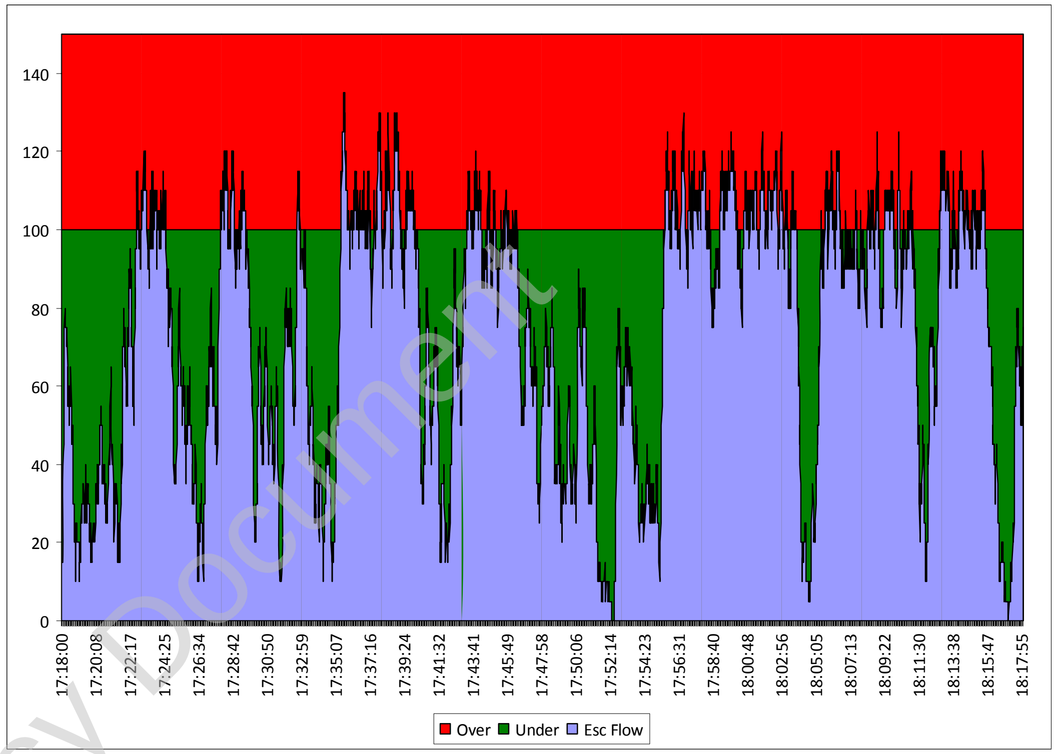
4.3.25 17h18-18h18, Platform Clearance CRL Eastbound



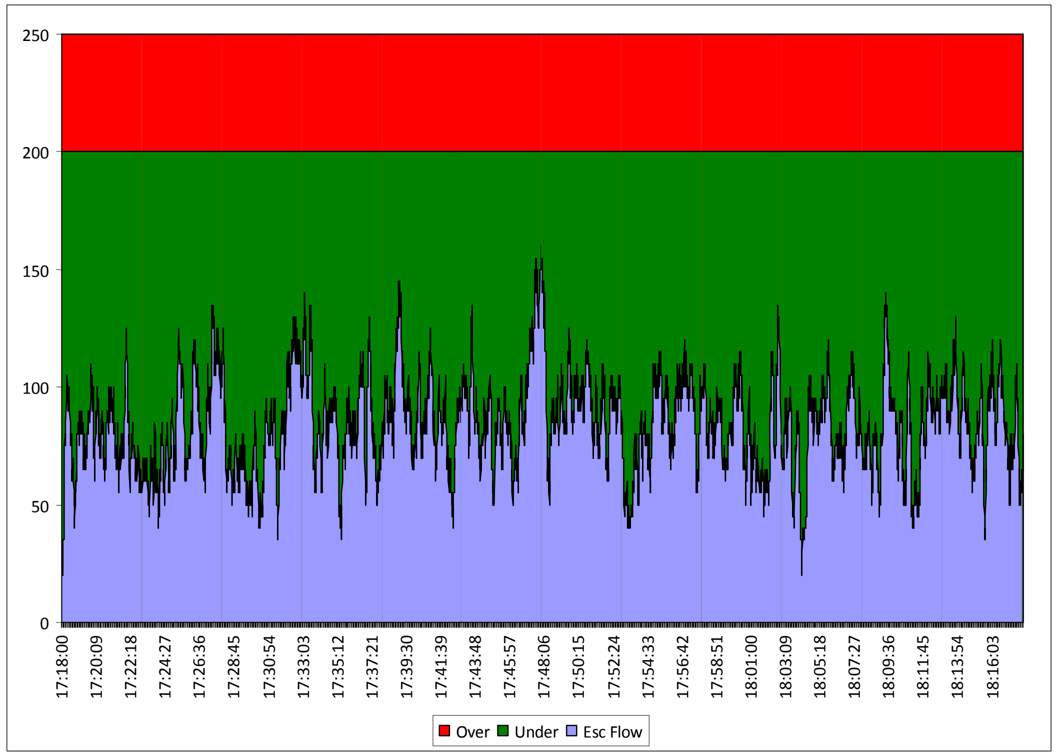
4.3.26 17h18-18h18, Platform Clearance CRL Westbound



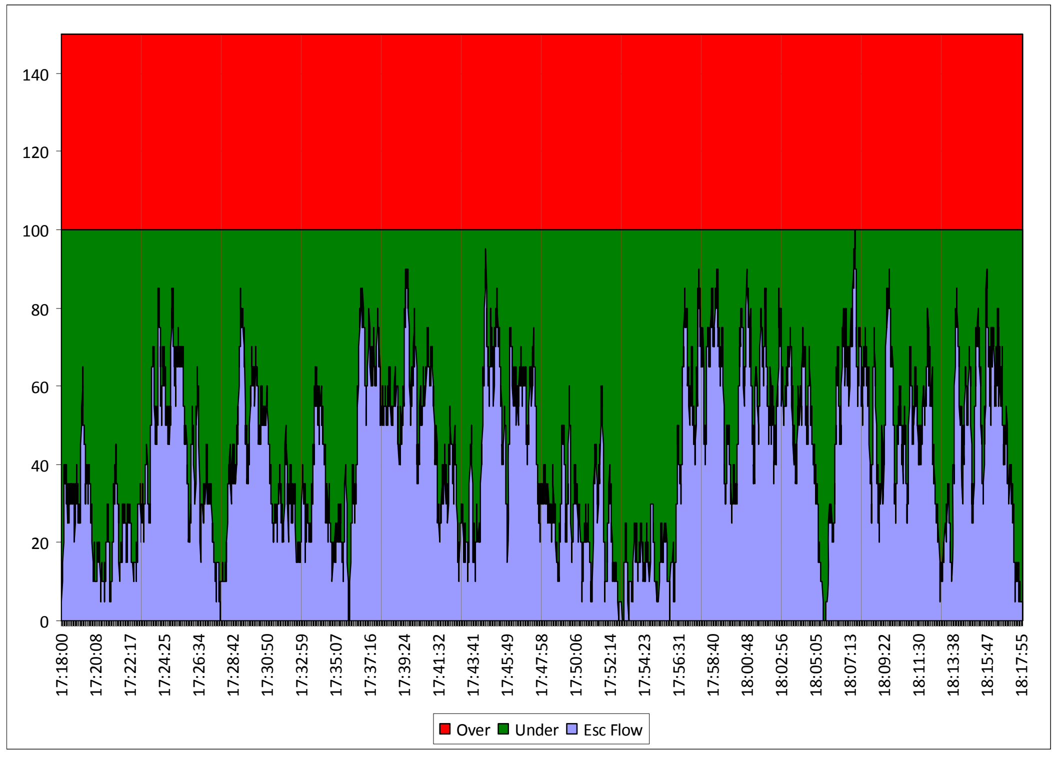
4.3.27 17h18-18h18, Upward Escalator Flow Rate



4.3.28 17h18-18h18, Downward Escalator Flow Rate



4.3.29 08h19-09h19, Escalator Flow toward Integrated Ticket Hall



4.4 2026 PM Peak Commentary

As with other London stations the primary flow during the evening peak are street to platform movements. Operational procedures should therefore be geared to accommodate the dominant entry (boarding) flows. It should be noted however that the evening peak at Farringdon is considerably less tidal than many other central London stations, with a significant number of opposing (alighting) movements forecast to occur - of the total flows using CRL services in the evening peak, only 56% are boarders, with 44% alighters.

Consequently, the patterns of passenger numbers test capacity in either direction. The primary strain upon infrastructure is on downward escalators and the dwell areas' ability to accommodate passenger build-up between headways (approximately 13,500 in three hours). In practice however, the lower alighting loads (approximately 10,500) due to their concentration into alighting surges place an almost equal strain on the venue, as the 200m+ platforms have considerable capacity to accommodate boarding passengers. This is reflected in the results shown above.

The western end of the Crossrail platform level shows their highest levels of service on the escalator approach. Here, higher levels of crowding are shown between 17h48 to 18h03 (following the cancelled train) at escalator run-on. Walkways mapping for this area will over-estimate congestion to an extent (passengers after all are slowed/queuing to board an escalator), but nonetheless the sustained LOS D before and after 18h00 represents a [minor] delay to exiting passengers.

Iterative modelling has been interrogated using 2 upward escalators (as in the morning peak). This provides more efficient performance at platform level but degrades performance at TL and interchange level to an unacceptable level, potentially blocking flows coming down from the Integrated Ticket Hall. In any event, escalators should be aligned to cater for the dominant flow, which for evening peak is the downward (boarding) flow.

The escalator flow rate graphs illustrate the flow rate up the single escalator. On concurrent (or near concurrent) arrivals the steady flow of alighters pushes flow to 120 passengers per minute, although flow drops off significantly between headways. For the downward escalators, the flow is almost continuously just below the 100 passenger per minute level, and often peaks well above 100. Most significantly, the flow rate never drops off, offering no recovery period. In the downward direction there is little respite in flow and for this reason, the two-down, one-up formation must be operated, even at the expense of the minor delay to upward travelling passengers. Between 17h18 and 17h33 the average journey time between the western most adit and the upward escalator is 28seconds. This increases to 46 seconds between 17h48 and 18h03. Although density values do increase as passengers slow and congregate, their actual journey experience is not significantly altered.

Should mitigation be sought to alleviate this, then it is suggested that staff intervention, signage or announcements could guide passengers towards the eastern end of the station,

Conditions on the platforms themselves are unimpeded throughout the peak hour, with density values not exceeding LOS B in the queuing maps assessing dwell time performance. Where passengers congregate at PEDs, these increase to walkways LOS D (LOS E at doorways themselves) but using these maps to assess platform accumulation would be a serious overestimation.

At the East end of the station the very low passenger demand results in free-flow conditions at all times with no areas of congestion concern. The bank of two escalators at the Eastern end provides more than sufficient capacity to process the board/alight flows during the evening peak.

As in the morning peak modelling, alighters comfortably clear the Eastbound platform for all headways, with only one or two exceptions on the Westbound platform. Where platforms fail to clear, this is due to the short headways and the possible journey length a passenger at the extreme of a platform might have to undertake. In any event, the graph reveals less than 10 passengers failing to clear on these occasions.

Circulatory areas of the Integrated Ticket Hall operate without any congestion – the 3 escalators plus stair provide sufficient capacity to process both Thameslink Northbound and Crossrail related demand, whilst the gateline area shows little congestion in either Walkways or Queuing maps. The escalator flow rate graph (4.3.29) reveals no capacity based reason for passengers to ascend by stairs. As with the AM peak period, the stair at 2026 demand level represents a significantly under-utilised station element.

The Eastern Ticket Hall operates without congestion throughout the peak hour. Passenger flows here are low and do not place any strain on the escalator or gating provision at the Eastern end of the station.

Mitigation may be sought to alleviate the minor congestion and delay experienced at the base of the upward CRL escalator, perhaps through increased use of the eastern end. In practice this may not be necessary – any delay experienced is brief and follows a cancelled train.

Graphical outputs for the London Underground and Thameslink platforms (and a brief commentary on results) are shown in Appendix B, Section 10.3.

5 Results – 2026 +28% Demand

Please refer to Figure 1.1 for the Fruin Level of Service threshold boundaries and performance levels.

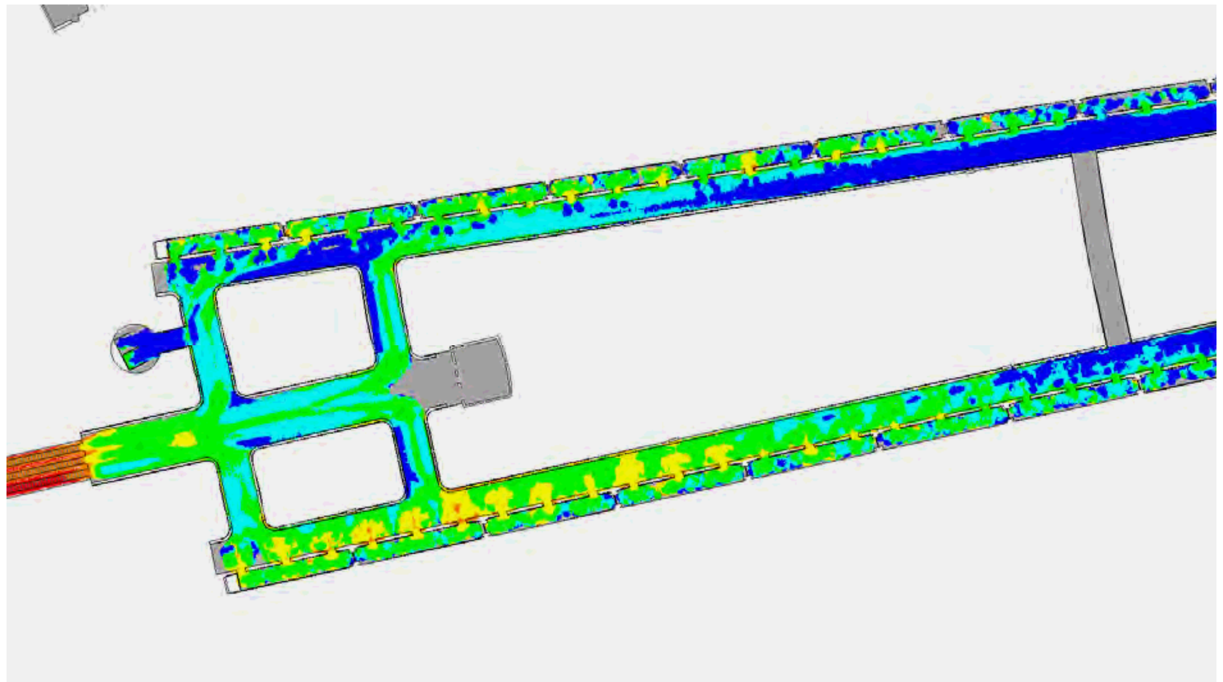
LUL and Thameslink results are shown [with a following commentary] in Appendix B.

5.1 AM 2026+28% Peak Modelling, 07h00-10h00

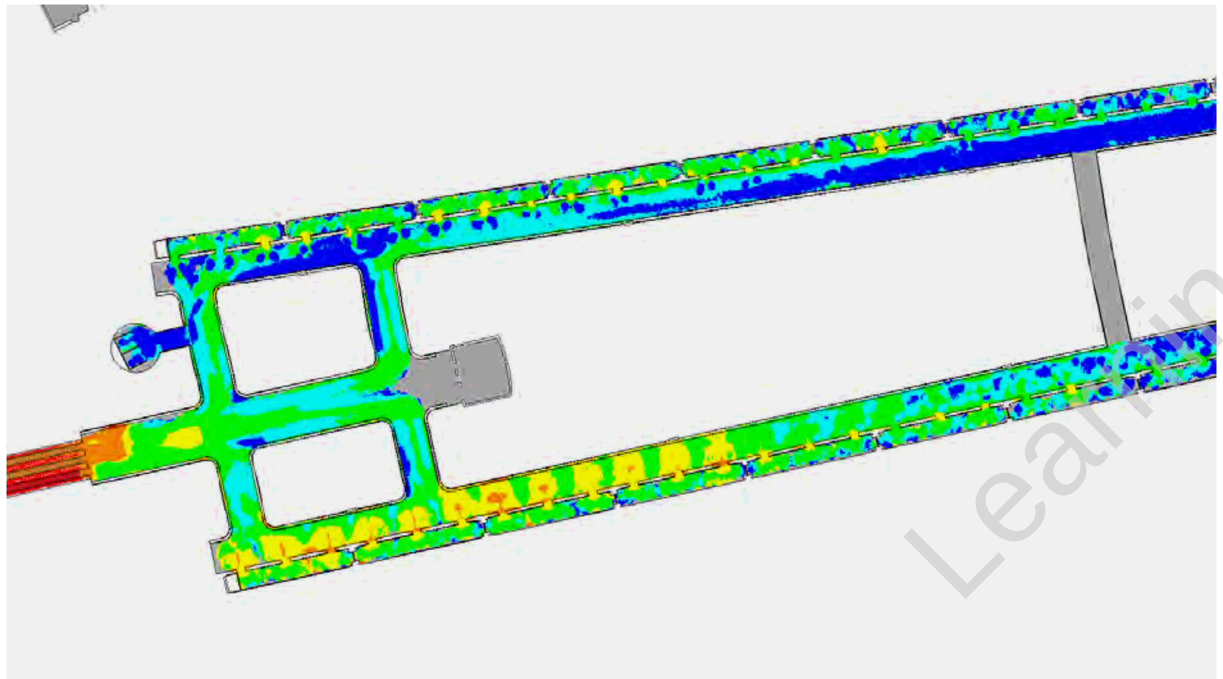
Results are shown for West and East ends of the station, and for the Integrated Ticket Hall.

A commentary on the results follows the images and graphs.

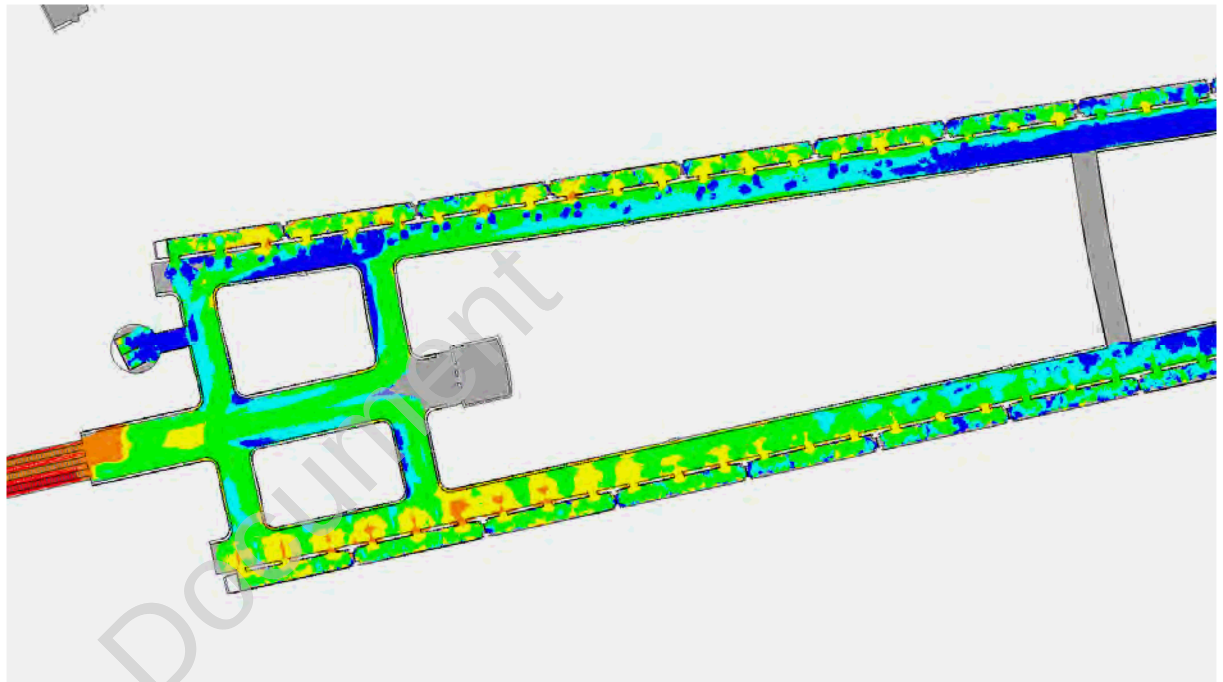
5.1.1 08h19-08h34, Mean Density (Walkways) WEST



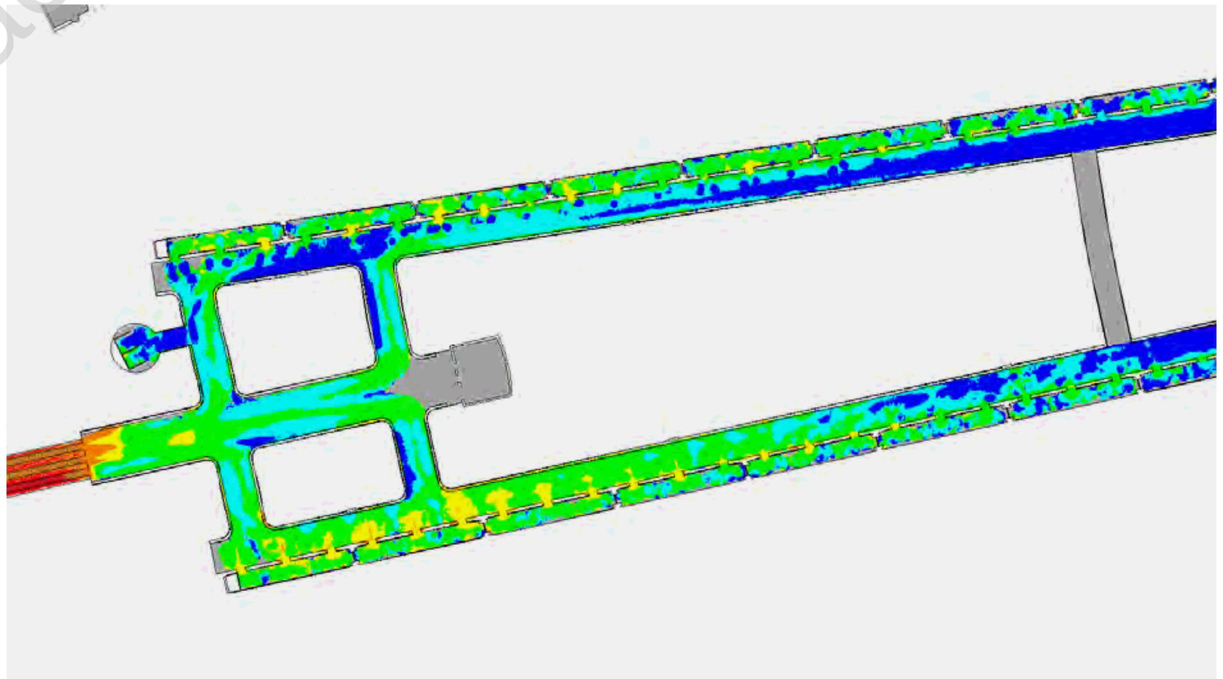
5.1.2 08h34-08h49, Mean Density (Walkways) WEST



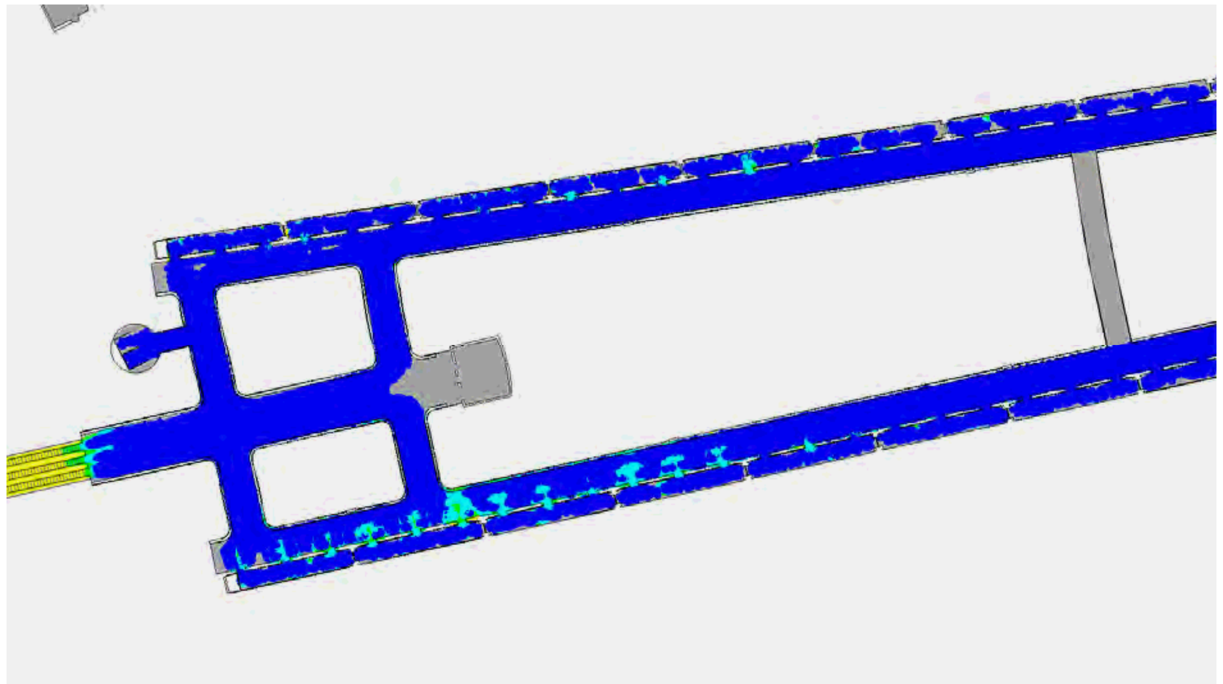
5.1.3 08h49-09h04, Mean Density (Walkways) WEST



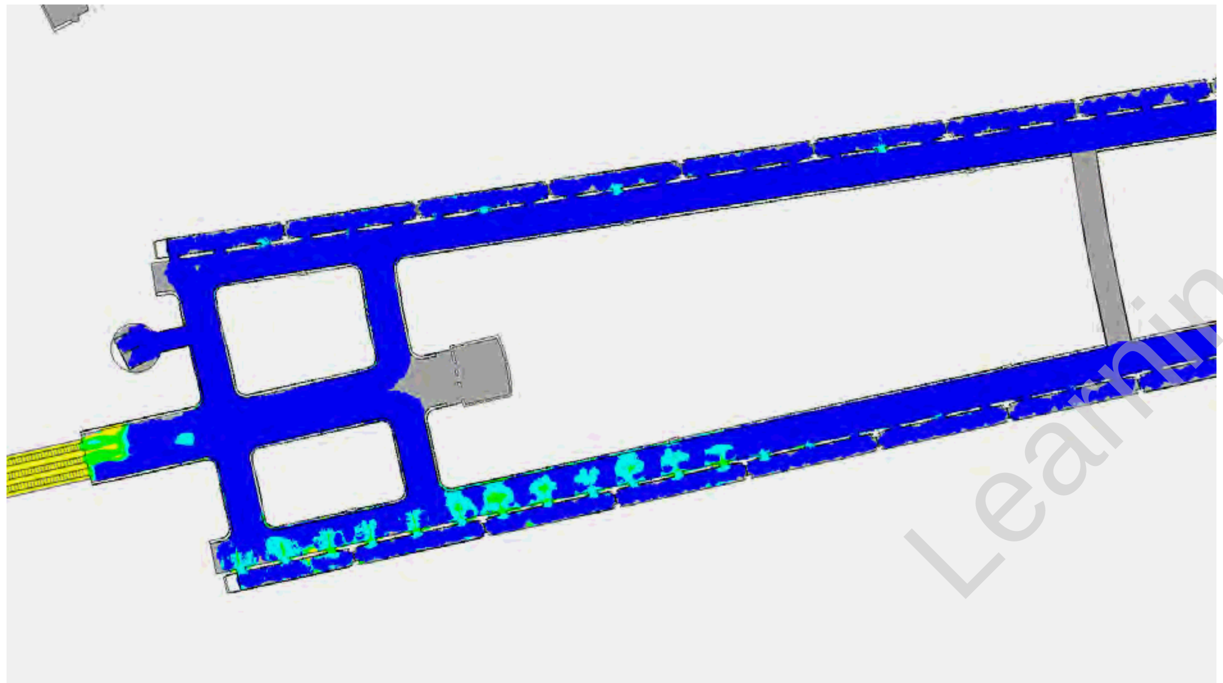
5.1.4 09h04-09h19, Mean Density (Walkways) WEST



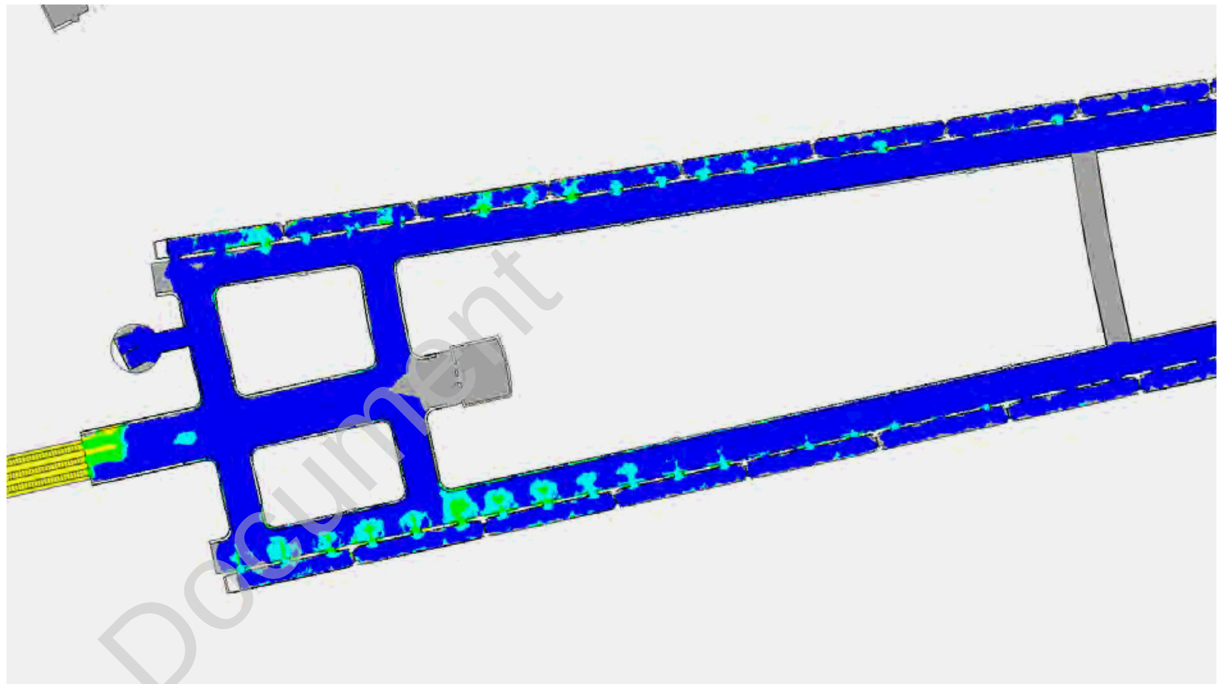
5.1.5 08h19-08h34, Mean Density (Queuing) WEST



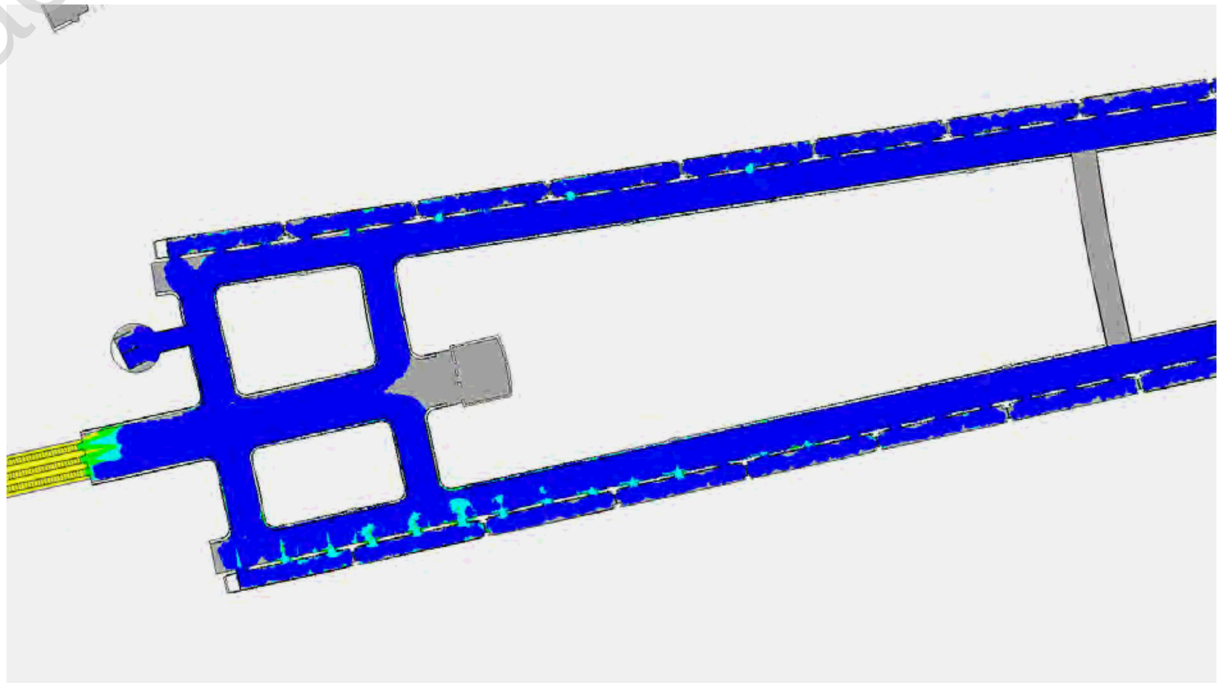
5.1.6 08h34-08h49, Mean Density (Queuing) WEST



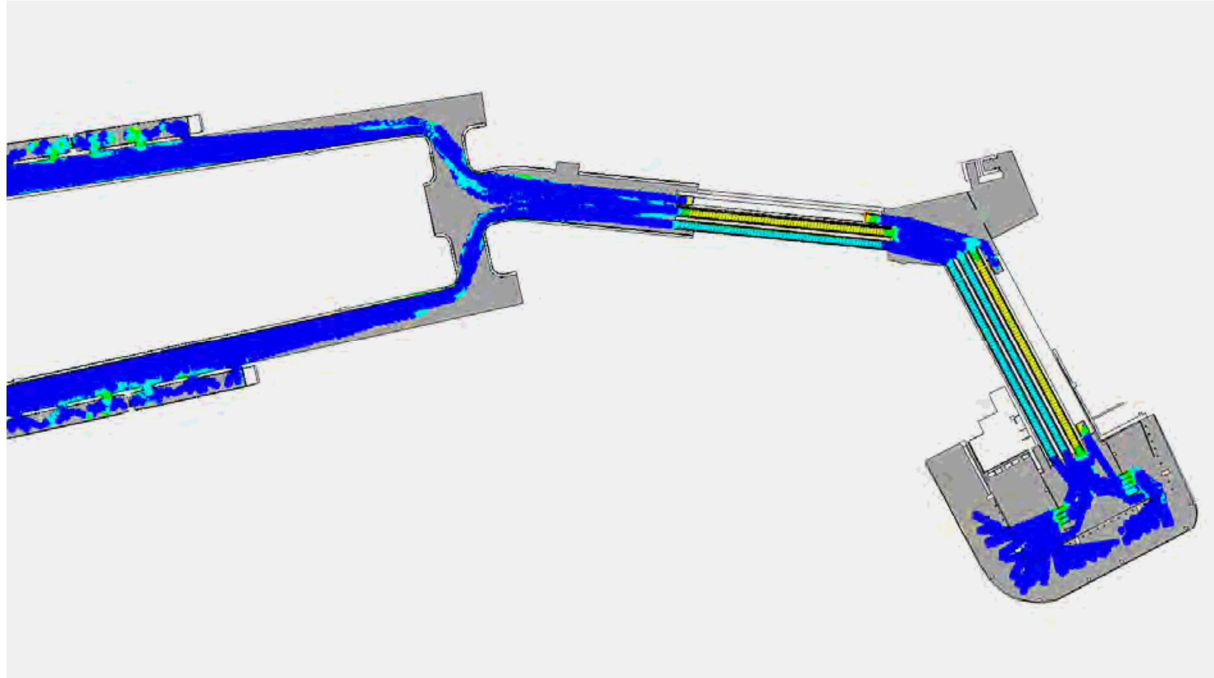
5.1.7 08h49-09h04, Mean Density (Queuing) WEST



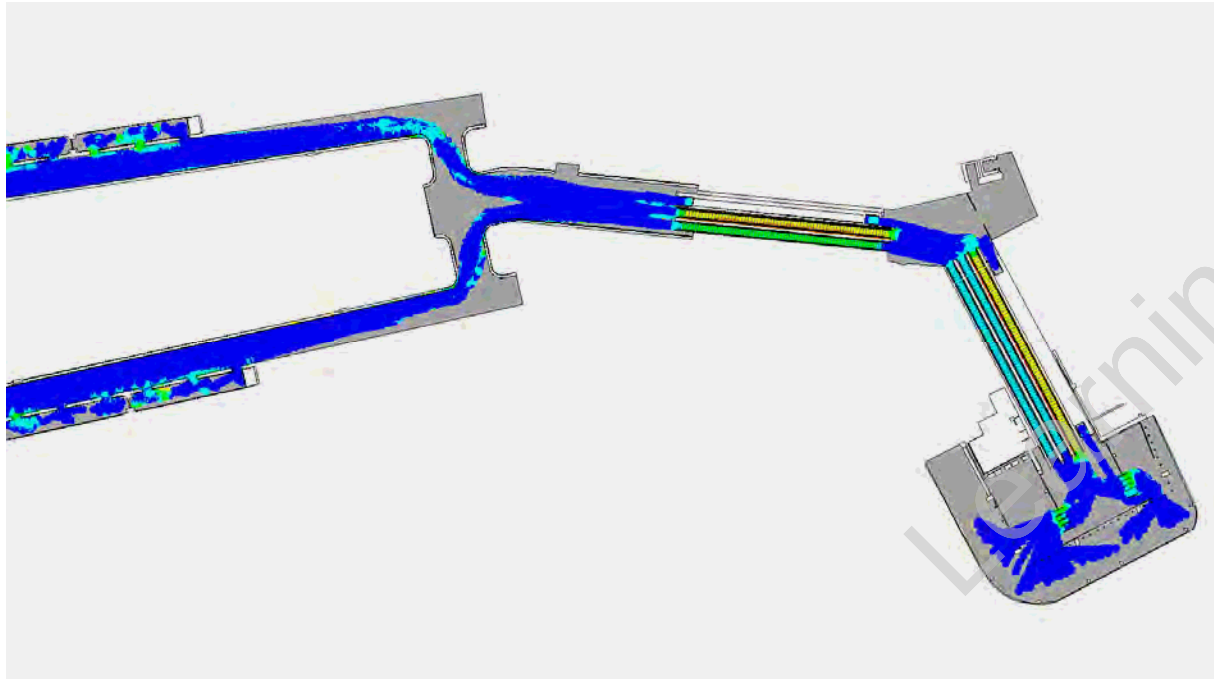
5.1.8 09h04-09h19, Mean Density (Queuing) WEST



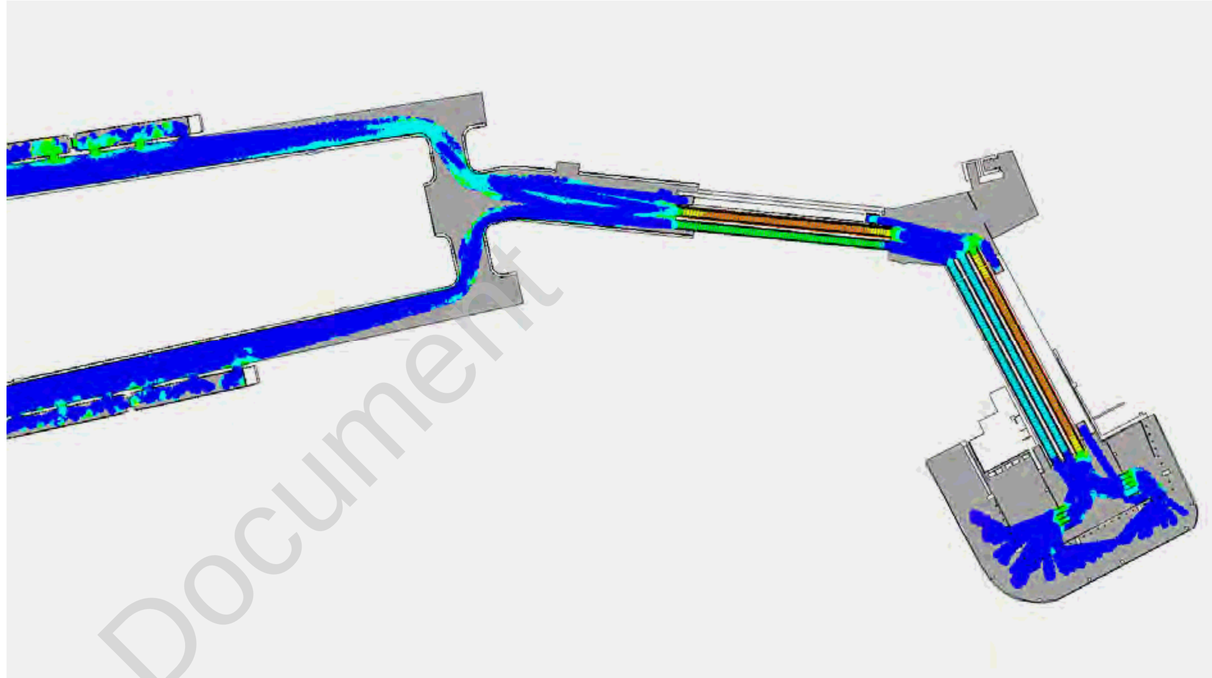
5.1.9 08h19-08h34, Mean Density (Walkways) EAST



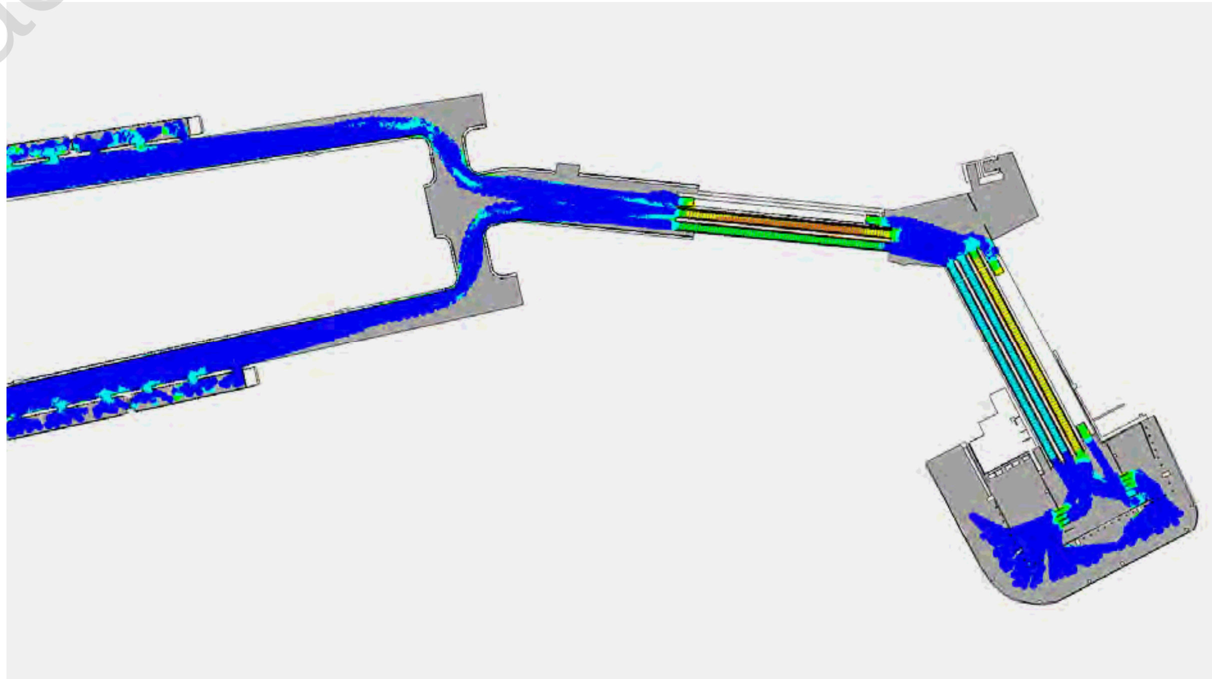
5.1.10 08h34-08h49, Mean Density (Walkways) EAST



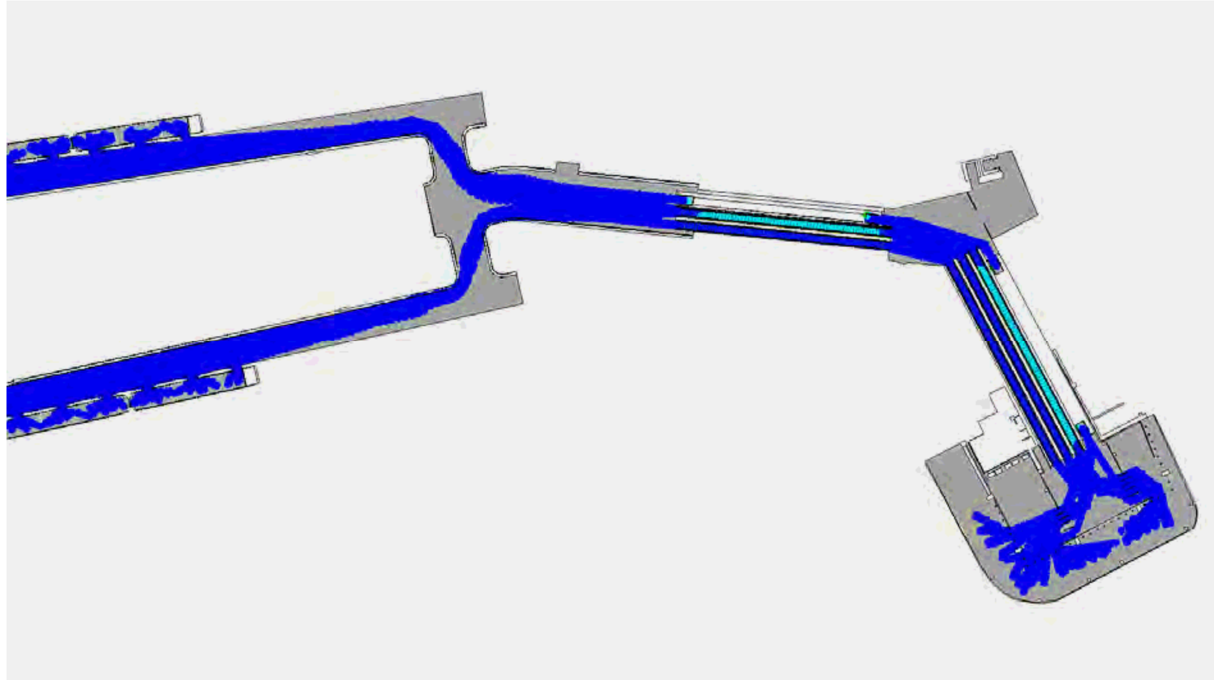
5.1.11 08h49-09h04, Mean Density (Walkways) EAST



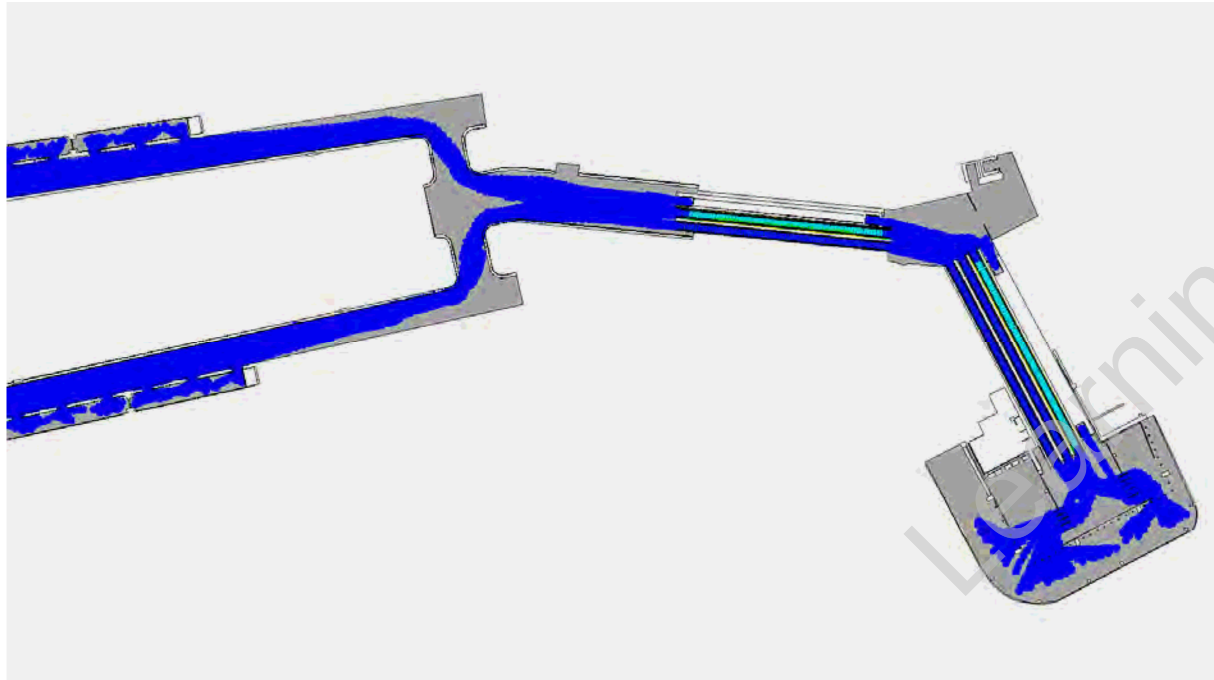
5.1.12 09h04-09h19, Mean Density (Walkways) EAST



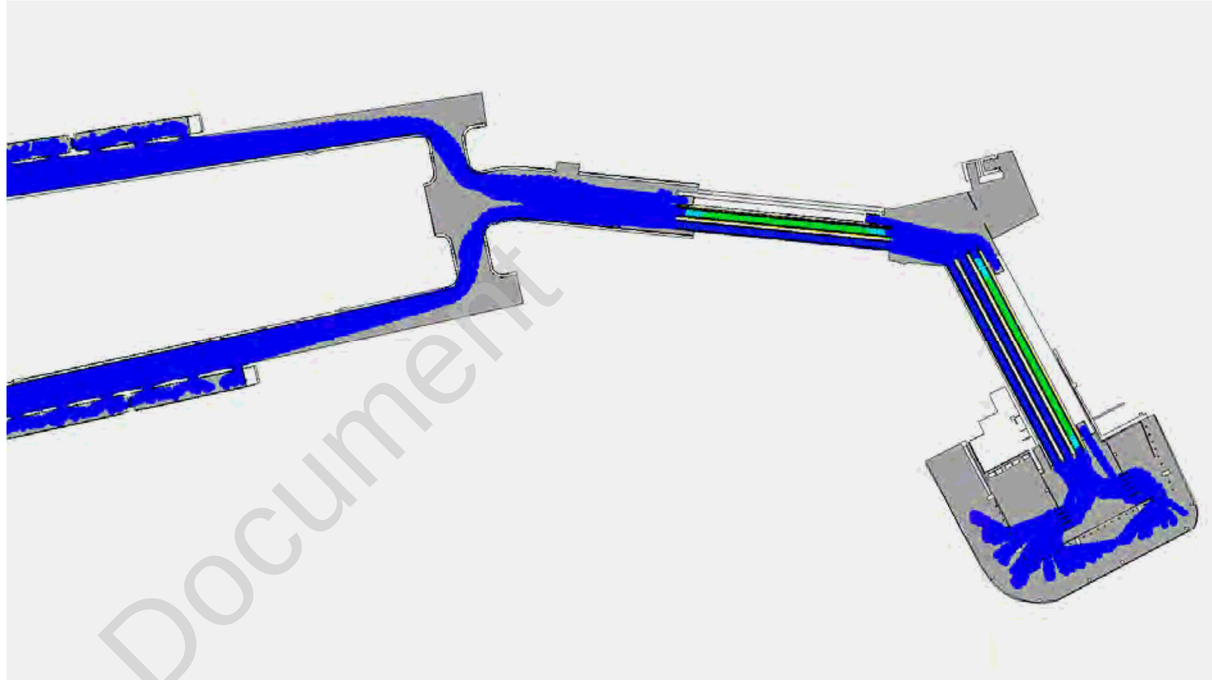
5.1.13 08h19-08h34, Mean Density (Queuing) EAST



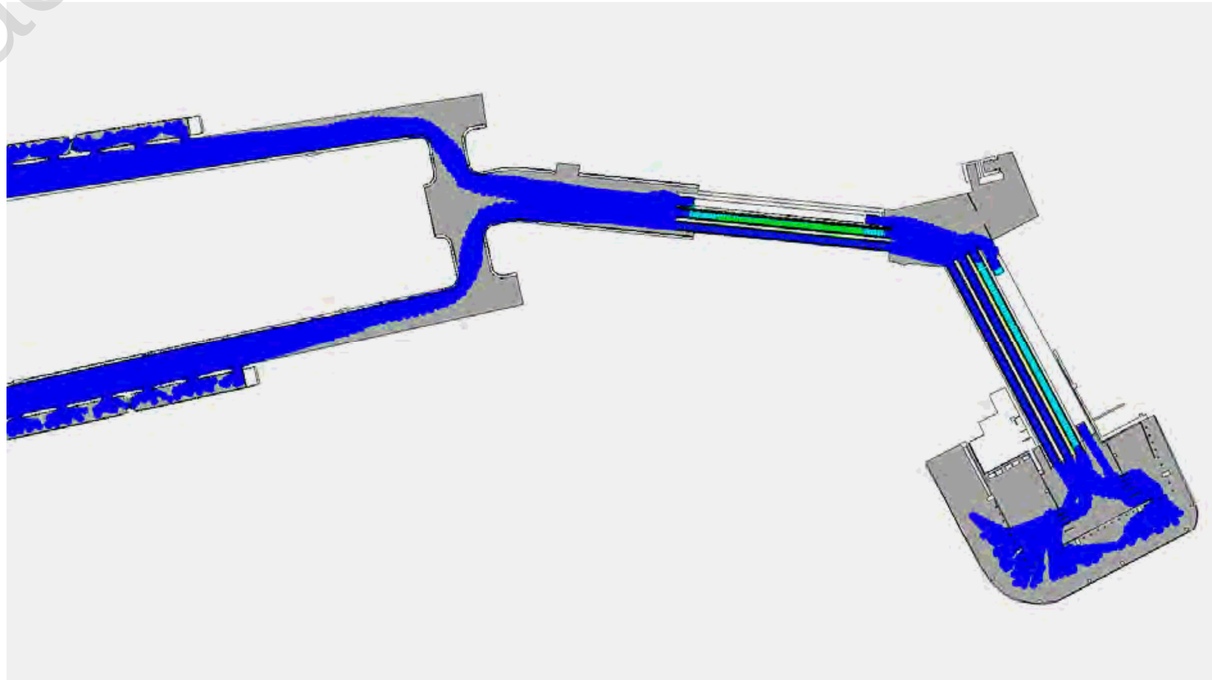
5.1.14 08h34-08h49, Mean Density (Queuing) EAST



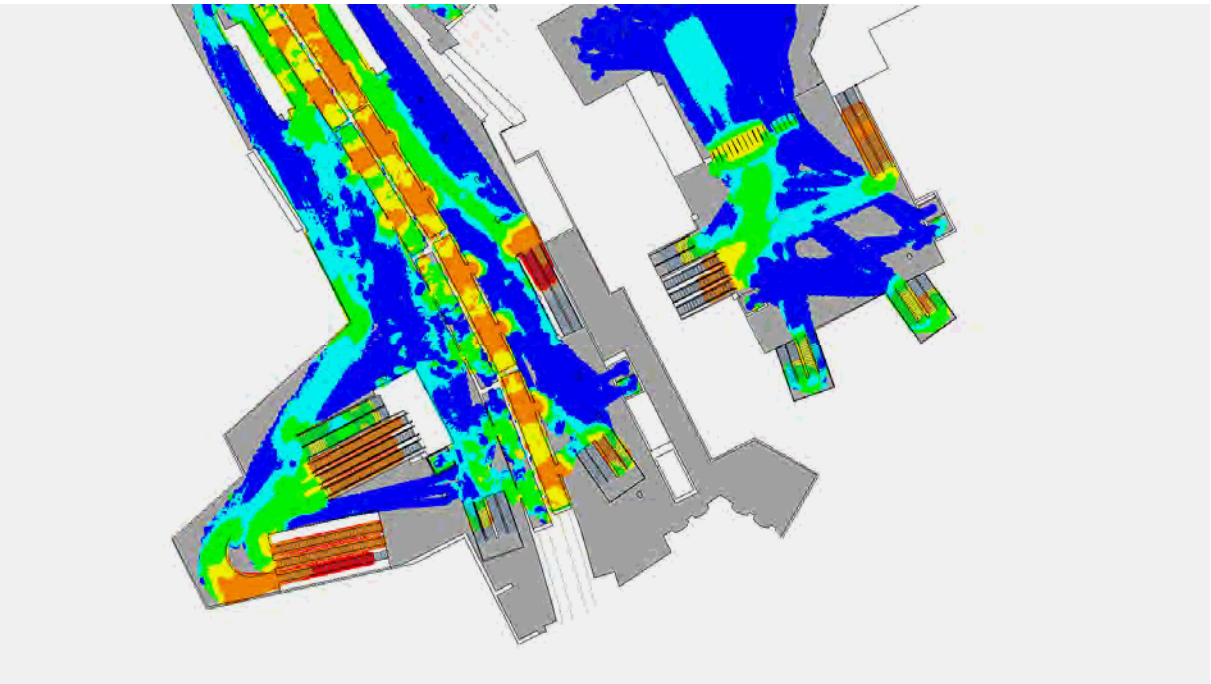
5.1.15 08h49-09h04, Mean Density (Queuing) EAST



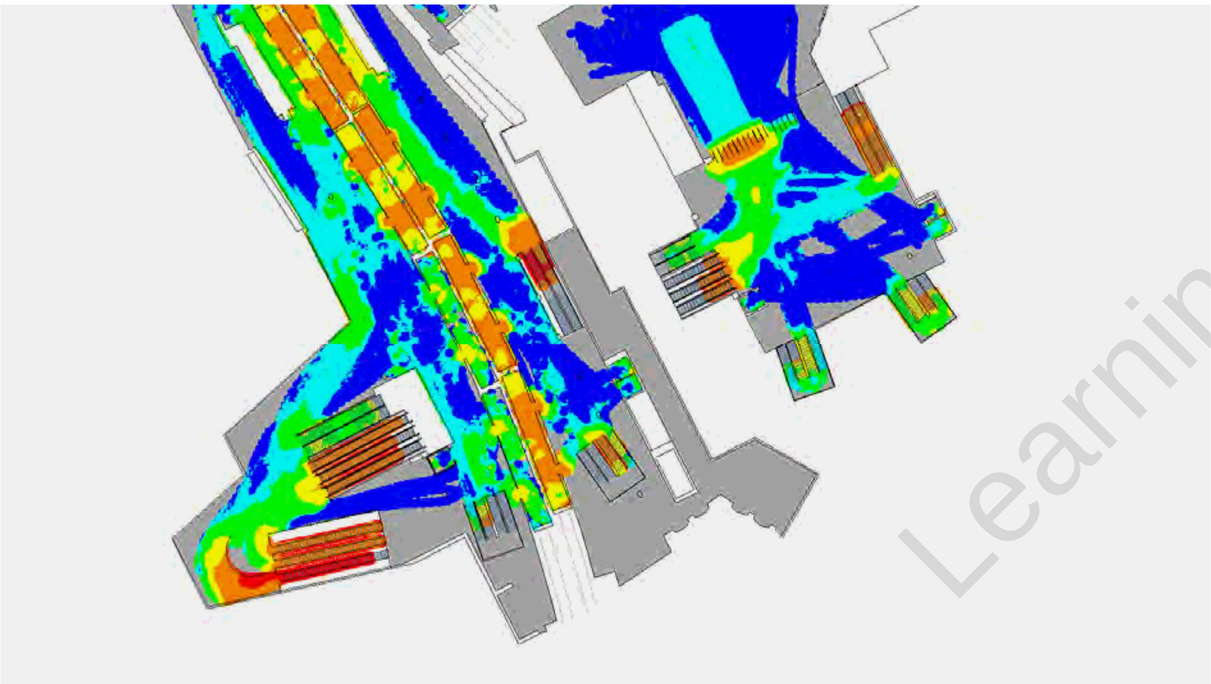
5.1.16 09h04-09h19, Mean Density (Queuing) EAST



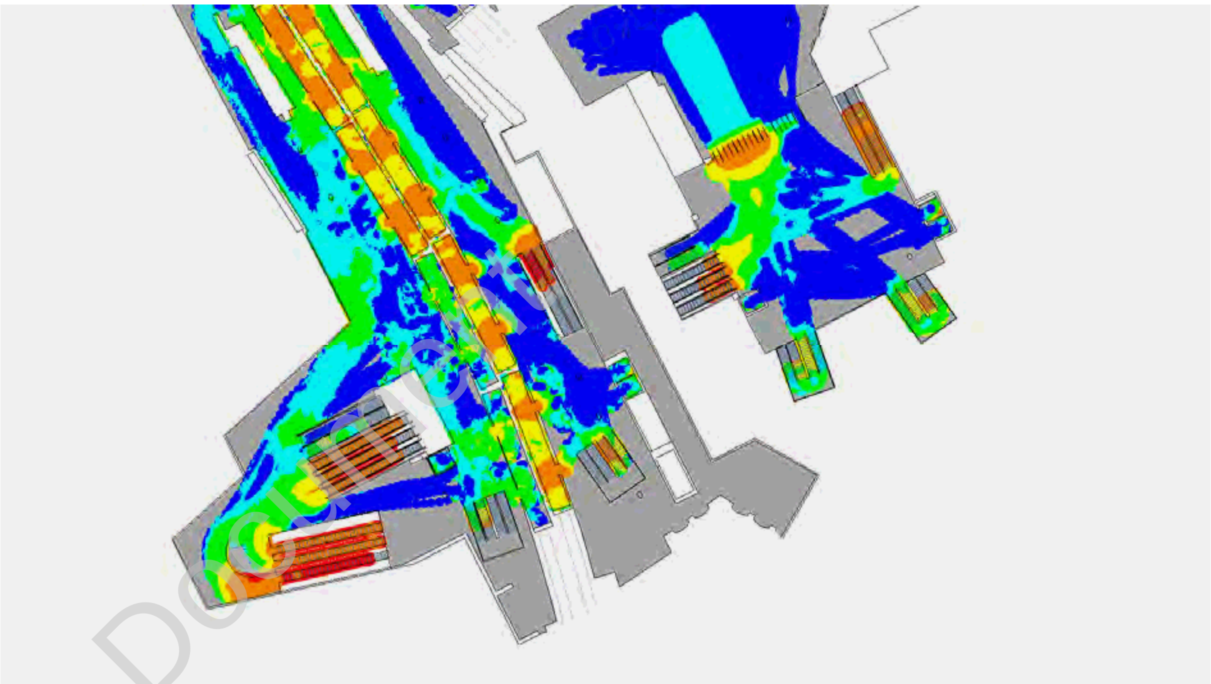
5.1.17 08h19-08h34, Mean Density (Walkways) TICKET HALL



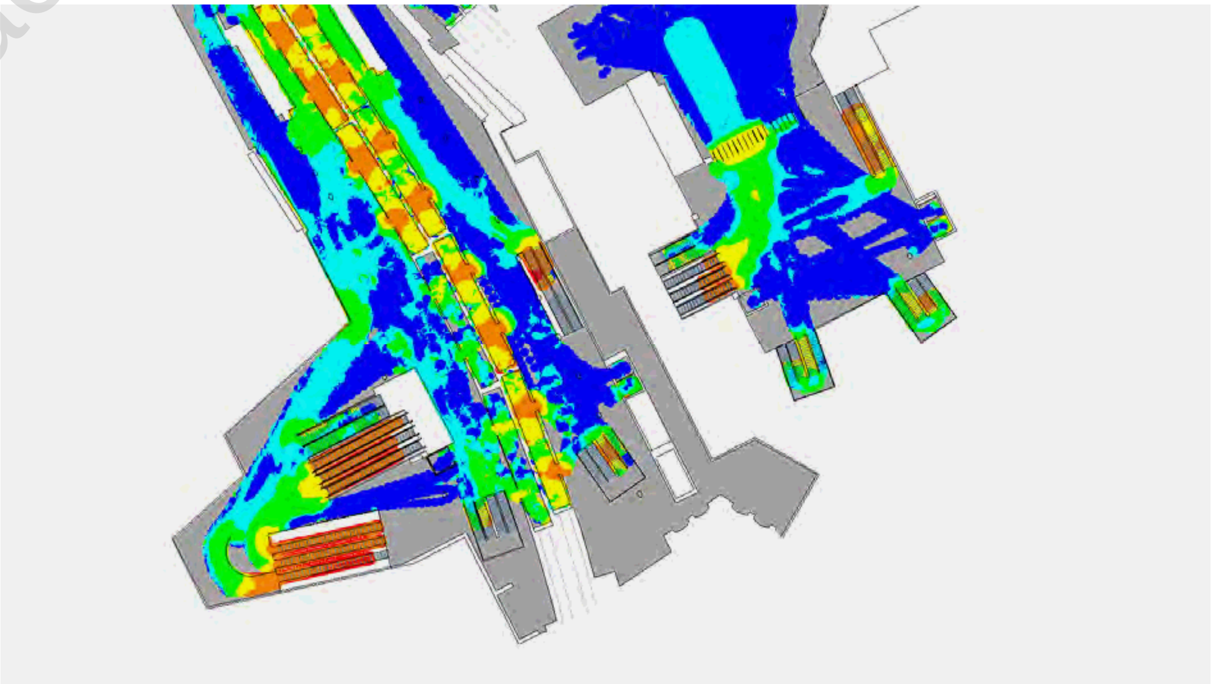
5.1.18 08h34-08h49, Mean Density (Walkways) TICKET HALL



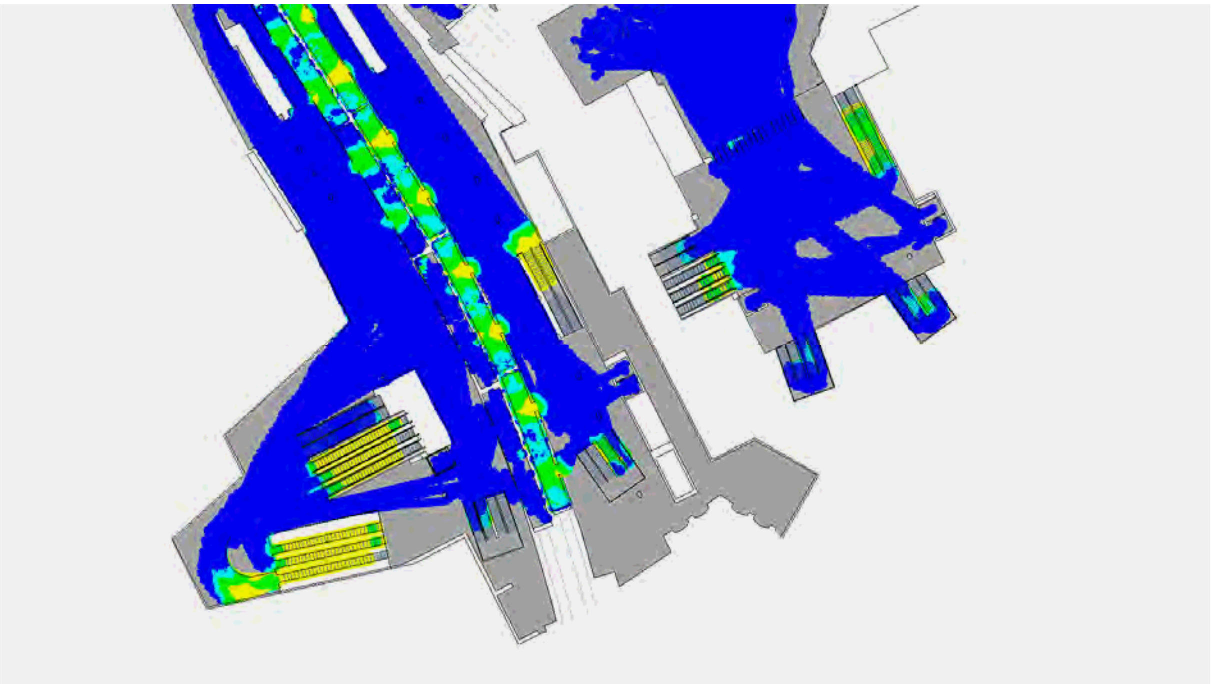
5.1.19 08h49-09h04, Mean Density (Walkways) TICKET HALL



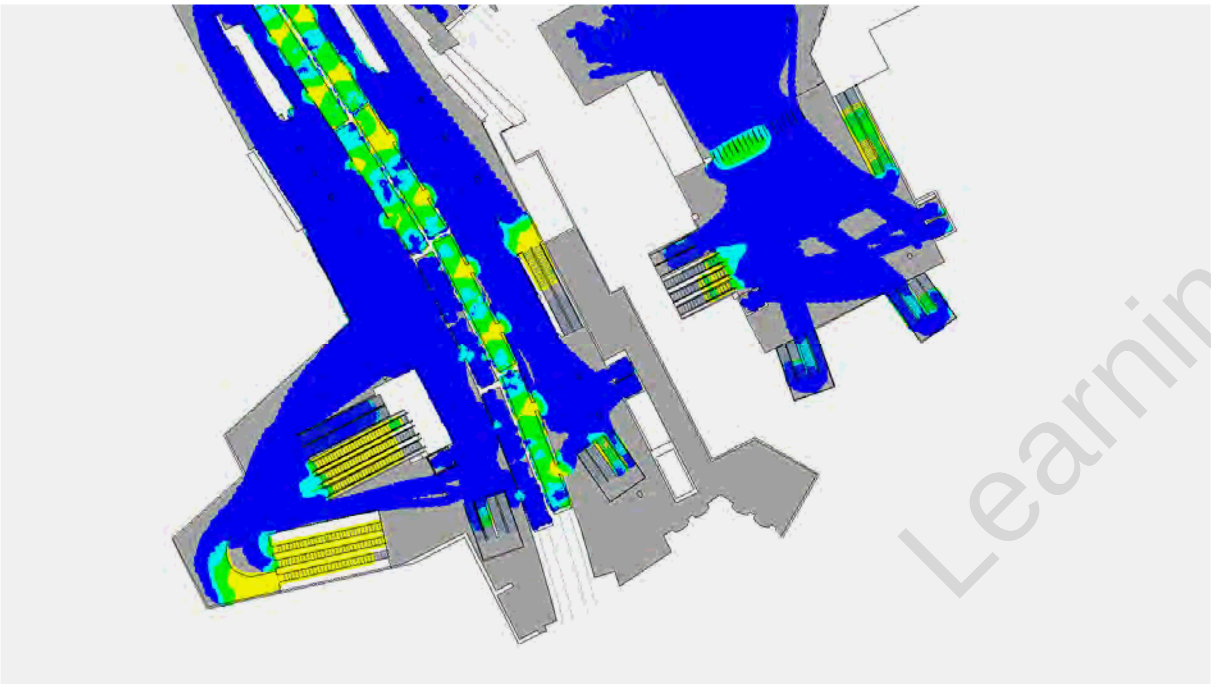
5.1.20 09h04-09h19, Mean Density (Walkways) TICKET HALL



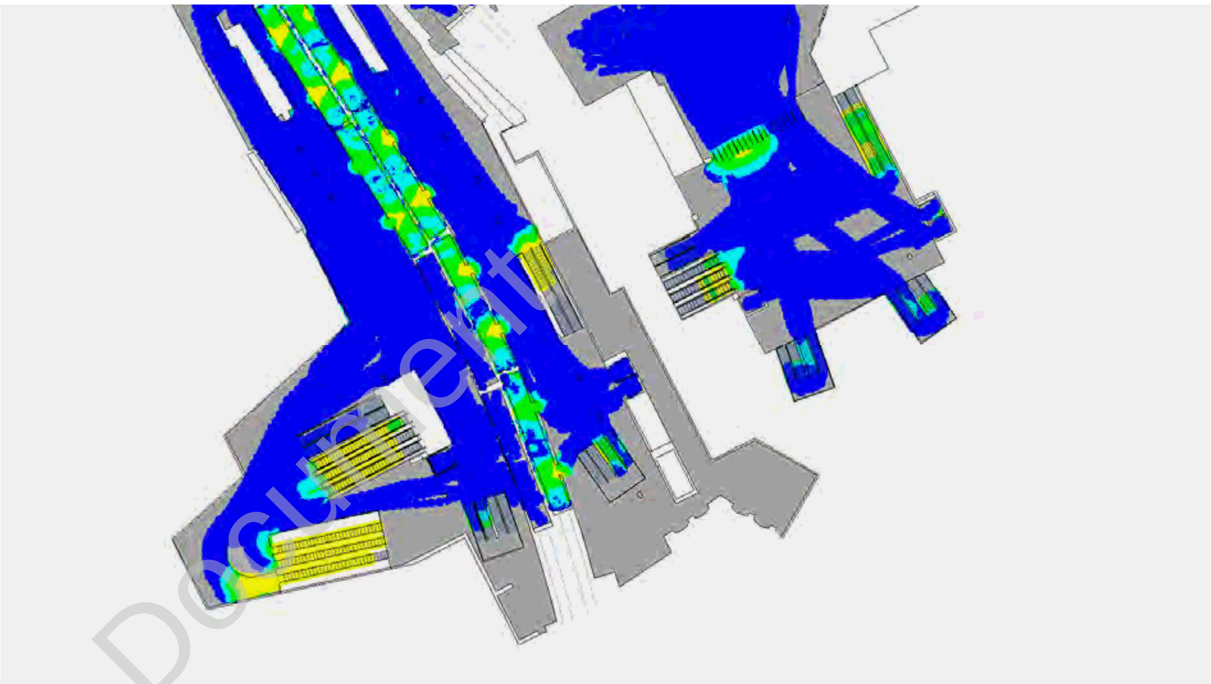
5.1.21 08h19-08h34, Mean Density (Queuing) TICKET HALL



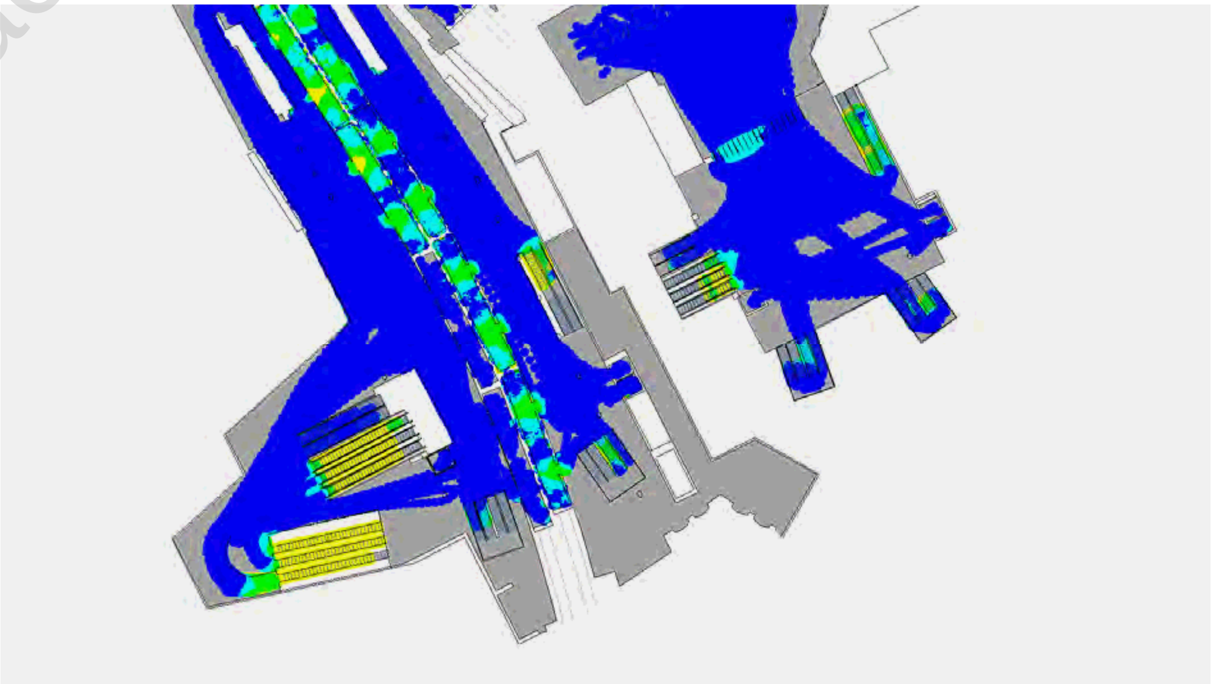
5.1.22 08h34-08h49, Mean Density (Queuing) TICKET HALL



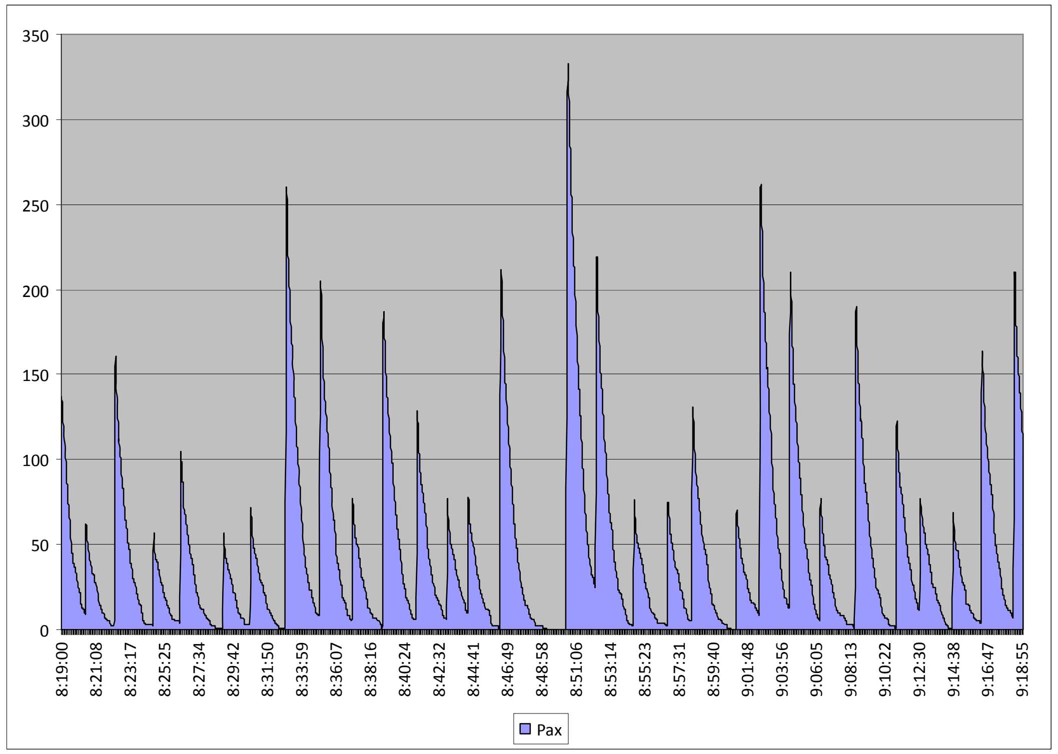
5.1.23 08h49-09h04, Mean Density (Queuing) TICKET HALL



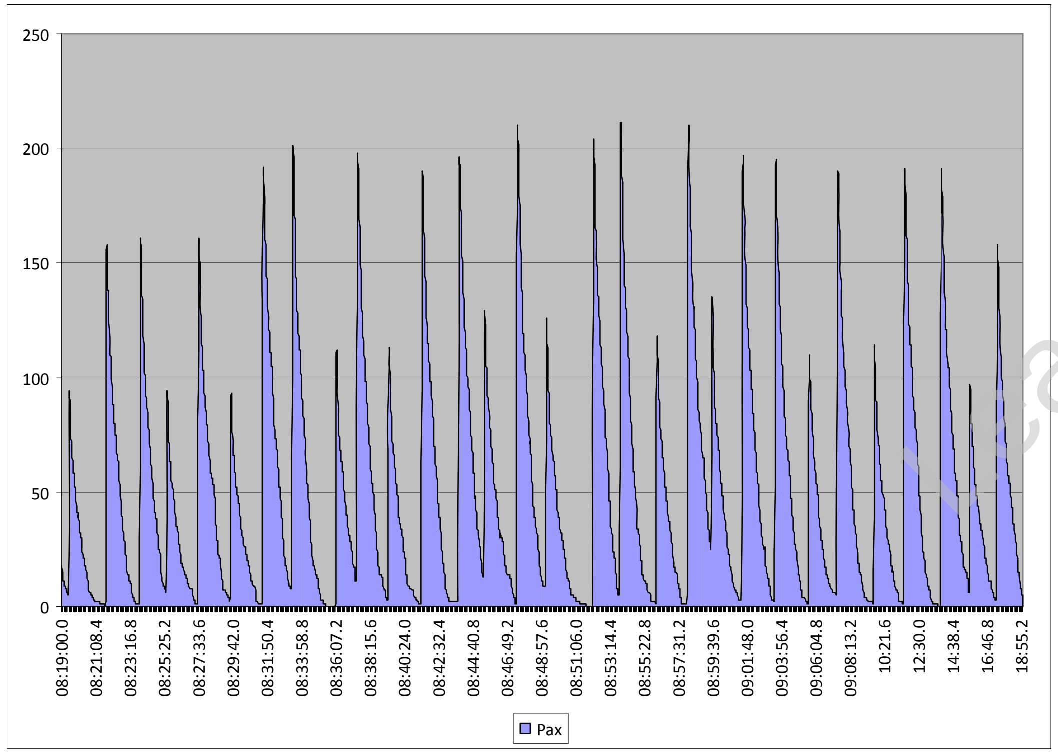
5.1.24 09h04-09h19, Mean Density (Queuing) TICKET HALL



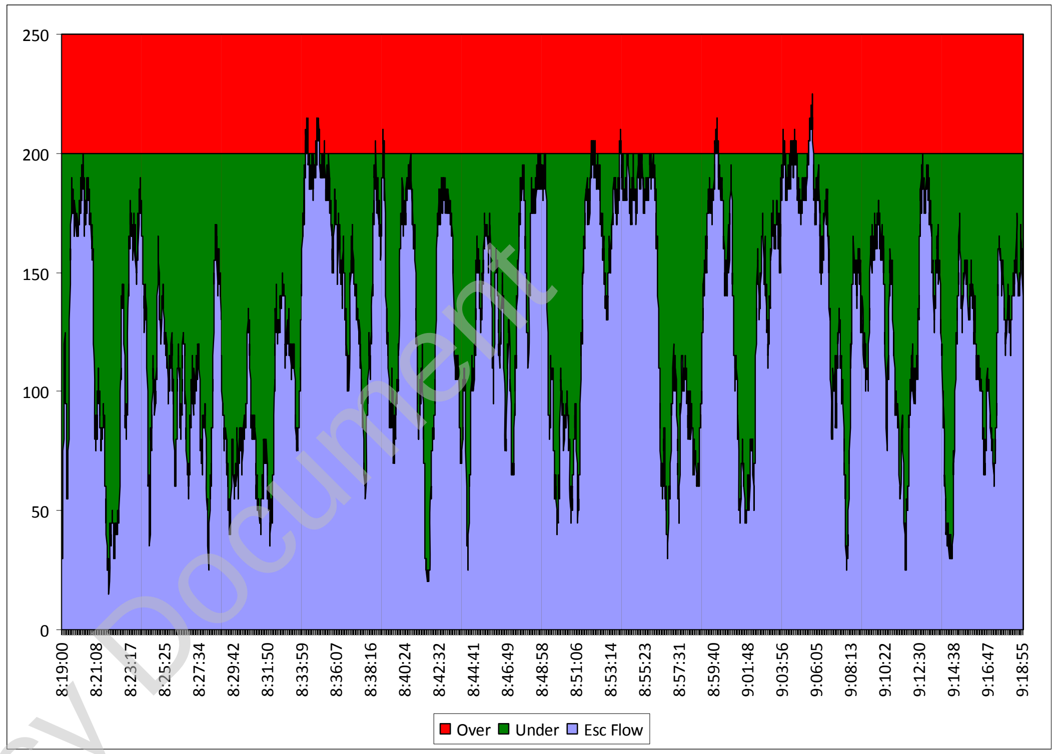
5.1.25 08h19-09h19, Platform Clearance CRL Eastbound



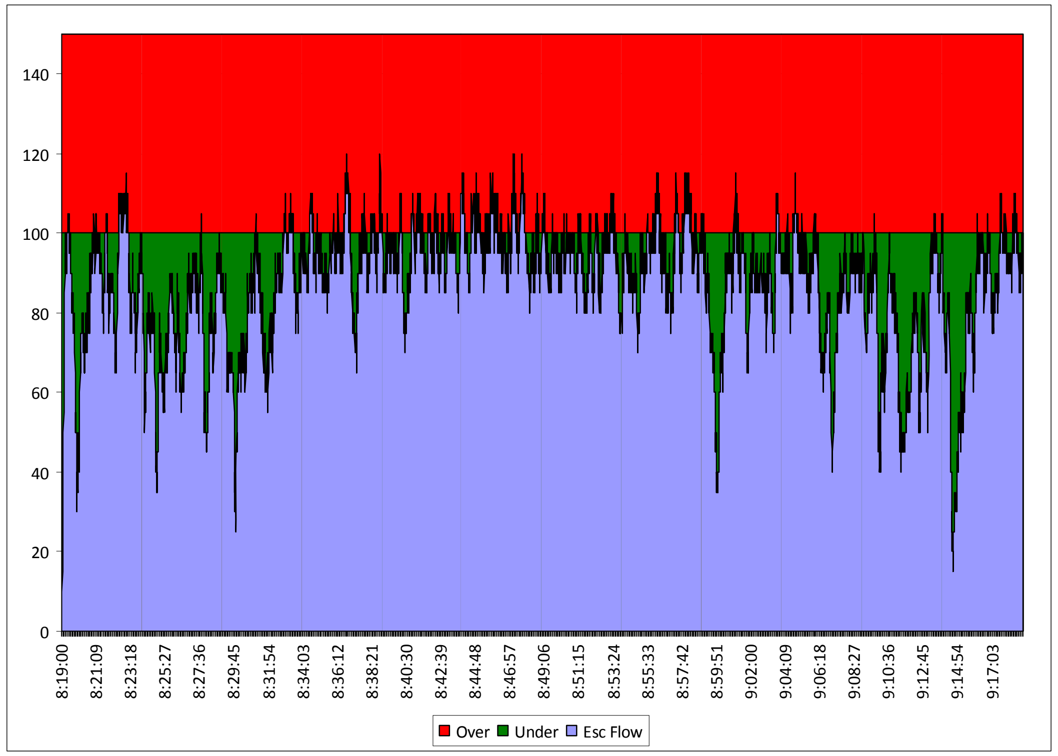
5.1.26 08h19-09h19, Platform Clearance CRL Westbound



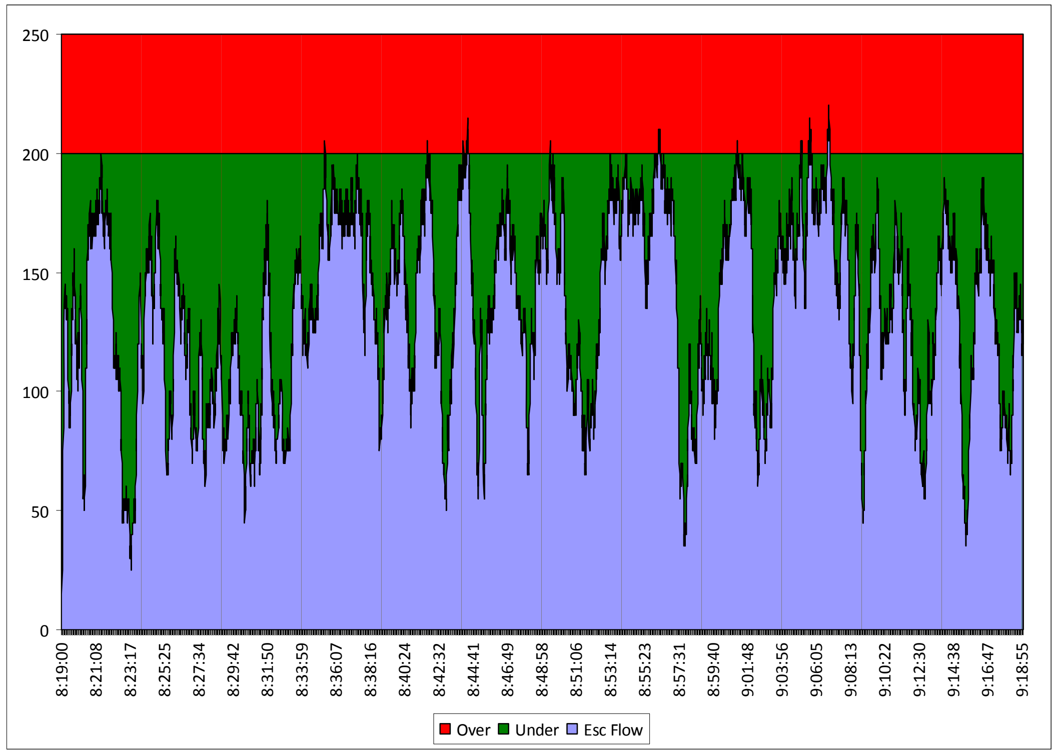
5.1.27 08h19-09h19, Upward Escalator Flow Rate



5.1.28 08h19-09h19, Downward Escalator Flow Rate



5.1.29 08h19-09h19, Escalator Flow toward Integrated Ticket Hall



5.2 2026 +28% AM Peak Commentary

Results should be considered in the context of the 2026+28% demand scenario this model assesses - this is a worst case 2076 forecast, operating at full 30TPH, from which the Crossrail Transport Planning team do not expect to see congestion free stations ("cope" is the CPFR wording).

Even with this level of patronage CRL platforms generally operate efficiently and without any serious or sustained congestion throughout the entire 08h19-09h19 peak hour.

Higher levels of services are shown in the walkways mapping towards the front edge of both platforms (particularly westbound) but these areas represent dwell zones where passengers group at PEDs and should therefore be viewed through Queuing maps. These show nothing more severe than an acceptable Level of Service C (green), suggesting conditions have not decayed from 2026 performance levels.

Higher LOS is shown in both Walkways and Queuing maps towards the west/central platform areas. The boarding-by-car proportions are heavily weighted towards these front Westbound carriages (and rear Eastbound), resulting in the sliding scale of crowding to the east. Boarding proportions are a prescribed input from Crossrail Central – they are fixed and do not reflective the natural shift of passengers into less utilised areas when an accumulative occurs. However, any relative crowding at the western end is not severe, and at no time does it restrict free movement to and from the platforms.

Circulatory areas all operate at (or below) a compliant LOS C with the exception of the central area of the western passageway which peaks at LOS D as passengers orientate themselves in either direction. Higher LOS in this passageway area is an expected occurrence and is caused by the natural closing of space as passenger move around the corner.

The "run-on" to the Western escalators shows LOS C (with a negligible patch of LOS D) in Queuing maps, suggesting passengers are delayed only very briefly as they move upwards.

At the East end of the station the low passenger demand results in complete free-flow conditions at all times and no areas of congestion concern. The bank of two escalators at the Eastern end provides more than sufficient capacity to process the board/alight flows. A considerable transfer of passengers from west to east could be accommodated should station control deem this necessary.

The platform clearance graphs reflect the unimpeded circulatory conditions at Crossrail platform level. Clearance between headways is achieved for virtually all train arrivals at both westbound and eastbound platforms throughout the peak hour. On the one occasion this is not achieved (EB and WB train in the period before 09h00) where only a small number of alighters remain on platform areas (maximum of about 25). This is a function of smaller headway gaps with a 30TPH service (headway gaps are random within the logical constraints of delivering 30TPH), cancelled train loadings and the walk-distances, rather than the capacity of the platform itself.

The two western-end upward escalators peak with each alighting surge as expected. In the middle of the peak hour at highest loadings they briefly exceed a flow rate of 200 passengers per minute, but only do so for very brief periods, and drop off considerably between headways. As the LOS mapping shows, the upward escalators do not delay or congest the route out of the station (see Queuing maps for the West end of platforms).

In the downward direction the single escalator operates just below capacity (100 per minute) throughout much of the peak hour, but occasionally peaks over capacity (about 120 per minute). This correlates with findings from the static assessment which showed that the increased number of boarders in the morning peak (in the new forecast) pushes the requirement close to, but **still** under, 1 escalator. Indeed, only 12% of the peak hour experiences utilisation above the 100 per minute capacity threshold, and an average flow rate of 88 passengers per minute suggests passengers could make more efficient use of the single escalator (and therefore lessen crowding) than the model is achieving (note this may be the cause for any difference seen between historic model runs). Irrespective, the sustained high utilisation of this single escalator in the new demand scenario does cause congestion at the top of the Western escalators (at Thameslink platform level). The Queuing maps for this area show widespread LOS D (yellow) during 08h49-09h04, although this congestion clears in the following 15minute period. The more extreme walkways maps should be disregarded for an area in which passengers are expecting slowed and congregated movement and queuing, but nonetheless do highlight the short-term congestion experienced here. As an aside, the handrail installed in the model to help separate flows provides an "edge" around which the Legion entities seek to walk as they try to minimise their journey – this itself will increase LOS seen in this area.

With regard to mitigation, a 4th escalator (to provide 2 up and 2 down) would alleviate this brief congestion, but for a number of fundamental reasons (structural, geological, business case) installing this is not feasible, and is not considered a realistic option. The 4th escalator would mitigate congestion at the absolute peak of the daily peak (in the highest demand scenario) but would be relatively underused outside of the high peak, and in any case this is not a demand level the station is expected to operate congestion free at. Furthermore and potentially altering the commentary above, the level of patronage originating from TL services may not be representative of expected passenger numbers (i.e. over estimated, see Section 3.3).

If the forecast +28% level of demand is reached, then utilisation of the CRL escape stairs would offer some mitigation and the additional capacity required, although this is not desirable for day-to-day operations.

If mitigation is not possible, then a nominal breakpoint for this area of the station is deemed to be 2026+21%, although it should be noted this area does not "break" in a failure-of-model sense, rather it experiences increasing levels of crowding at the high peak leading to slower movement. Journey time moving through this area increases from 17 seconds in 2026; 20 seconds in 2026 +14%; 23 seconds in 2026 +21%; to over 60 seconds in 2026 +28% (times use consistent start/stop point in all scenarios).

Circulatory areas of the Integrated Ticket Hall operate without sustained congestion – the 3 escalators plus stair provide sufficient capacity to process both Thameslink Northbound and Crossrail related demand, whilst the gateline area shows little congestion in either Walkways or Queuing maps. As in 2026 modelling, the stairs are used sporadically and remain a relatively redundant element, with only 54 passengers in the three hour morning peak using the stair route to ticket hall. In terms of operational flexibility however, an alternative means of vertical circulation must remain here.

The Eastern Ticket Hall operates without congestion throughout the peak hour. Passenger flows here are low and do not place any strain on the escalator or gating provision at the Eastern end of the station.

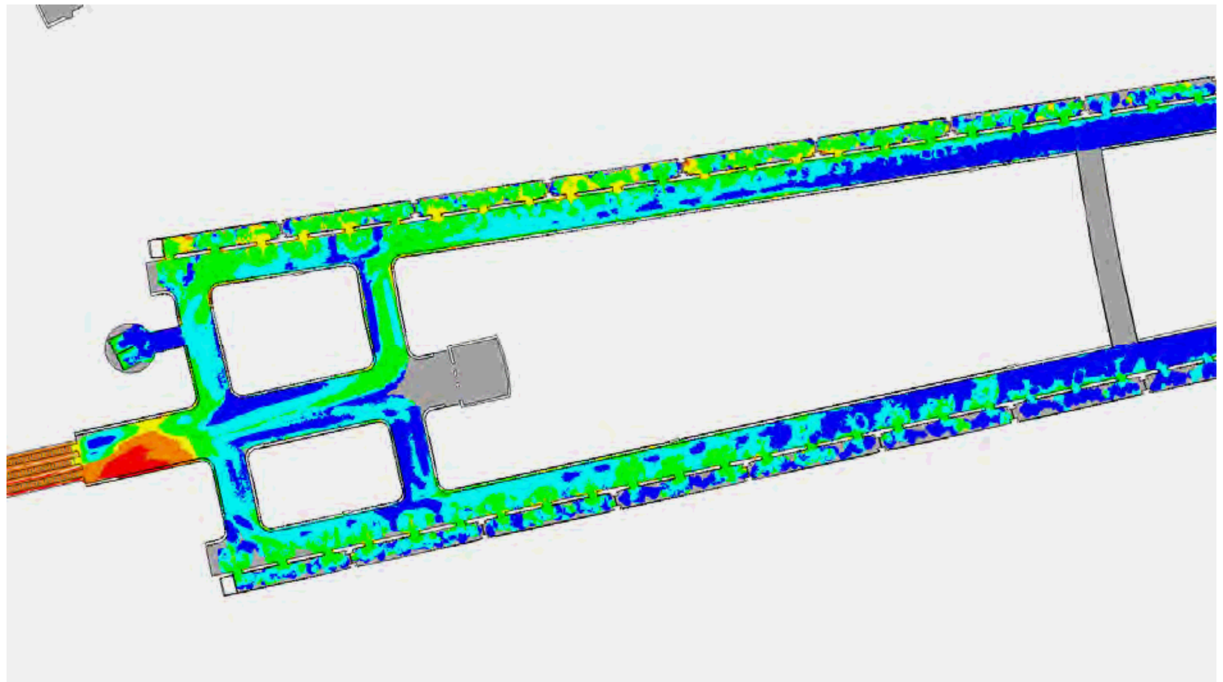
Graphical outputs for the London Underground and Thameslink platforms (and a brief commentary on results) are shown in Appendix B, Section 10.2.

5.3 2026+28% PM Peak Modelling, 16h00-19h00

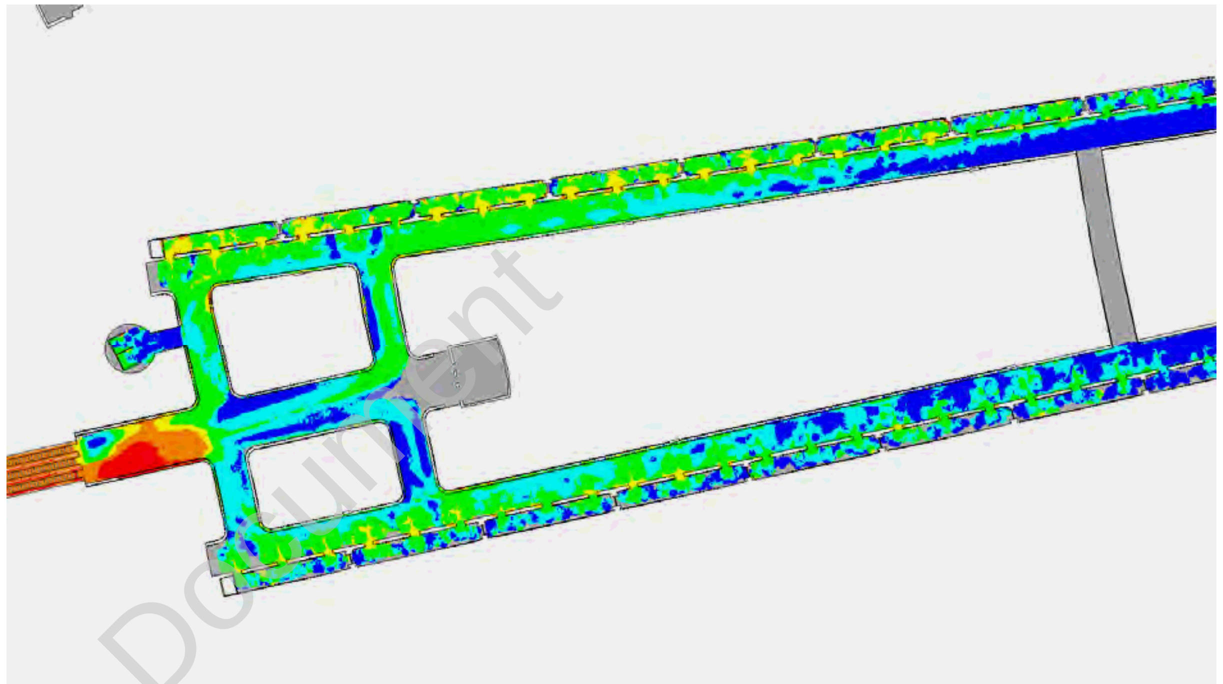
Results are shown for West and East ends of the station, and for the Integrated Ticket Hall.

A commentary on the results follows the images and graphs.

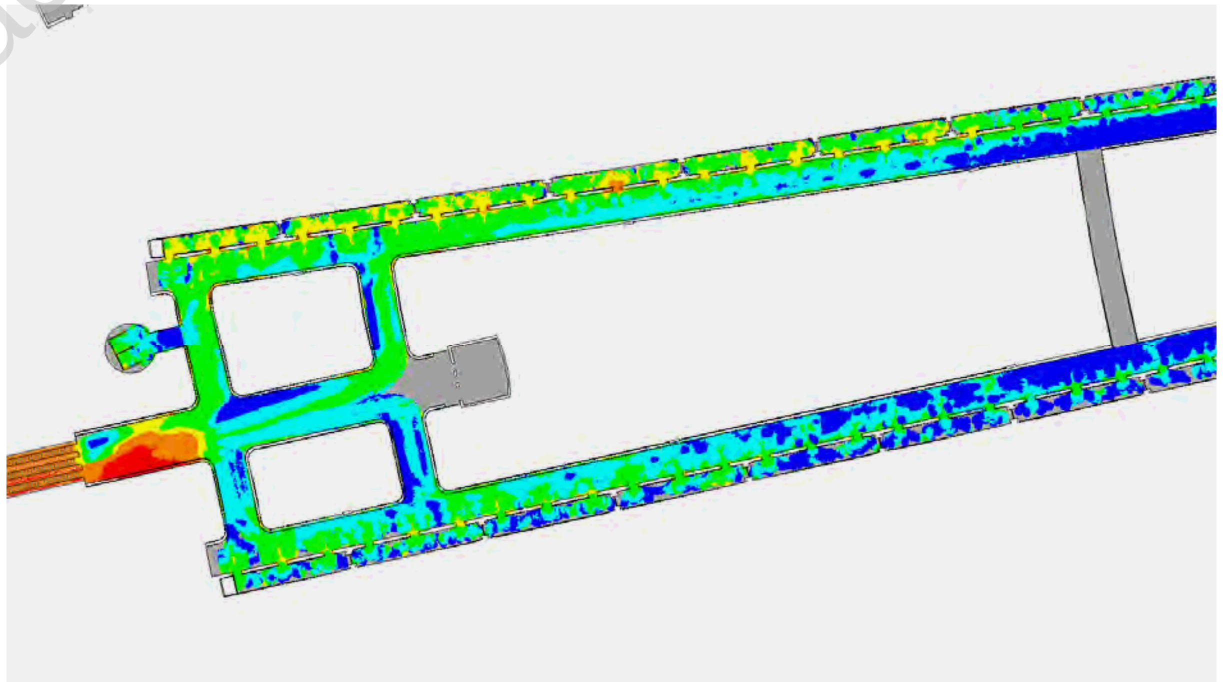
5.3.1 17h18-17h33, Mean Density (Walkways) WEST



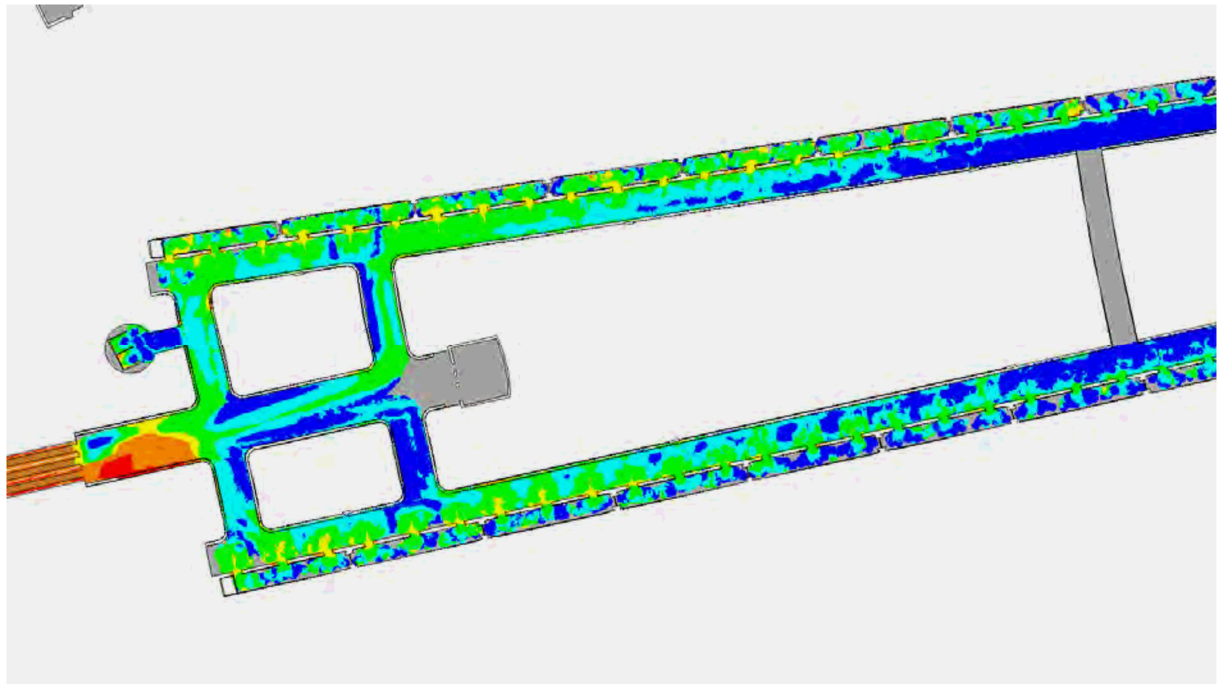
5.3.2 17h33-17h48, Mean Density (Walkways) WEST



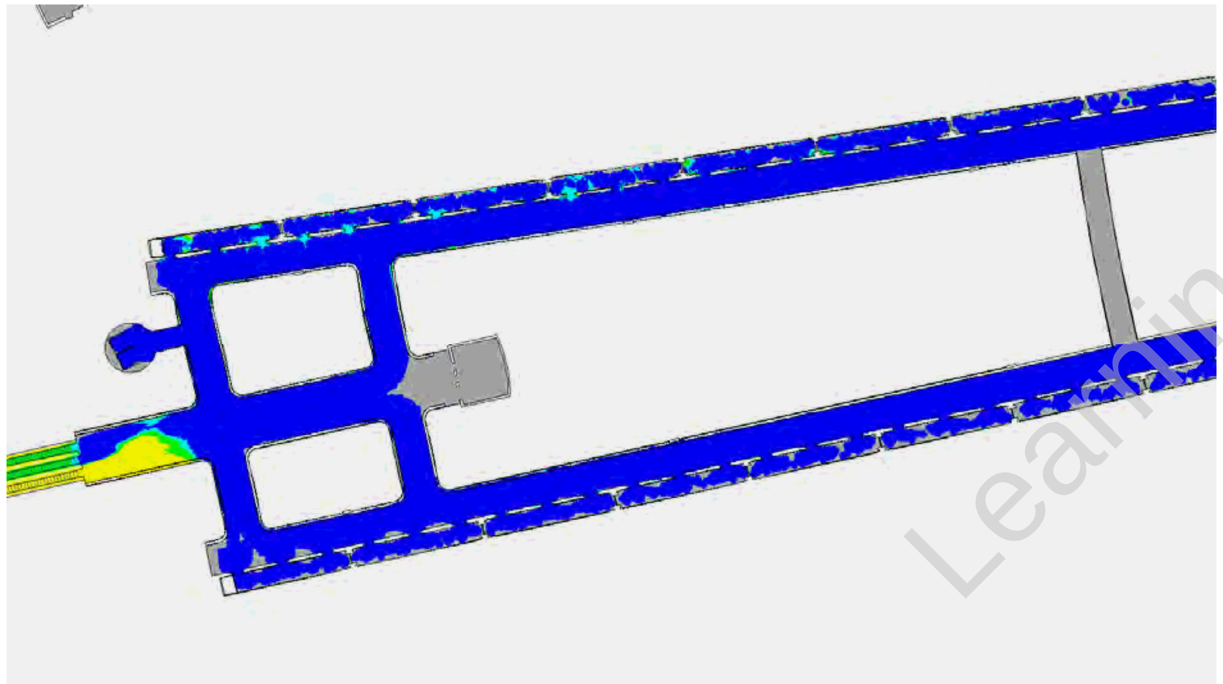
5.3.3 17h48-18h03, Mean Density (Walkways) WEST



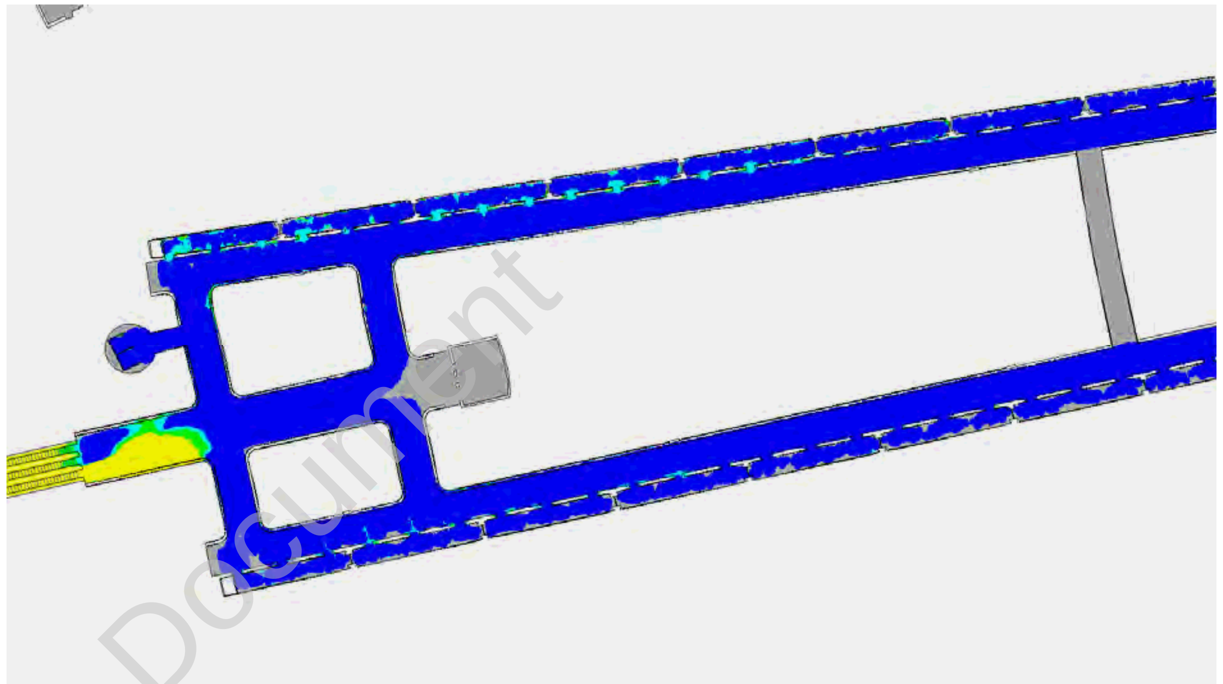
5.3.4 18h03-18h18, Mean Density (Walkways) WEST



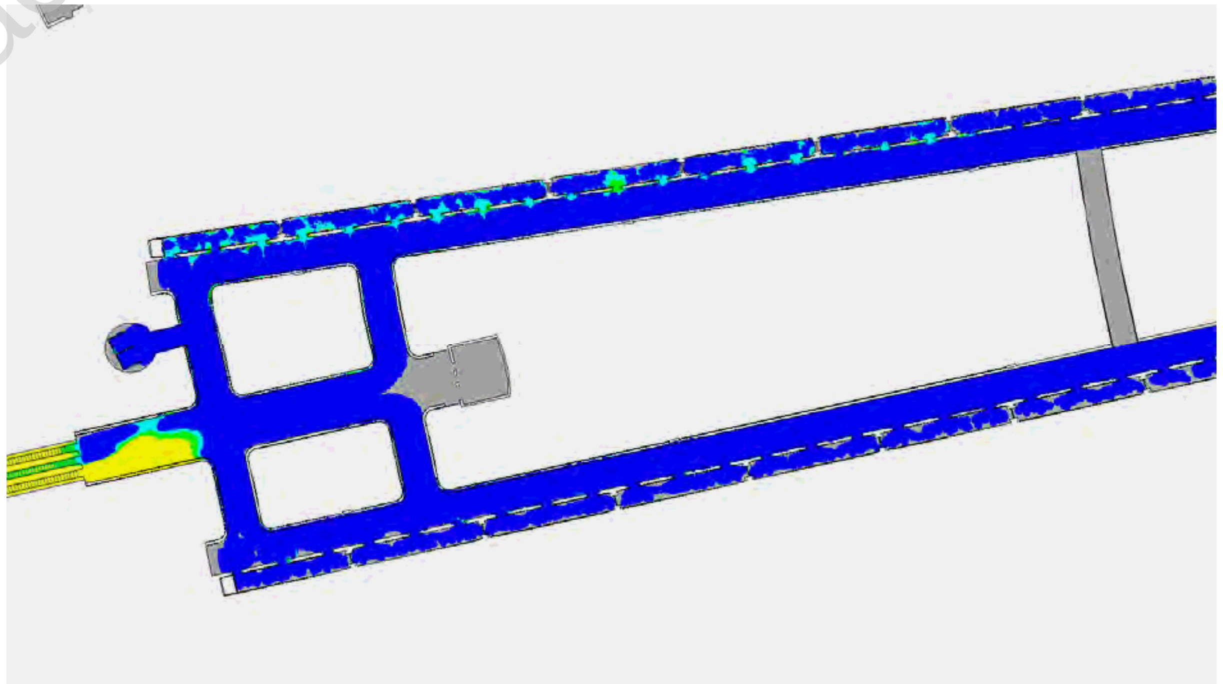
5.3.5 17h18-17h33, Mean Density (Queuing) WEST



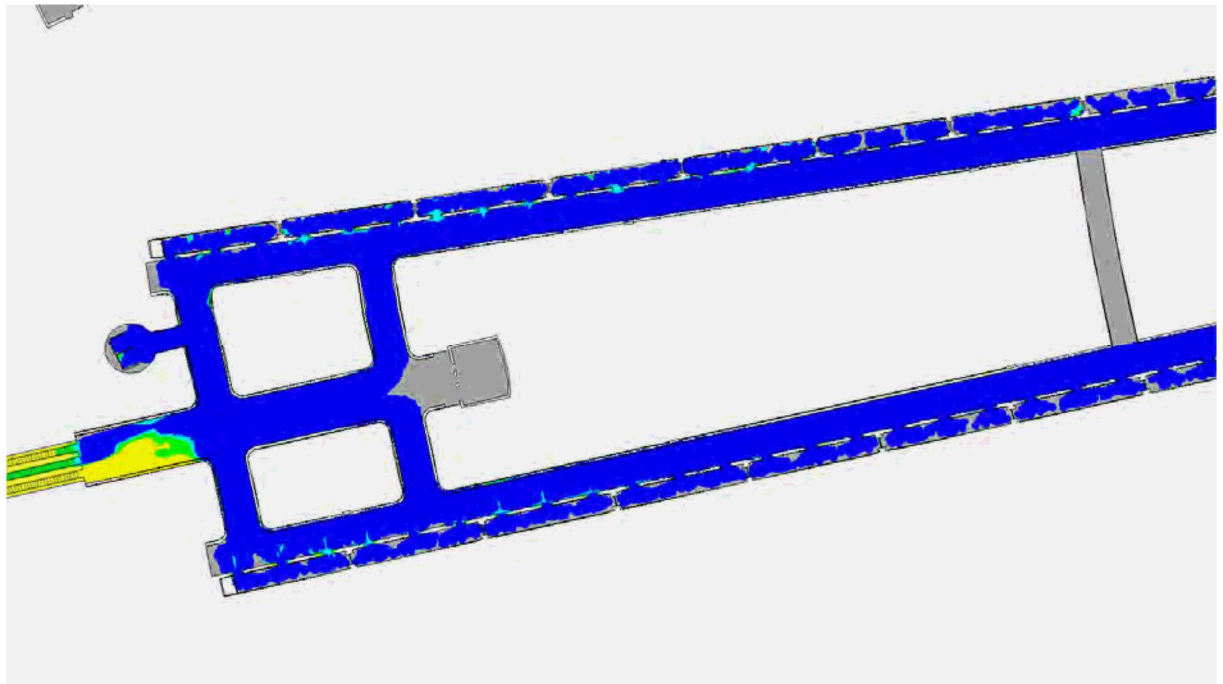
5.3.6 17h33-17h48, Mean Density (Queuing) WEST



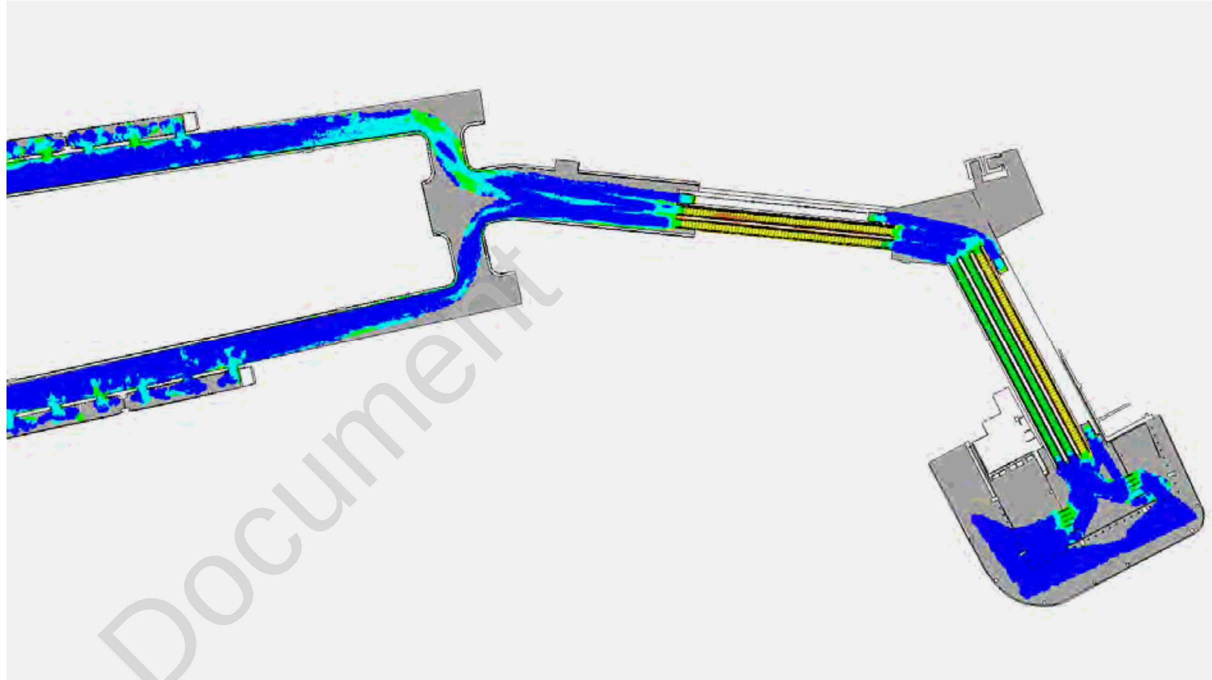
5.3.7 17h48-18h03, Mean Density (Queuing) WEST



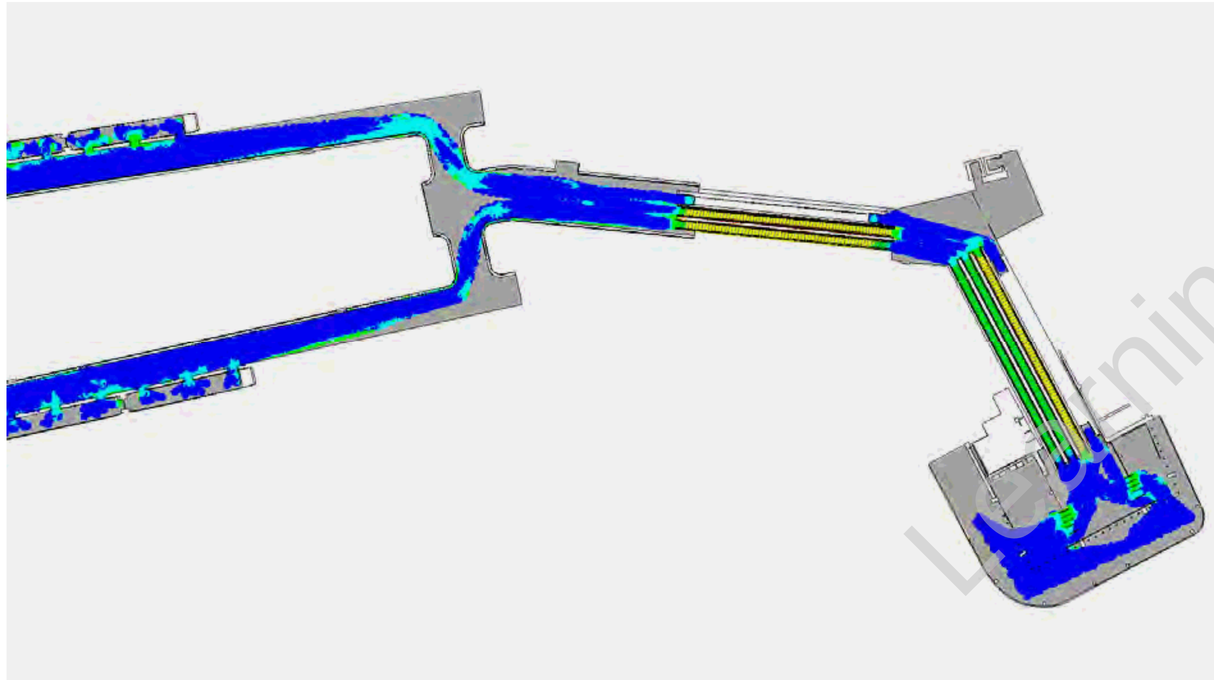
5.3.8 18h03-18h18, Mean Density (Queuing) WEST



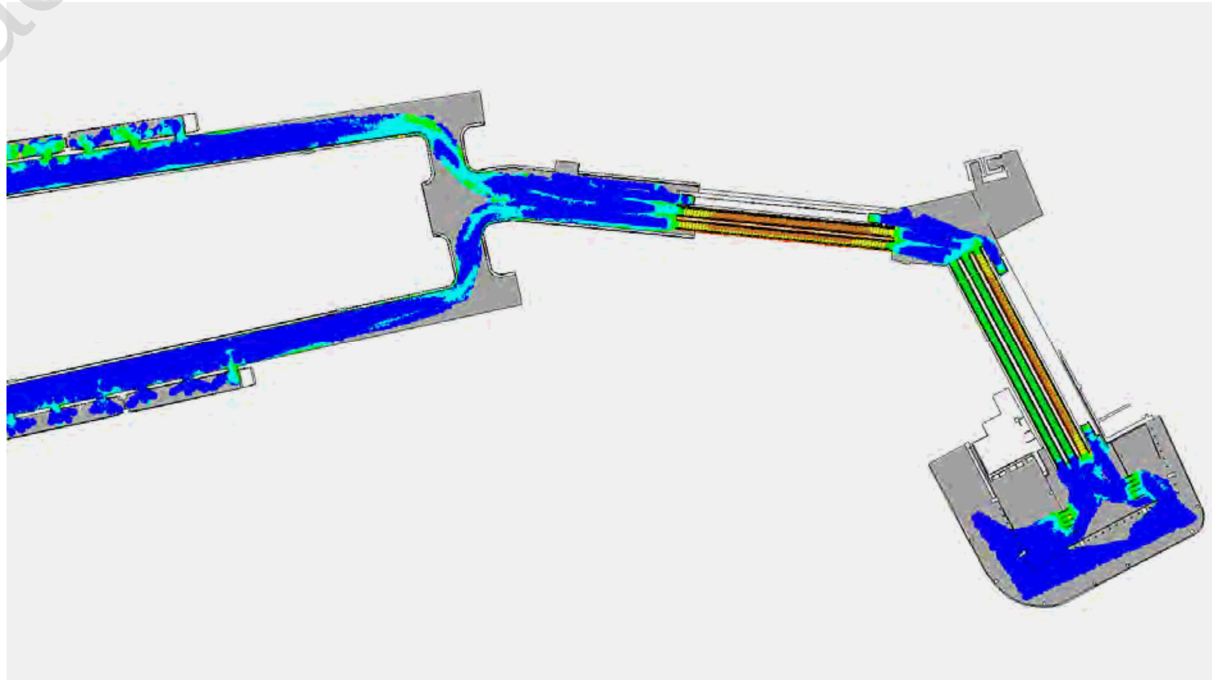
5.3.10 17h33-17h48, Mean Density (Walkways) EAST



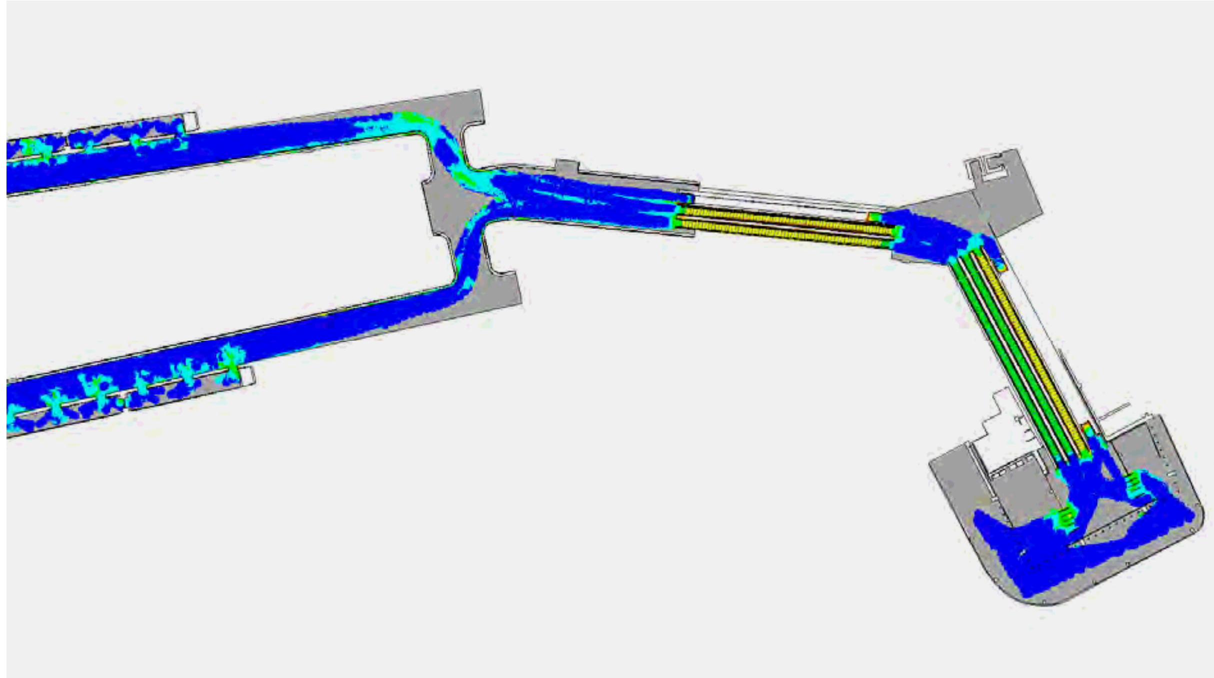
5.3.9 17h18-17h33, Mean Density (Walkways) EAST



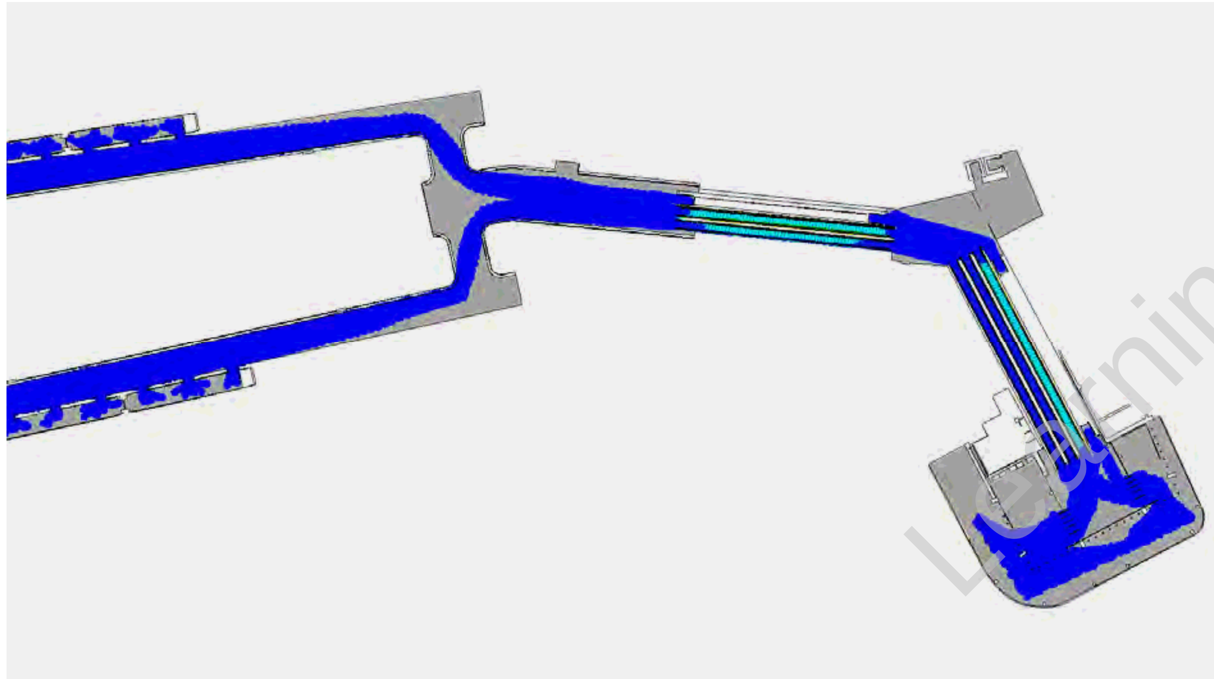
5.3.11 17h48-18h03, Mean Density (Walkways) EAST



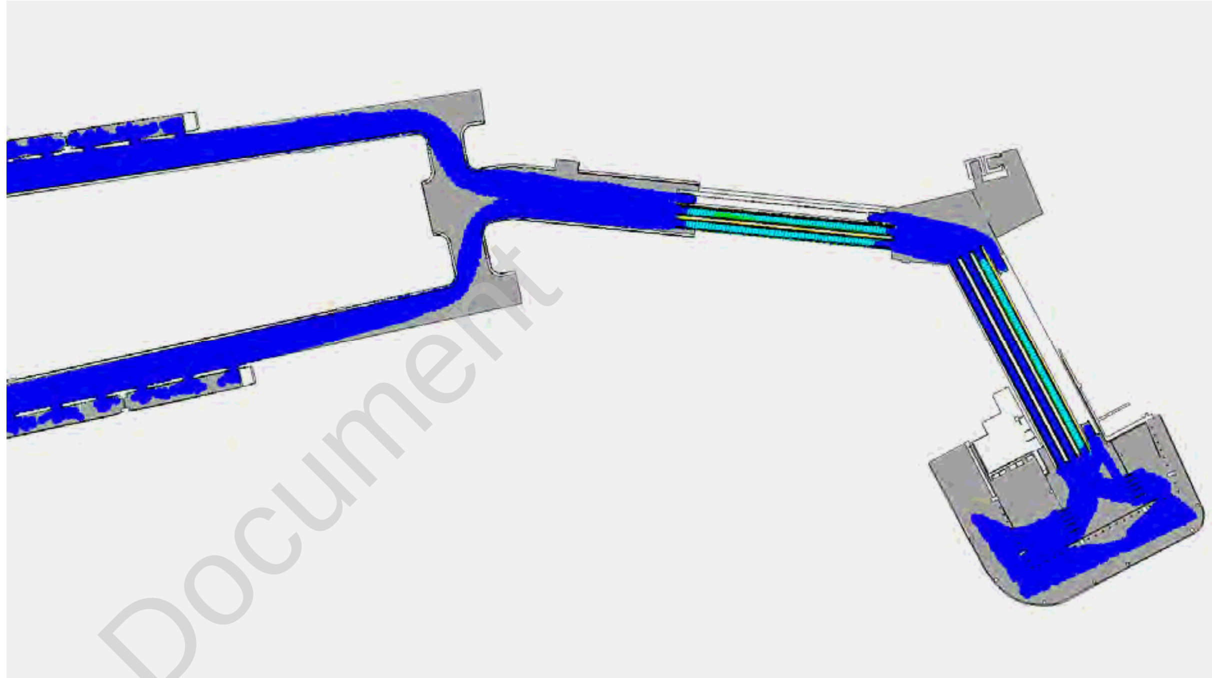
5.3.12 18h03-18h18, Mean Density (Walkways) EAST



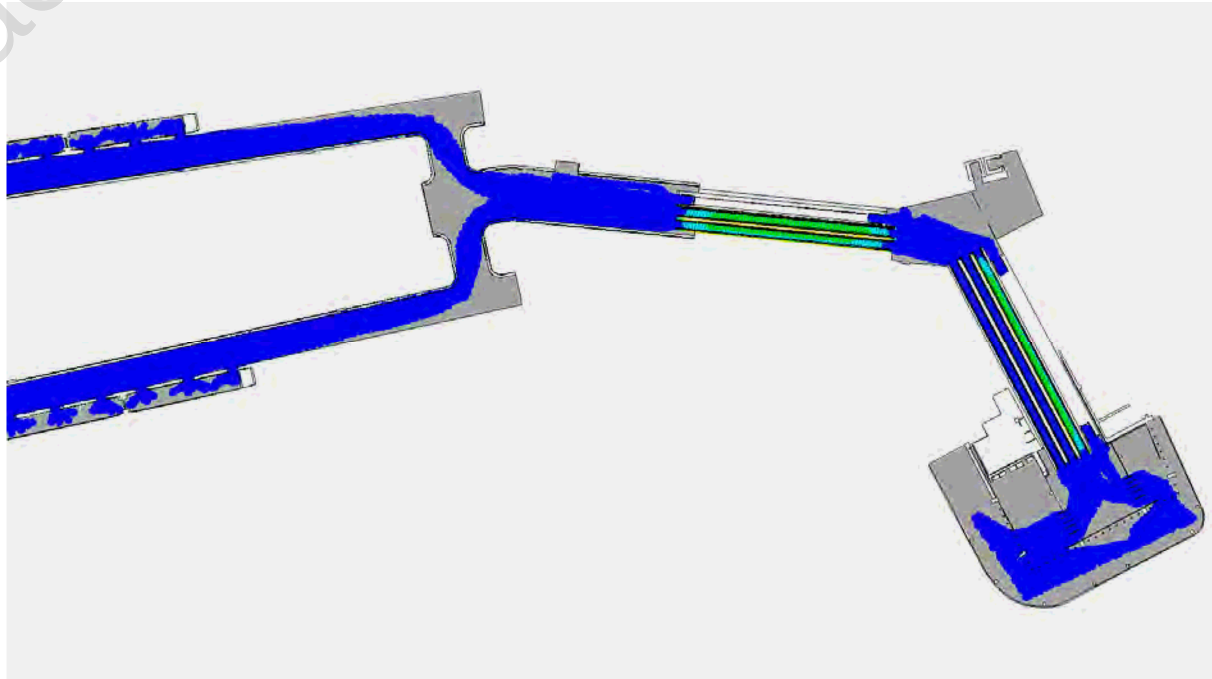
5.3.13 17h18-17h33, Mean Density (Queuing) EAST



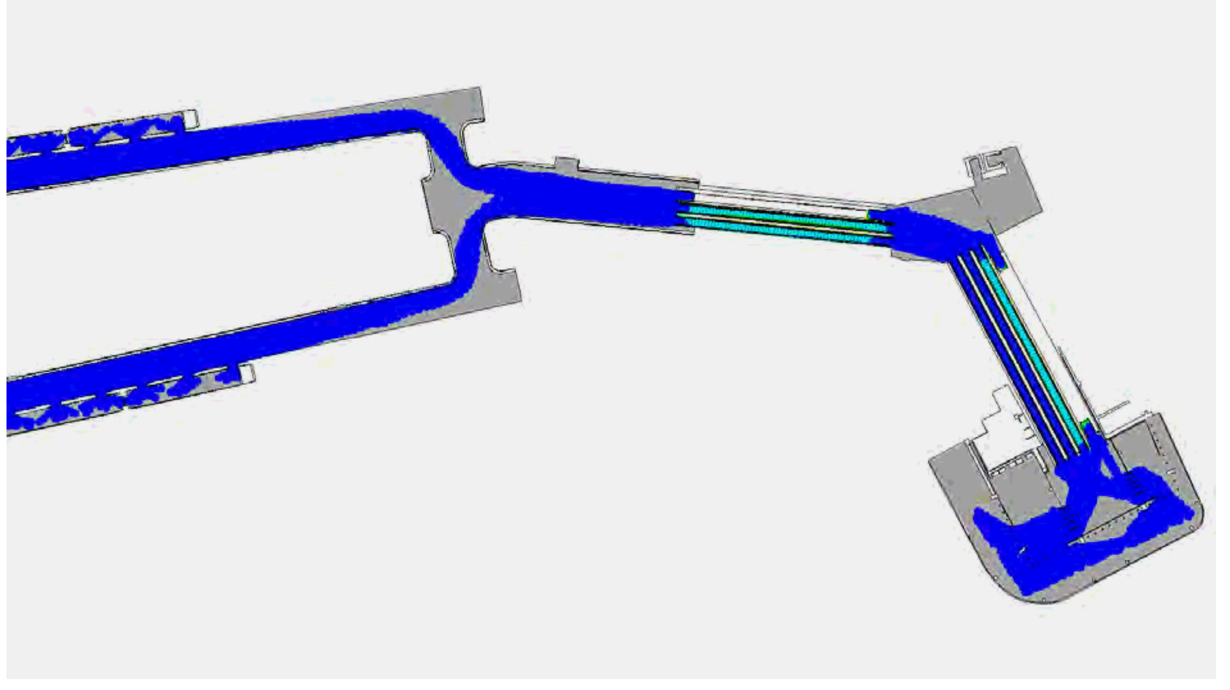
5.3.14 17h33-17h48, Mean Density (Queuing) EAST



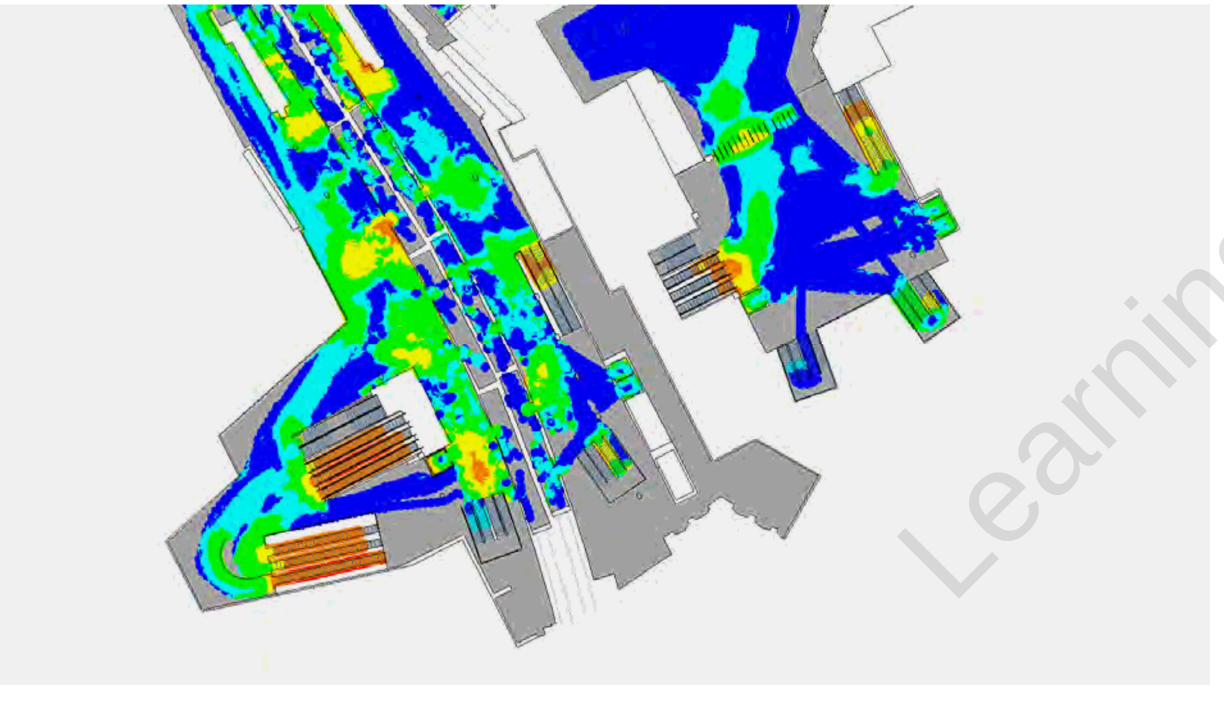
5.3.15 17h48-18h03, Mean Density (Queuing) EAST



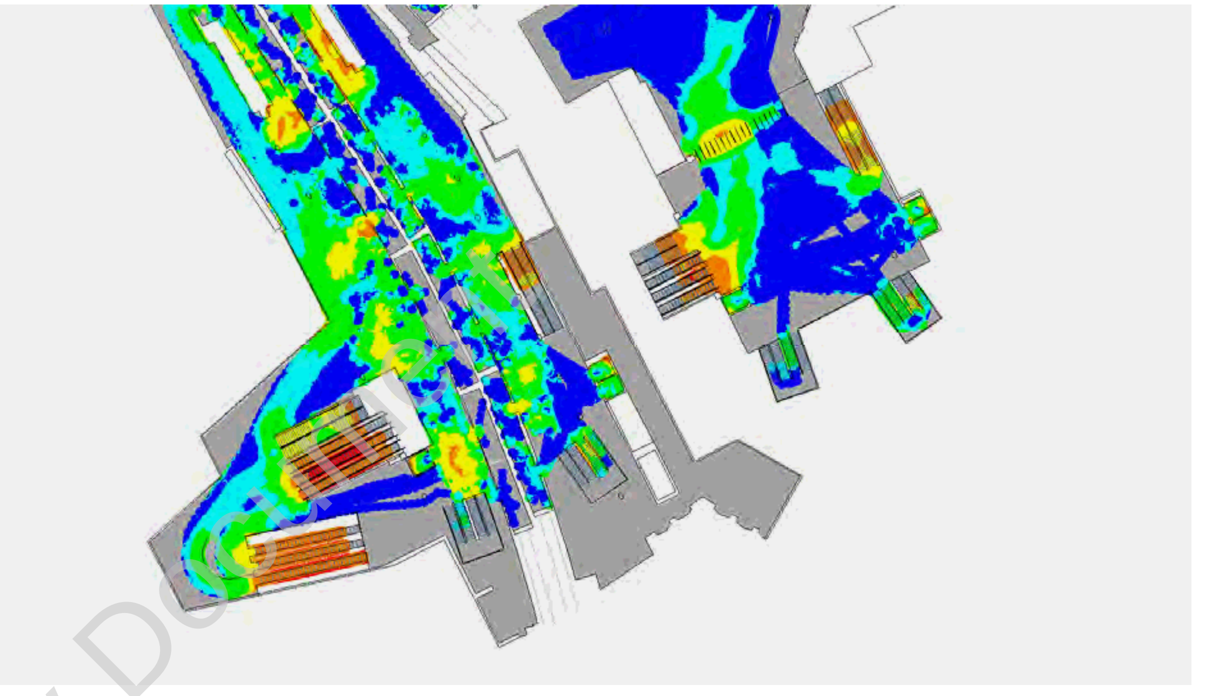
5.3.16 18h03-18h18, Mean Density (Queuing) EAST



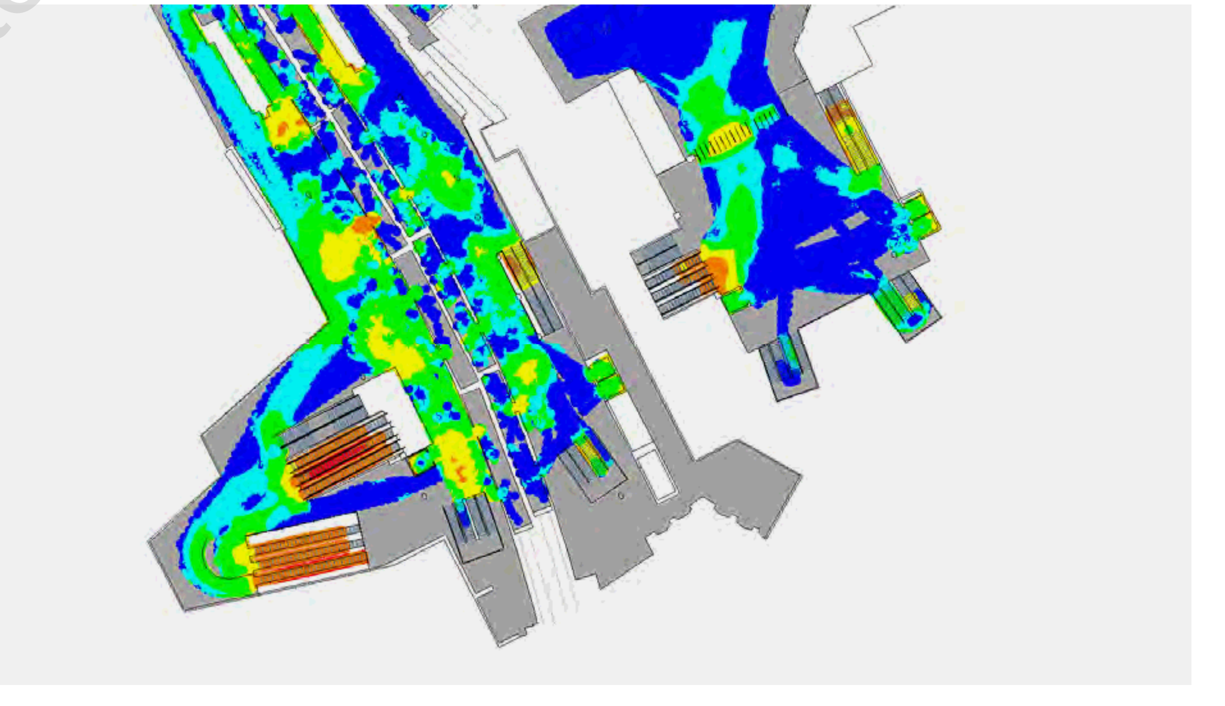
5.3.17 17h18-17h33, Mean Density (Walkways) TICKET HALL



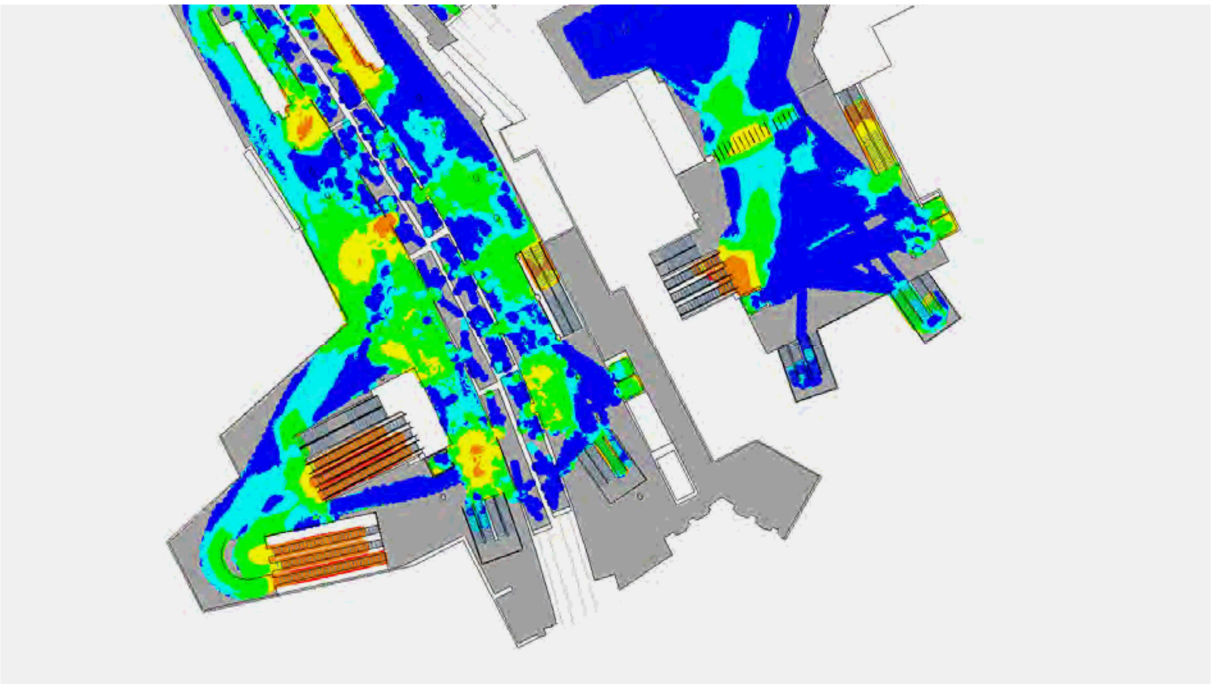
5.3.18 17h33-17h48, Mean Density (Walkways) TICKET HALL



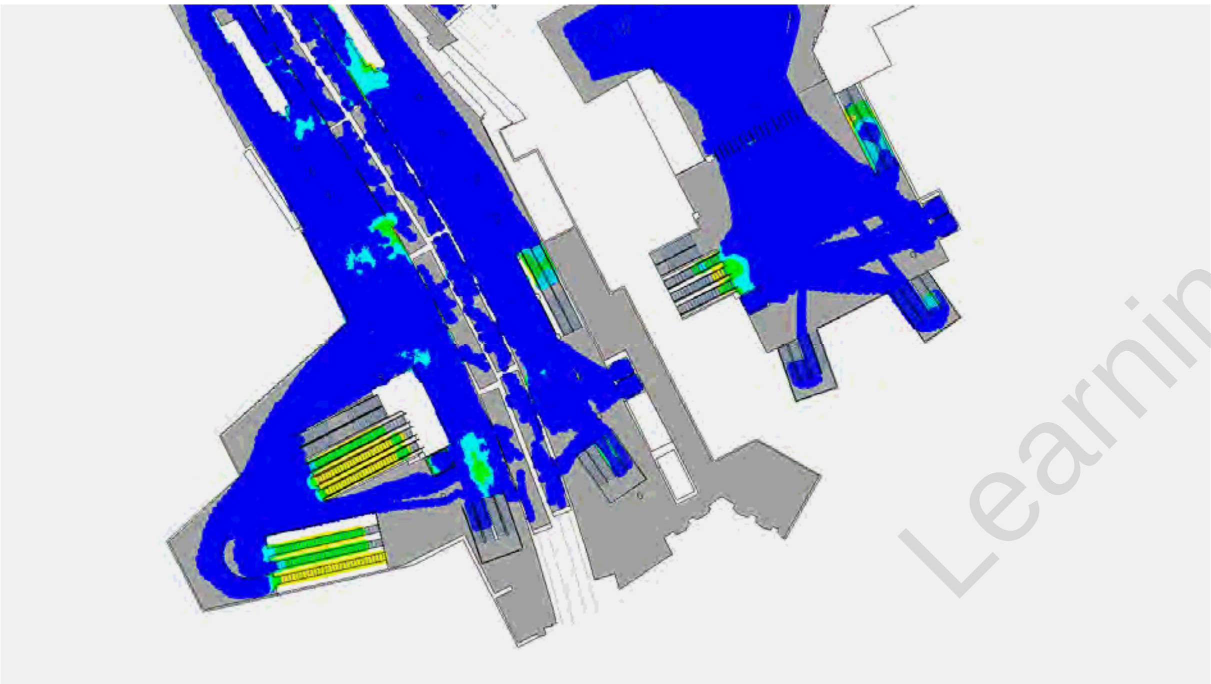
5.3.19 17h48-18h03, Mean Density (Walkways) TICKET HALL



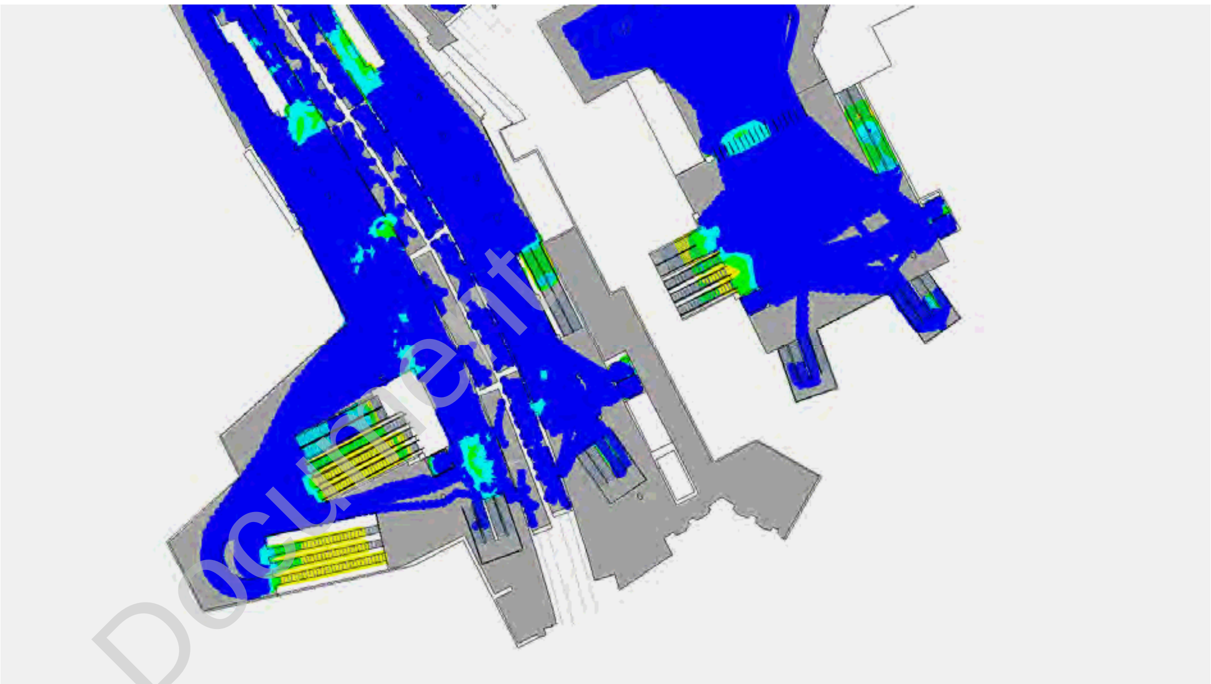
5.3.20 18h03-18h18, Mean Density (Walkways) TICKET HALL



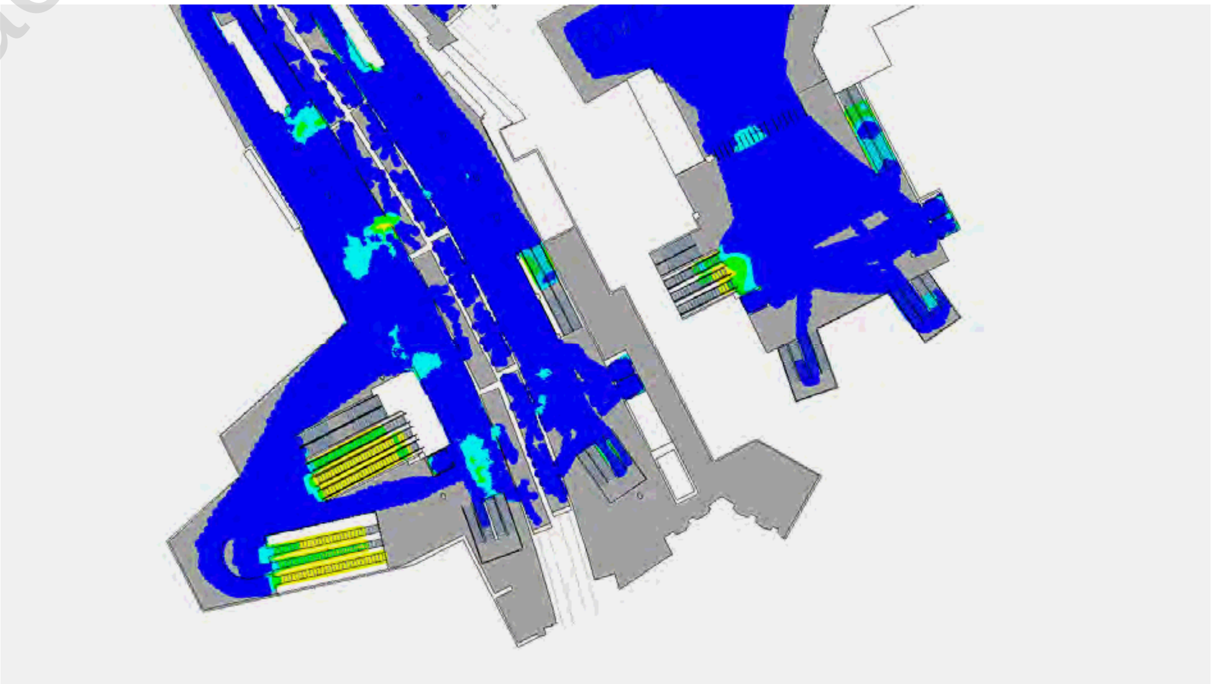
5.3.21 17h18-17h33, Mean Density (Queuing) TICKET HALL



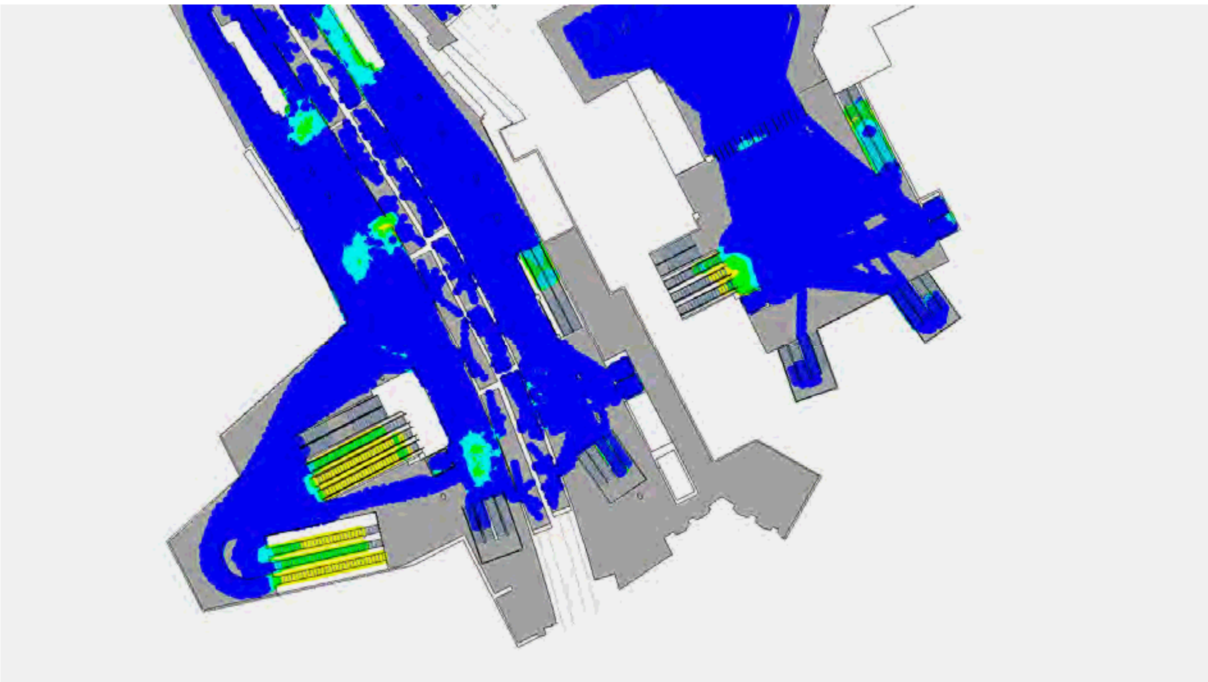
5.3.22 17h33-17h48, Mean Density (Queuing) TICKET HALL



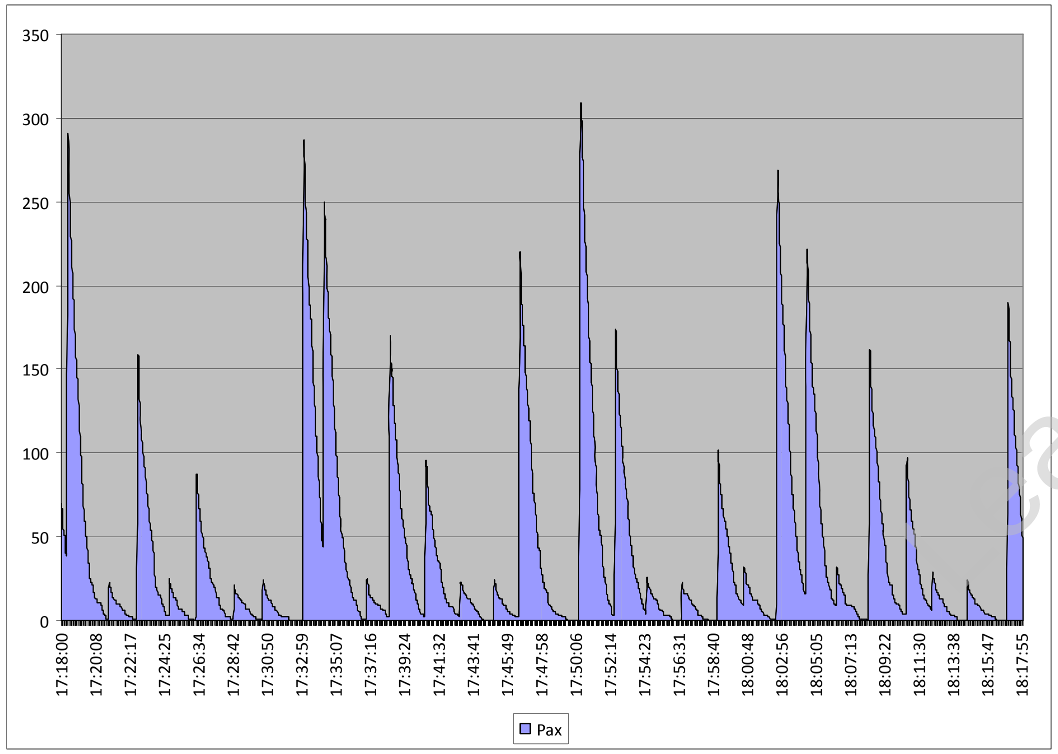
5.3.23 17h48-18h03, Mean Density (Queuing) TICKET HALL



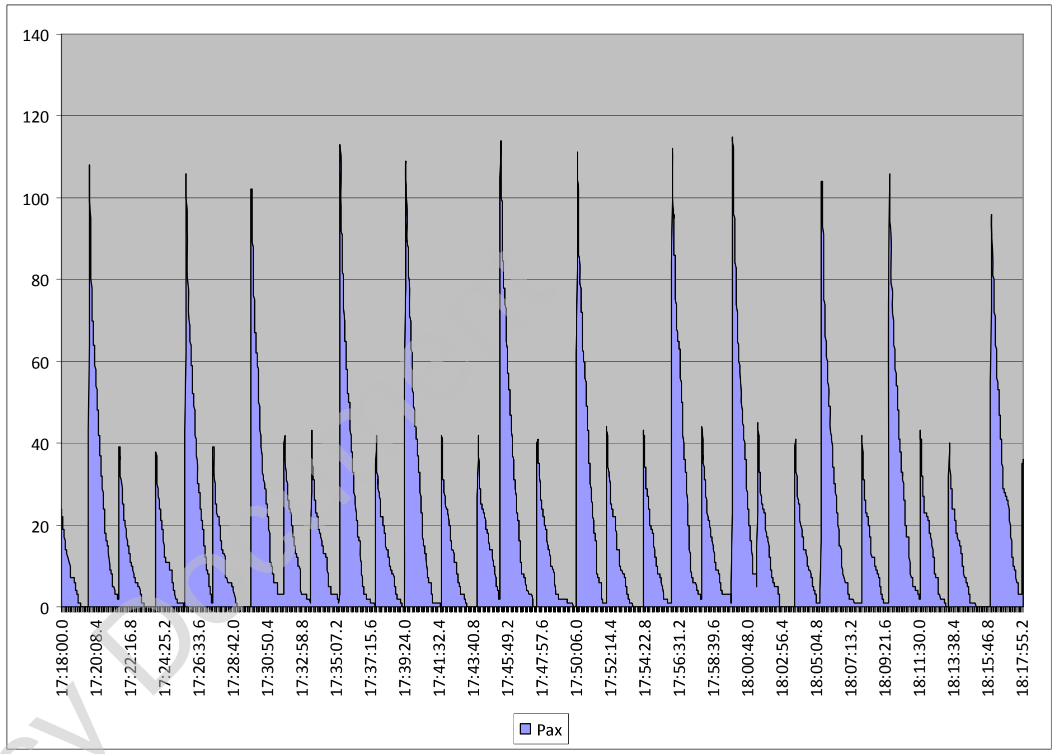
5.3.24 18h03-18h18, Mean Density (Queuing) TICKET HALL



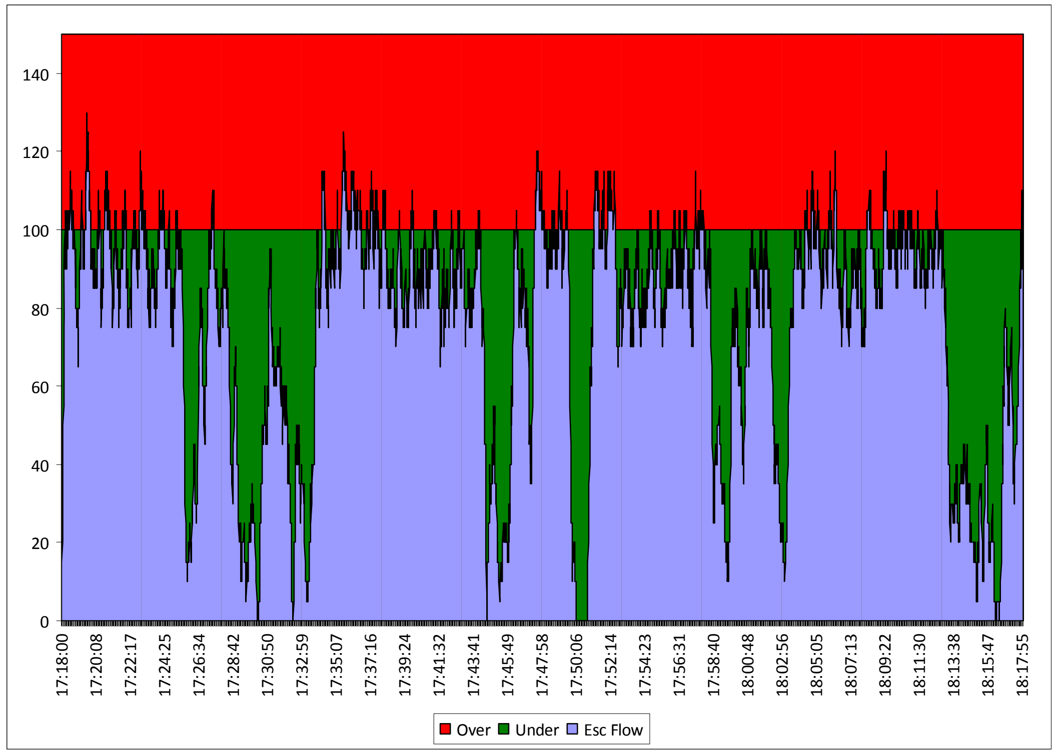
5.3.25 17h18-18h18, Platform Clearance CRL Eastbound



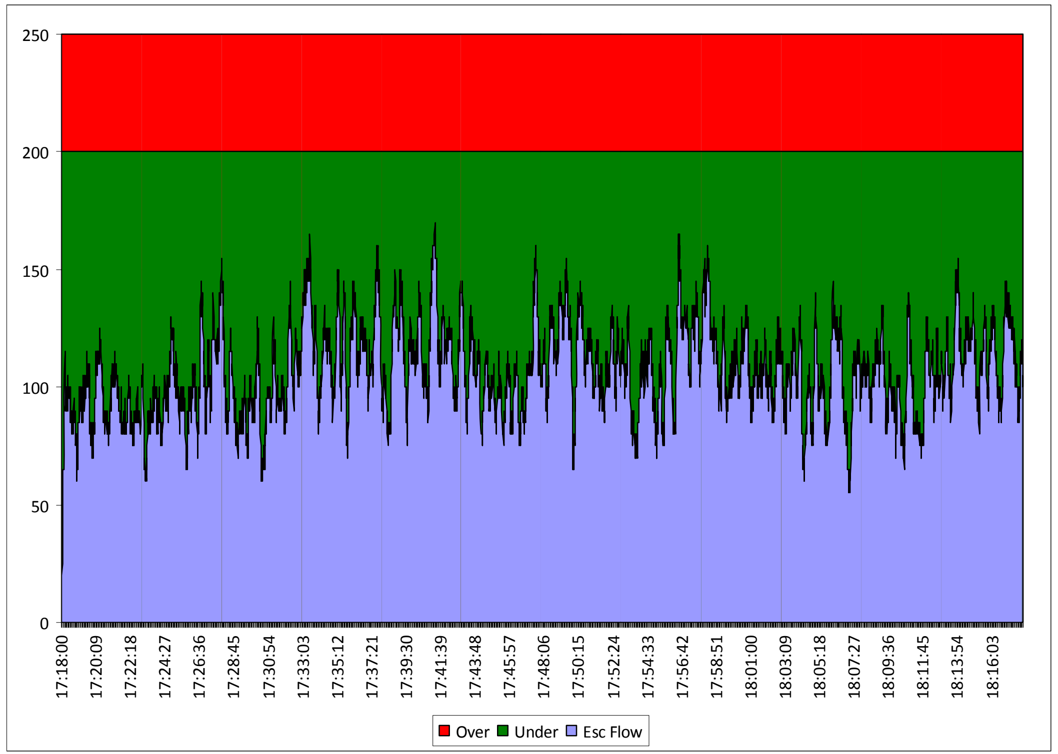
5.3.26 17h18-18h18, Platform Clearance CRL Westbound



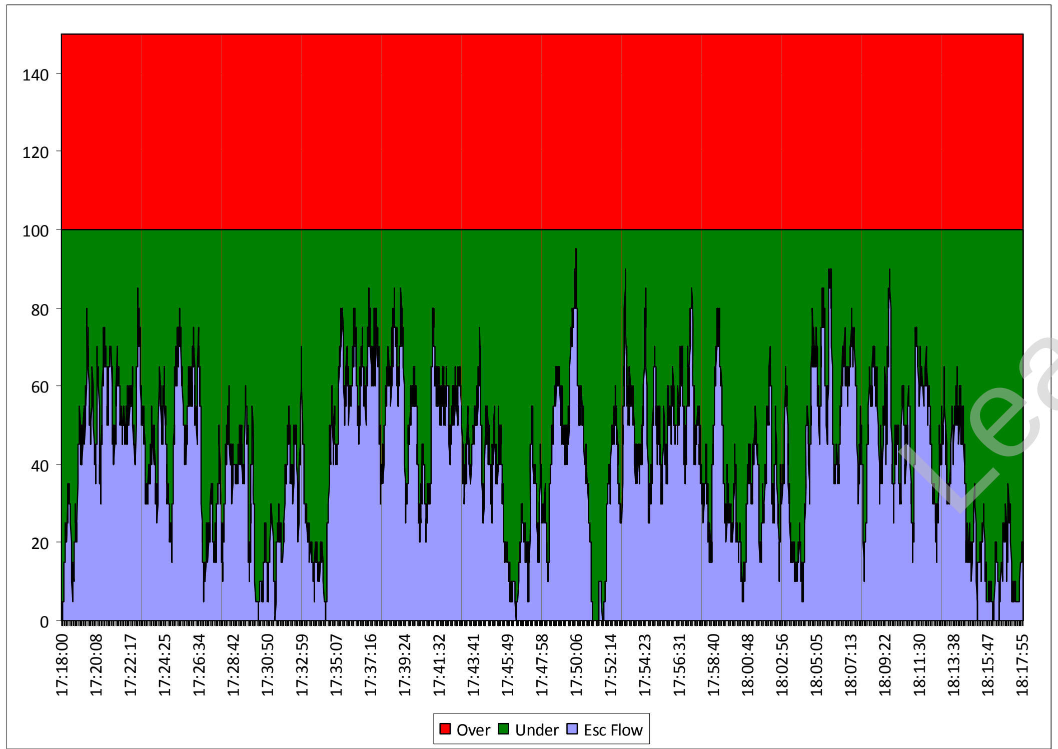
5.3.27 17h18-18h18, Upward Escalator Flow Rate



5.3.28 17h18-18h18, Downward Escalator Flow Rate



5.3.29 08h19-09h19, Escalator Flow toward Integrated Ticket Hall



5.4 2026+28% PM Peak Commentary

The primary flow in this scenario remains street to platform movements, meaning that the station should operate to accommodate entry flows through gates and down escalators. As before however, there remains a significant alighting movement in the opposite direction. This presents the only real capacity concern related to PM peak operations, as generally conditions in the +28% evening peak remain virtually congestion free across the CRL venue.

The western end of the Crossrail platform level shows the highest levels of service on the approach to the western escalators. Here, high levels of service are shown at escalator run-on, between 17h48 to 18h03 following the cancelled train. The walkways results for this area over-estimate congestion (passengers after all are queuing to board an escalator), but nonetheless the sustained LOS D (see queuing maps) before and after 18h00 represents a noticeable delay to exiting passengers. Compared to the 2026 modelling, the LOS degradation in this area is not as severe as might be expected, and the level of delay remains comparable with 2026 levels. This is because the higher train frequency (24 to 30 TPH) distributes the increased demand to the extent that a similar operation performance level as 2026 is seen.

As with 2026 before, iterations have been examined with 2 upward escalators. This provides more efficient performance at platform level but degrades performance at TL interchange level to an unacceptable and potentially unsafe level. In any event, escalators should be aligned to cater for the dominant flow, which for evening peak is the downward (boarding) flow.

The escalator flow rate graphs illustrate the flow up the single escalator. With concurrent (or near concurrent) arrivals the steady flow of alighters pushes flow near to 120 passengers per minute, but generally operates near or below the typical operating capacity of 100 passengers per minute for much of the peak hour. There is noticeable drop-off between headways. Static assessment results previously undertaken, demonstrated that a further 10-15% growth was needed before a second upward escalators are needed; however, dynamic modelling suggests there is not room for quite such latent growth. The difference between the two approaches is that dynamic modelling better represents surges off trains, which is the cause of the sustained higher utilisation of the single up escalator.

For the same reasons described in the 2026+28% AM commentary, above, a 4th escalator cannot be installed, but mitigation for the upward congestion could be achieved through increased use of the eastern end of the station (whether through intervention, signage or announcements).

For the downward escalators, the flow is continuously above the 100 passenger per minute level, and often peaks nearer 160. Crucially, flow rate never drops off, offering little recovery period, and underlining why the two-down, one-up formation must be operated at the expense of the delay to upward travelling passengers.

Conditions on the platforms themselves are essentially free-flow throughout the peak hour, with density values not exceeding LOS B in the queuing maps (assessing dwell performance).

At the East end of the station the very low passenger demand results in free-flow conditions at all times with no areas of congestion concern. The bank of two escalators at the Eastern end provides more than sufficient capacity to process the board/alight flows during the evening peak.

As in the morning peak modelling, alighters comfortably clear both Eastbound and Westbound platforms for all headways, with only one or two exceptions. Where platforms fail to clear, this is due to the shorter headways (at 30 TPH) and the possible journey distance a passenger at the extreme of a platform might have to undertake.

Circulatory areas of the Integrated Ticket Hall operate without any congestion – the 3 escalators plus stair provide sufficient capacity to process both Thameslink Northbound and Crossrail related demand, whilst the gateline area shows little congestion in either Walkways or Queuing maps. The escalator flow rate graph (4.3.29) reveals that there is still no need for passenger to ascend by stairs at 2026+28% evening peak level.

The Eastern Ticket Hall operates without congestion throughout the peak hour. Passenger flows here are low and do not place any strain on the escalator or gating provision at the Eastern end of the station.

During the PM peak at +28% demand level, mitigation may be sought through increased usage of the under utilised eastern end of the station. This would alleviate congestion seen at the base of the CRL western escalators (but not eliminate).

Graphical outputs for the London Underground and Thameslink platforms are **not shown** for this scenario due to the failure of the model to process the high TL demand in the +28% scenario.

5.5 Escalator Failure Scenarios

Escalator failure modelling has not been undertaken on the post-audit models, as the conclusions drawn from the previous version of this report remain valid:

- For the station to operate with an escalator failure at the western end of the CRL platforms, a significant migration of passengers from West to East needs to take place to process the upward demand. This would need to be at least 33% of all CRL to Integrated Ticket Hall flows leaving the station via Lindsey Street;
- For this to be achieved a concerted communication effort and considerable staff presence at CRL platform level would be required.

6 Further Modelling Scenarios

6.1 Thameslink "Breakpoint" Modelling

Following a meeting with London Underground on 10th May 2011, C136 were asked to examine the "breaking point" of the Thameslink Station. This is to better inform on congestion, resilience and the required mitigation associated with the high Thameslink patronage (and the lack of repeatability) in the highest passenger demand scenarios – see Sections 3.3 and 3.4, or the summary below.

6.1.1 Background

2026+28% modelling to date has shown a very poor degree of repeatability, making the derivation of results demonstrating Crossrail station performance and space proofing a difficult task indeed.

To address this, "cordon" models were set up at this highest demand level in which <u>only passengers who had zero impact on CRL</u> were removed from the simulation at their point of origin. Examples of these include: LU to TL movements via the northern interchange bridge, LU and TL flows to and from the Turnmill ticket hall and so on. Passengers that walked, infringed or dwelled on a CRL shared piece of infrastructure were retained in the modelling so that their impact could be quantified. By doing so, repeatable models were achievable, and C136 was able to deliver a 2026+28% assessment of the CRL station.

The fundamental reason for having to develop cordon models was the extremely high [revised] forecast for Thameslink services.

As noted in Section 3.4, design and analysis of the Thameslink station is beyond C136's remit – indeed a detailed modelling study has been undertaken throughout the GRIP process for Network Rail examining station design and space-proofing and mitigating its impact with London Underground. Crucially, this has been undertaken using a previously agreed passenger demand forecast, which most significantly is over 30% lower than the CRL issued figure for the same design year. In terms of alighting passengers (which drives AM peak performance at Farringdon, and therefore fundamentally dictates model performance) the progression of demand forecasts used for Farringdon in the approximate 2076 design year are:

Forecast	Approximate Year	Combined TL Alighters	As a % of Thameslink Forecast
Thameslink 2016+35%	2076	33,894	100%
CRL 2016+35%	2076	35,235	104%
CRL 2026+28%	2076	46,144	136%

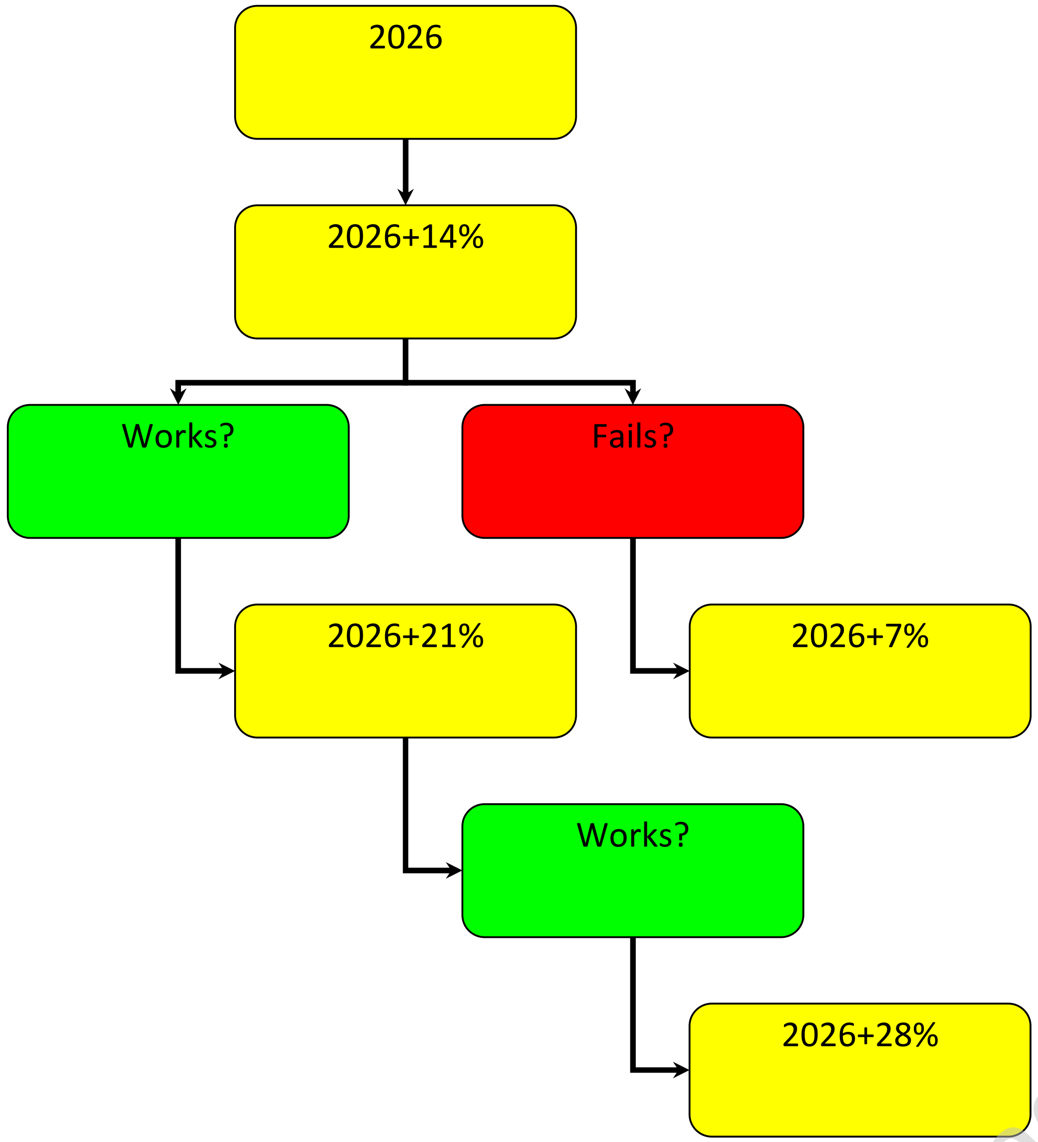
The Thameslink and CRL forecasts for 2016+35% (or 2076) are very similar. When 2076 is expressed as a 28% growth on 2026, then the significant step change in the level of patronage is clear – and it is this increase that leads to the unreliability and lack of repeatability.

Thameslink themselves are not space-proofing their design against the 2026+28% forecast – all the pedestrian flow analysis they conduct uses the 2016+35% data set. It is therefore entirely feasible that the 30% difference may account for the TL station being beyond its daily operating capacity, and in any event it is certainly well above the level of demand that Thameslink have designed the station to cope with. That the CRL models show no consistent repeatability seems to reinforce this notion – however it should be highlighted that not being repeatable does not equate directly to station failure; this is one of the nuances of random seed pedestrian simulation at high demand levels – a simulation run ten times may complete two or three times, and fail seven or eight times.

Notwithstanding these ideas and comments, LUL would like to understand the breaking point of the station: "at what level of demand after 2026 does the Thameslink station fail to operate?" The parameters used to assess this question are set out below.

6.1.2 Modelling Parameters

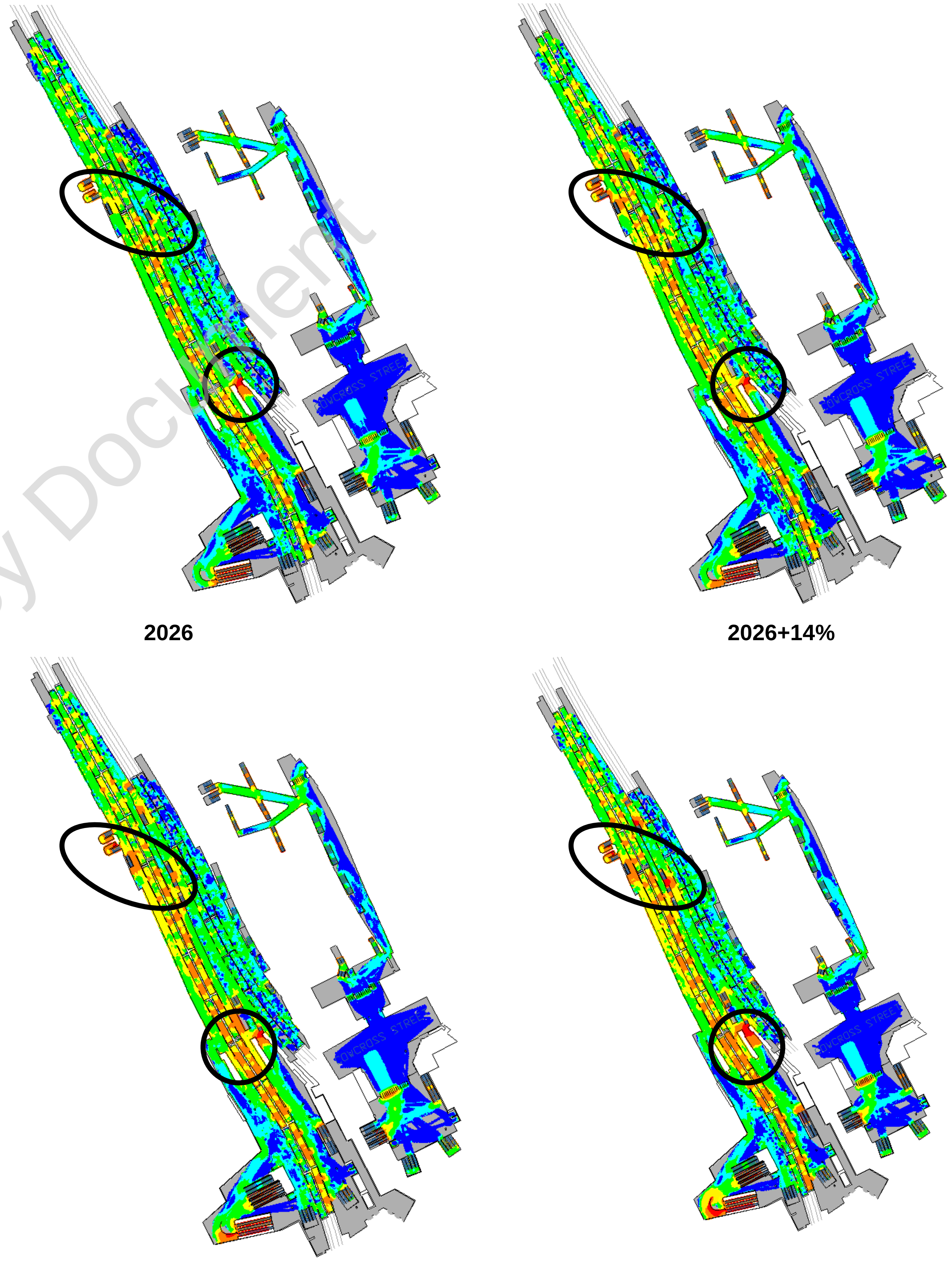
Taking the 2026 models as the starting point, the following testing structure has been applied to examine the breakpoint of the station:



Demand on each service within the station (LU, TL and CRL) has been grown by the corresponding growth factor.

Increases in train frequency that may be inherent in delivering demand to a nominal level have not been modelled (although this information was requested). On one hand this means that the level of growth may not be achievable with the simulated TPH, whilst on the other hand possibly the greater concentration (on fewer trains) will provide a stern test of station capacity. As these scenarios represent a high level examination of break point – and given the wide disparity in demand levels actually forecast for the station (above) this is not regarded as a shortcoming.

6.1.3 Thameslink Platforms - Peak 15 Minutes Comparison, Morning Peak



2026 **2026+14%**

2026+21% **2026+28%**

The images shown in 6.1.3 demonstrate the four stage progression between 2026 and 2026+28%. In the simulations presented here, all models did in fact complete their run-time; and the blockages which typically hinder the production of results did not occur (these are presented as the LUL/TL results for 2026+28% in Appendix B, Section 10.2).

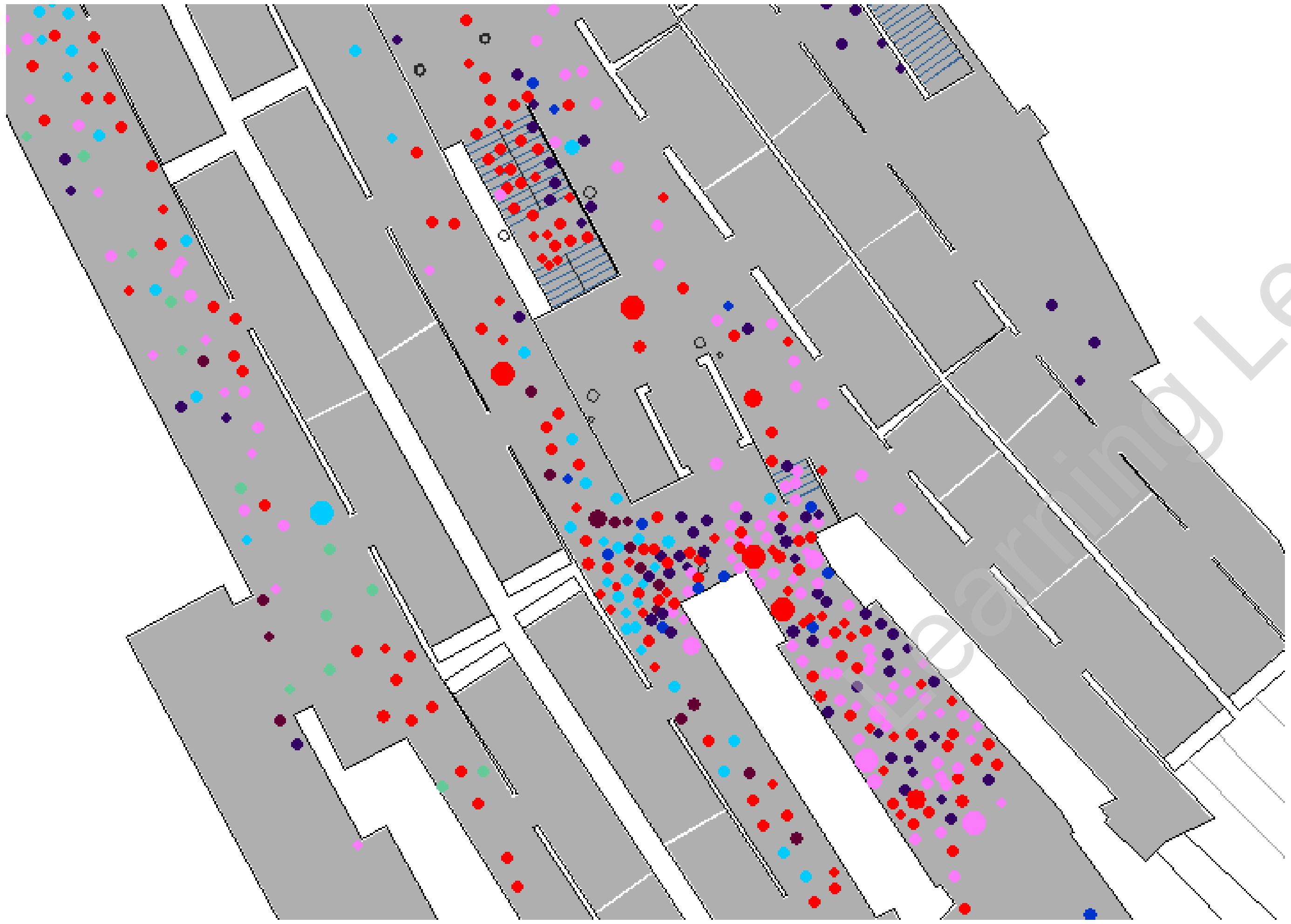
However, the areas that commonly lead to blockages do become increasingly distinct as demand progresses (circled in each of the 6.1.3 images). These are:

- Narrower section of Platform 4, adjacent and to the south of overbridge Stairs 09, 10 and 11;
- Platform 3, through the narrow central section to the immediate north of Stairs 08 and 12;
- Platform 3, leading to the narrow interchange Stair 06.

In the morning peak all of these areas are increasingly exacerbated by the extremely high alighting loads originating from Thameslink services, which exceed 46,000 in three hours in the +28% scenario.

The former and latter of these locations have blocked with most regularity. 6.1.4, below, illustrates an unrecoverable blockage in the Stair 06 area.

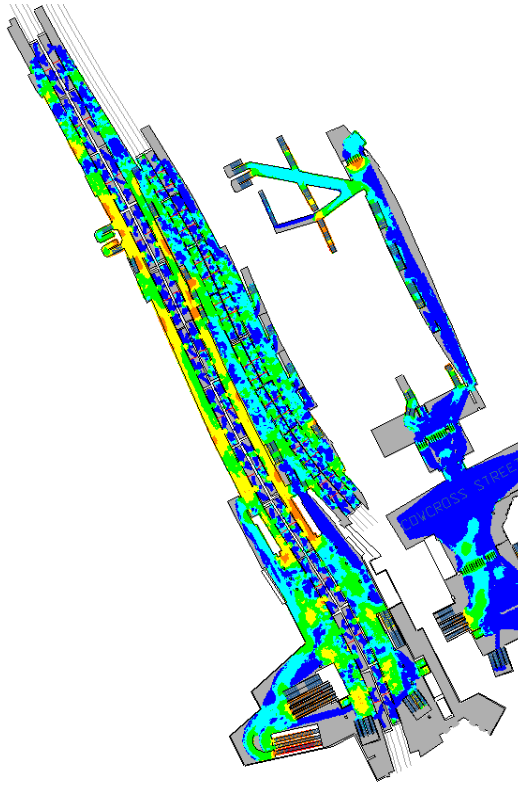
6.1.4 Platform 3 Blockage Adjacent to Stair 06



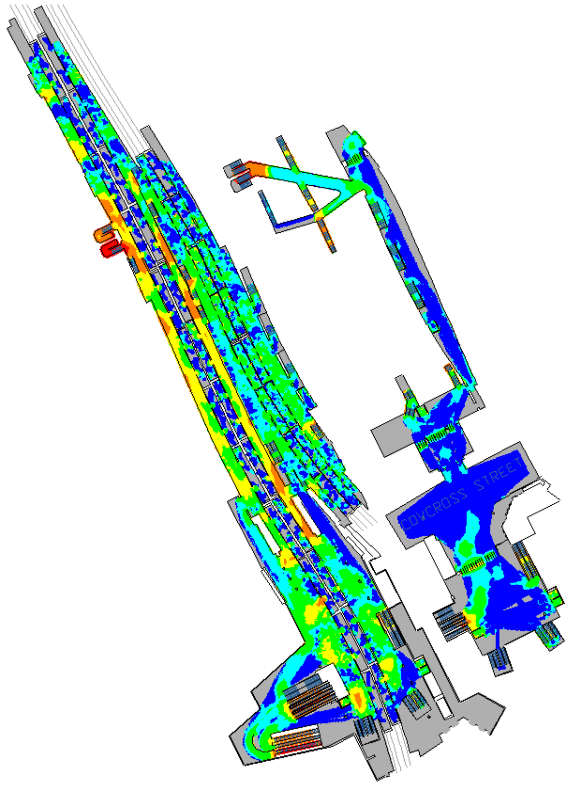
In this image, the pink passenger types are heading from Thameslink to Platform 2, the red from Thameslink to street and the purple from Thameslink to Platform 1. In the opposing direction, the navy blue pedestrians are heading onto Thameslink to board and the light blue are heading towards CRL. Although some of these conflicting flows are also served by other routes, it is unlikely pedestrians from the southernmost Platform 3 carriages would choose to either cross two gatelines (via both ticket halls and street) or walk the length of the platform [and past Stair 6] to access LUL via the Turnmill overbridge. All of these passengers have valid reasons to be here, which suggest the station may indeed suffer localised areas of high congestion indicated in the modelling. In the Legion context, this results in a failure to properly simulate, and therefore unreliable or unrepeatable performance. It does not indicate however a strict pass and failure demarcation, as models can [and do – as above] complete properly on occasions.

With the exception of the three highlighted areas, there is not a significant step change in Thameslink platforms performance throughout the demand series.

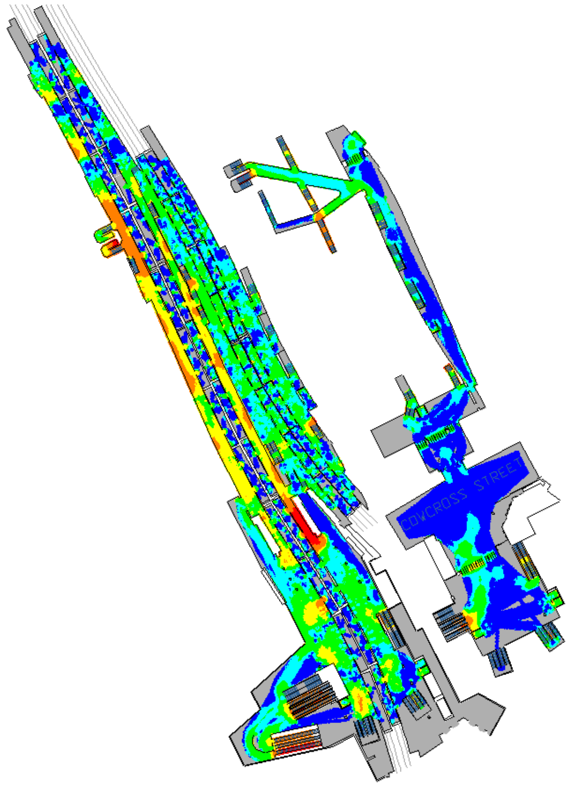
6.1.5 Thameslink Platforms - Peak 15 Minutes Comparison, Evening Peak



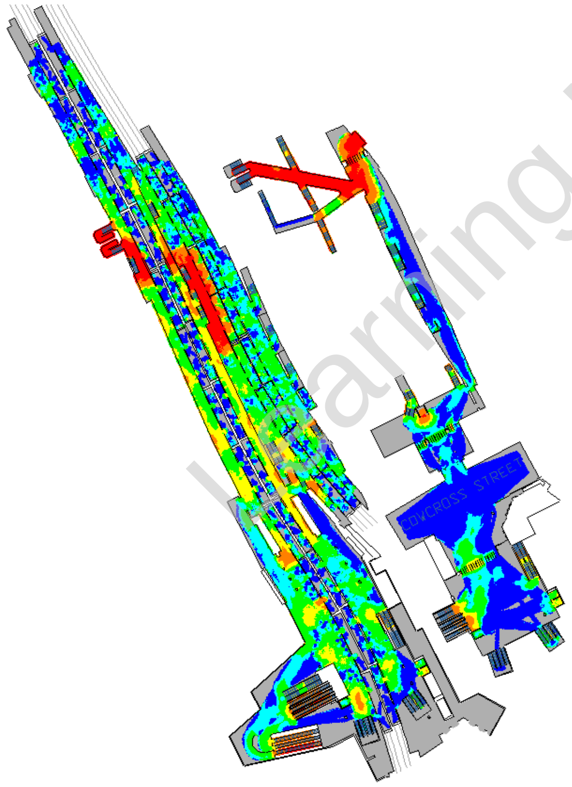
2026



2026+14%



2026+21%



2026+28%

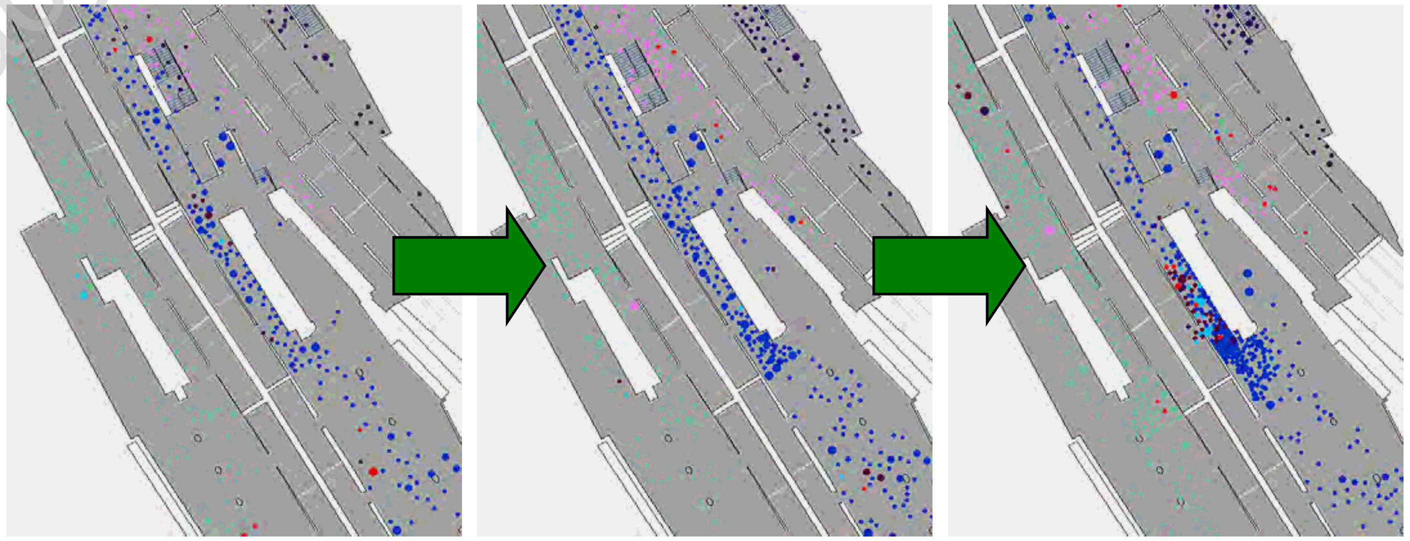
Flow patterns in the evening peak are principally street to platform movements. Although the two CRL forecasts do not differ as significantly as they do in the morning peak (2026+28% is 5-10% larger than 2016+35%), the 2026+28% forecast does differ appreciably from the original Thameslink forecast upon which station design and space proofing has been based. In terms of boarding loads for Thameslink platforms, the CRL 2026+28% (2076) demand is 31% greater than the 2076 Thameslink version.

Due to this high platform utilisation, blockage (and therefore model failure) occurs on both Thameslink platforms in very similar areas to the morning peak, such as:

- Narrower section of Platform 4, adjacent and to the south of overbridge Stairs 09, 10 and 11;
- Platform 3, leading to the narrow interchange Stair 06.

In the model screenshots above increasing congestion levels are seen in both locations, until the volume of dwelling passengers and the conflicting flows along, off and onto Platform 4 overload the northern section adjacent to Stairs 09, 10 and 11. The high inward flows quickly exacerbate this situation which is typical of the evening peak simulations undertaken. Clearly there is spare capacity further along the platform, but this cannot be used unless the highly utilised landing area from Stairs 10 and 11 clears quickly. Given the heavy and sustained interchange and entry loads there is limited scope for this to do so. The result of this in a modelling context is the regular blocking of the platform, stairs and overbridge. As noted above, this might not occur with actual human behaviour, but the implication taken from the model is that the loadings are high enough to cause regular crowding issues.

In a separate model run Platform 3 becomes highly congested due to the combination of dwell+board+alight+through-movements occurring. The image sequence below shows snapshots taken at **one minute intervals** to demonstrate the high demand and speed with which blockage can and does occur.



6.1.6 Conclusions

The sensitivity scenarios undertaken represent a high level examination of the station breakpoint. Furthermore they make use of a demand forecast that is significantly higher than that used by Thameslink to space proof their GRIP design process. It is no surprise therefore that the platforms experience very high utilisation in both peaks, and regularly block where opposing flows conflict with dwell accumulations.

The models are repeatable at all demands up to 2026+28%, and even at this level of demand the models do not always fail. The issue therefore is about repeatability rather than categorical station failure (and it was for this reason that “cordon” models focusing on the CRL areas of the station were created), because when simulations do complete the Level of Service metrics are not dissimilar to the 2026/+14/+21% iterations and the reasons for model failure are often very localised.

Given that more models fail than complete their simulation, then it is concluded that the breakpoint is between 2026+21% and 2026+28% **at this level of demand**.

Suggesting measures to combat congestion may be superfluous as the passenger numbers forecast might not occur in the lifespan of the station, or may simply be beyond the realistic capacity of the venue.

However in terms of mitigation, the following considerations are suggested for highest demand operations at Farringdon:

- Staff intervention or signage/announcements to encourage full use of the platform length, particularly on Platform 4. This needs to encourage passengers to move away from narrower sections adjacent to stair landing areas. In inclement weather, or times of perturbation, these measures may be difficult to implement.

- Promotion of alternative access and egress routes avoiding Stair 06 – although this route represents the shortest (and therefore most likely) route for a number of origin and destination pairs within Farringdon.

7 Conclusions

At 2026 demand level Farringdon station operates at near free-flow level throughout the venue, with only small delay to upward movements during the absolute peak of the evening period.

At 2026+28%, modelling results are derived from Crossrail cordon models due to the potentially over-capacity growth in the Thameslink station. These models simulate all CRL elements of the station and use all CRL related demand through the venue. Elements of Thameslink demand (not relevant to the CRL design) have been removed to ensure repeatable modelling.

The wider station venue experiences breakpoint at 2026+21%, and fails due to the excessive patronage of the Thameslink station.

The peak passenger flows derived from the 2026+28% forecasts would be efficiently and safely accommodated within the current design for the Farringdon Crossrail station in both morning and evening peak periods. For almost all station elements, free flow conditions remain as seen in the 2026 modelling.

Some small areas of congestion are shown in normal operations; these are not regarded as a major concern, but are seen at:

- Top of downward CRL platform escalator in the period before and after 09h00 in the morning peak modelling;

- Delay and localised crowding moving onto single upward escalator during the peak period of the evening peak model. Additional vertical circulation cannot be installed here, and in any event catering for the worst moment of the highest demand forecast is not the objective of the +28% modelling.

- Western most dwell areas on the Westbound CRL platform during the morning peak (caused by dwelling close to PEDs).

Crucially, none of the congested areas highlighted above have any impact on other movements within the station complex, and at no point do not lead to a breakdown in flow. Rather they represent a slowing and congregation of passengers, in an environment that is more congested, but not unsafe.

Mitigation for the single upward escalator crowding during the PM peak could be achieved through the transfer of passengers to the eastern end of the station. This is underutilised and could accommodate more passengers than are forecast to use it.

For the AM peak downward congestion (at TL level) then only use of the escape stairs would offer mitigation, unless entering passengers can be diverted at street level to make use of the eastern entrance (seems unlikely). This problem is arguably skewed by the extreme TL demand – therefore the need to consider use of escape stairs may prove a false recommendation.

All peak period modelling incorporates a cancelled train occurring at the busiest time on the busiest platform. This alone ensures confidence in the station design and resilience, and places greater strain on performance than a typical “normal-day” model scenario.

In a more onerous abnormal scenario (such as escalator failure) the East-West orientation and access affords it a good degree of operational flexibility. Through staff intervention and the transfer of passengers from the busier Western end to the highly underutilised Eastern Ticket Hall the station could continue to operate with only an up and down escalator at each end of the CRL station.

8 Recommendations

The Crossrail station operates without significant sustained congestion and does not fail to process passenger movements at any time. Although small instances of congestion and crowding do occur, these do not block circulation and are not deemed worthy of increasing capacity. They also largely occur at the higher demand forecast. Mitigating factors have been specified throughout this document that may help alleviate any congestion occurring.

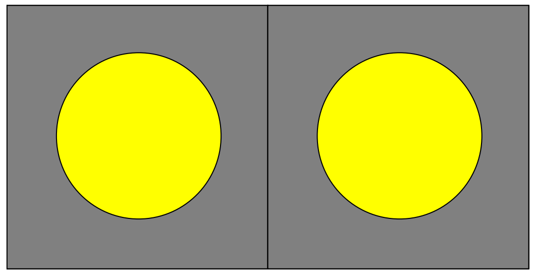
In an escalator failure scenario, staffing presence would have to be increased, and/or a communication campaign undertaken to ensure an effective (and large-scale) redirection of passengers via the Eastern Ticket Hall.

An LUL-Crossrail-Thameslink forum is suggested to investigate the considerable increase on the passenger demand against which the Thameslink station has been sized. Above all other factors, this influences the results presented for the +28% scenario in this document.

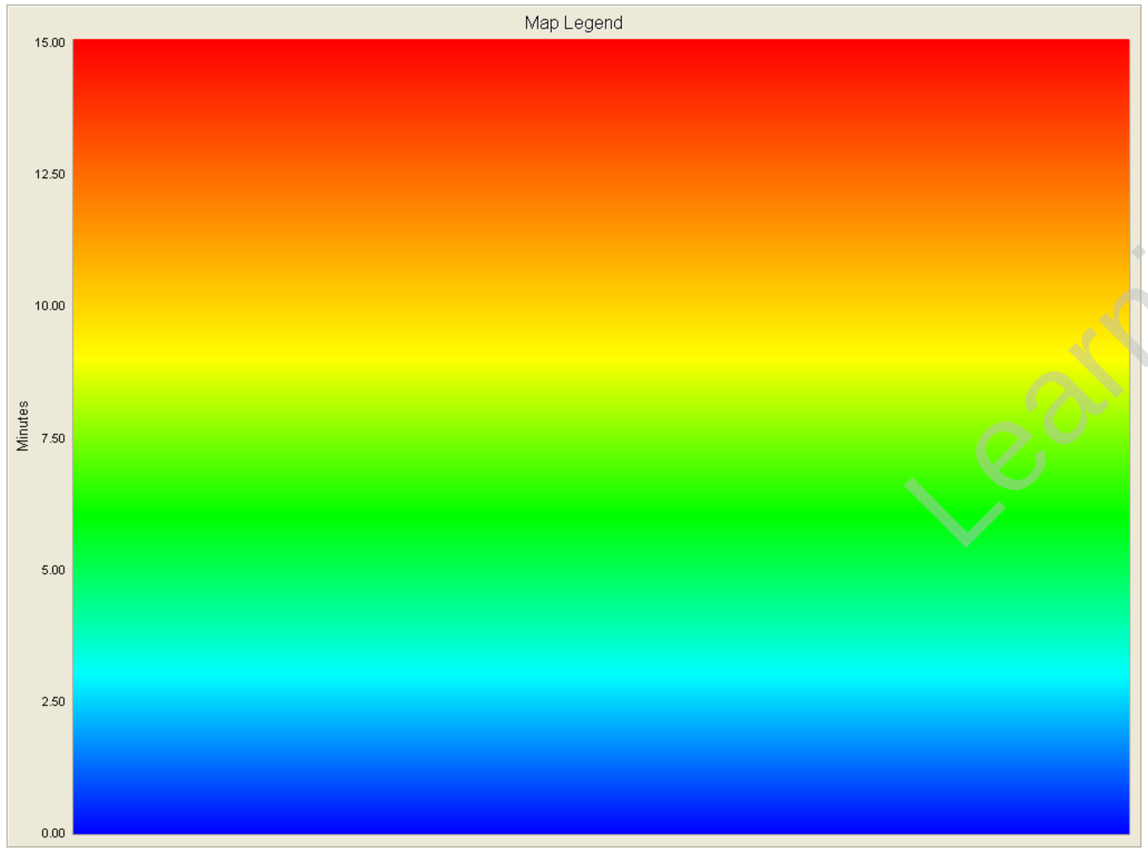
9 Appendix A – Cumulative High Density Maps

Cumulative High Density (CHD) illustrates the amount of time spent above a specified density value. They focus on how sustained utilisation above or below a pre-set limit is – they do not reflect an actual density or congestion value, although confusingly, they do use the same colour range (blue to red).

A standard measure for assessing station performance is the provision of 0.8sqm per person within the venue. This is typically a comfortable environment expected of a busy, but efficiently performing station (0.8sqm per person roughly equates to the LOS C - LOS D boundary). A representation of space allocation is shown in the image below, in which two 0.8sqm areas are occupied by pedestrians of typical UK size (0.3msqm). Their proximity indicates the level of space allocation at which CHD maps start accumulating time data.

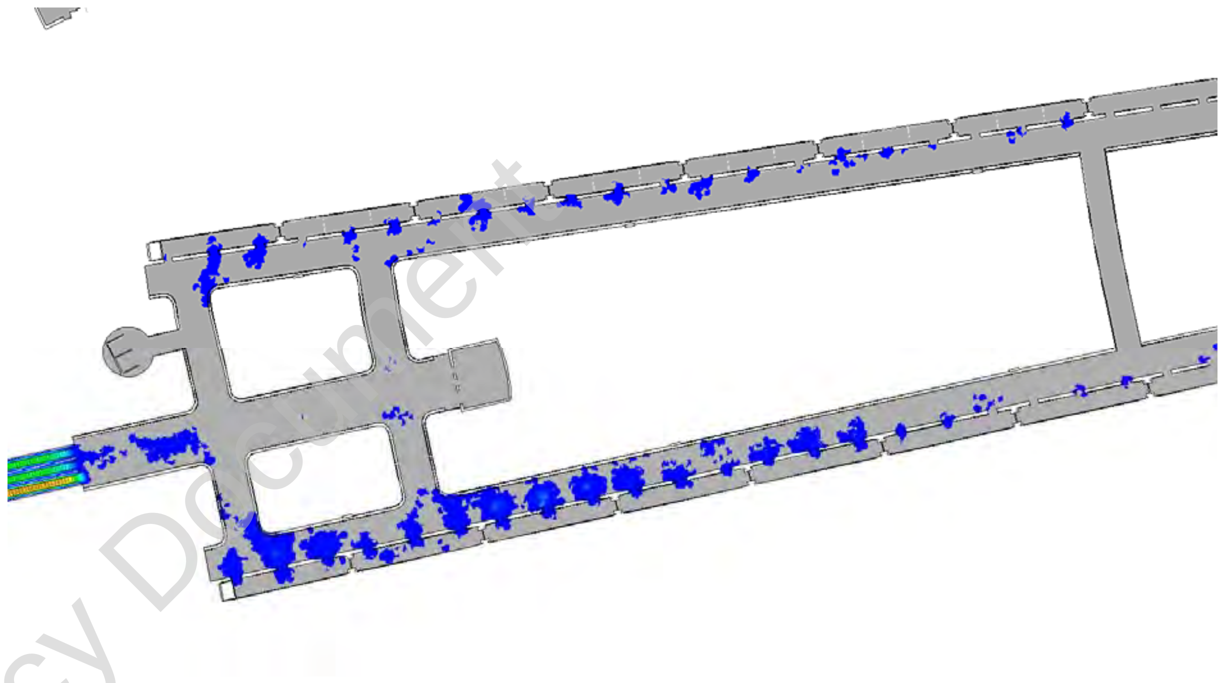


The colour range below ranges from blue (0mins) to red (15mins). Depending on the length of time each 15minute period is occupied at worst than 0.8sqm per person, then the appropriate colour will be assigned There are no set guidelines for an acceptable level of occupancy, although typically up to 5 out of 15minutes is accepted. Using the threshold below, 5minutes is a solid green colour (note that stairs and escalators should be excluded from this type of analysis, 0.8sqm is a circulatory comfort level).

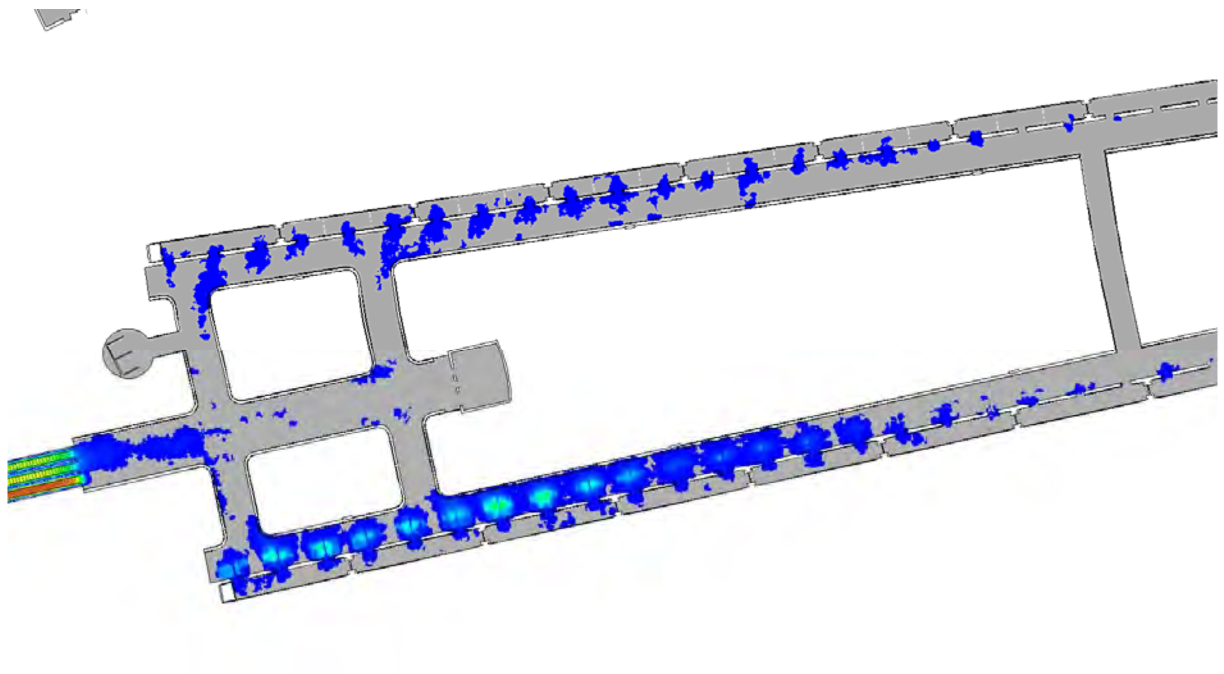


9.1 2026 AM Peak Modelling, 07h00-10h00

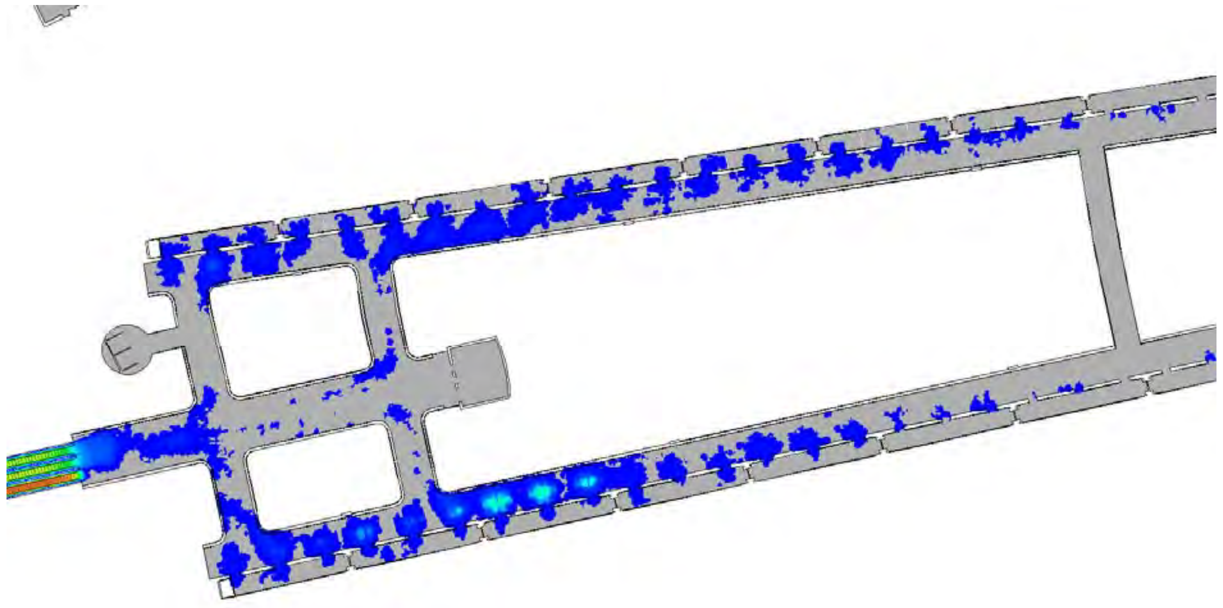
9.1.1 08h19-08h34, High Density WEST



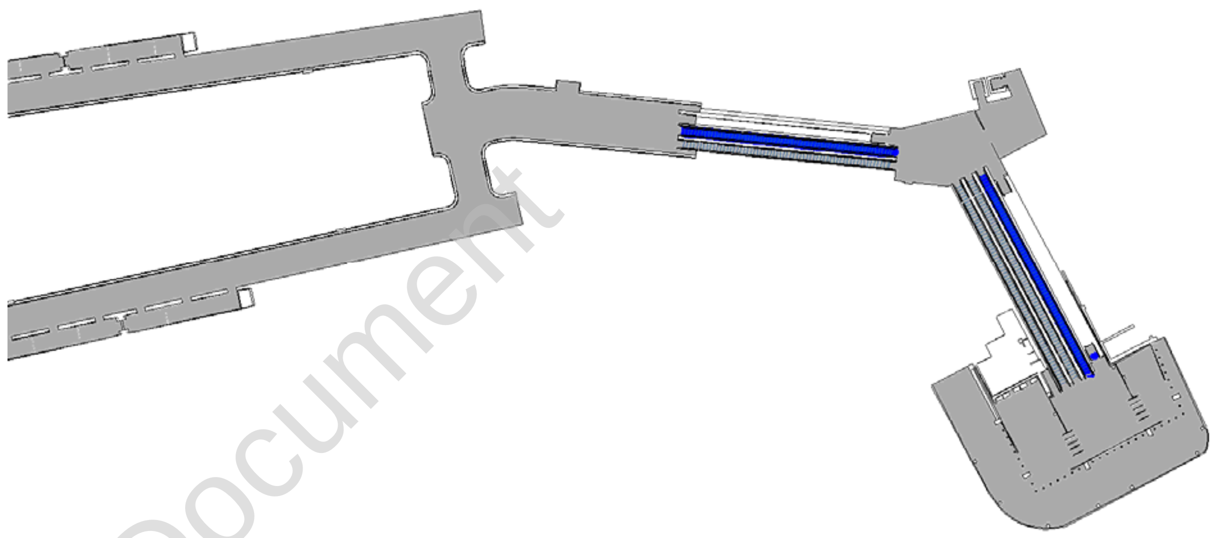
9.1.2 08h34-08h49, High Density WEST



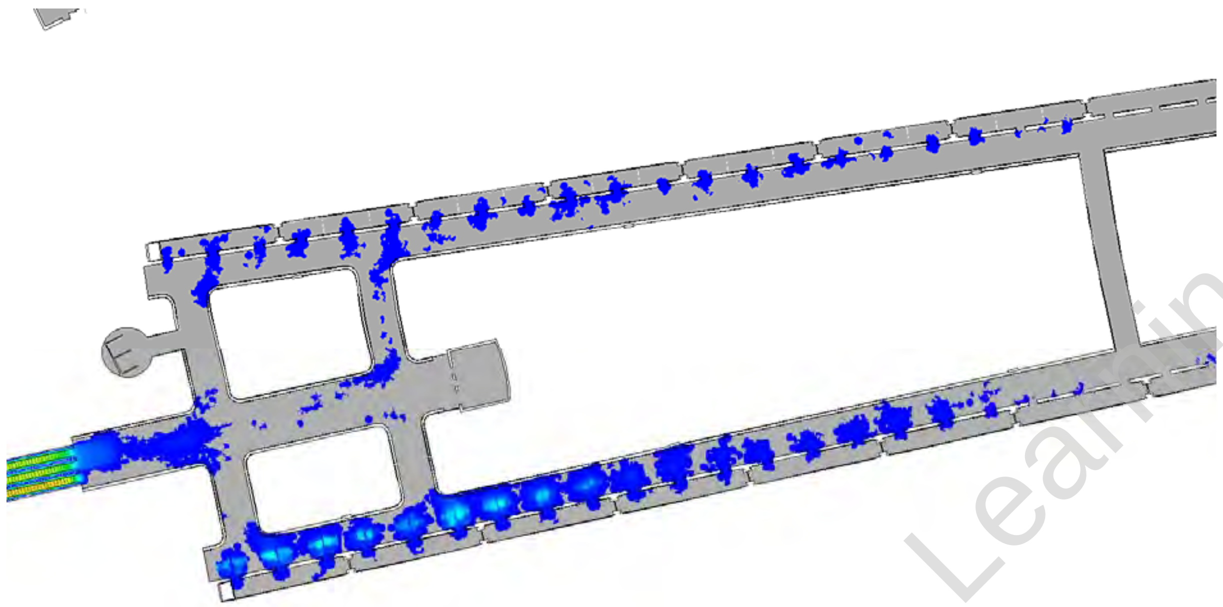
9.1.3 08h49-09h04, High Density WEST



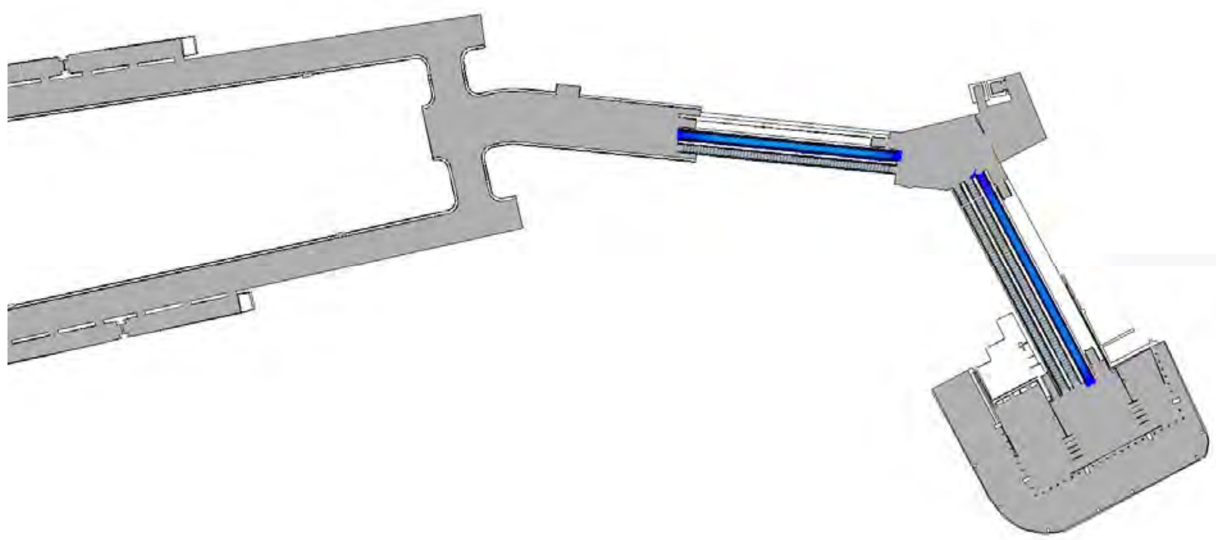
9.1.5 08h19-08h34, High Density EAST



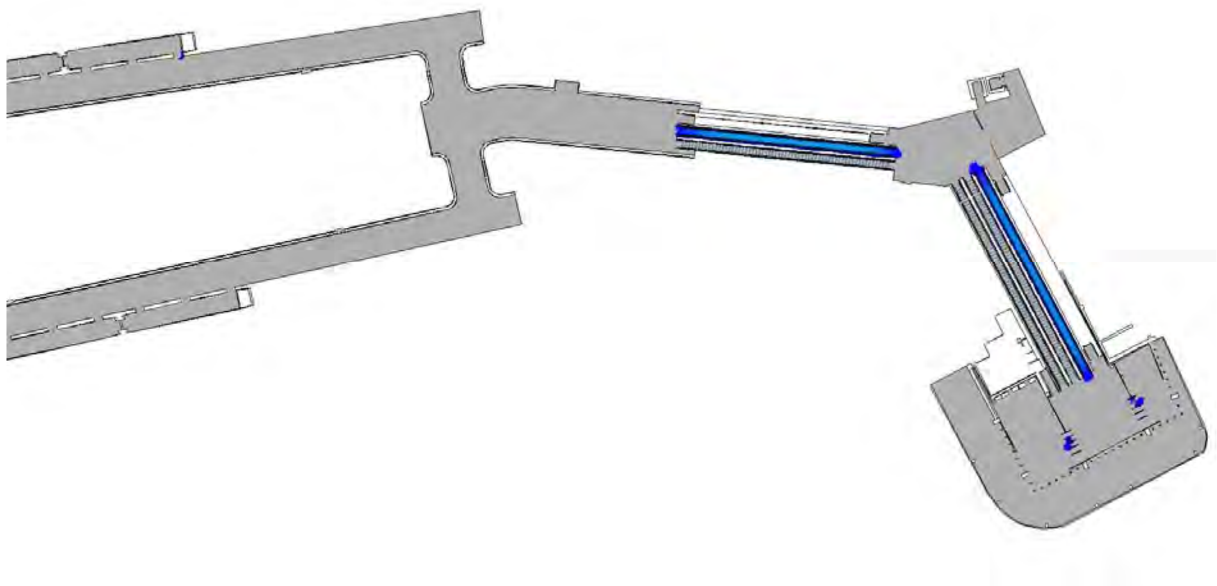
9.1.4 09h04-09h19, High Density WEST



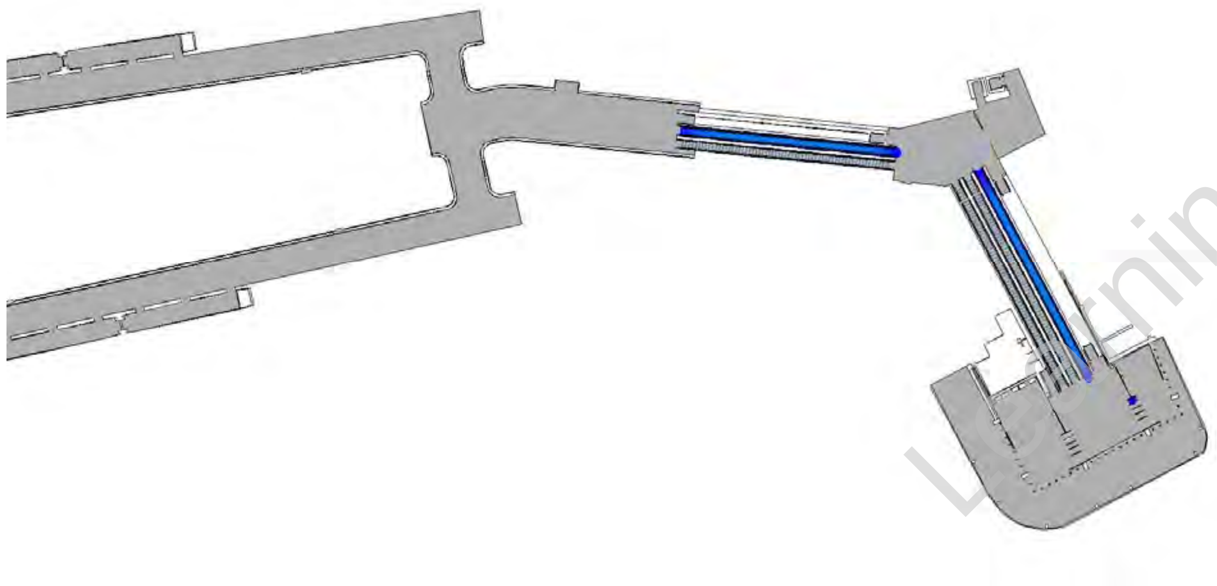
9.1.6 08h34-08h49, High Density EAST



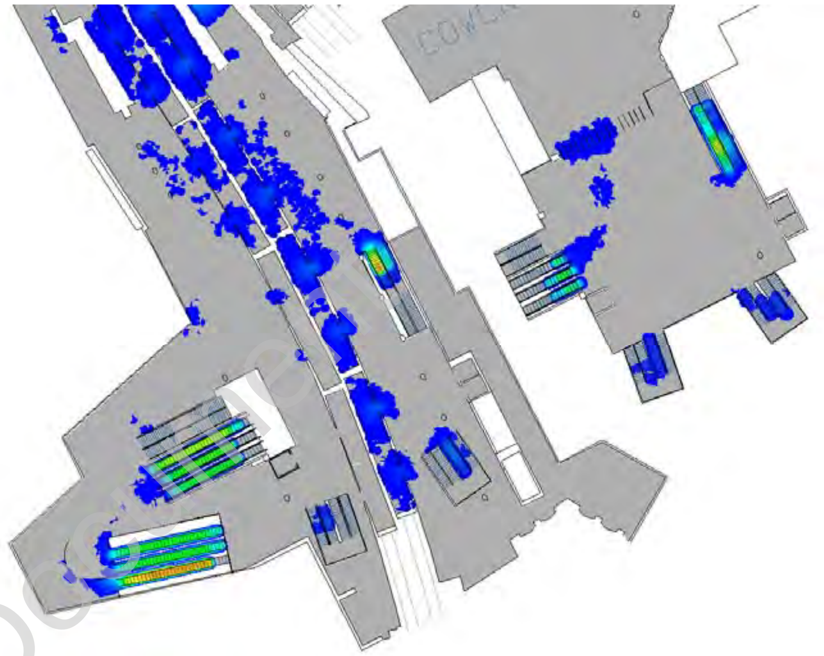
9.1.7 08h49-09h04, High Density EAST



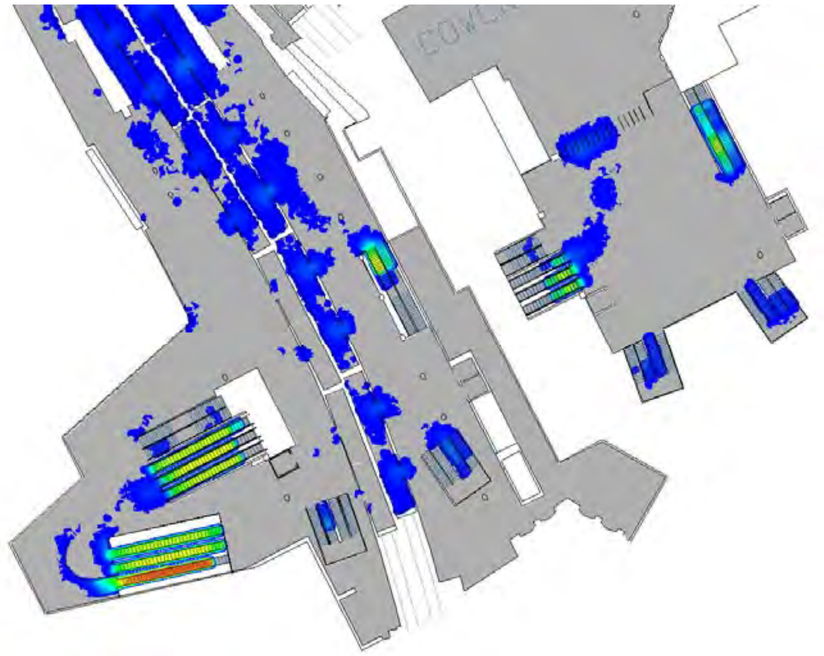
9.1.8 09h04-09h19, High Density EAST



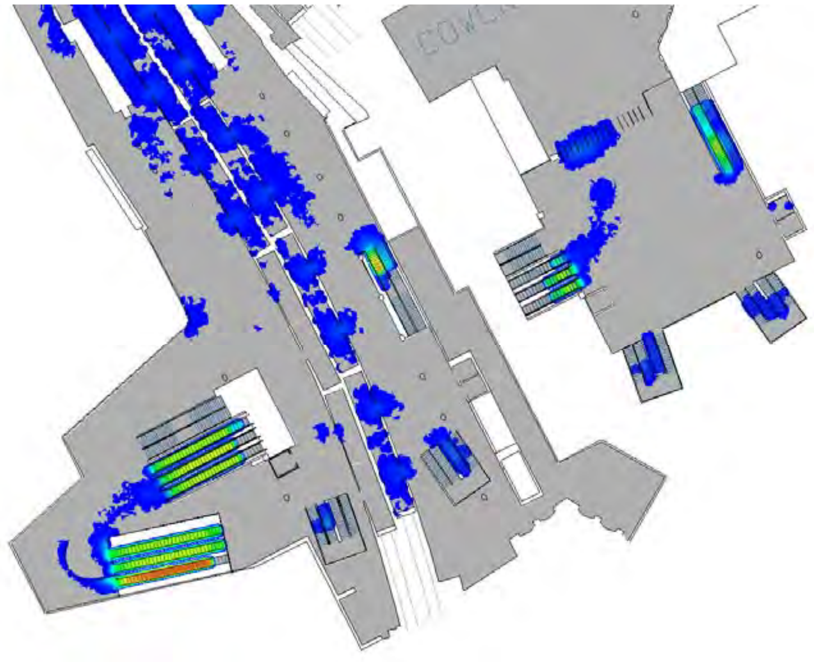
9.1.9 08h19-08h34, High Density TICKET HALL



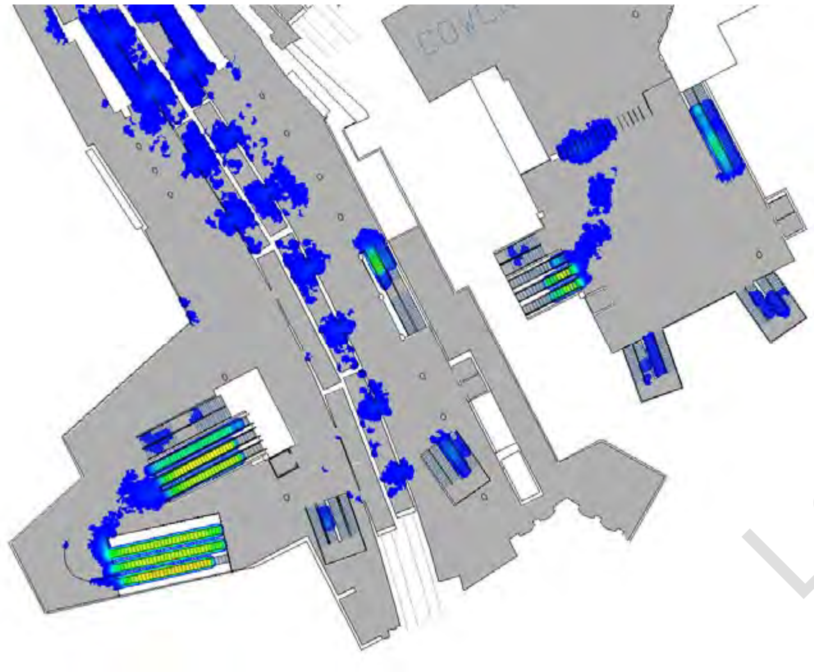
9.1.10 08h34-08h49, High Density TICKET HALL



9.1.11 08h49-09h04, High Density TICKET HALL

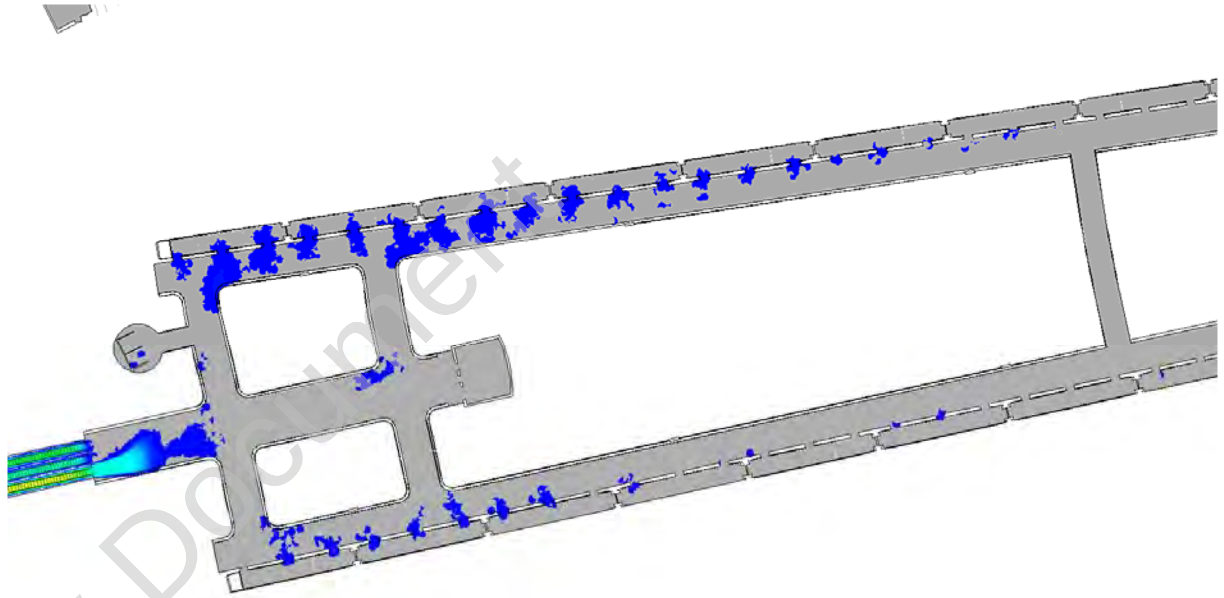


9.1.12 09h04-09h19, High Density TICKET HALL

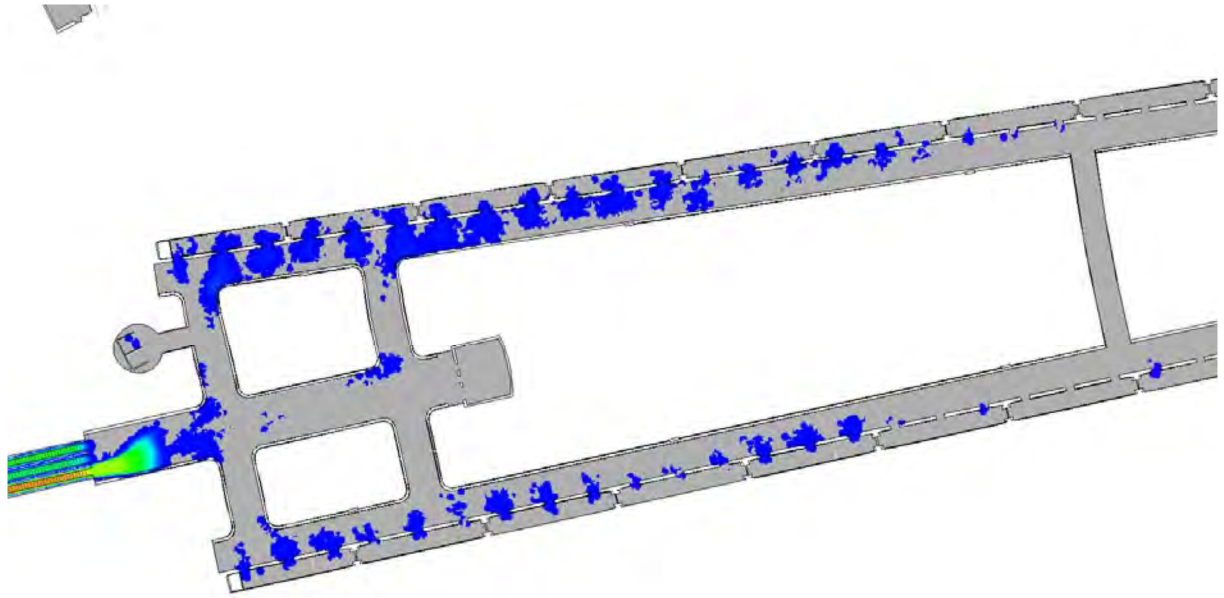


9.2 2026 PM Peak Modelling, 16h00-19h00

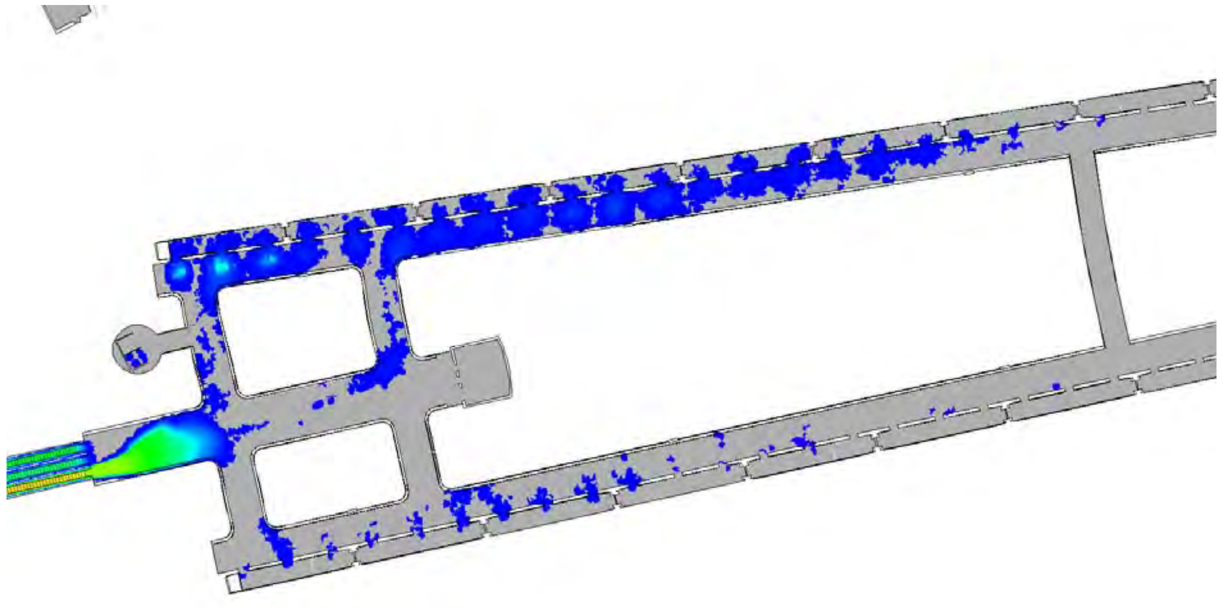
9.2.1 17h18-17h33, High Density WEST



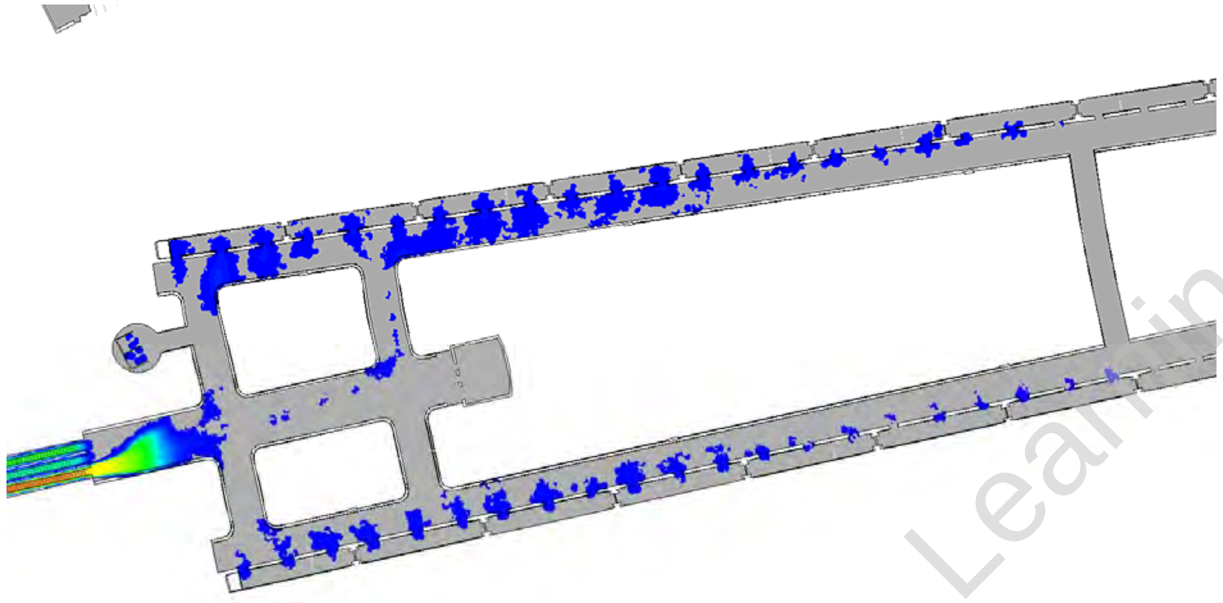
9.2.2 17h33-17h48, High Density WEST



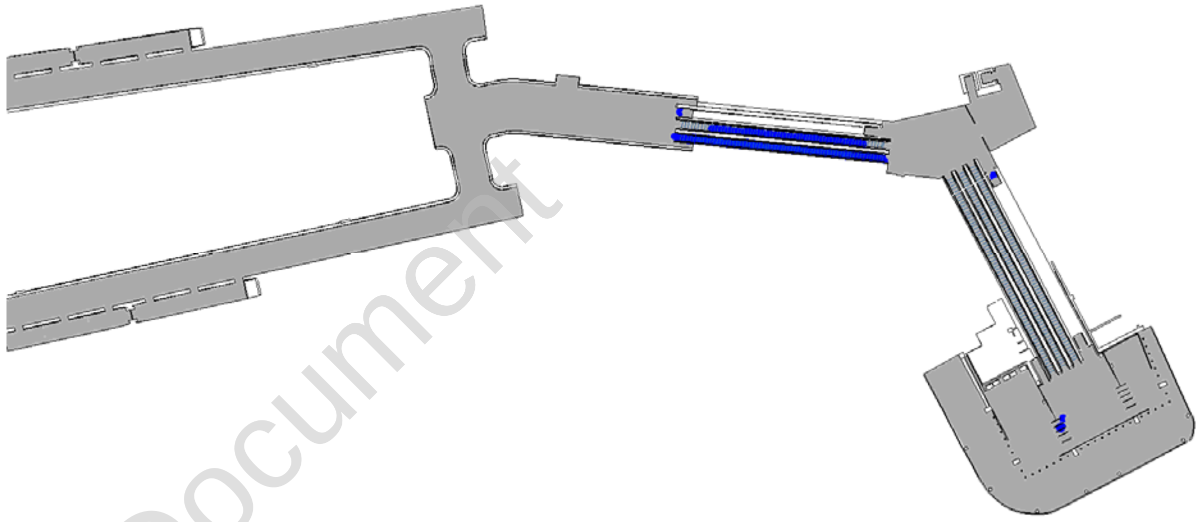
9.2.3 17h48-18h03, High Density WEST



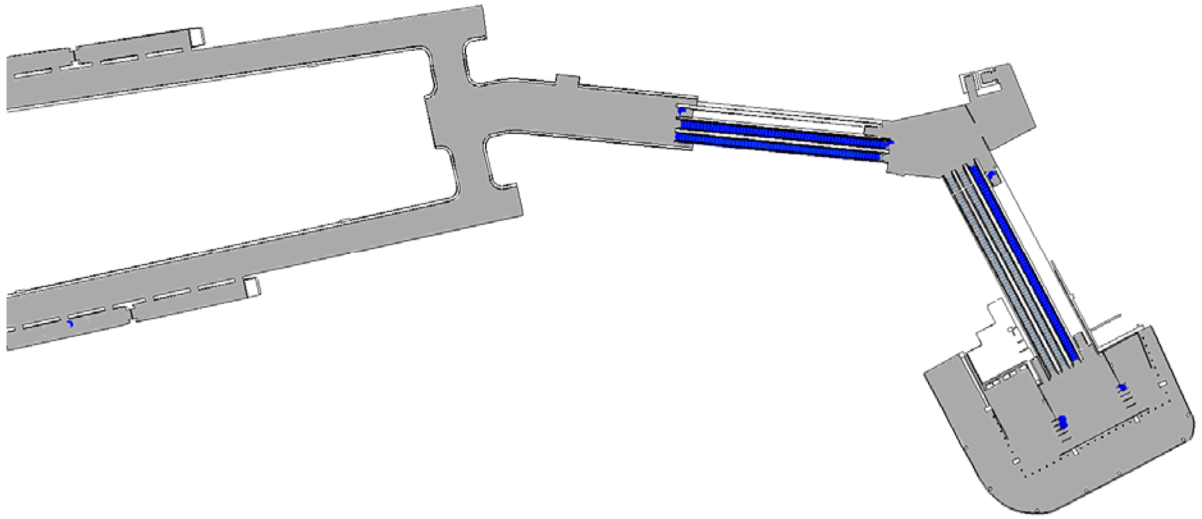
9.2.4 18h03-18h18, High Density WEST



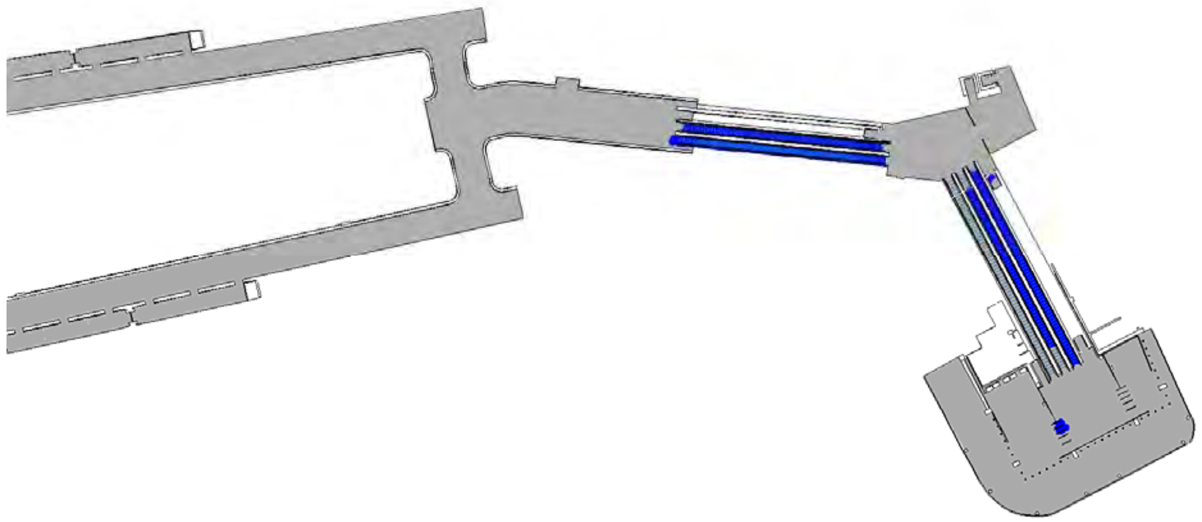
9.2.5 17h18-17h33, High Density EAST



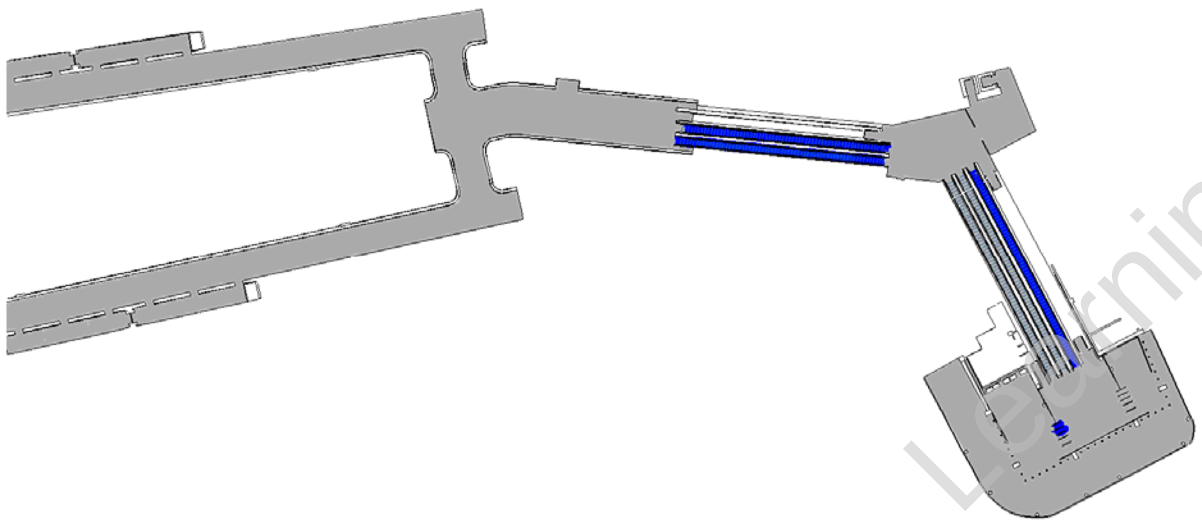
9.2.6 17h33-17h48, High Density EAST



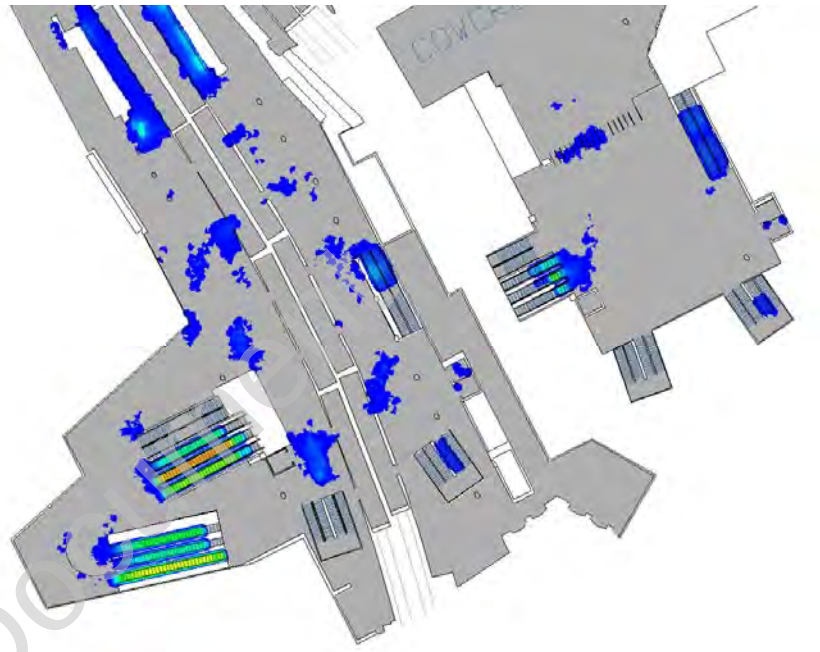
9.2.7 17h48-18h03, High Density EAST



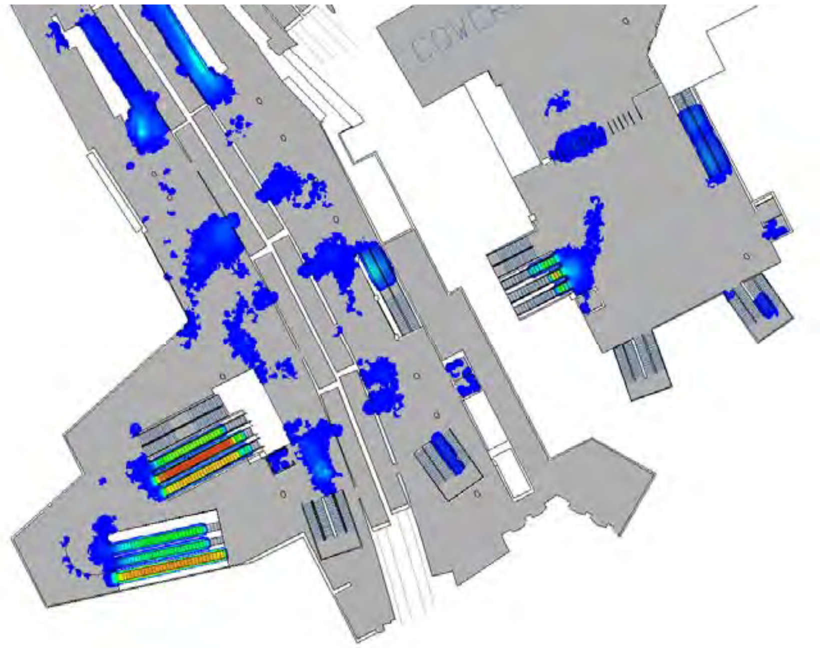
9.2.8 18h03-18h18, High Density EAST



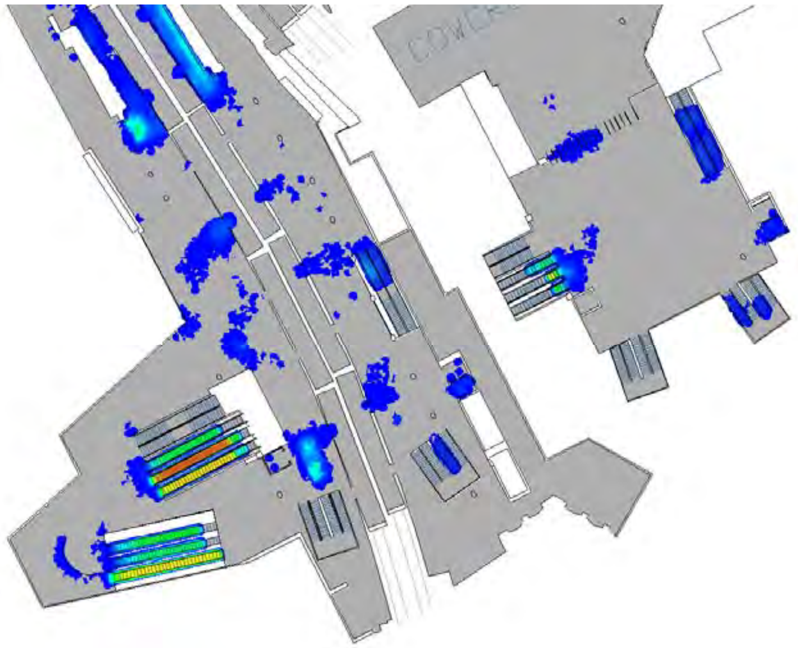
9.2.9 17h18-17h33, High Density TICKET HALL



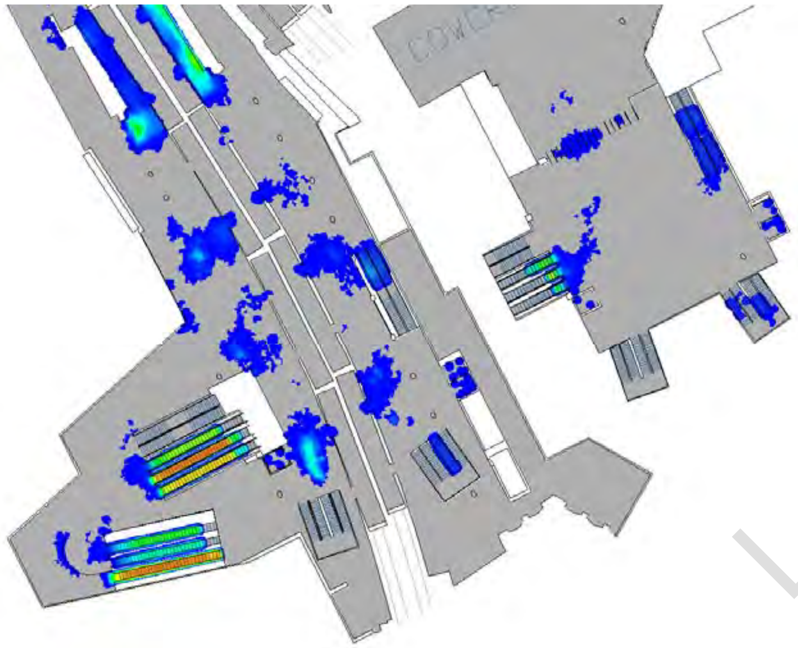
9.2.10 17h33-17h48, High Density TICKET HALL



9.2.11 17h48-18h03, High Density TICKET HALL

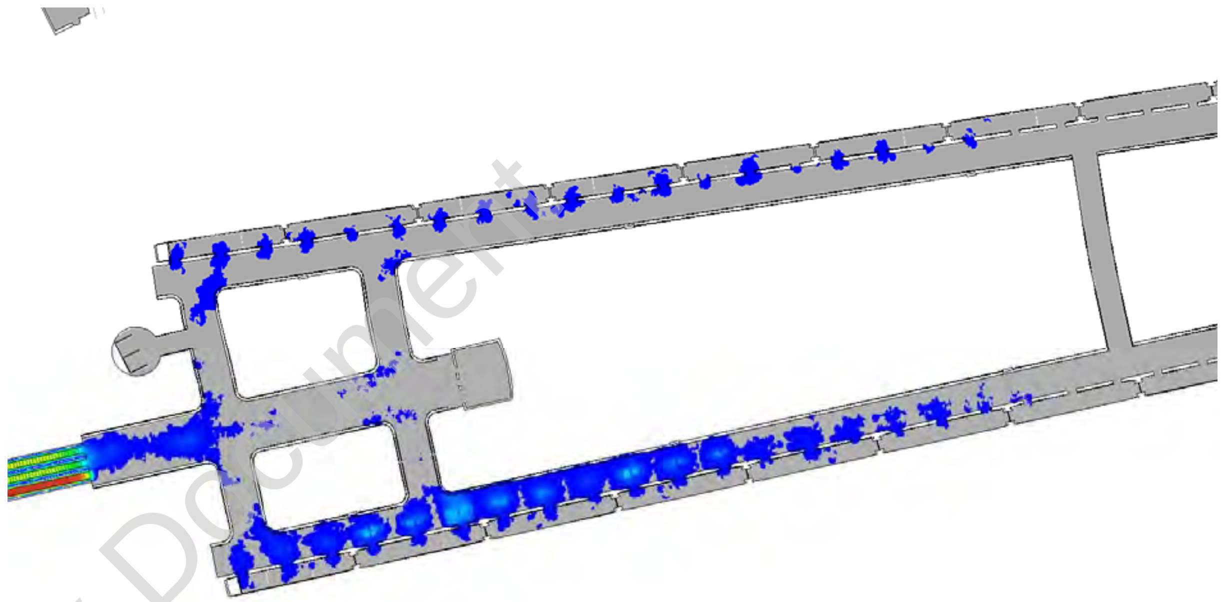


9.2.12 18h03-18h18, High Density TICKET HALL

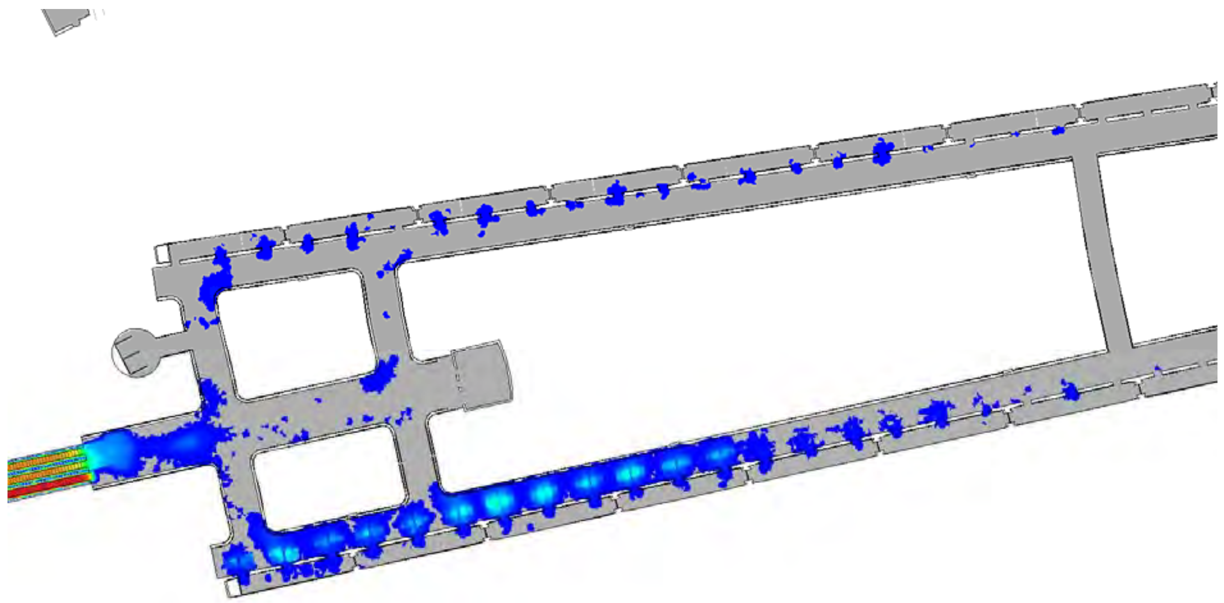


9.3 2026+28% AM Peak Modelling, 07h00-10h00

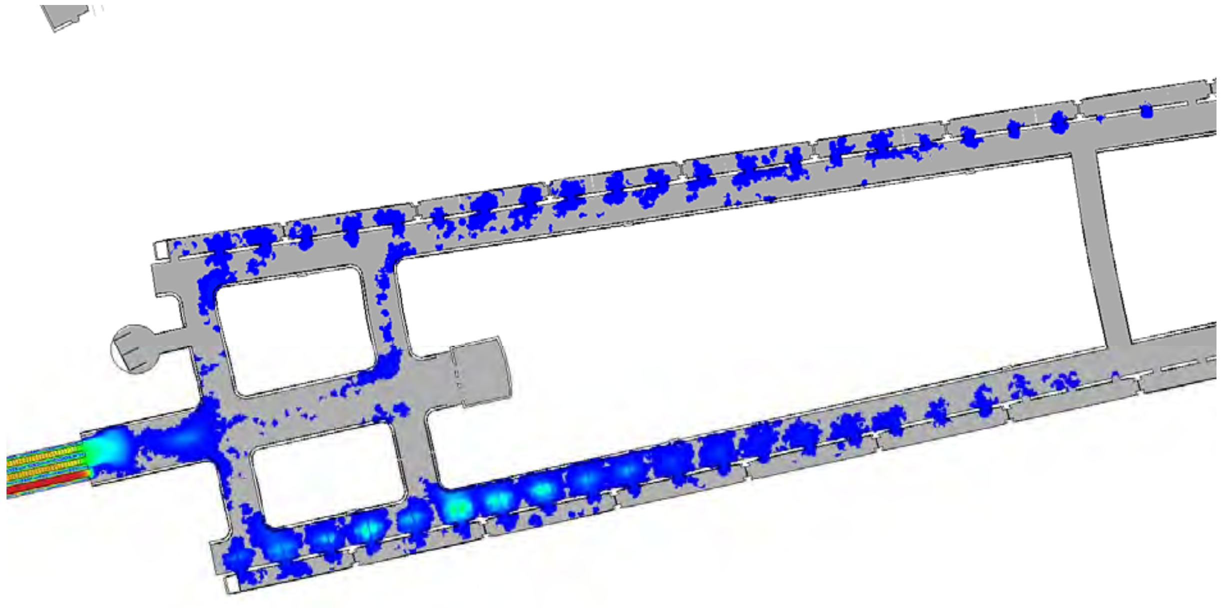
9.3.1 08h19-08h34, High Density WEST



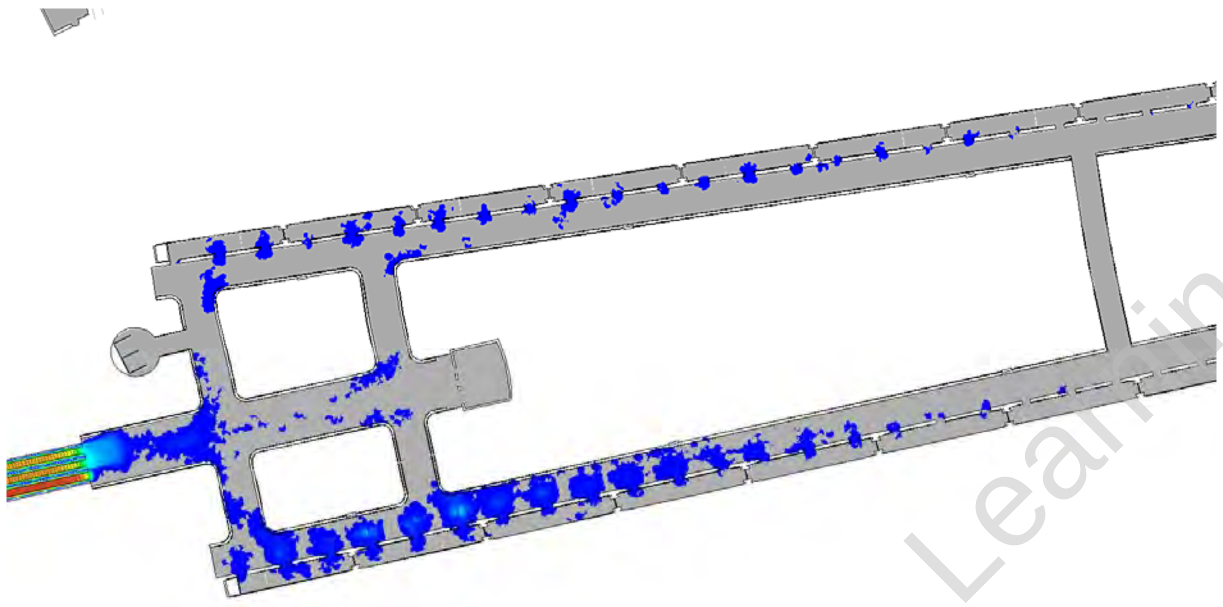
9.3.2 08h34-08h49, High Density WEST



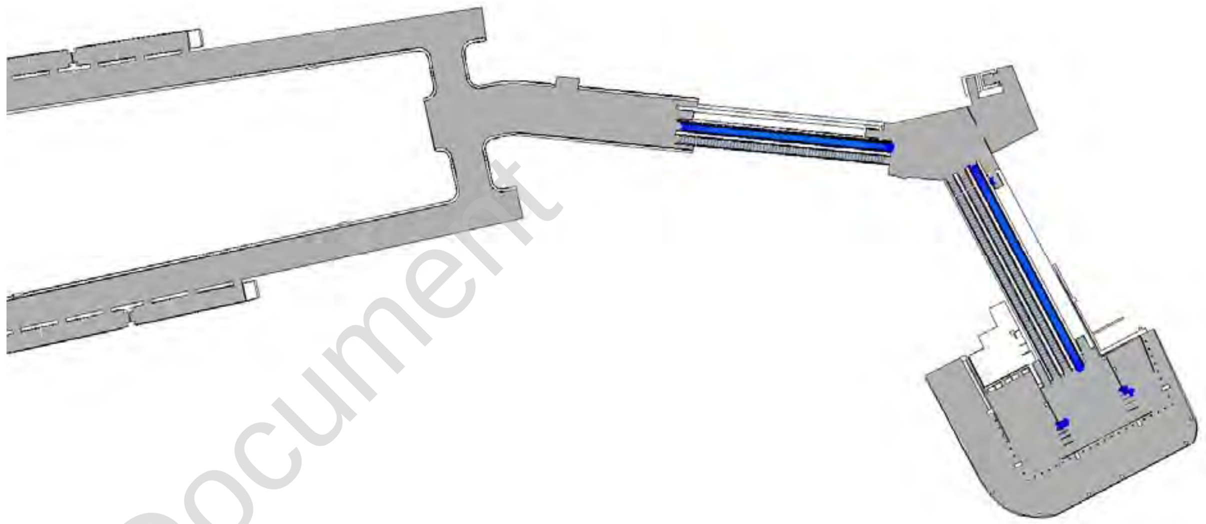
9.3.3 08h49-09h04, High Density WEST



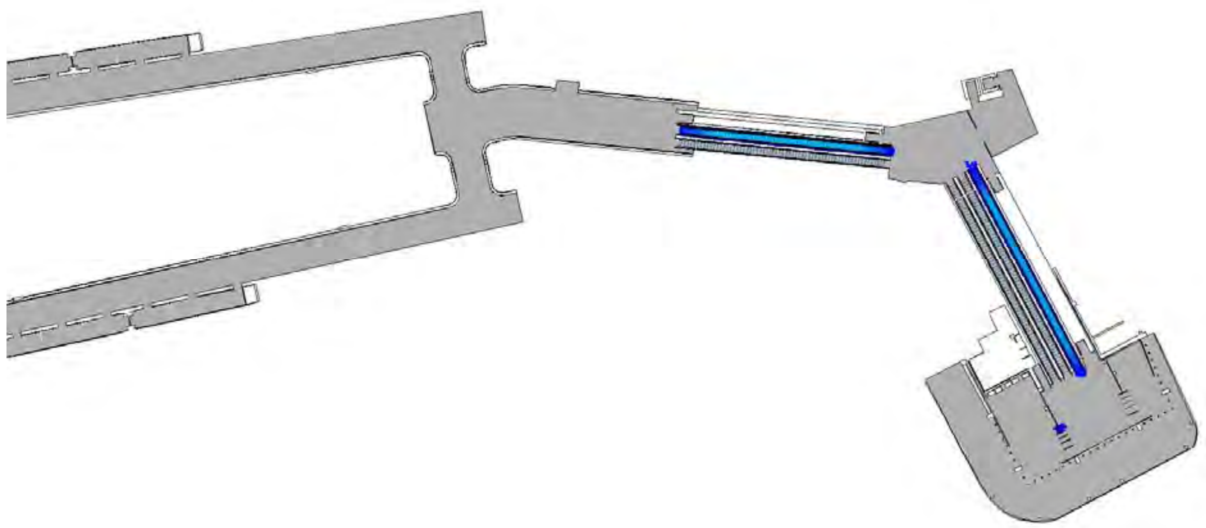
9.3.4 09h04-09h19, High Density WEST



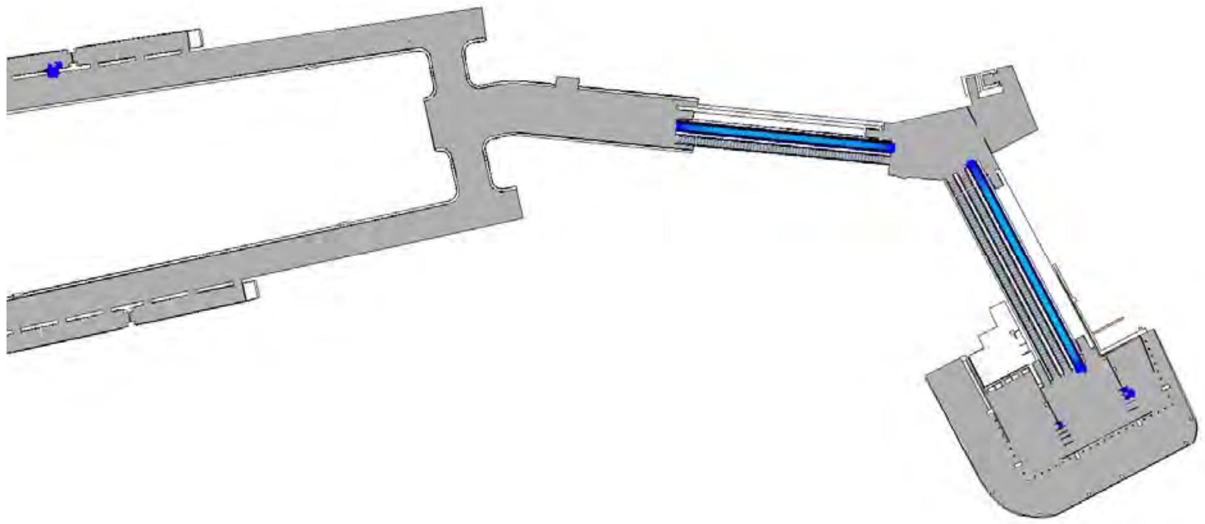
9.3.5 08h19-08h34, High Density EAST



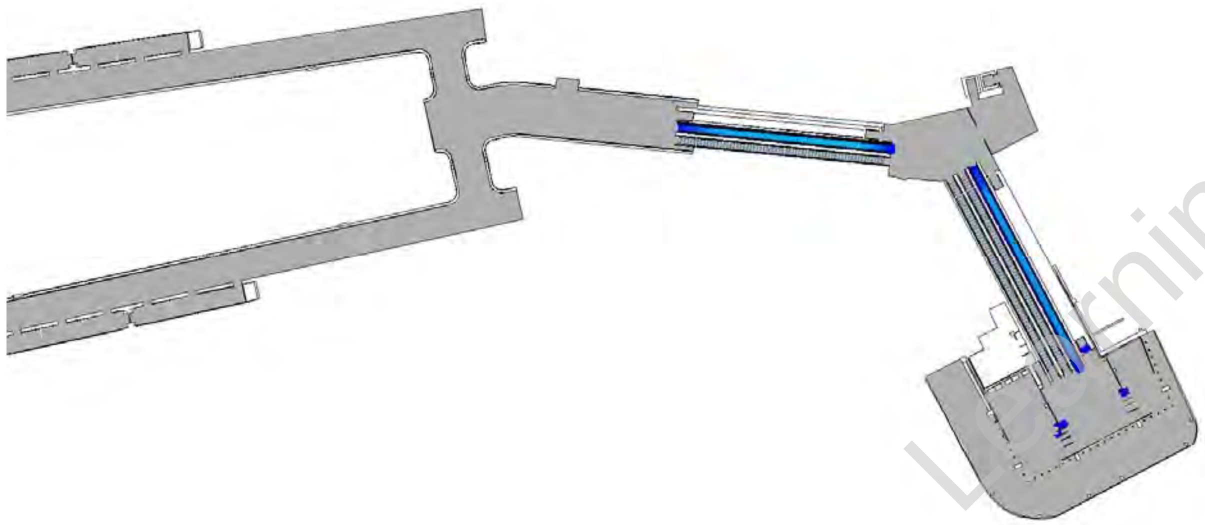
9.3.6 08h34-08h49, High Density EAST



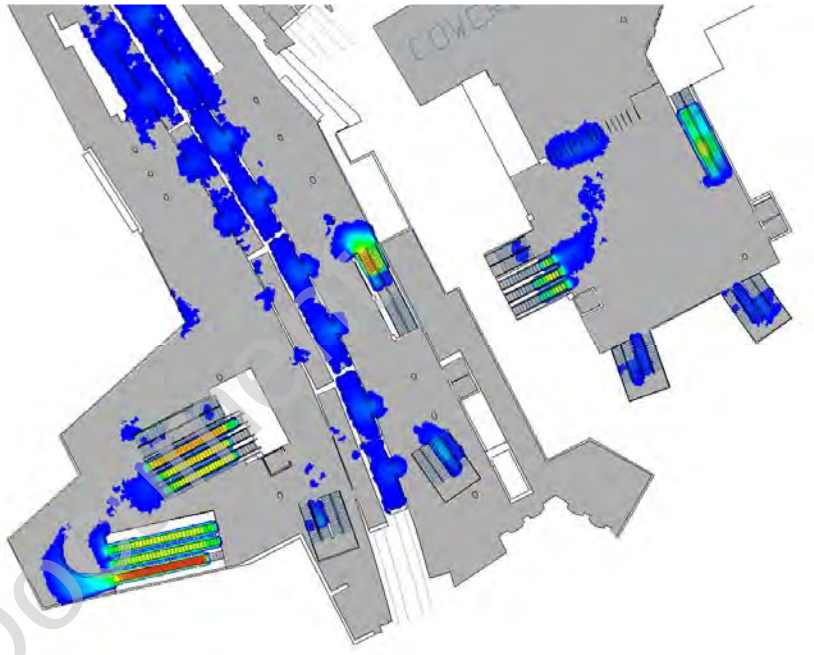
9.3.7 08h49-09h04, High Density EAST



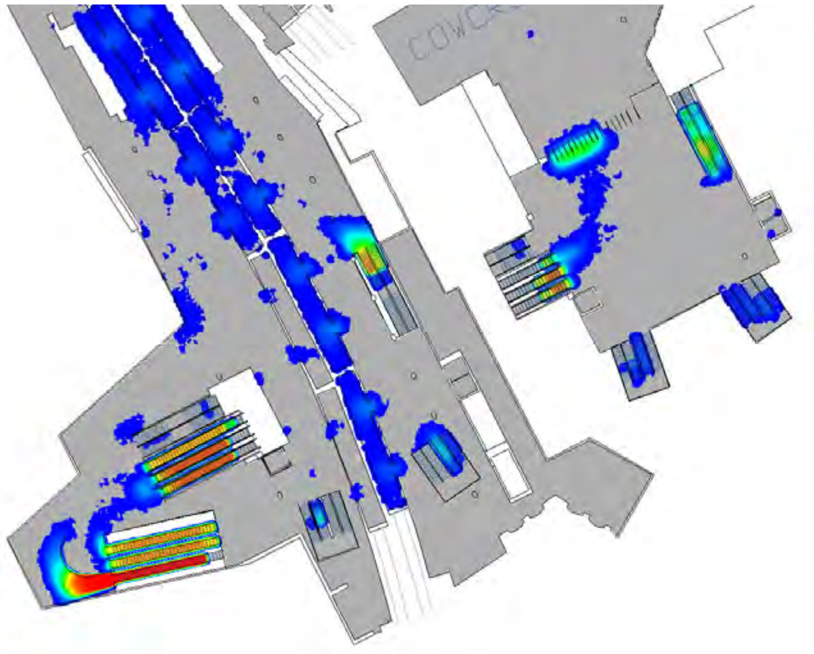
9.3.8 09h04-09h19, High Density EAST



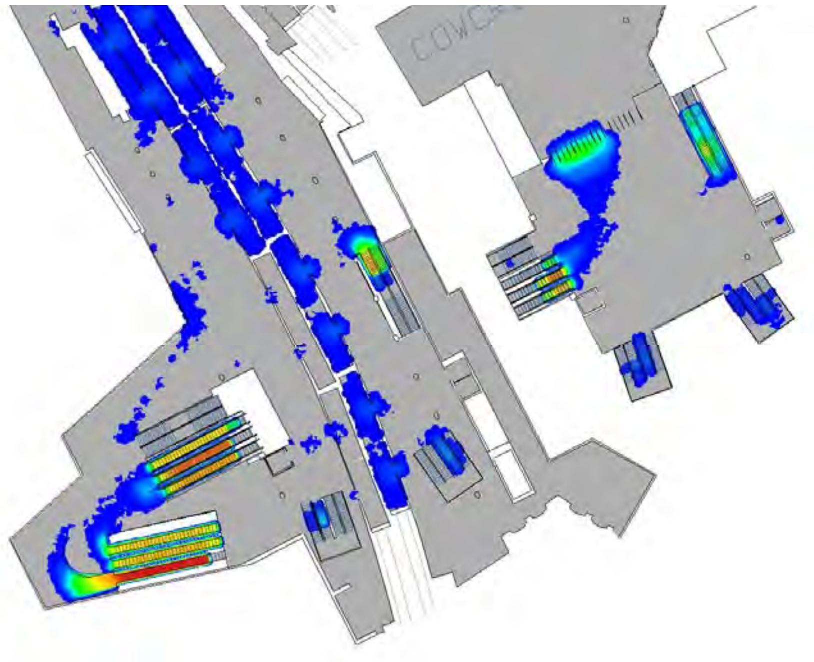
9.3.9 08h19-08h34, High Density TICKET HALL



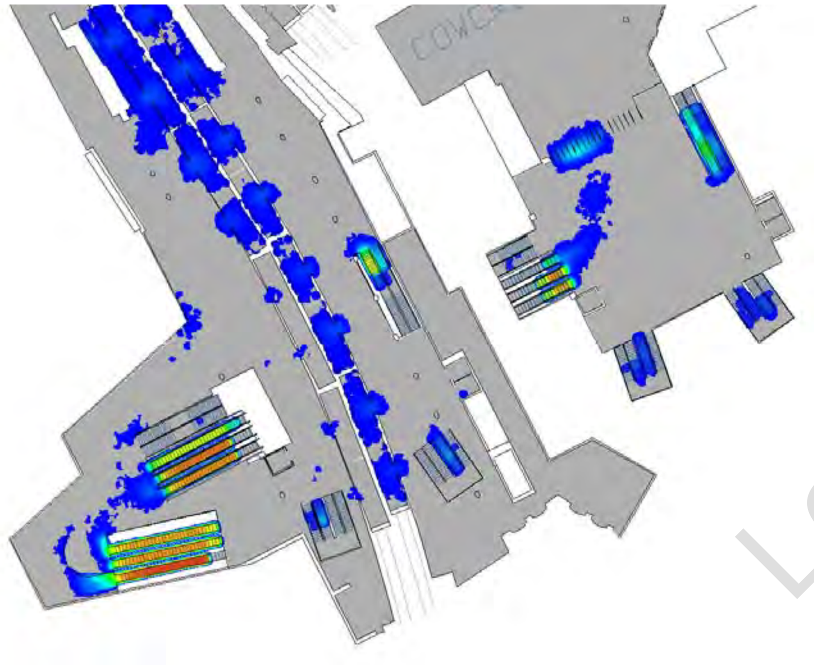
9.3.10 08h34-08h49, High Density TICKET HALL



9.3.11 08h49-09h04, High Density TICKET HALL

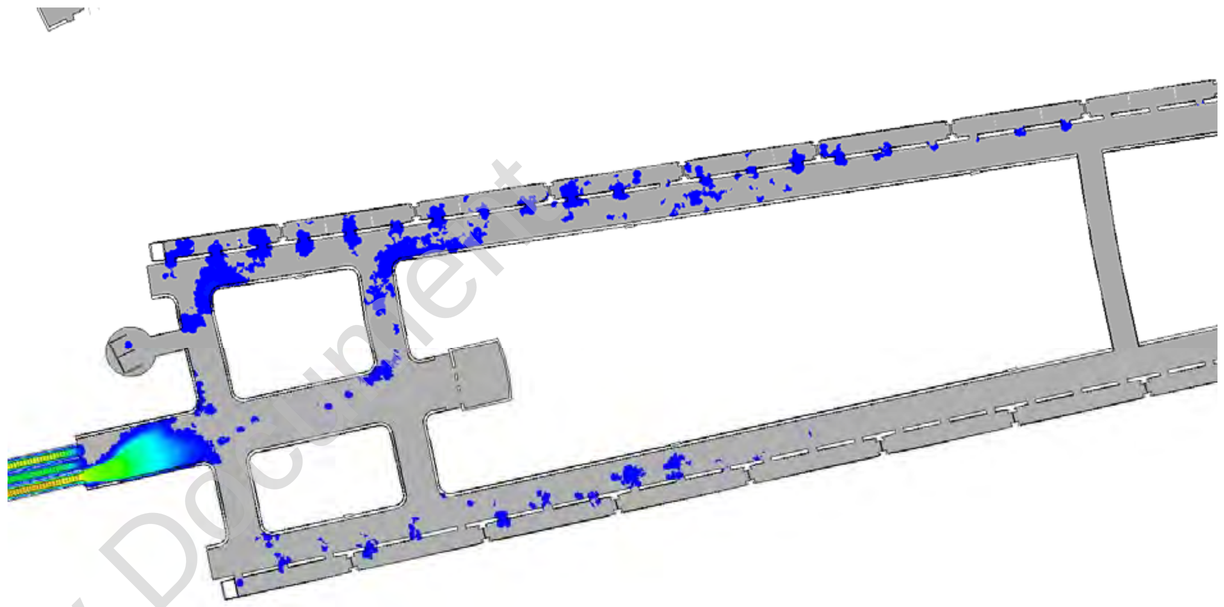


9.3.12 09h04-09h19, High Density TICKET HALL

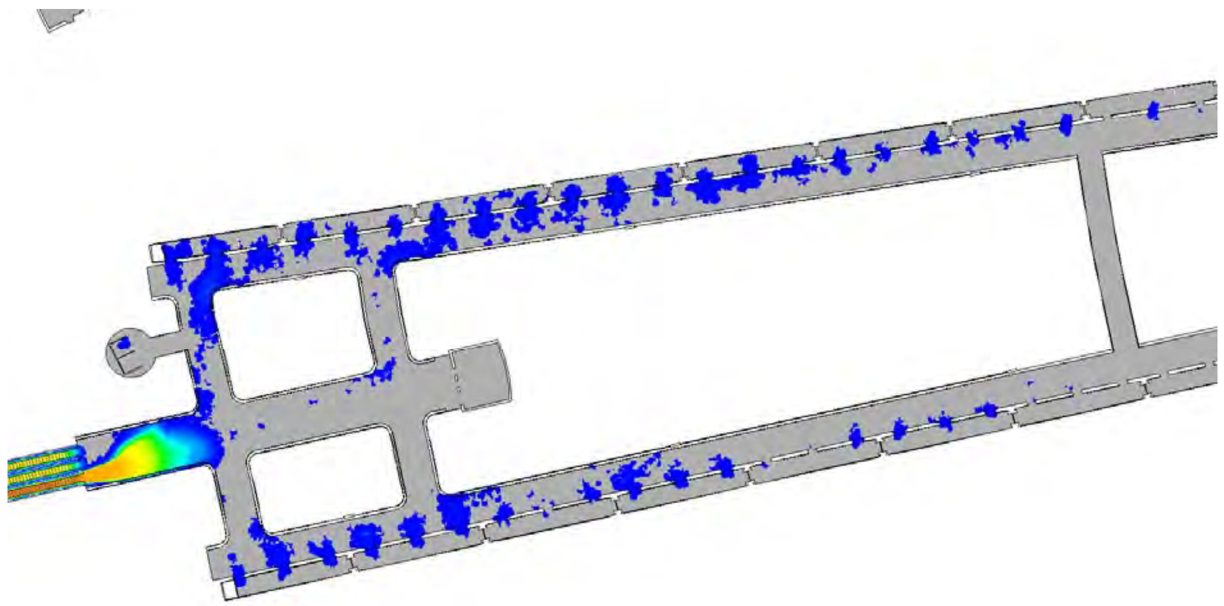


9.4 2026+28% PM Peak Modelling, 16h00-19h00

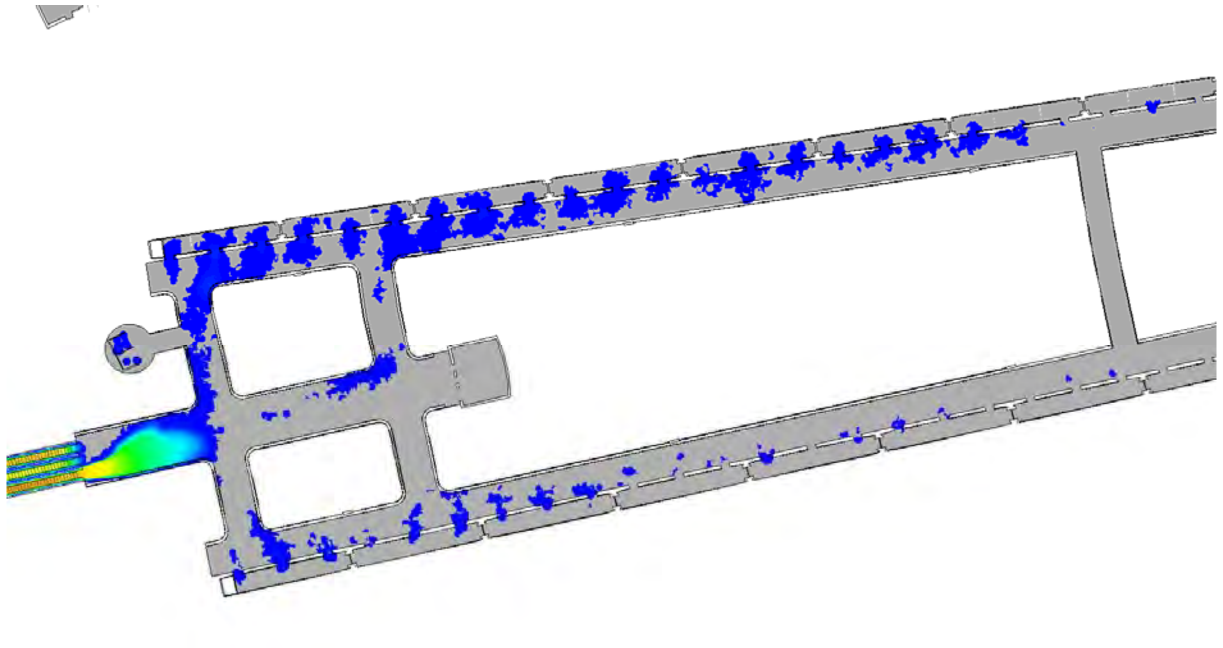
9.4.1 17h18-17h33, High Density WEST



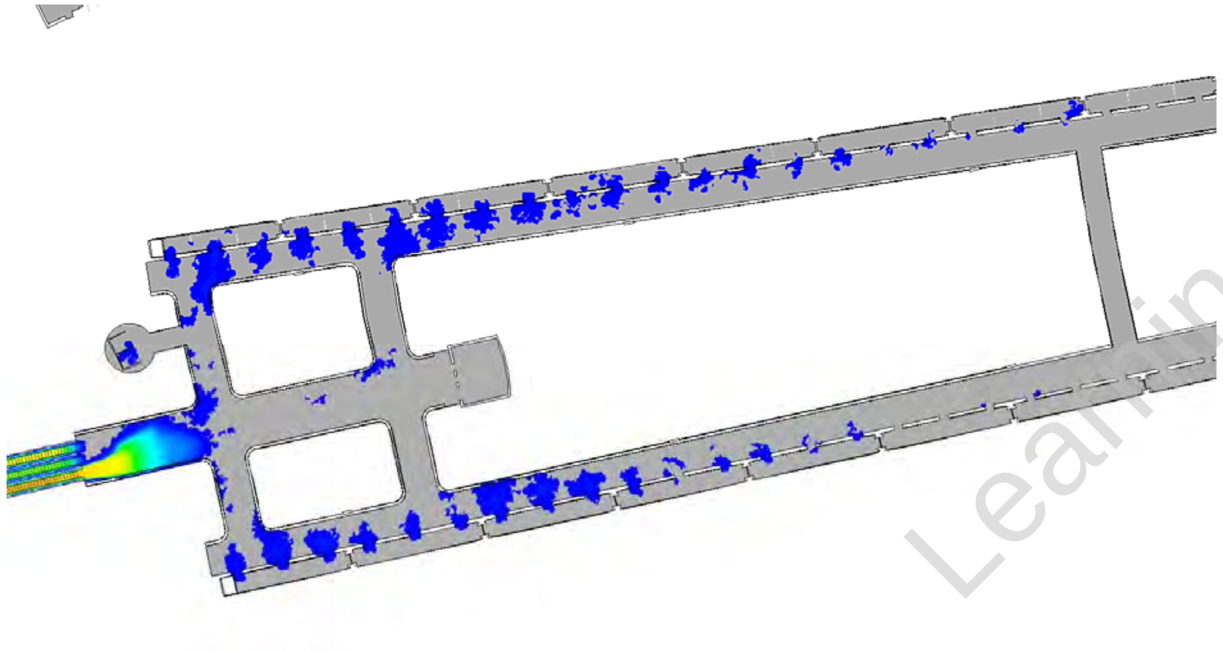
9.4.2 17h33-17h48, High Density WEST



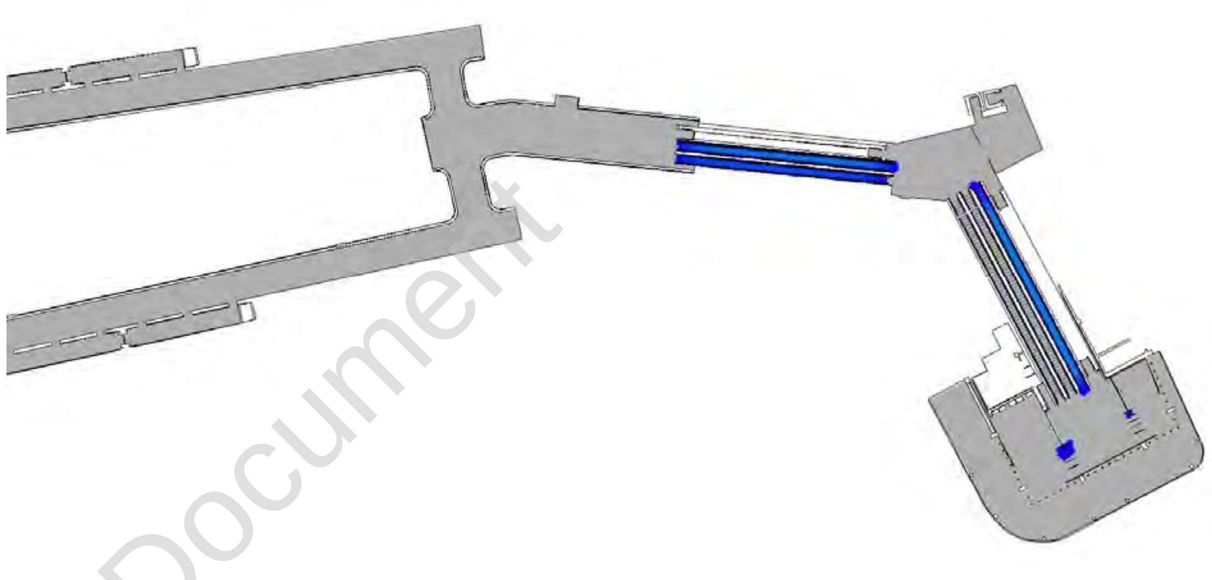
9.4.3 17h48-18h03, High Density WEST



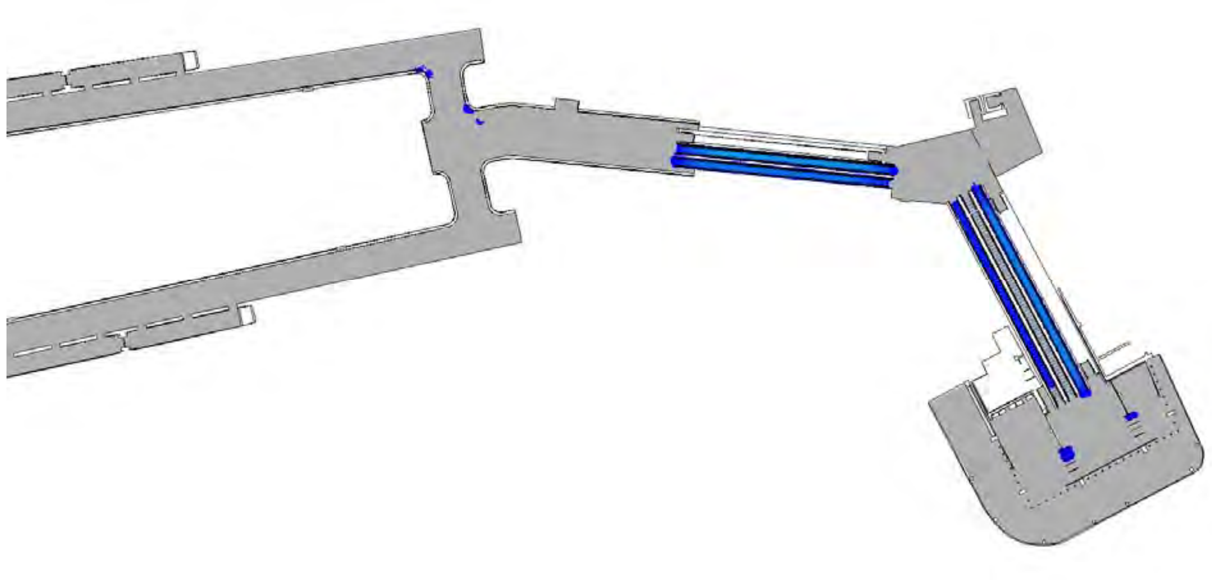
9.4.4 18h03-18h18, High Density WEST



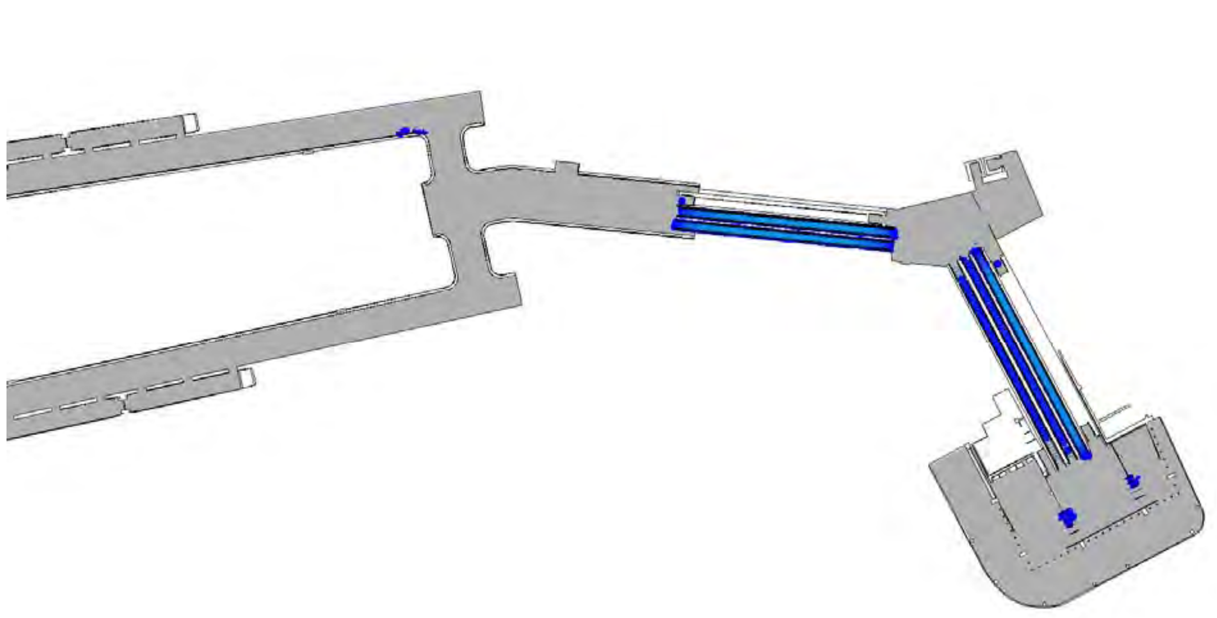
9.4.5 17h18-17h33, High Density EAST



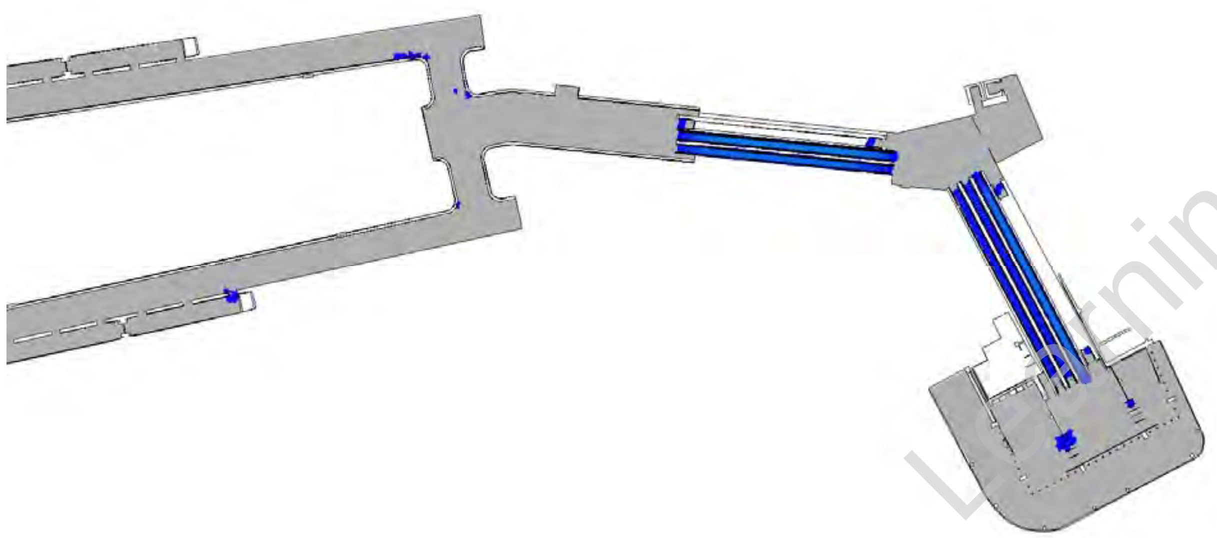
9.4.6 17h33-17h48, High Density EAST



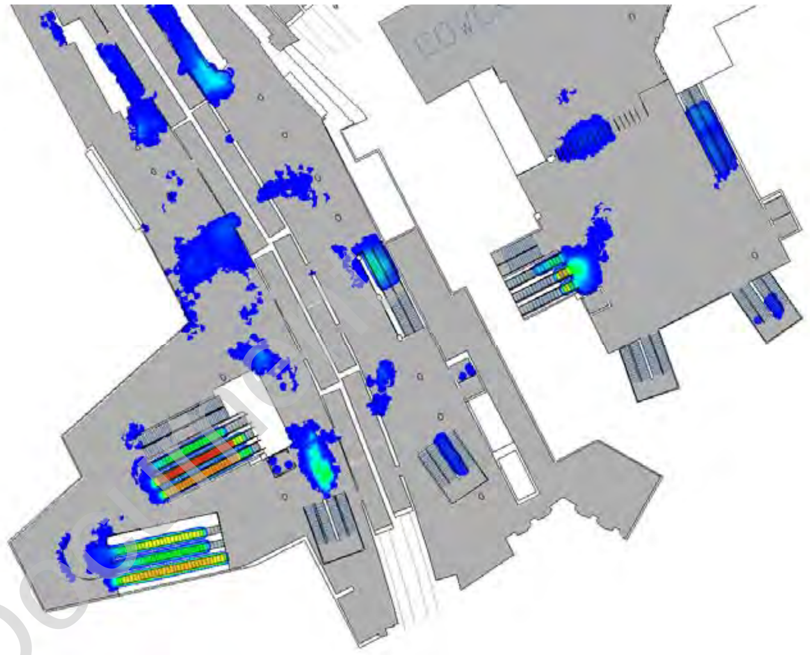
9.4.7 17h48-18h03, High Density EAST



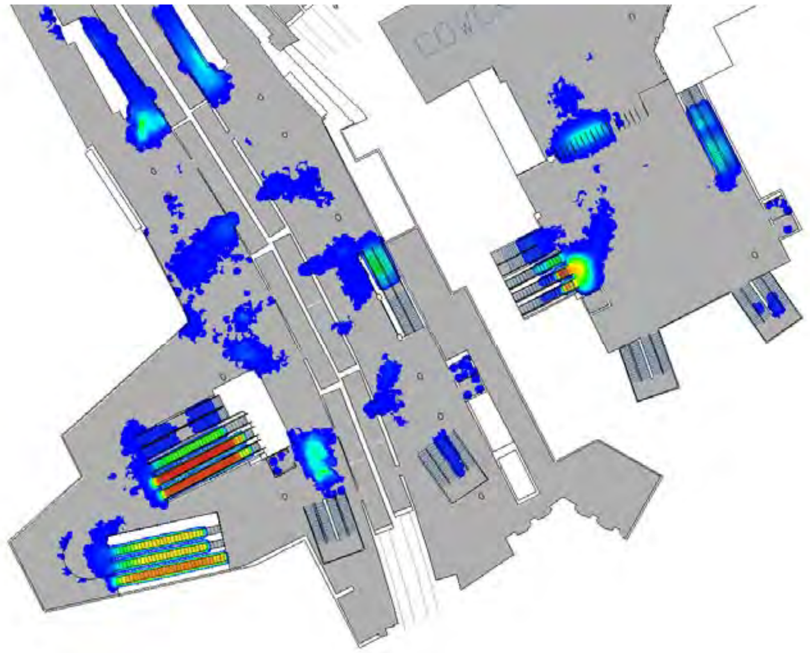
9.4.8 18h03-18h18, High Density EAST



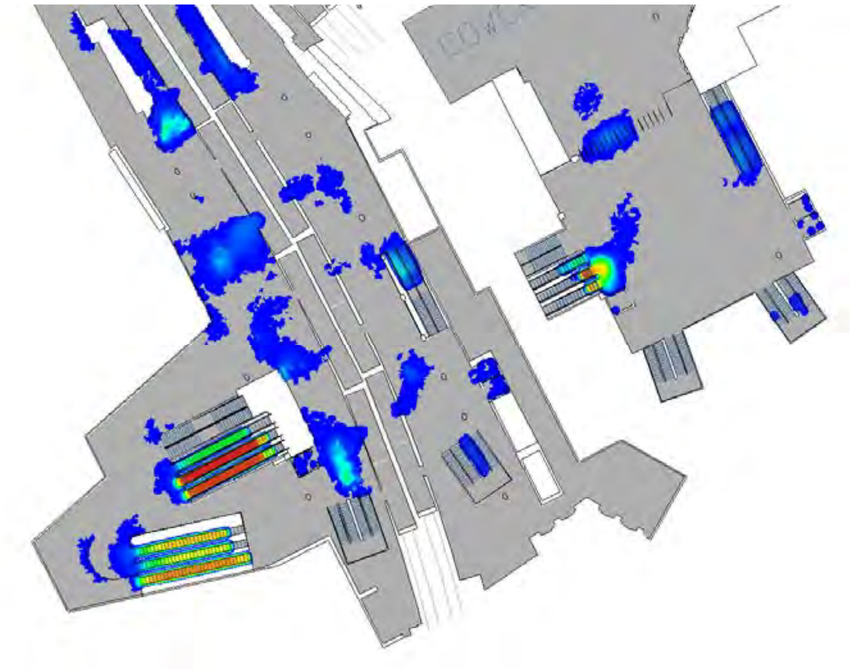
9.4.9 17h18-17h33, High Density TICKET HALL



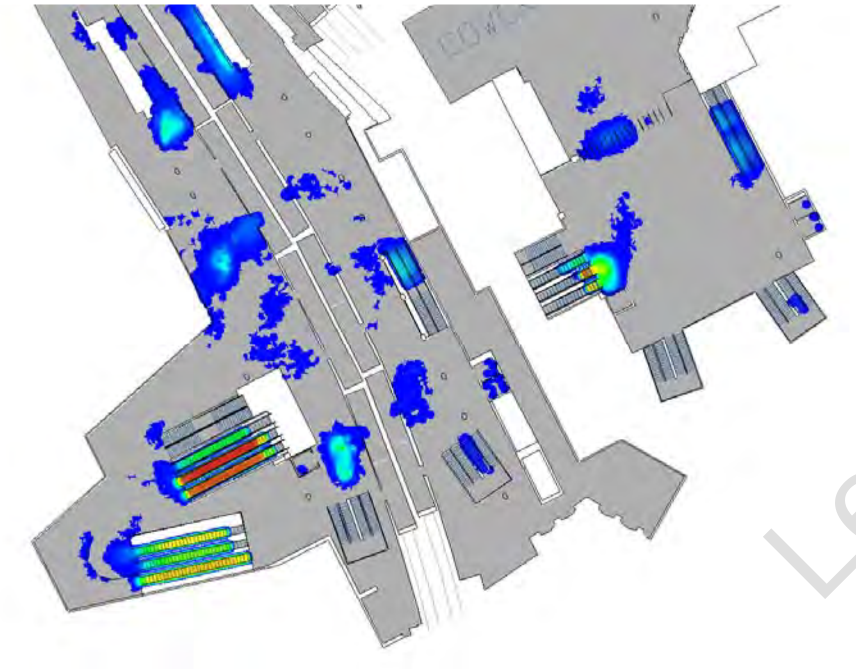
9.4.10 17h33-17h48, High Density TICKET HALL



9.4.11 17h48-18h03, High Density TICKET HALL



9.4.12 18h03-18h18, High Density TICKET HALL

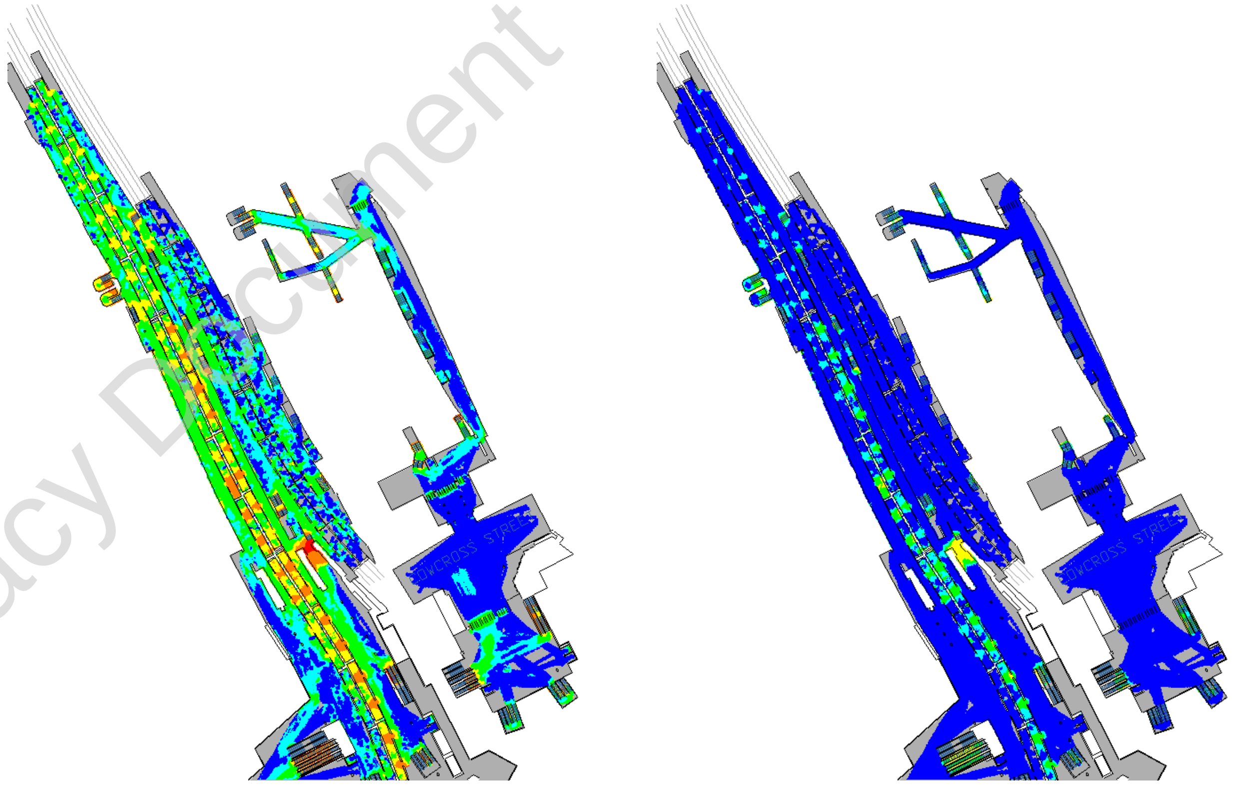


10 Appendix B – London Underground and Thameslink

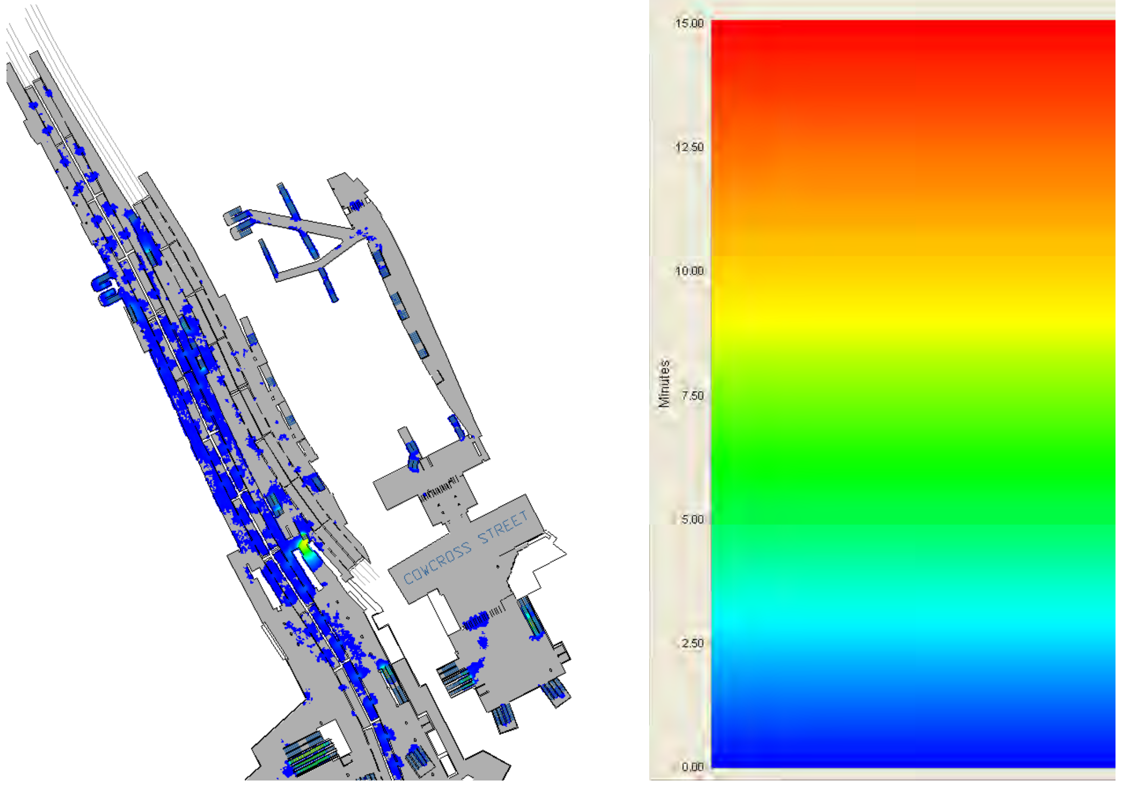
Cumulative mean density maps are shown for the wider station in Appendix B. These are shown for both the 2026 and 2026+28% scenarios where applicable (i.e. AM 2026+28% are derived from the single completed model run, whilst PM peak fails to run at +28% making results derived from this modelling unrepresentative). Maps are shown for Walkways and Queuing Levels of Service, and for Cumulative High Density (duration where <0.8sqm per person is exceeded, using the threshold colour range shown).

10.1 2026 AM Peak Modelling, 07h00-10h00

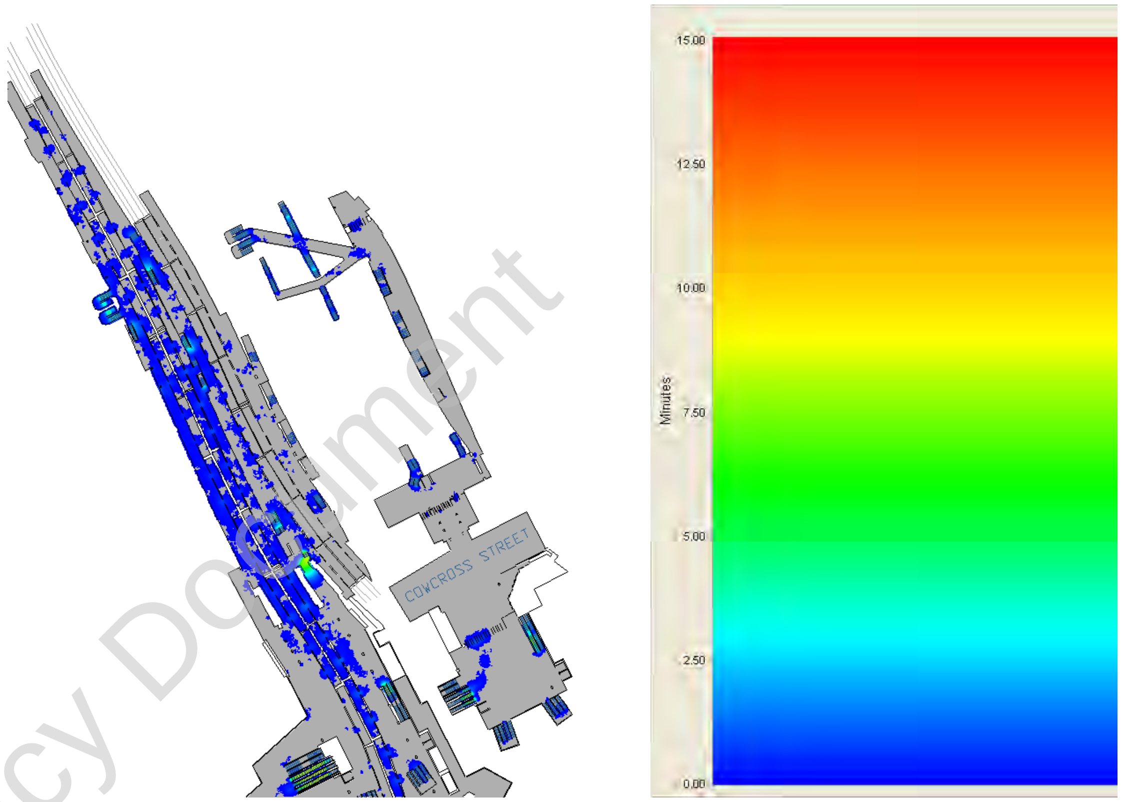
10.1.1 08h19-08h34, Walkways / Queuing



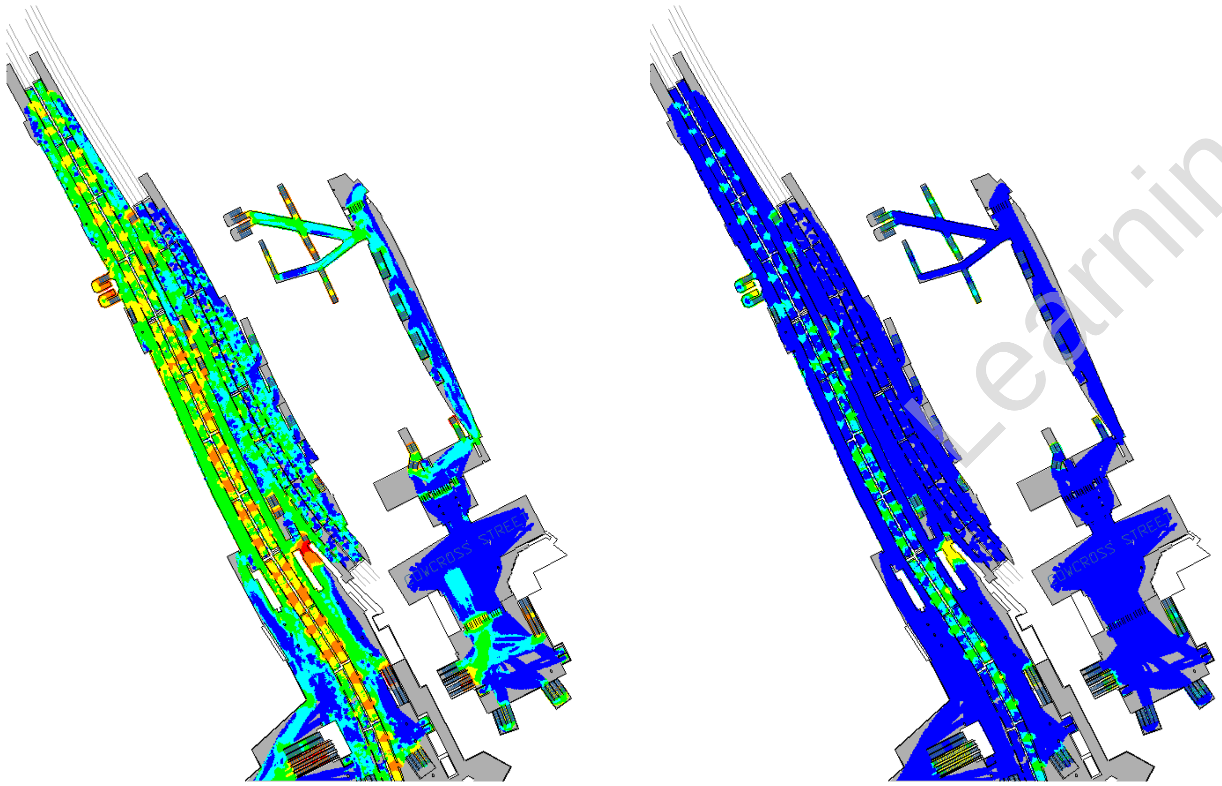
10.1.2 08h19-08h34, High Density, <0.8sqm



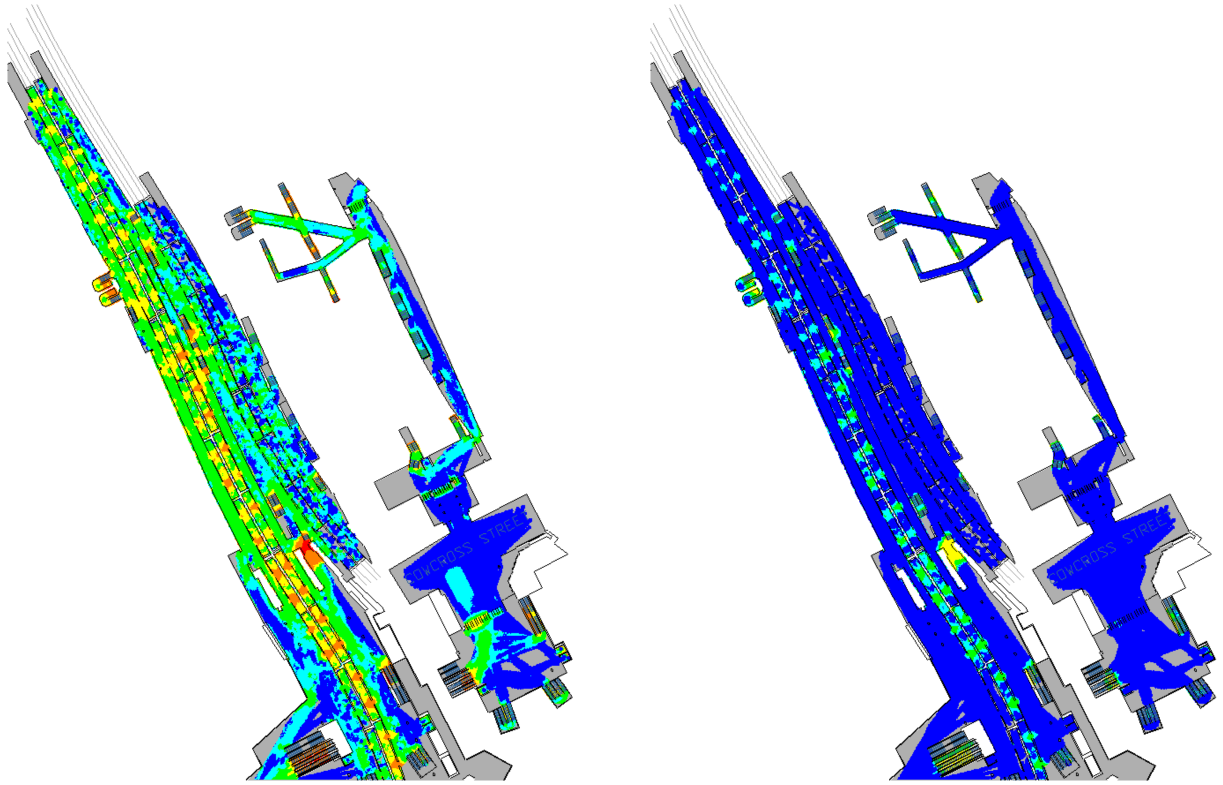
10.1.4 08h19-08h34, High Density, <0.8sqm



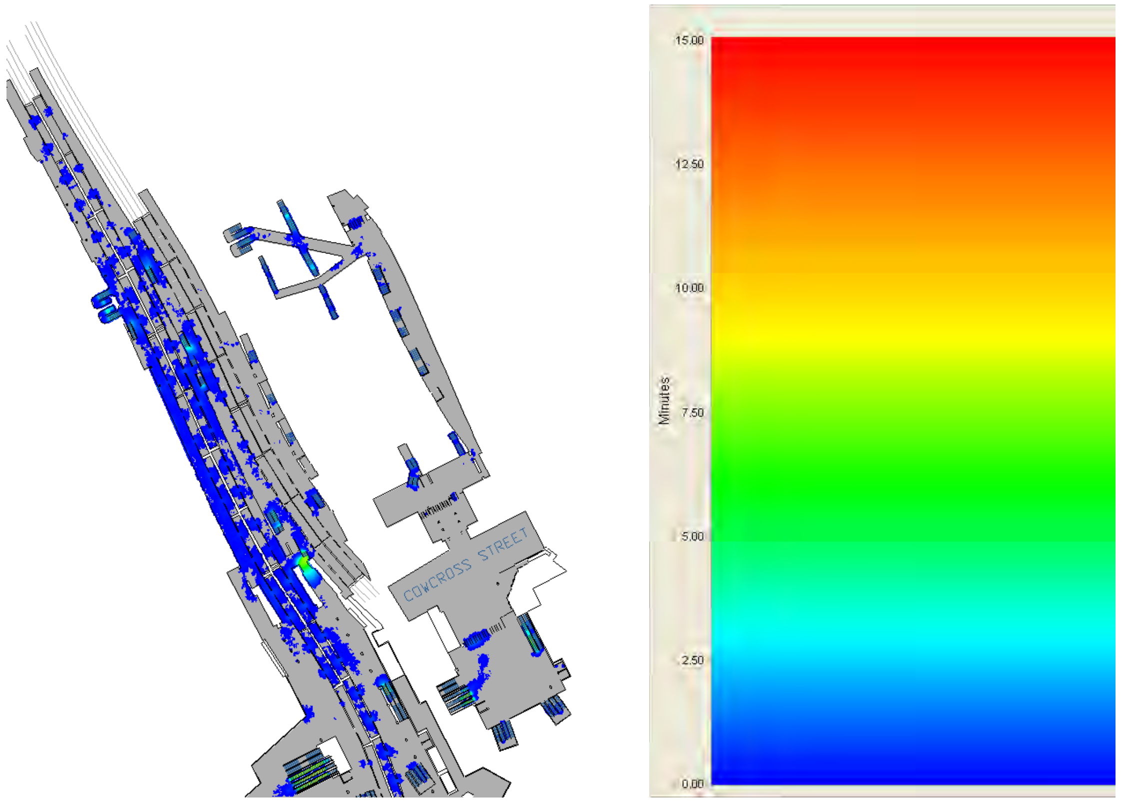
10.1.3 08h34-08h49, Walkways / Queuing



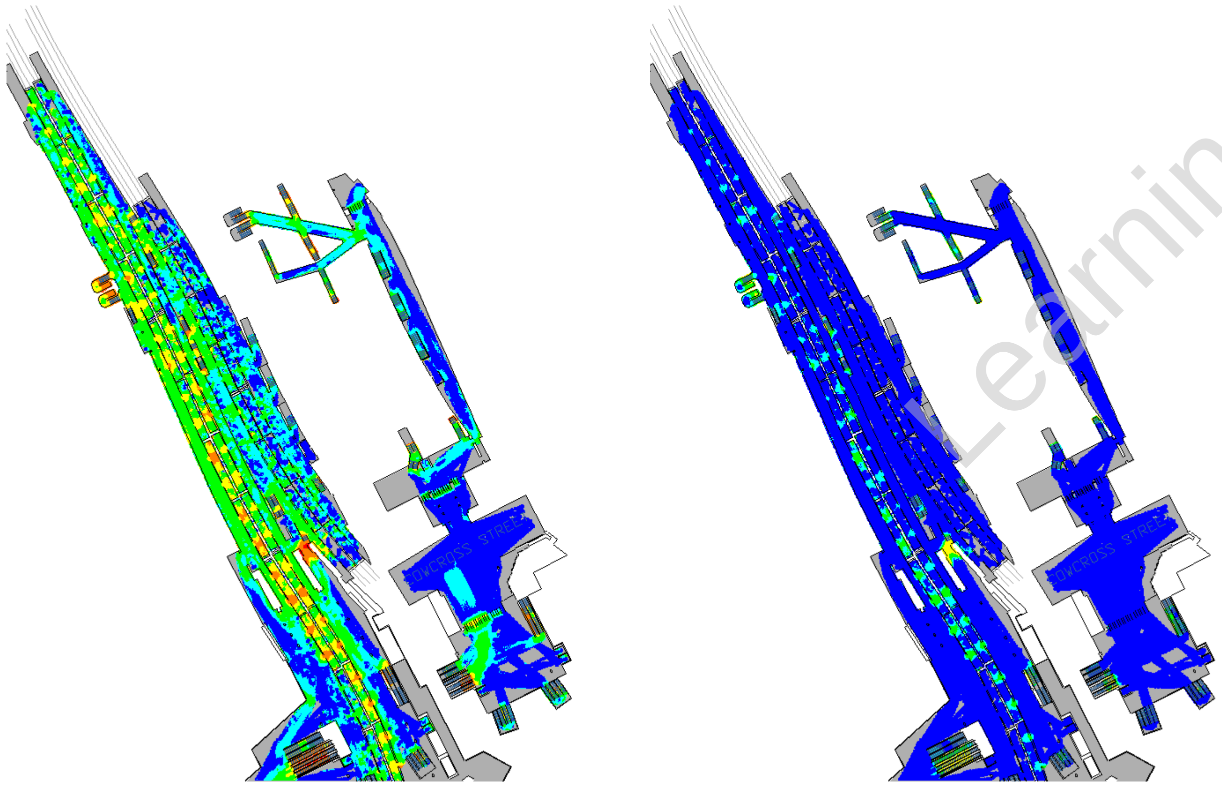
10.1.5 08h49-09h04, Walkways / Queuing



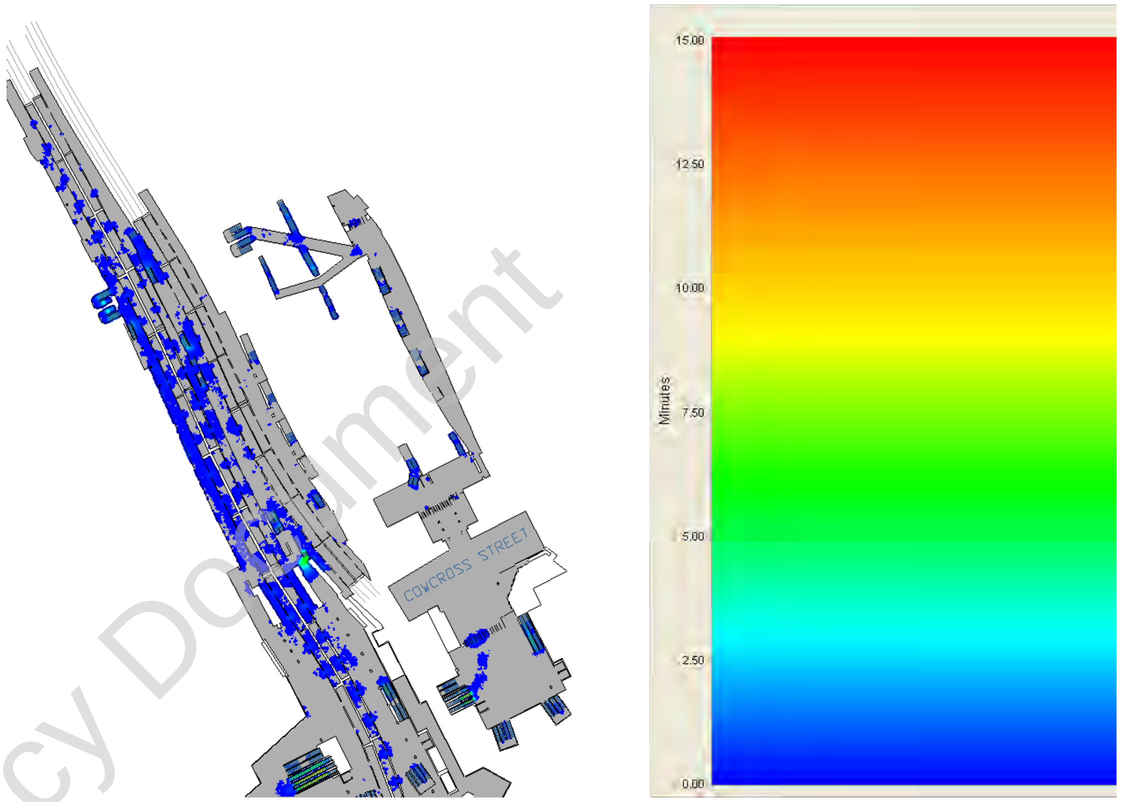
10.1.6 08h49-09h04, High Density, <0.8sqm



10.1.7 09h04-09h19, Walkways / Queuing



10.1.8 09h04-09h19, High Density, <0.8sqm



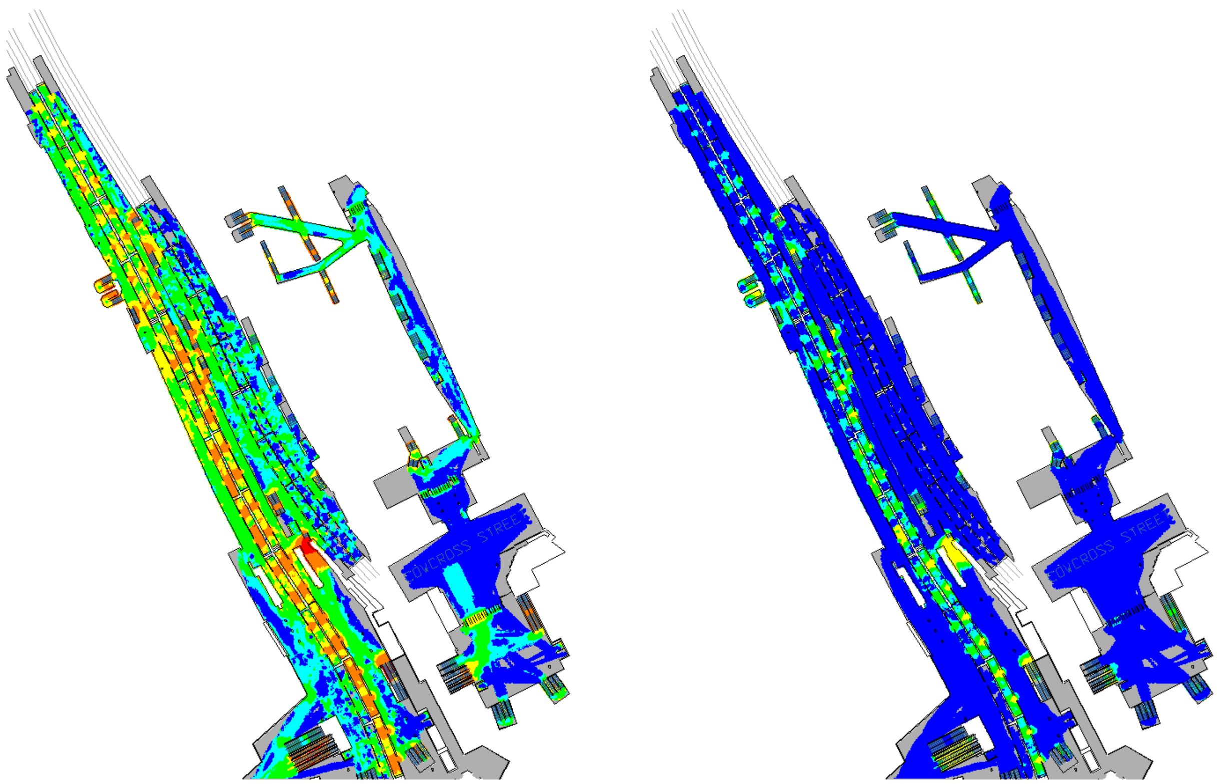
At 2026 highest levels of service are seen around Stair 06 (southernmost P2 and P3 interchange stair), leading very short term congestion and delays moving between the platforms. However these do not register on the High Density mapping as occurring for any more than 2 or 3 minutes (out of 15minutes), nor do they lead to a breakdown in flow. The nature of the future station and the popularity of the P2/P3 route (effectively this replaces the defunct Moorgate branch Thameslink formerly served) means that congestion here is unavoidable without forcing passengers to use the interchange steps further to the north of P3. At this level of demand, Stair 06 is busy but not problematic; in 2026+28% scenarios the lack of capacity here may be a concern to station operation.

Ticket halls and circulatory areas operate without any evident congestion throughout the peak period, with free-flow conditions achieved at all times. Because the AM peak is characterised by heavy alighting flows, the Queuing maps only demonstrate the considerable space available for the relatively small number of AM peak boarders.

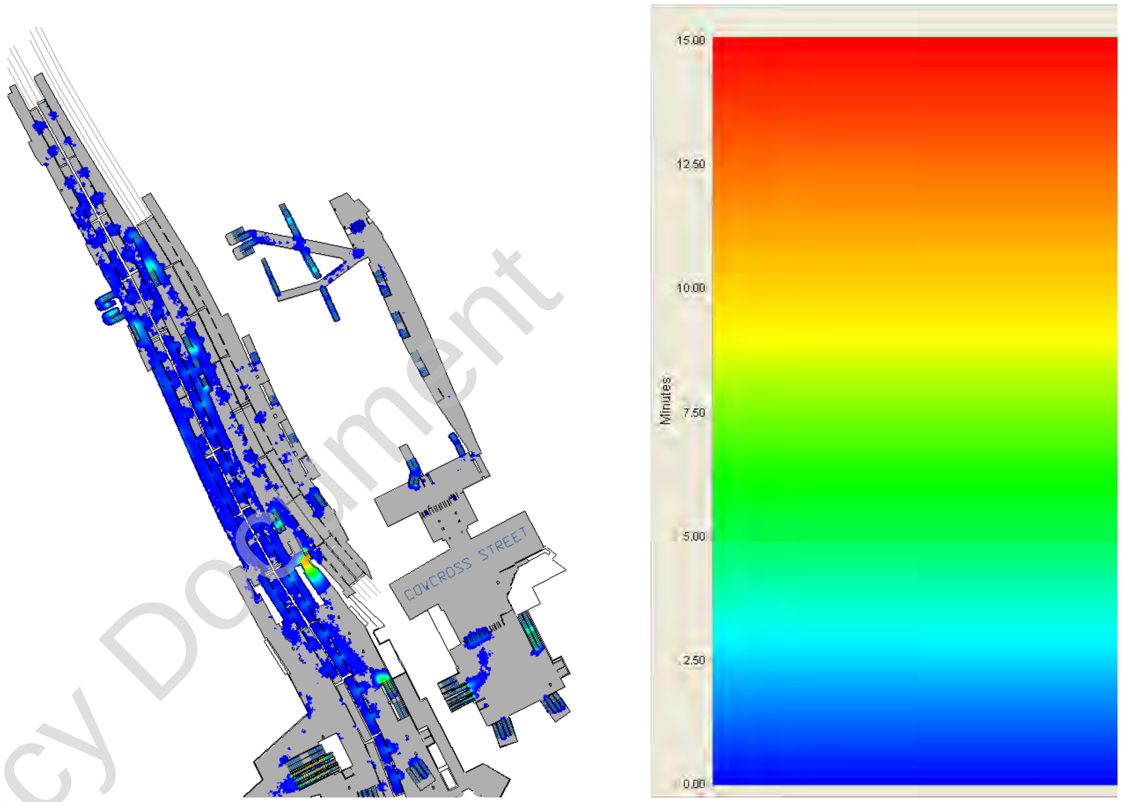
Carriage internal spaces do show higher levels of service where passengers are seeded near doorways. This is a modelling trait and not a problem area.

10.2 2026+28% AM Peak Modelling, 07h00-10h00

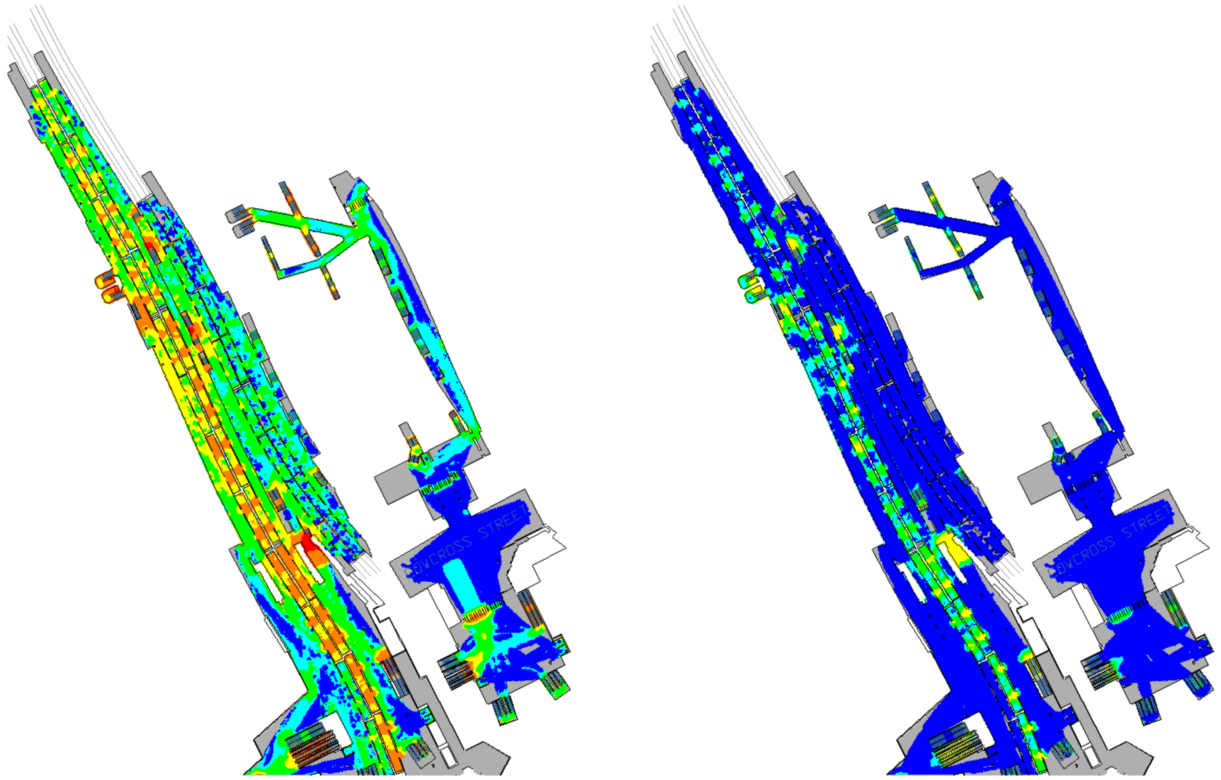
10.2.1 08h19-08h34, Walkways / Queuing



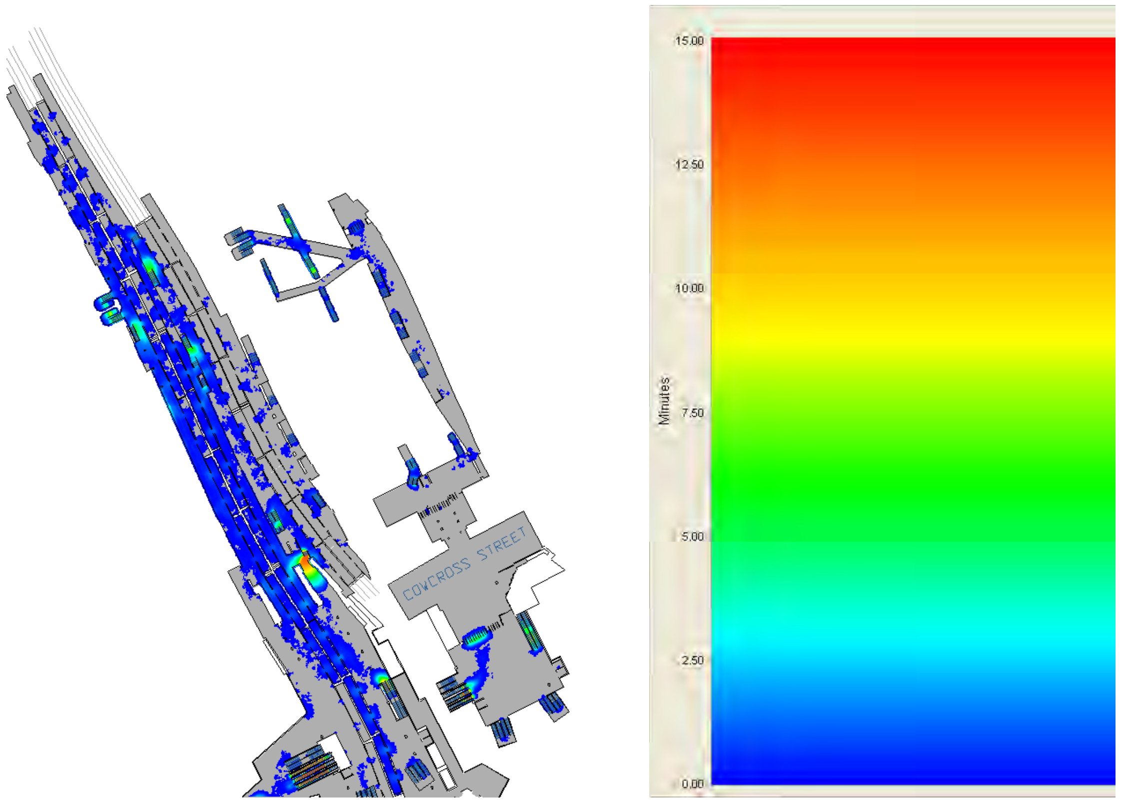
10.2.2 08h19-08h34, High Density, <0.8sqm



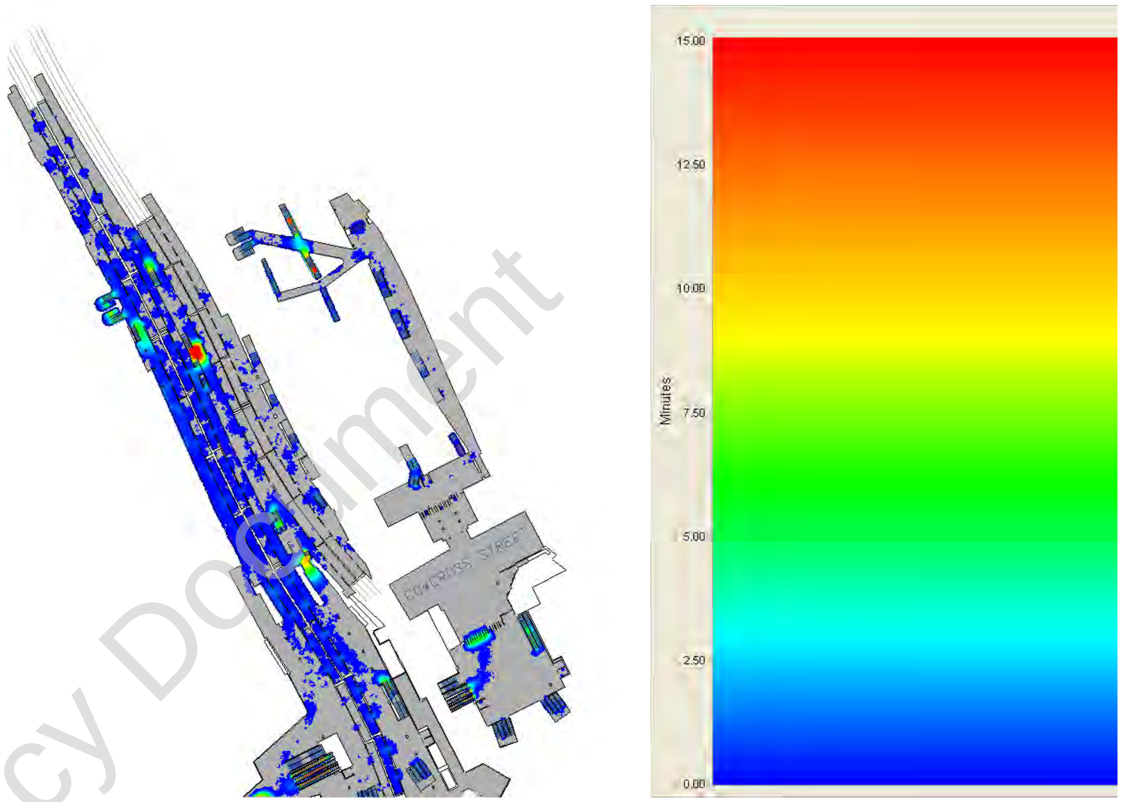
10.2.3 08h34-08h49, Walkways / Queuing



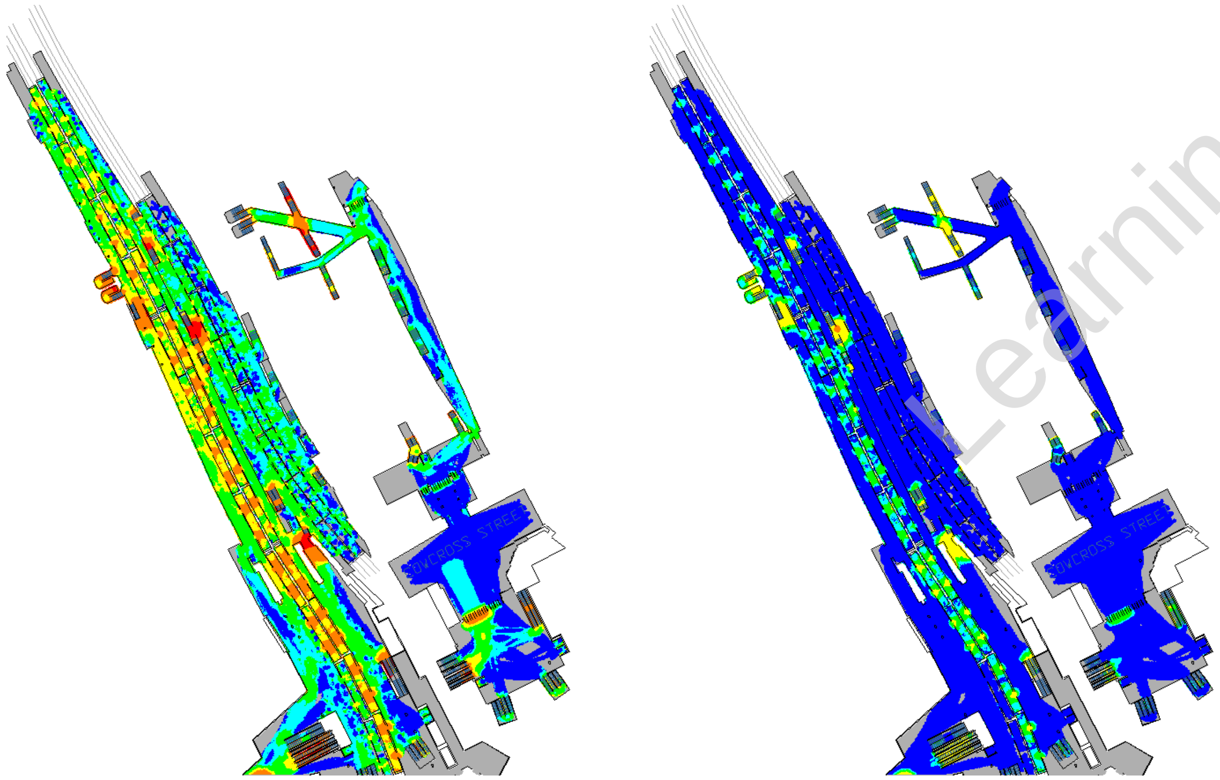
10.2.4 08h19-08h34, High Density, <0.8sqm



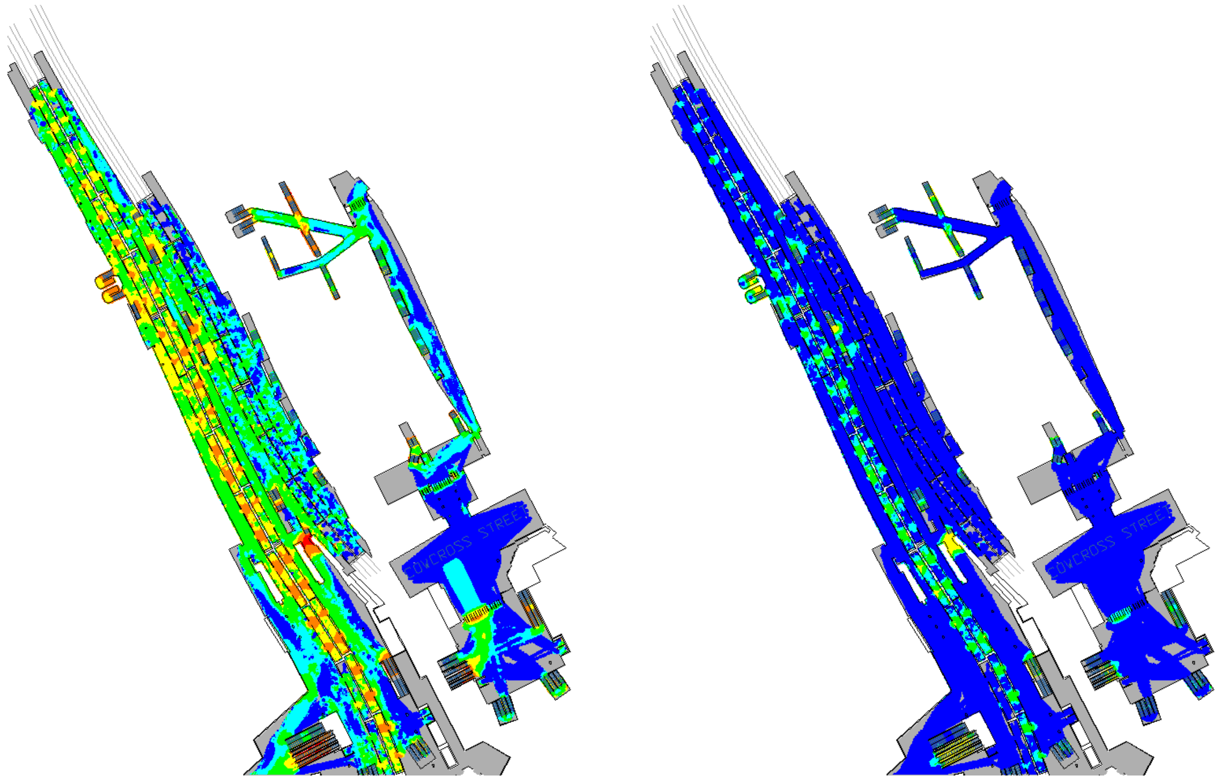
10.2.6 08h49-09h04, High Density, <0.8sqm



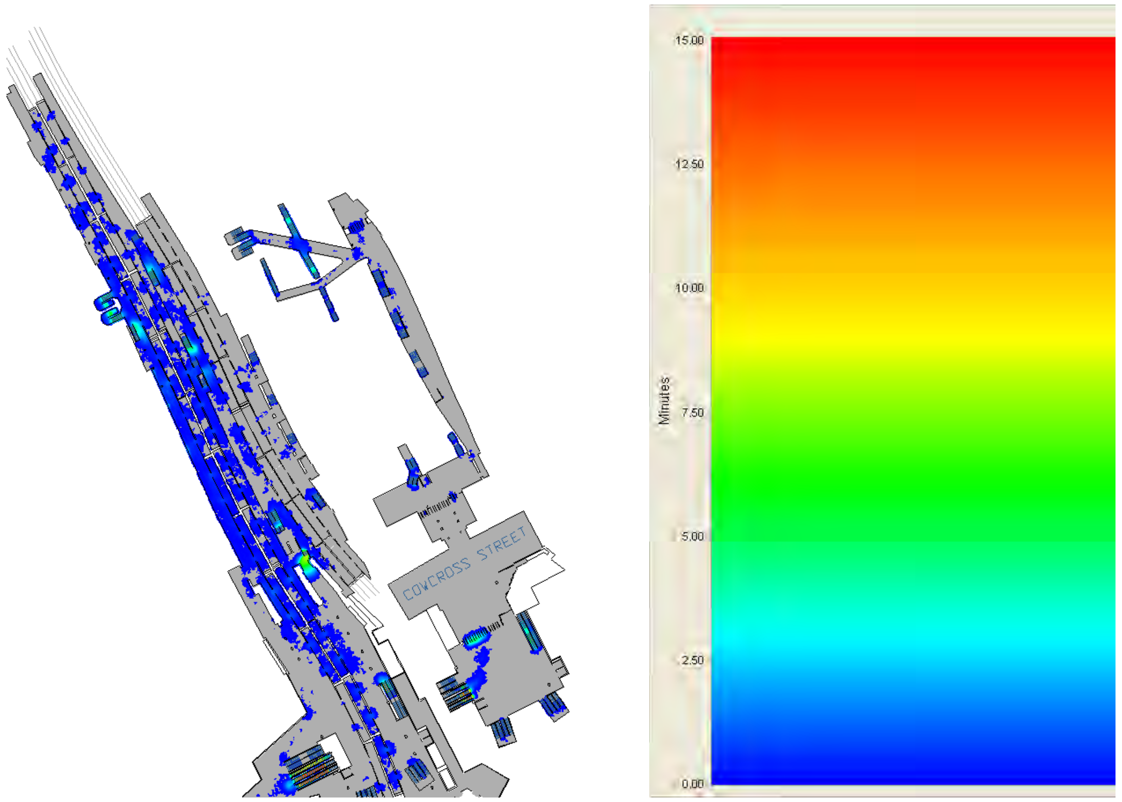
10.2.5 08h49-09h04, Walkways / Queuing



10.2.7 09h04-09h19, Walkways / Queuing



10.2.8 09h04-09h19, High Density, <0.8sqm



This results presented in this section are derived from one of the numerous simulations attempted for the 2026+28% AM peak scenario. In the vast majority of cases the models fail due to the extremely high alighting loads, and the problems Legion has in dealing with high bi-directional flow in relatively narrow areas such as Stair 06 and the northerly "interchange" areas of P3 and P4. However, as these demonstrated in the results in this section, when Legion manages to process the passengers, then levels of service do not depart significantly from those seen in 2026, and the station copes adequately with the high demand.

This is seen particularly on LUL platforms, where the increase in demand is countered by the increase in services (which therefore distributes alighters and removes boarders more quickly). On the TL platforms the train service is at peak level already by 2026, making the 28% demand increase more significant.

As argued in the Section 6 the Thameslink station has been designed for a lower demand forecast, making its resilience to this CRL data set poor. There does remain a large number of alternative routing options within the station for entry, exit and interchange – which undoubtedly human passengers will make better use and more intelligent use of compared to virtual passengers However for these to be utilised, it is suggested that staff intervention and/or prominent signage is in place. The conclusions drawn from TL's own modelling study are unknown, but on the basis of this modelling, and manner in which Legion routes people (shortest distance, fewest occupants etc) then it seems likely that Stair 06 will present a severe constraint on functioning capacity given the desirability of P2/P3 interchange, and that the central-northern areas of P3 and P4 will be heavily utilised.

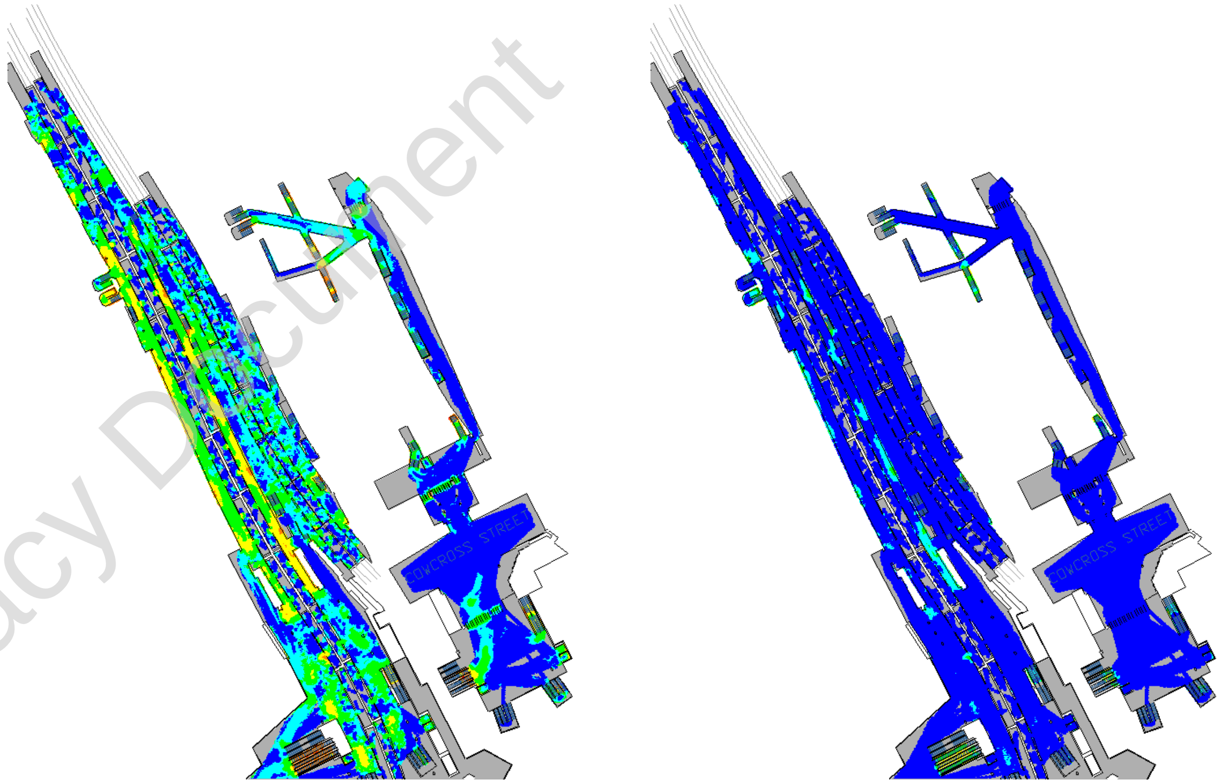
For one 15minute period (08h49-09h04) the heavy alighting loads from P3 using the P2 side exits effectively limit the clearance capacity from P2, leading to an area of LOS E/F at the base of Stair 08. This does not occur in the 2026 model.

Outside of these areas, ticket halls and circulatory elements continue to operate without any significant congestion throughout the peak period. Because the AM peak is characterised by heavy alighting flows, the Queuing maps only demonstrate the considerable space available for the relatively small number of AM peak boarders.

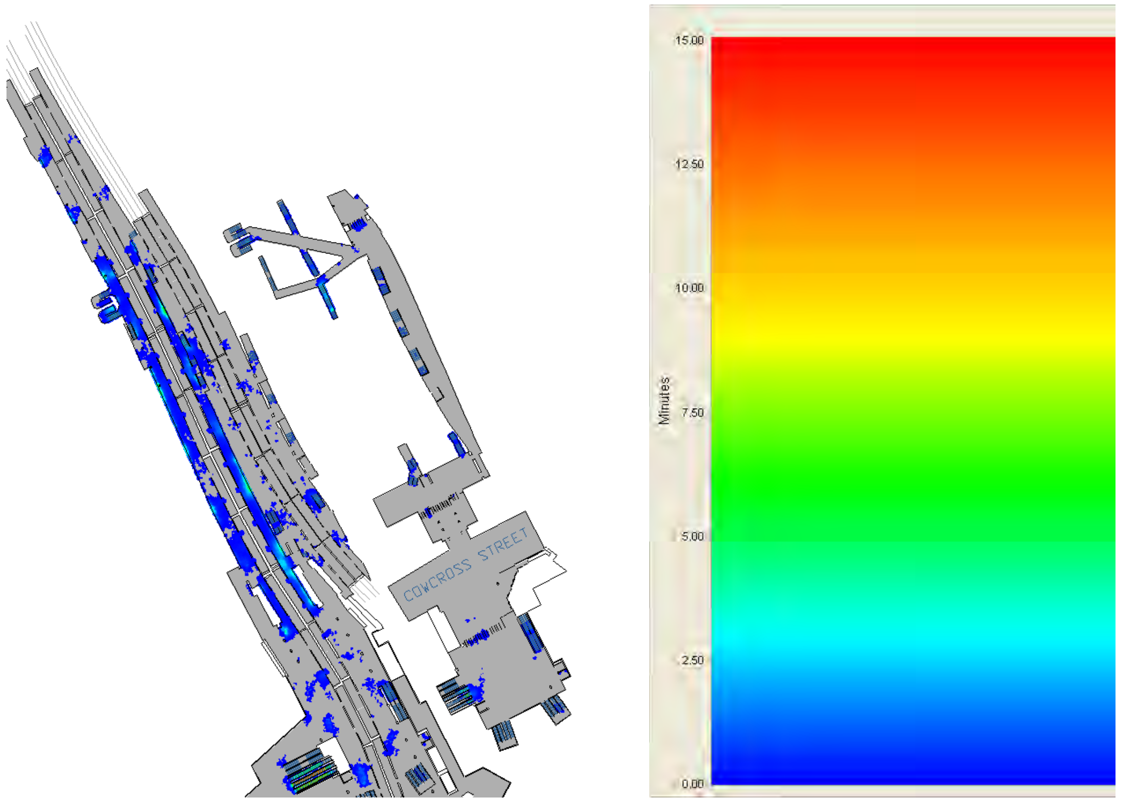
Carriage internal spaces do show higher levels of service where passengers are seeded near doorways. This is a modelling trait and not a problem area.

10.3 2026 PM Peak Modelling, 16h00-19h00

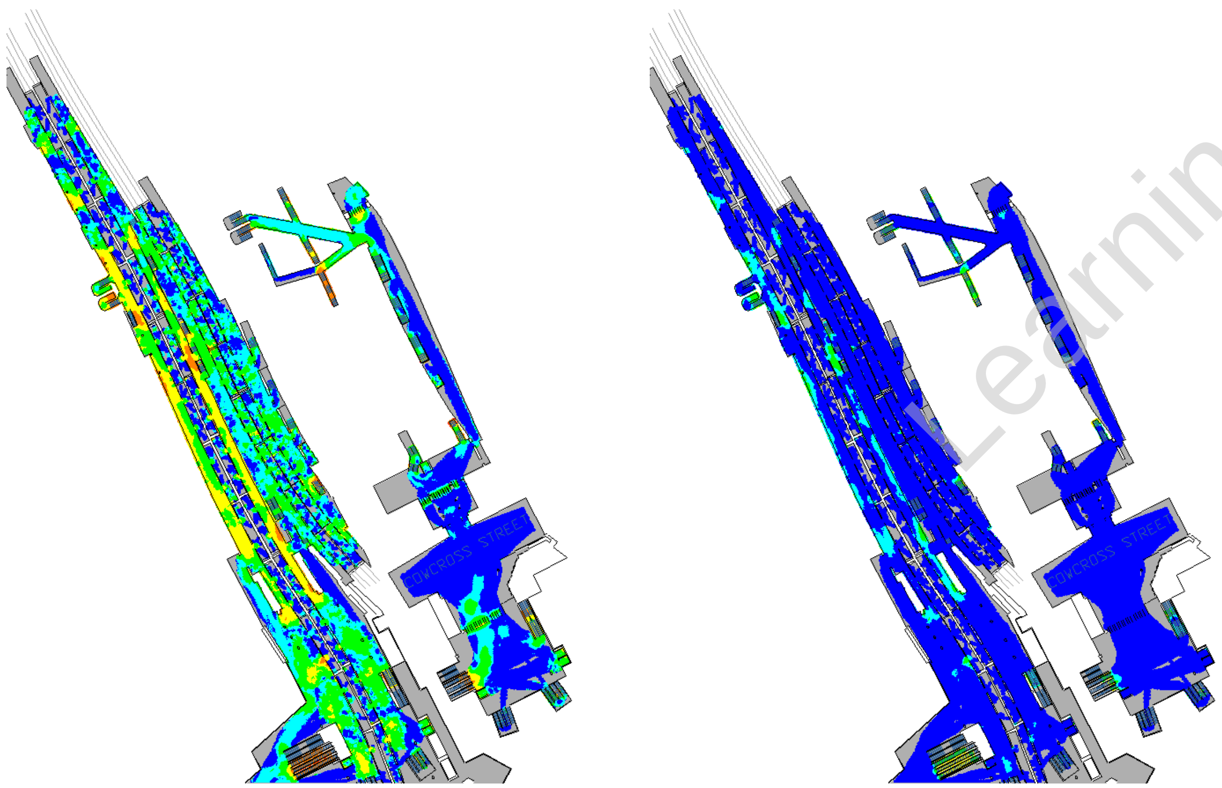
10.3.1 17h18-17h33, Walkways / Queuing



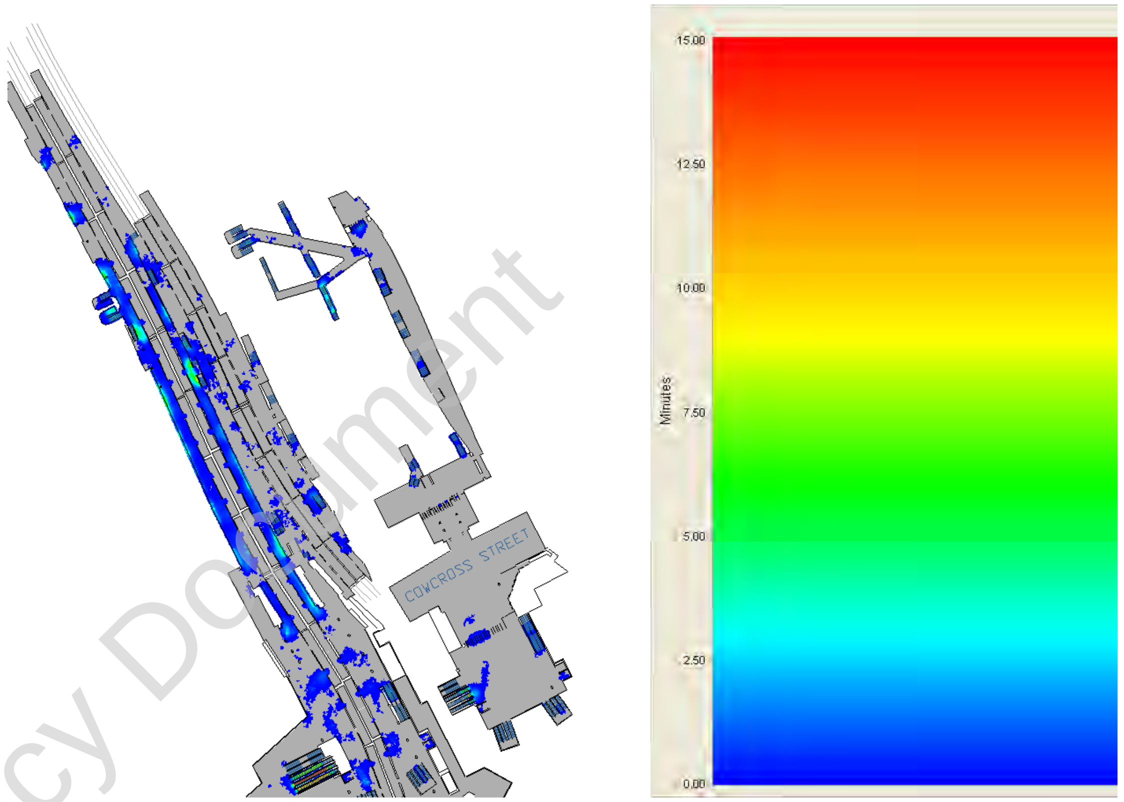
10.3.2 17h18-17h33, High Density, <0.8sqm



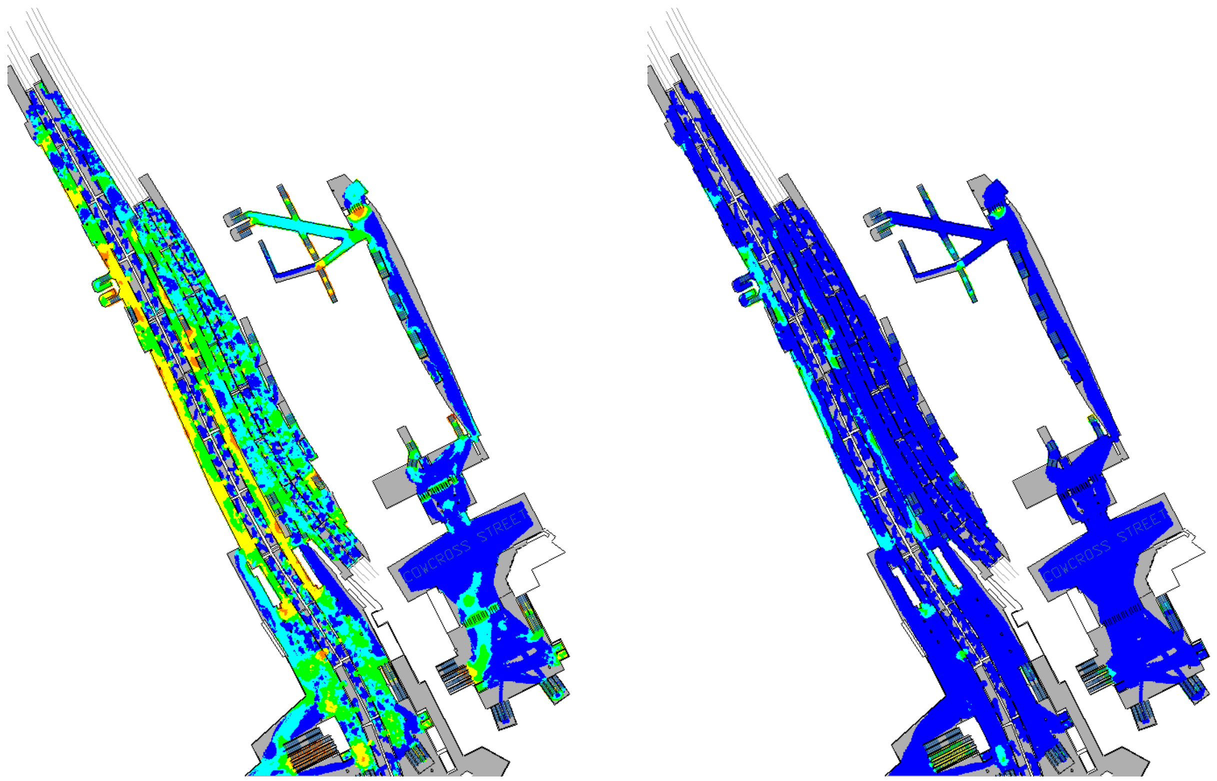
10.3.3 17h33-17h48, Walkways / Queuing



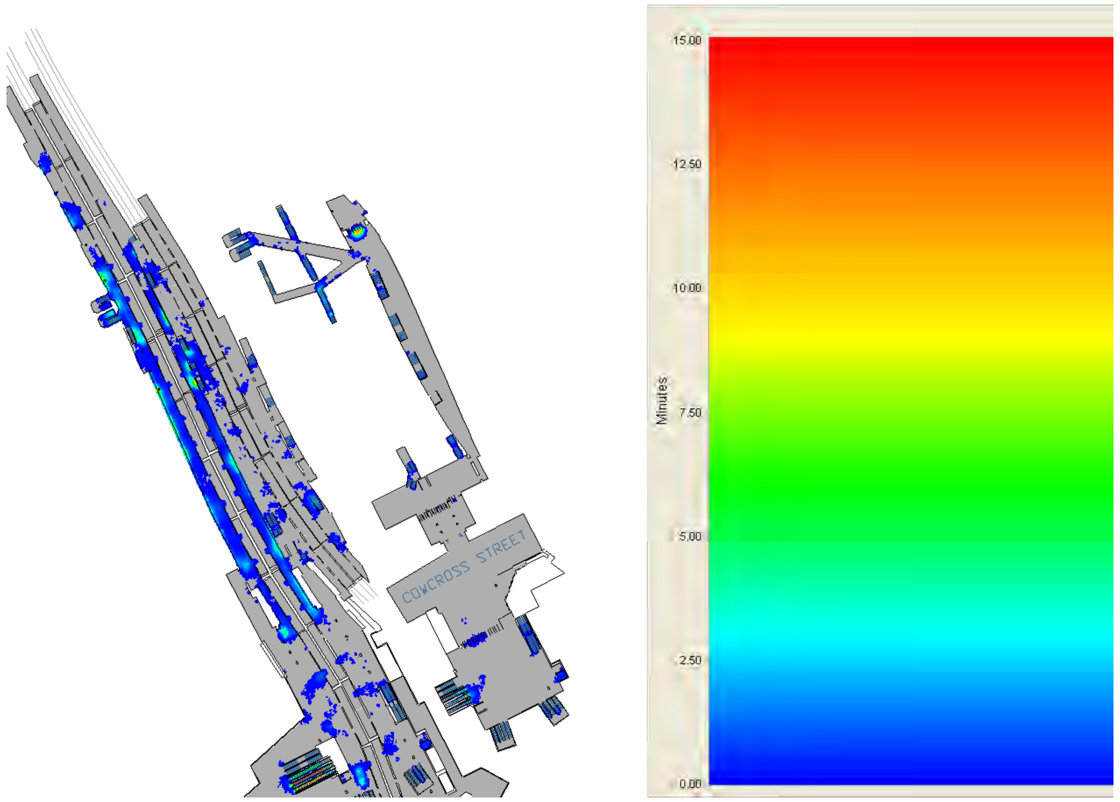
10.3.4 17h33-17h48, High Density, <0.8sqm



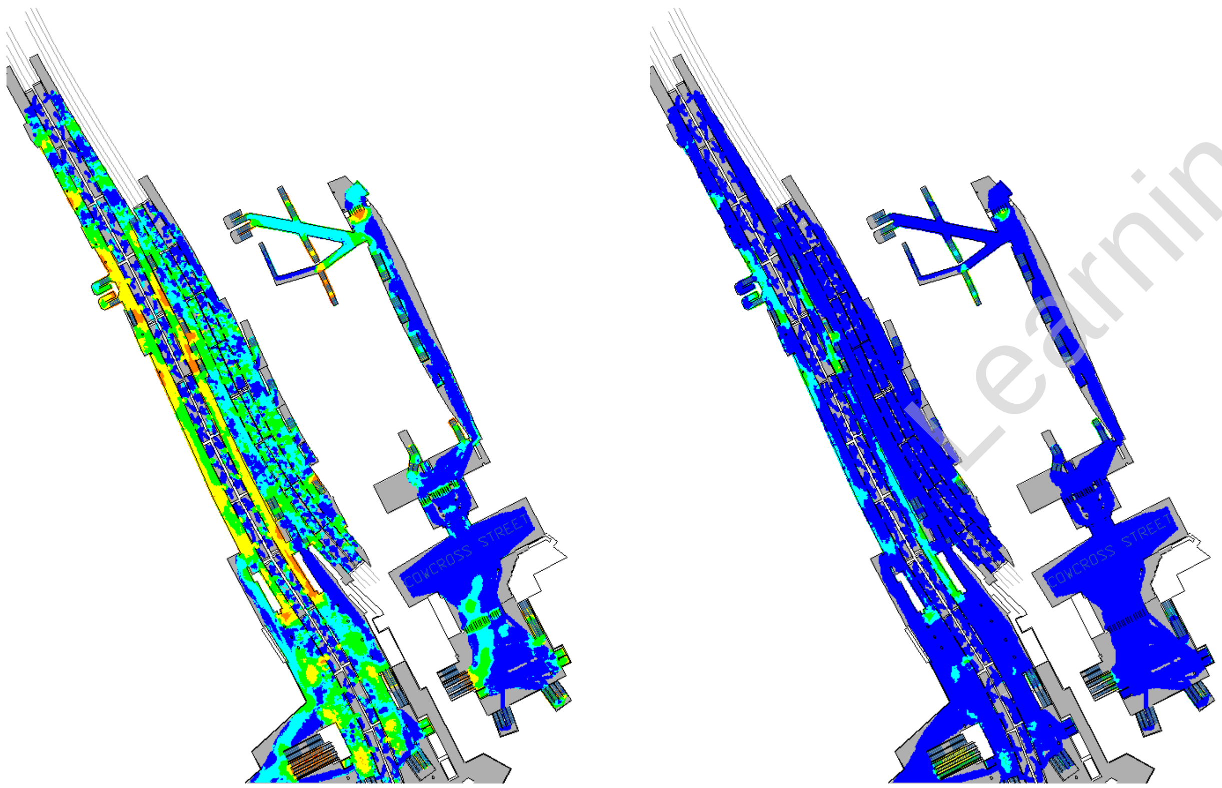
10.3.5 17h48-18h03, Walkways / Queuing



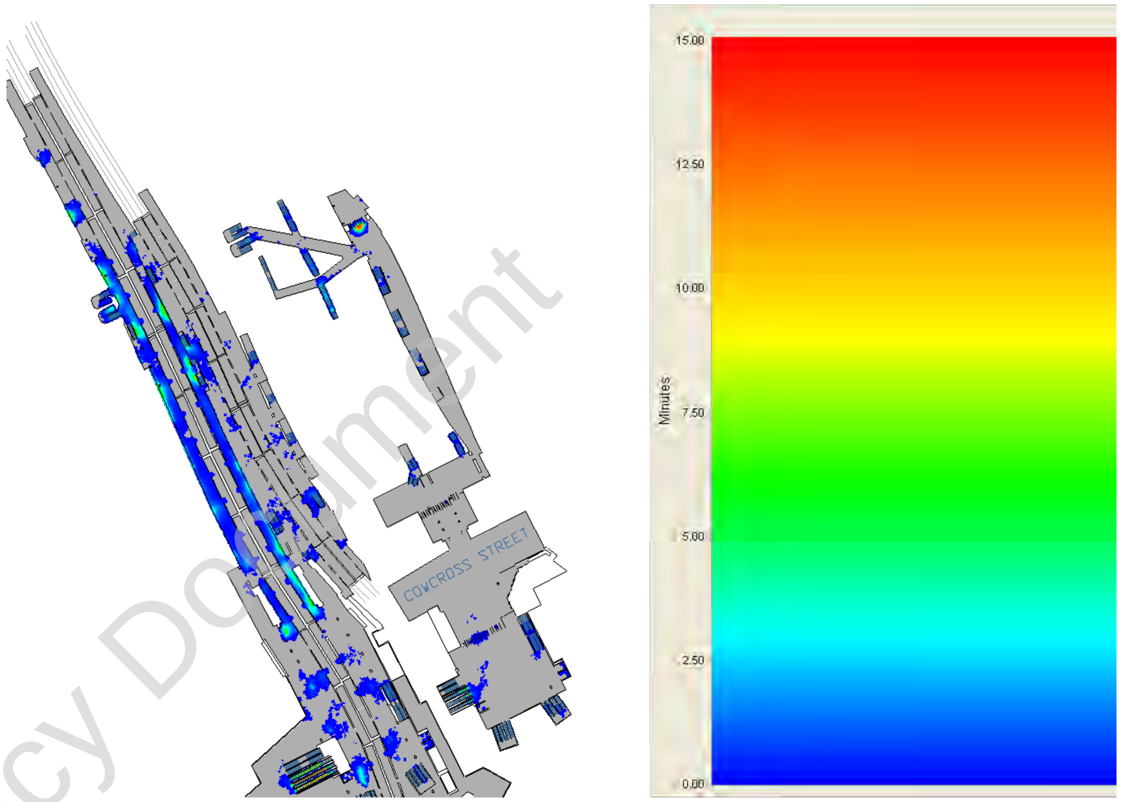
10.3.6 17h48-18h03, High Density, <0.8sqm



10.3.7 18h03-18h18, Walkways / Queuing



10.3.8 18h03-18h18, High Density, <0.8sqm



At the 2026 level of demand the station copes very effectively with passenger circulation and dwell (which is the key feature of PM peak operations).

Ticket halls and gatelines do not demonstrate occupancy above the LOS B/C and the main desire lines into the station remain congestion and delay free.

Platform 1 to 4 movements are a key route in the PM peak – this effectively mirrors the Moorgate replacing P3 to P1 movements seen in the AM peak. As such, central P4 areas do experience the highest levels of utilisation, although these occur at a maximum of LOS D (and LOS B in the more appropriate Queuing graphics). In any event, there remains consider latent capacity along both Thameslink platforms, which signage, staff intervention or natural spread would make use of.

At this level of demand, there are no congestion concerns whatsoever.

10.4 2026+28% PM Peak Modelling, 16h00-19h00

For the reasons explained and demonstrated in Section 6, above, graphics are not shown for the 2026+28% PM modelling.

Full demand modelling of this scenario offers little repeatability as the known station pinch-points lead to continual blockage and failure. It should be noted this is very much a Thameslink platform specific problem related to the considerable growth in boarding numbers (and variation from Network Rails comparable 2076 data set).

Performance in this scenario is driven by the following factors:

- Growth in boarding figures. The station has been space-roofed against Thameslink's Key Output 2 forecast for 2076 of 38,000 passengers over 3 hours. The equivalent CRL forecast number is 53,000
- Stair 06 falls on a major desire line in both peaks, but offers very limited capacity.

- High levels of interchange to P4 leads to continued congestion, blockage and failure at the base of the Turnmill end interchange stairs (Stairs09, 10 and 11), exacerbated by the relatively narrow width of the platform in this specific area. Latent capacity remains, but the model is unable to use it due to blockage at stair base.

Mitigation could be sought through staff intervention, signage, and temporary closure of the station entrance – or may even be achieved through the natural spread of passengers into under-used areas as they seek to move away from highly congested areas.

In any event, it is recommended that the Thameslink Project Development Manager is consulted with regard to the conclusions drawn from their more specific station assessment programme.