Combined terminal/airside/airspace model of Dublin airport

Patricia Martín Fernandez

Alexandra Dudášová

Peter Straka

04 May 2026

Content

Context

The Irish Aviation Authority (IAA) is responsible for economic regulation and for slot allocation at Dublin Airport. To ensure that optimal decisions are made, IAA uses a fast time simulation (FTS) model of Dublin airport.

The simulation model was originally developed in 2017 and has since been used to:

- Support decisions related to setting seasonal slot coordination parameters,
- Assess capacity and efficiency implications of the Capital Investment Programme (CIP),
- Assess operational benefits of the Programme of Airport Campus Enhancement (PACE).

Up until now, the model was able to simulate airside and airspace operations around Dublin.

However, as the airside performance is partly dependent on efficiency and capacity of various processors inside the terminal building(s), the IAA has asked To70 to expand the scope of the existing model to include also passenger journey across the T1 and T2 at Dublin.

This document provides evidence on performance (accuracy) of the combined PTB/airside/airspace model of Dublin airport.

Context

The main purpose of the model expansion was to:

- Create a single, unified platform for capacity/efficiency modelling of passenger and aircraft process at Dublin. The combined PTB/airside/airspace model is now capable of replacing the previously used AirTOP+Pedestrian Dynamics set of models for airside and PTB respectively.
- Create a model where PTB and airside modules of the same model "talk" to each other. This means that events happening inside the terminal building (i.e. passengers late to the gate) will have direct impact on performance of airside operations and vice versa (i.e. arriving aircraft being assigned a different gate will trigger passengers to move to the newly assigned gate).
- Develop a future-proof solution for independent airport performance analyses in support of:
    - The current (and future) CIP processes,
    - Seasonal capacity declaration processes.

The existing model was expanded with these main PTB features:

- Passenger show-up profiles modelling,
- Multiple passenger routes from/to various destinations within both T1 and T2,
- Check-in process modelling: Self-service kiosks, check-in desks and bag-drop,
- Boarding pass scanners,
- Security control,
- Passenger waiting areas,
- Dynamic boarding gates allocation,
- Passenger boarding process,
- Passenger disembarkation,
- Immigration process,
- Baggage collection,
- Transfers,
- TSA/CBP.

Approach

- The process of expanding the existing FTS model consisted of several steps:
  - Qualitative discussions with daa to understand the current operational practice and limitations (several meetings over Q4/25, Q1/26 and Q2/26).
  - Review of quantitative data and assumptions from daa in advance of, and during model development.
  - Development of a stand-alone PTB model only.
  - Several review cycles with daa and IAA to ensure the stand-alone PTB model performs sufficiently well.
  - Implementation of the stand-alone PTB model into an existing airside/airspace model.
  - Re-validation of the newly created model to ensure that even after merger of the PTB module, the integrated model can still deliver credible results.

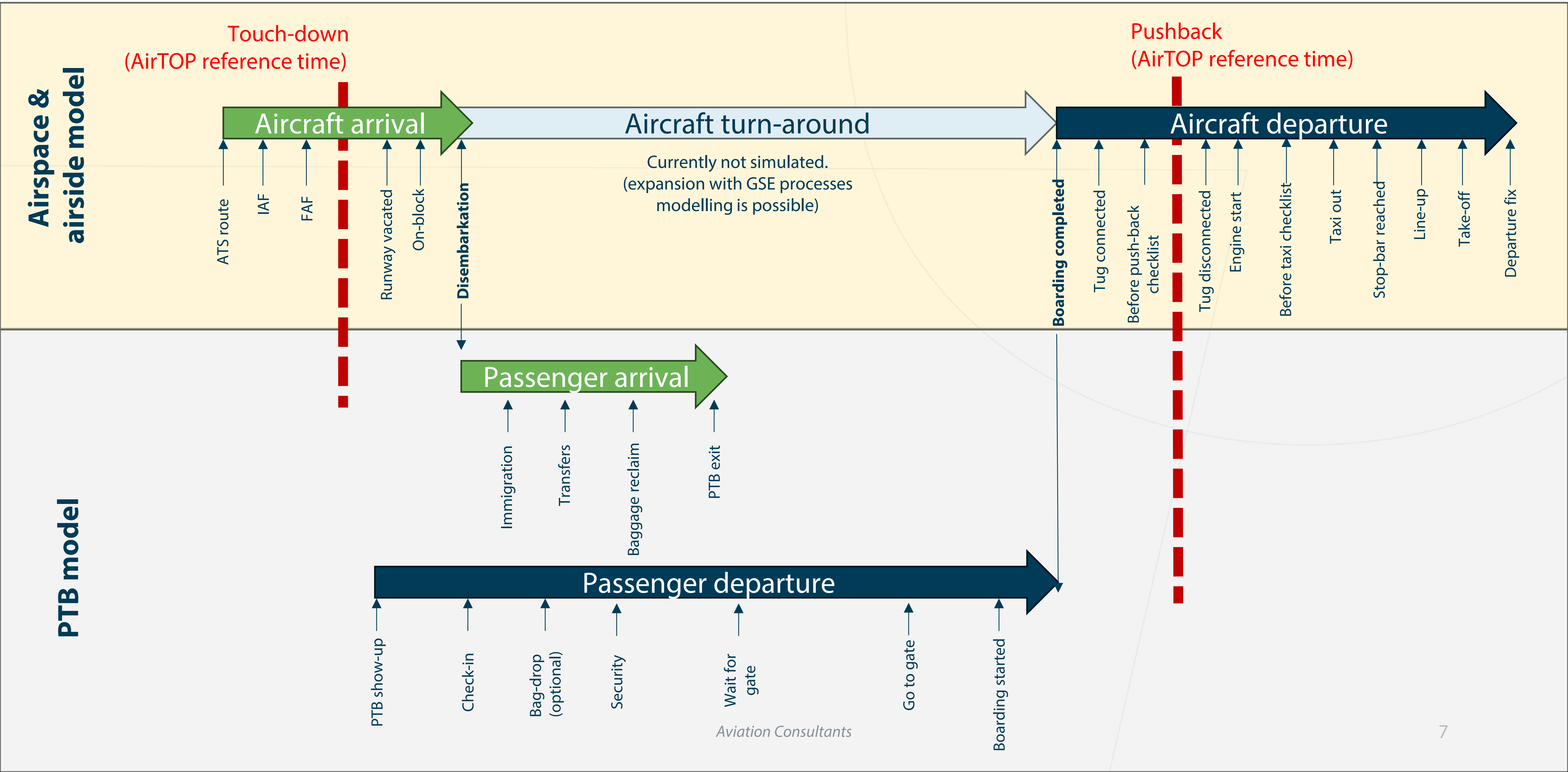
Link between the terminal and airside modules explained

- The airside and terminal Airtop models have been built independently and later merged into one model that can simulate both the aircraft and passenger movement and behaviour.

- In this model, both aircraft and passengers influence each other, bidirectionally. This bidirectional interaction between airside and terminal models is mainly reflected in two ways:
  - If an aircraft is late (in-block and/or off-block times) the boarding or disembarking time of passengers will be correspondingly modified. Including also re-allocation of aircraft stand (passenger will walk to a different boarding gate).
  - Passengers can also affect the aircraft off-block time and turn-around duration if they are still boarding or disembarking.

- From technical perspective, all events simulated in the model, regardless of whether these belong to airspace, airside or PTB operations, are calculated from two main time-stamps called Reference times. These are different for arrivals and for departures and need to be provided as inputs:
  - Reference time for all departure events is off-block time (push-back).
  - Reference time for all arrival events is touch-down time.

Overview of events dependent on the Reference times



Model validation

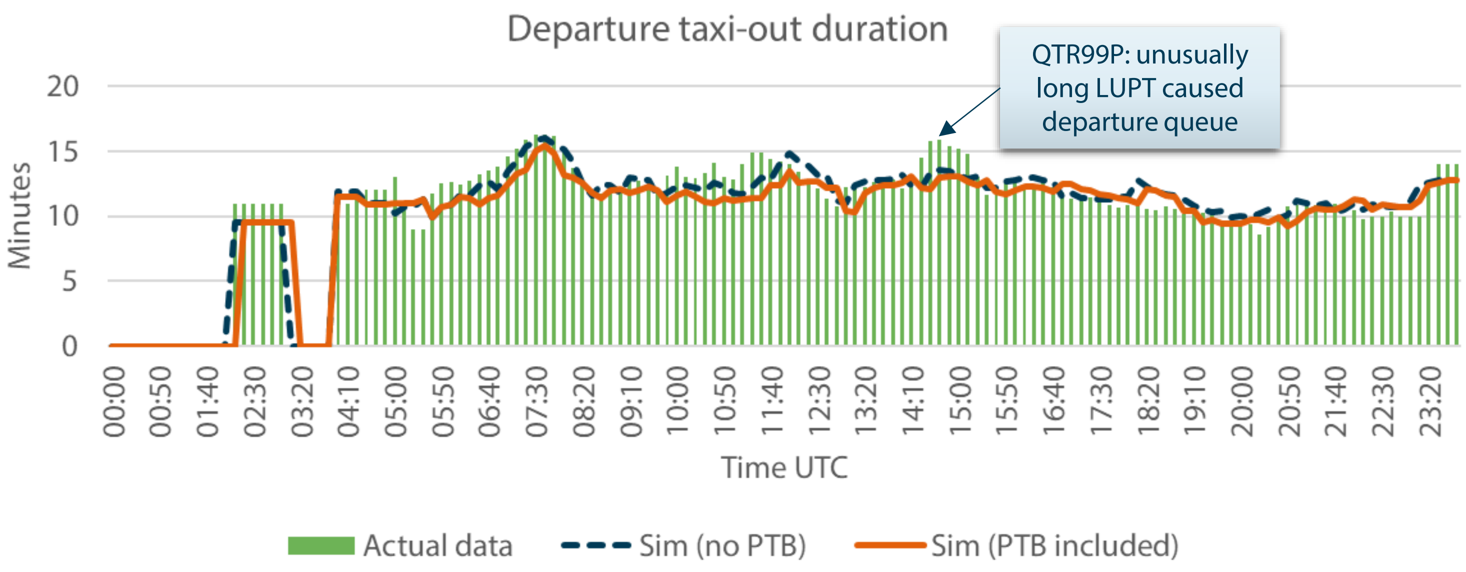
- 8th of November 2025 was used as a representative day for:
  - Airside/airspace model calibration,
  - PTB model development.

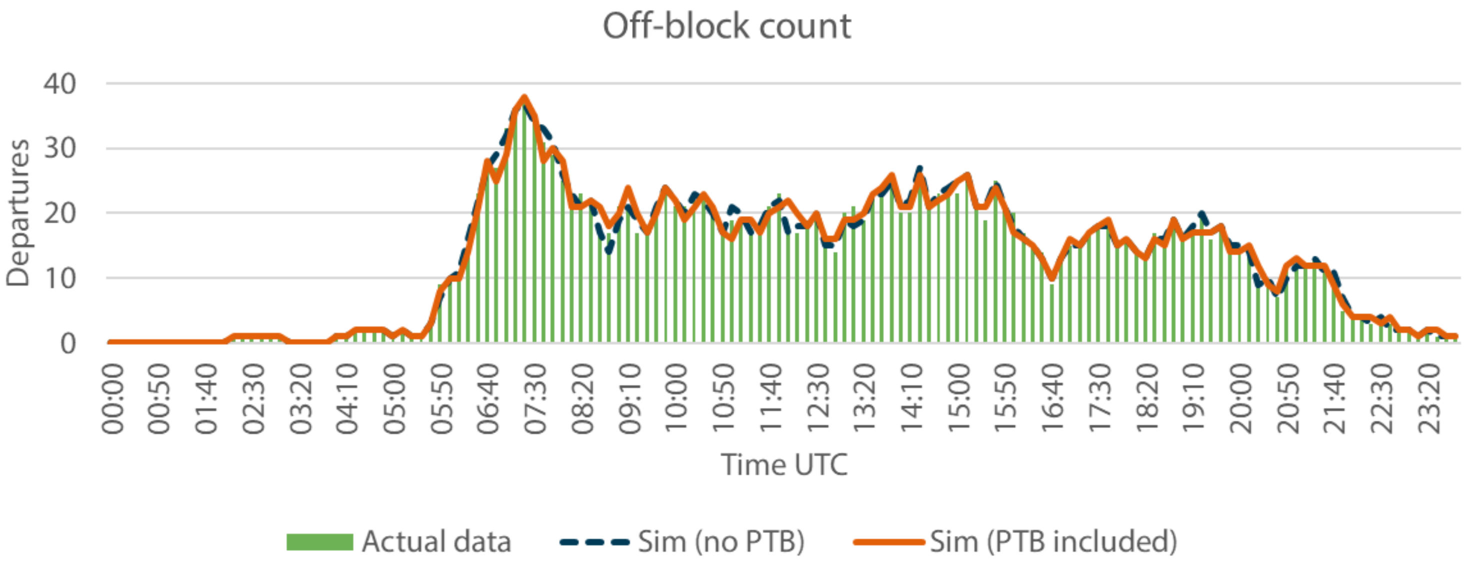
- The model was run from actual block times to take into account all delays.
- All traffic on the given day, incl. GA and cargo, was simulated.
- “Unusual” events due to operational irregularities were not simulated.

Mode of operations	Date	Arrivals	Departures	Passengers	Runway	Mixed operations (UTC)	Segregated operations (UTC)
Westerly	8/11/2025	312	314	85,442	28L/R	2300-0659 Departures from 28L Arrivals to 28L	0700-2259 Departures from 28R Arrivals to 28L

Model validation: Airside (RWY 28L/R)

Calibration of departure performance





Metric definition:

Time duration between the off-block time and aircraft lifting off.

*This graph is presented as a rolling 60-minute average (value for each time period has been calculated as average of values of all events occurring within the T-60 minutes window from the start of the measurement).

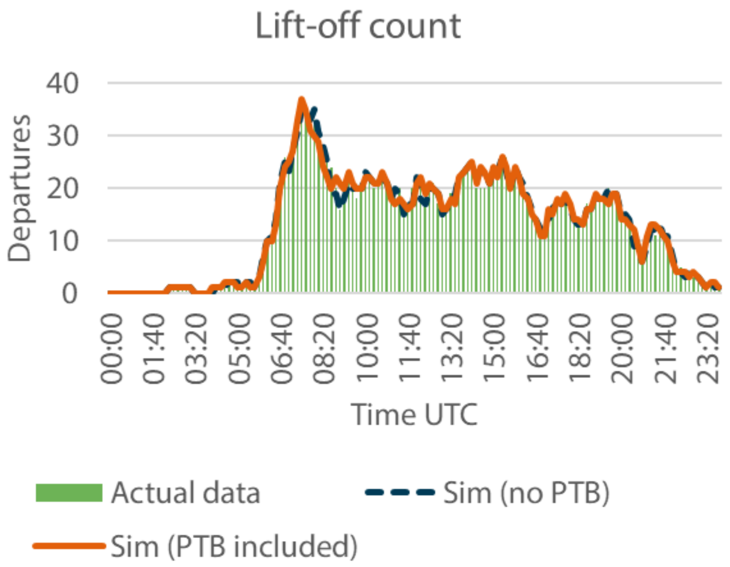
AirTOP uses off-block time as the reference time for all departures. Therefore, there is a good degree of match between simulation and historical data in the off-block count metric. The occasional differences between the performance of a stand-alone airside model and a combined PTB/airside model are caused by delays in the boarding process (pushback delayed because of gate delays). This inherently creates a different situation on the taxiway network, leading to differences in departure taxi out profiles modelled with (and without) the PTB model active.

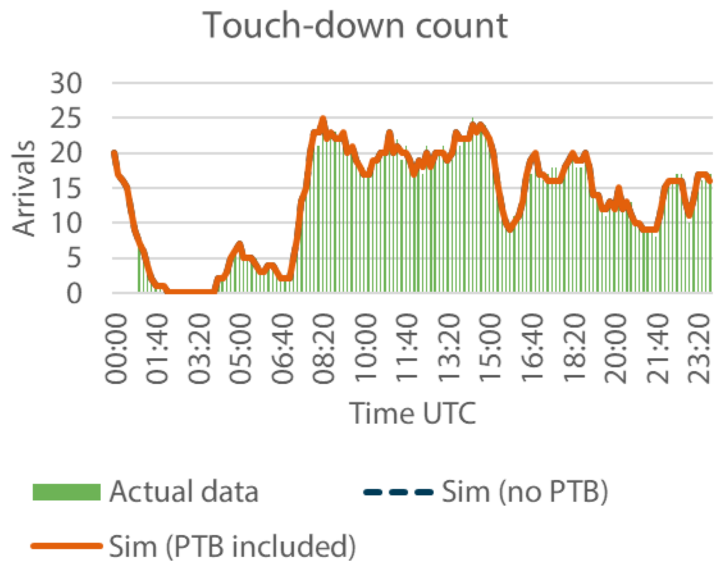
Metric definition:

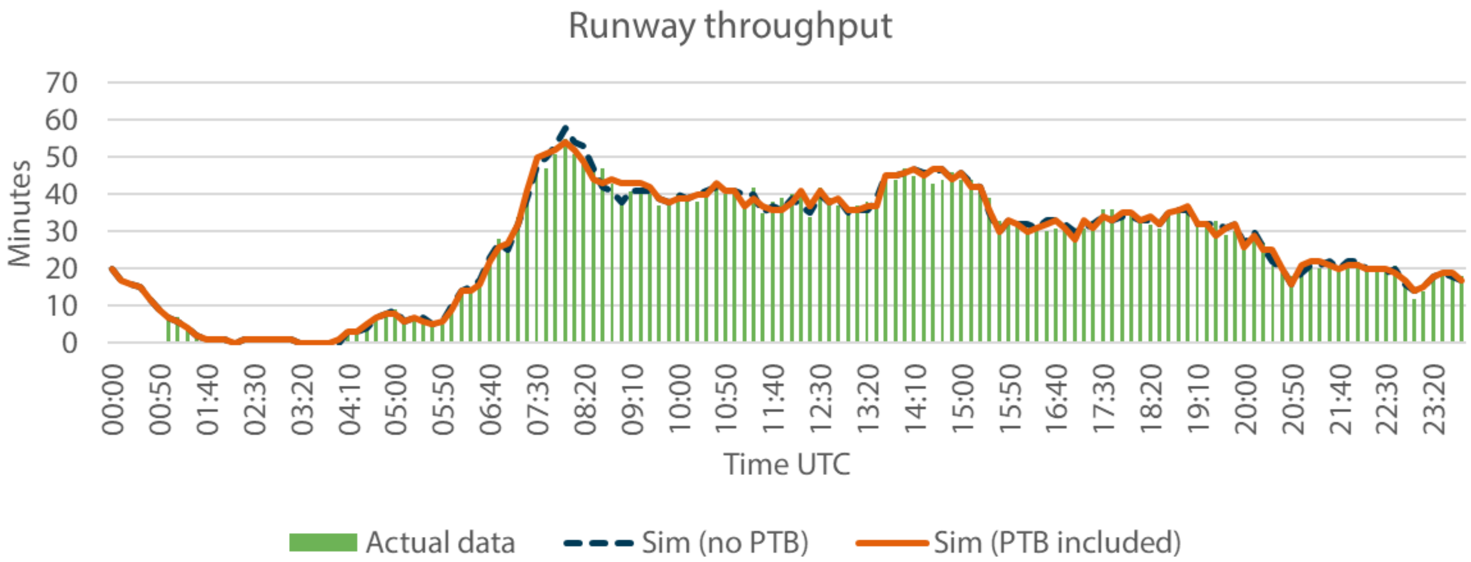
The number of aircraft that have been pushed back in the last rolling period. The count is incremented when the aircraft leaves its departure parking position (either being pushed back at gate or taxiing / pulled away from a parking position).

* This graph is presented as a rolling 10-minute average (value for each time period has been calculated as average of values of all events occurring within the T-60 minutes window from the start of the measurement).

Calibration of runway performance







AirTOP uses arrival (touchdown) time as a reference time for arrivals. As there is no involvement of any PTB processes before the aircraft touches down, the performance of the touch-down count metric is identical whether run from a stand-alone airside model or a combined PTB/airside model. Lift-off count is influenced by the time the aircraft pushes back and how long it takes to taxi to the runway. This has impact on the departure sequence which, in this case, manifests as a slight variation in the lift-off count metric - visible in the version of the model with PTB elements included.

Metric definition:

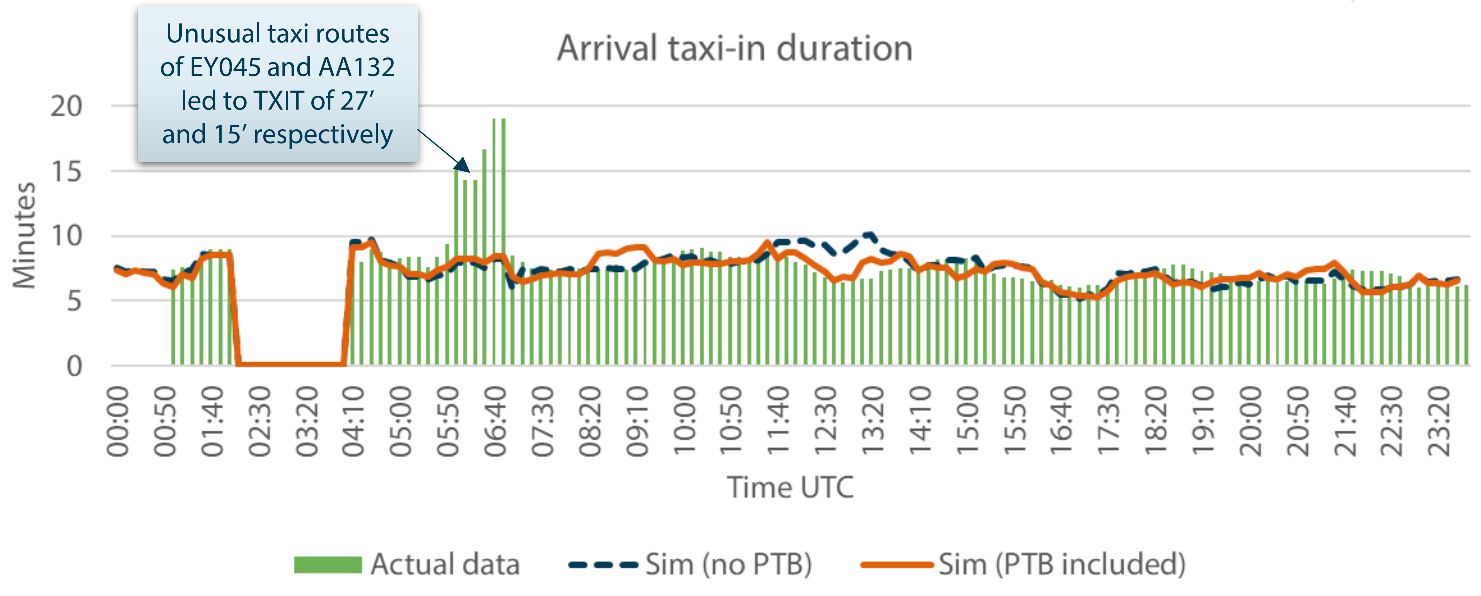
Lift-off count: The number of aircraft that have lifted off in the 60-minute rolling period. The count is incremented when the aircraft passes over the opposite end of the runway.

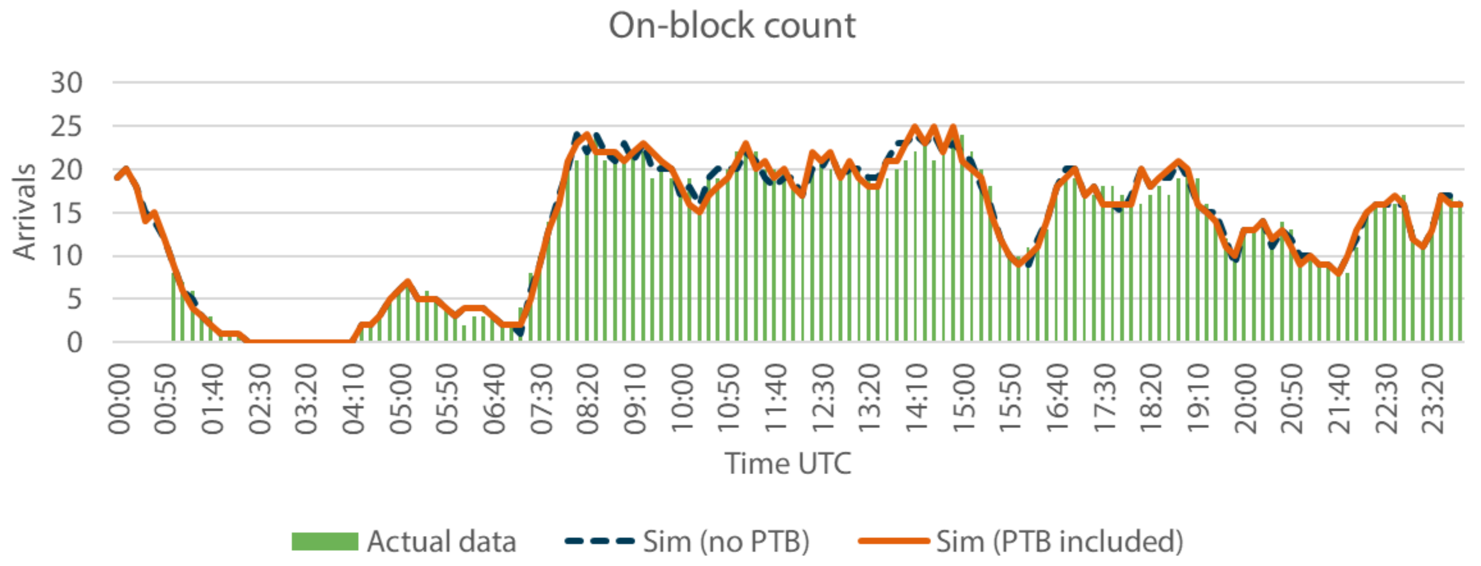
Touch-down count: The number of aircraft that have touched down in the 60-minute rolling period.

Runway throughput: Sum of all aircraft touching down and lifting-off in the 60-minute rolling period.

* All graphs are presented as a rolling 60-minute average (value for each time period has been calculated as average of values of all events occurring within the T-60 minutes window from the start of the measurement).

Calibration of arrival performance





Metric definition:

Time duration between touch-down and aircraft parking on-blocks.

*This graph is presented as a rolling 60-minute average (value for each time period has been calculated as average of values of all events occurring within the T-60 minutes window from the start of the measurement).

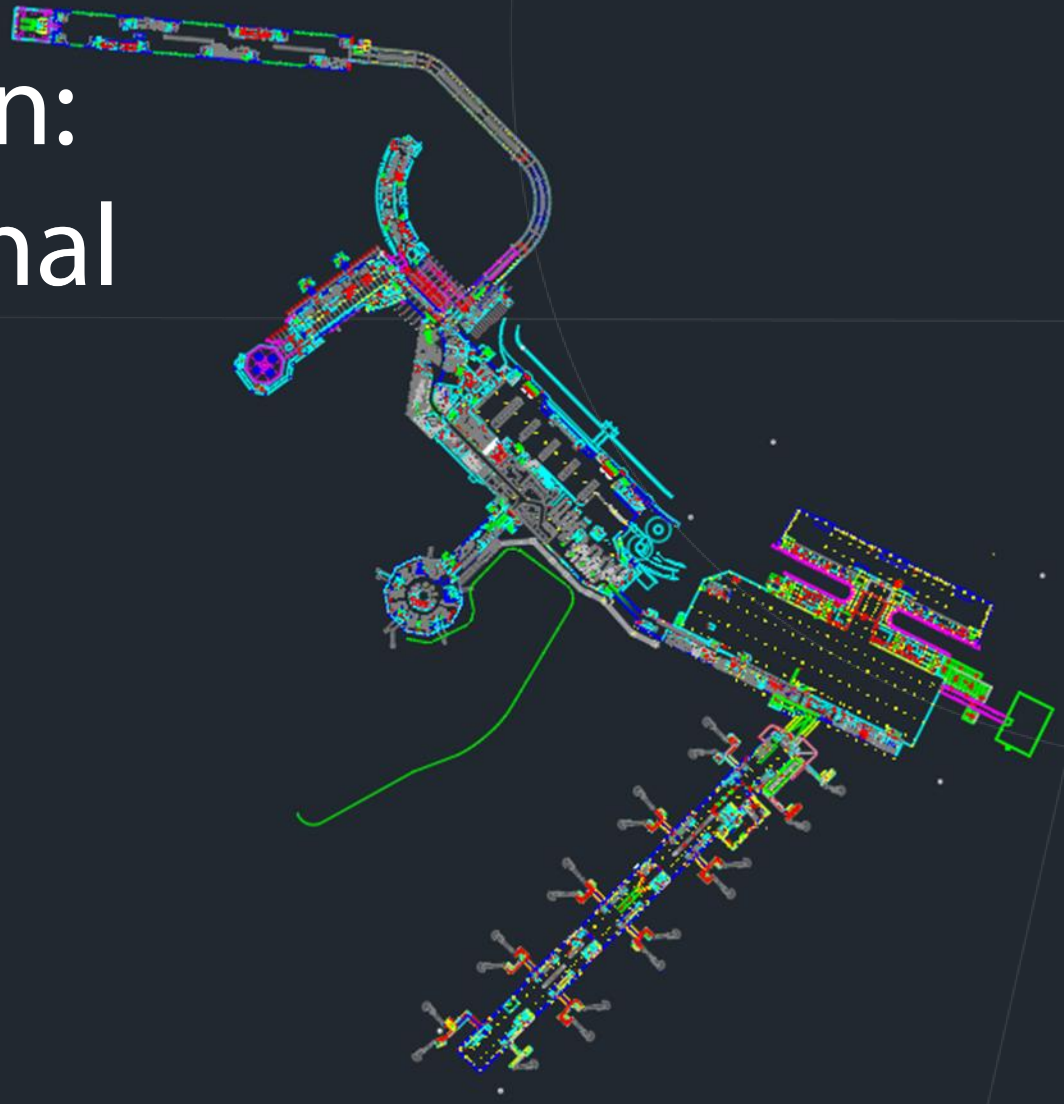
Although the touch-down times in both the stand-alone airside model and the combined airside/PTB model are identical, the taxi times show a minor variation. This can be explained mainly by two factors: (1) some departing aircraft pushing back later because of gate delays creating different situations on the taxiway network, leading to different arrival taxi in times, and (2) some arrival aircraft being assigned a different gate (leading to different taxi times) because there was still a delayed departure simulated at the gate originally assigned to the arriving aircraft.

Metric definition:

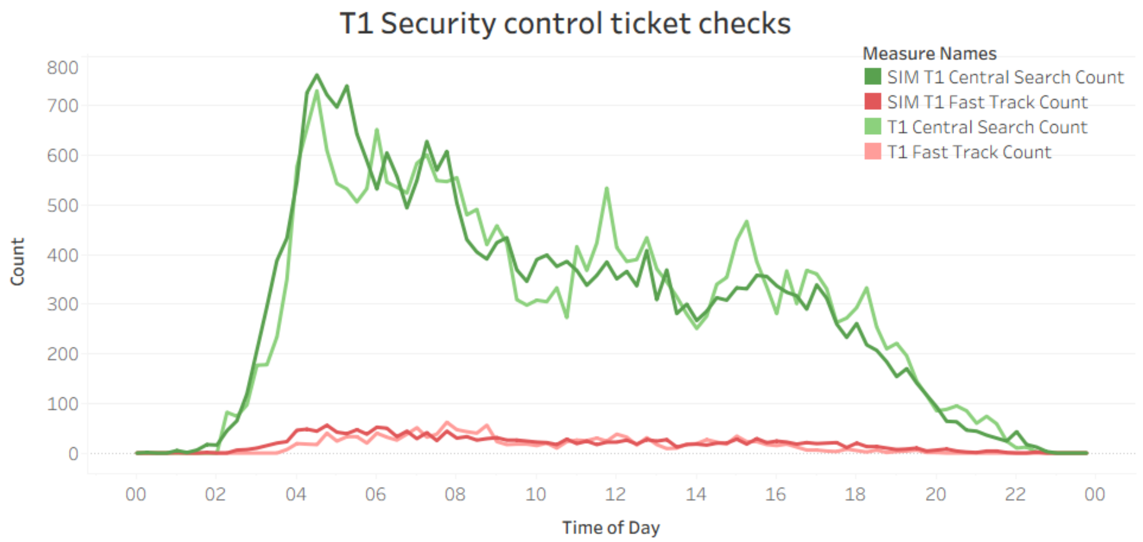
The number of aircraft that have reached their arrival parking position in the last rolling period. The count is incremented when the aircraft reaches its in-blocks position.

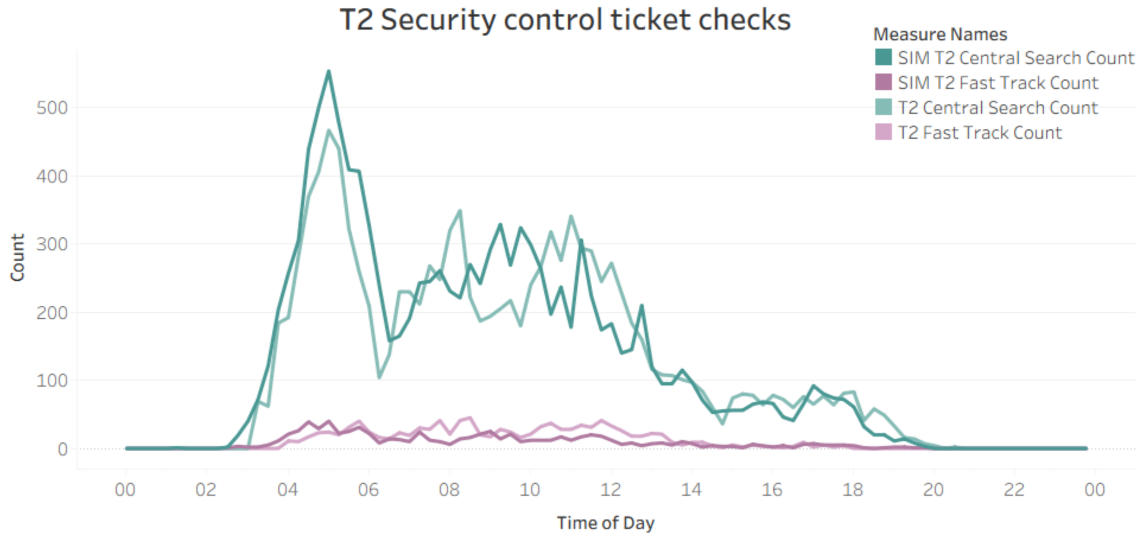
* This graph is presented as a rolling 60-minute average (value for each time period has been calculated as average of values of all events occurring within the T-60 minutes window from the start of the measurement).

Model validation: Passenger terminal buildings



Security control ticket checks





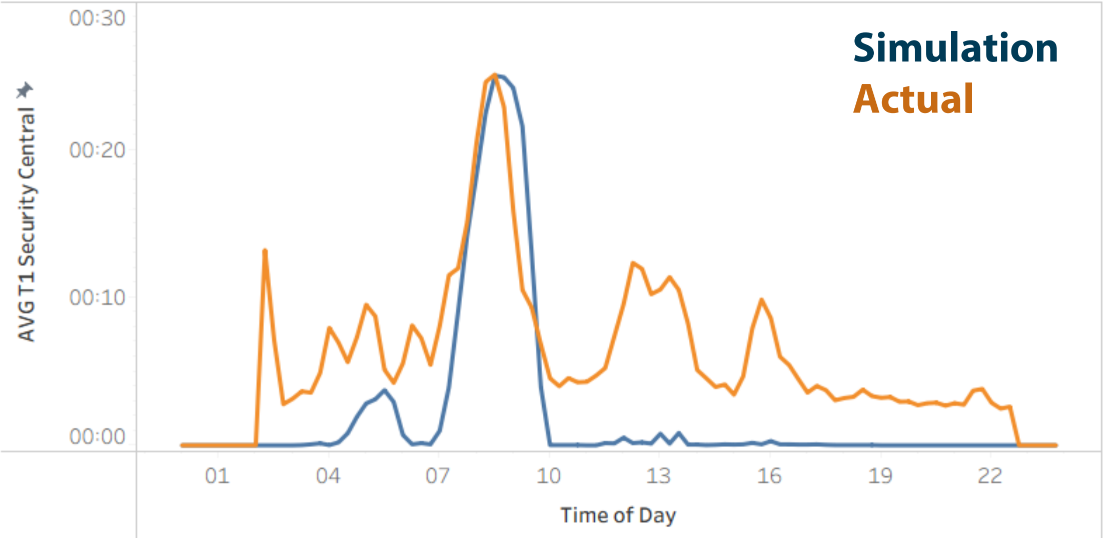
Metric definition:

Number of passengers that scan their boarding passes before security control per 15-minute window. Simulation output vs operational data.

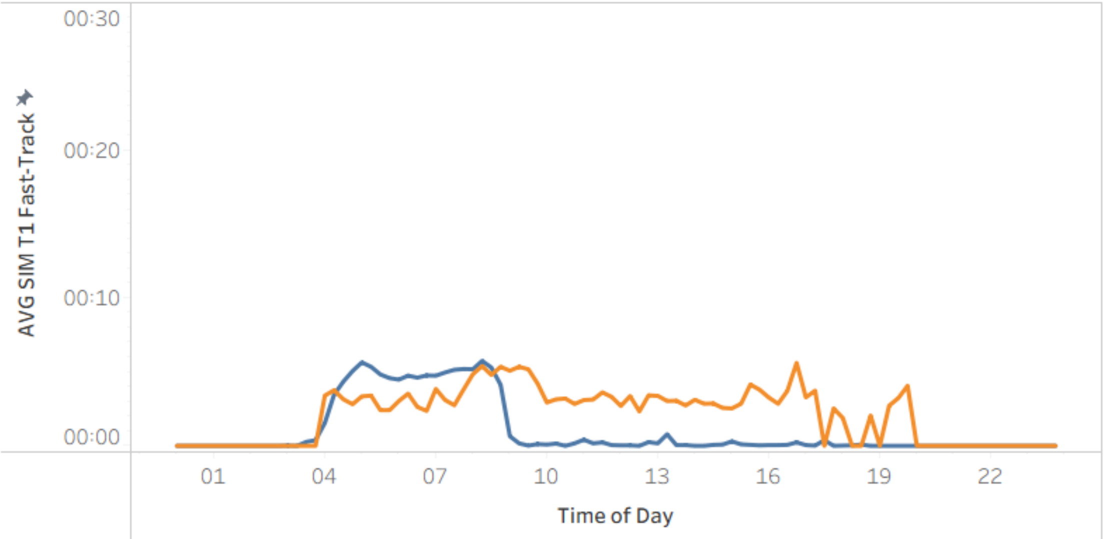
- T1 central search
- T1 Fast-Track
- T2 central search
- T2 Fast-Track

T1 security queuing time

T1 Security Central search - Average queueing time



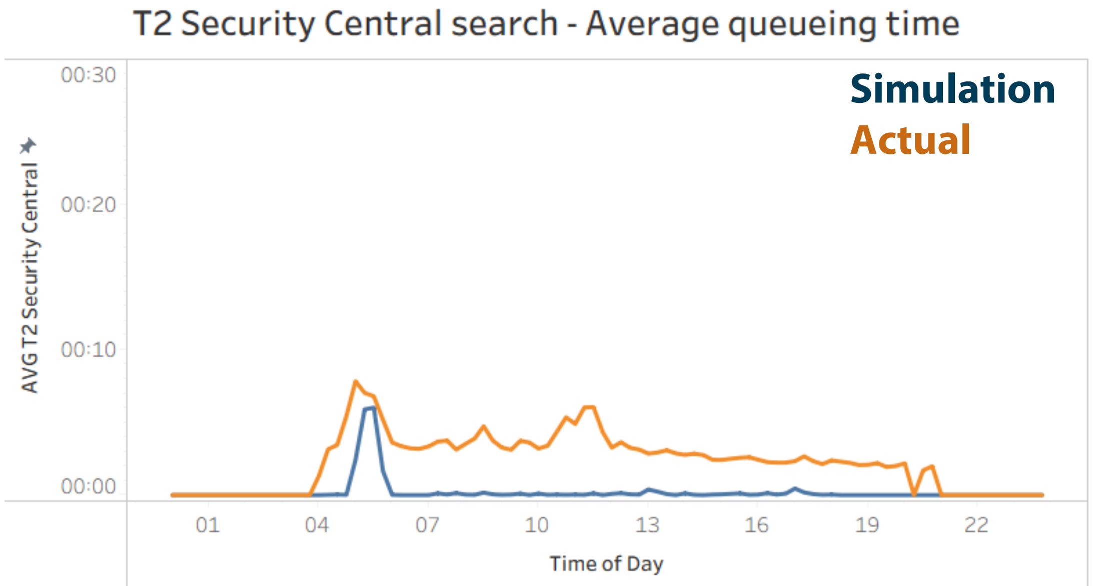
T1 Security Fast-Track - Average queueing time

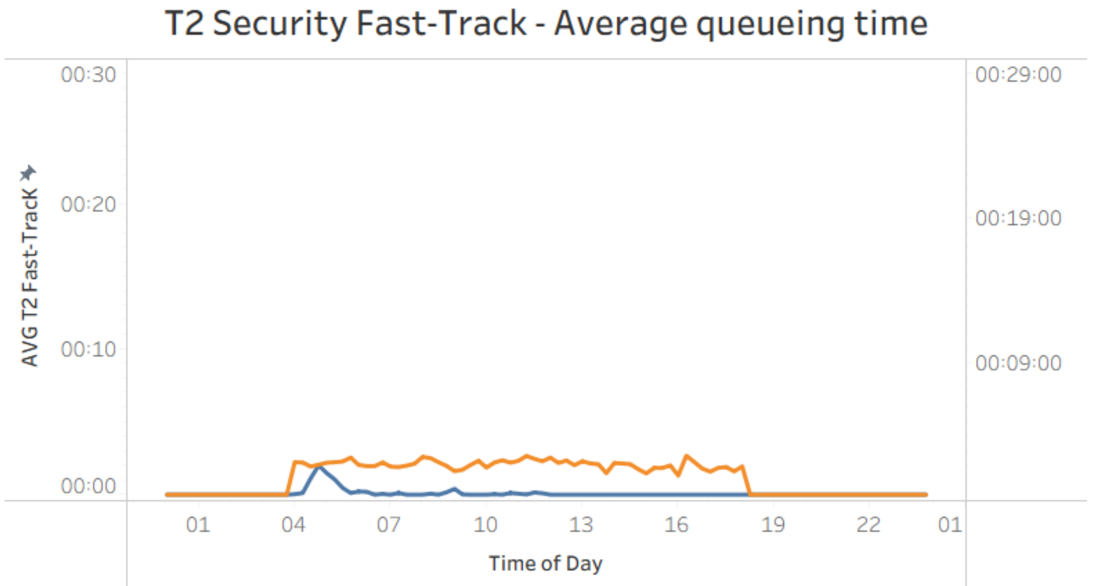


Metric definition:
Average time per passenger spent queueing at security control, per 15-minute window. Simulation output vs operational data.

- T1 central search
- T1 Fast-Track
- T2 central search
- T2 Fast-Track

T2 security queuing time

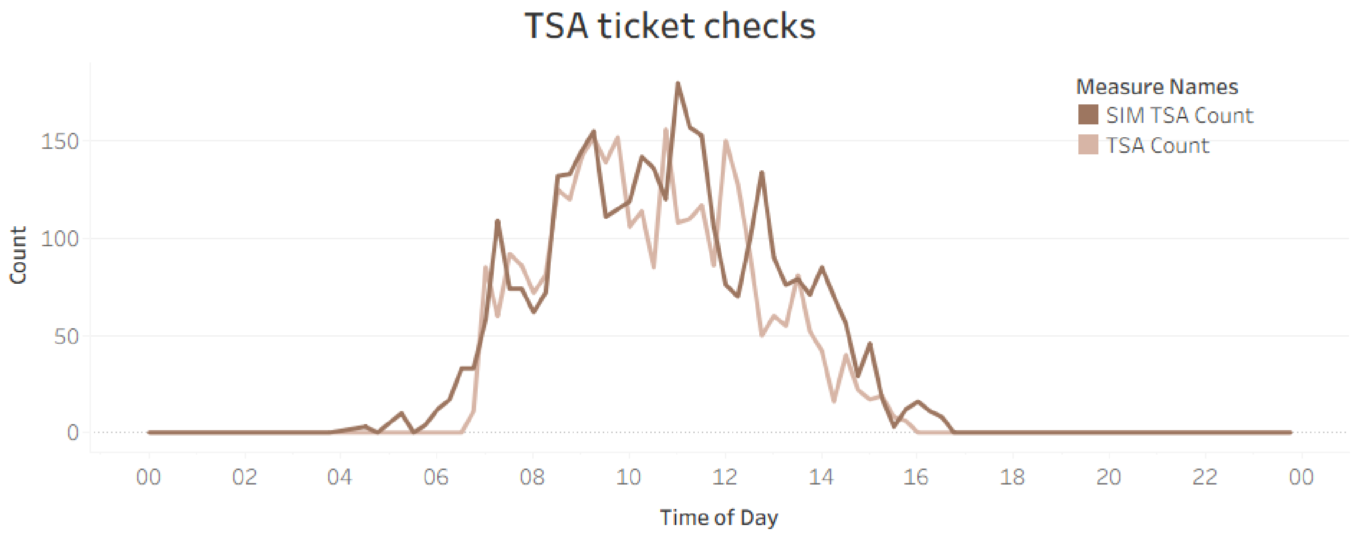




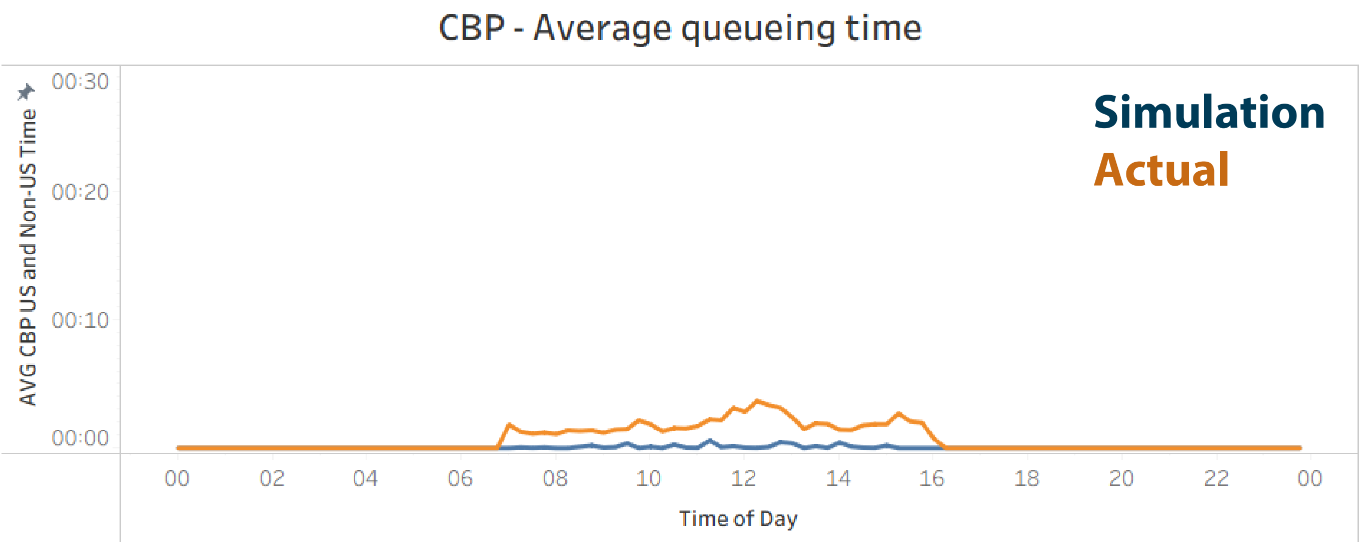
Metric definition:
Time spent queueing at security control, per 15-minute window. Simulation output vs operational data.

- T1 central search
- T1 Fast-Track
- T2 central search
- T2 Fast-Track

TSA scans and CBP queuing time

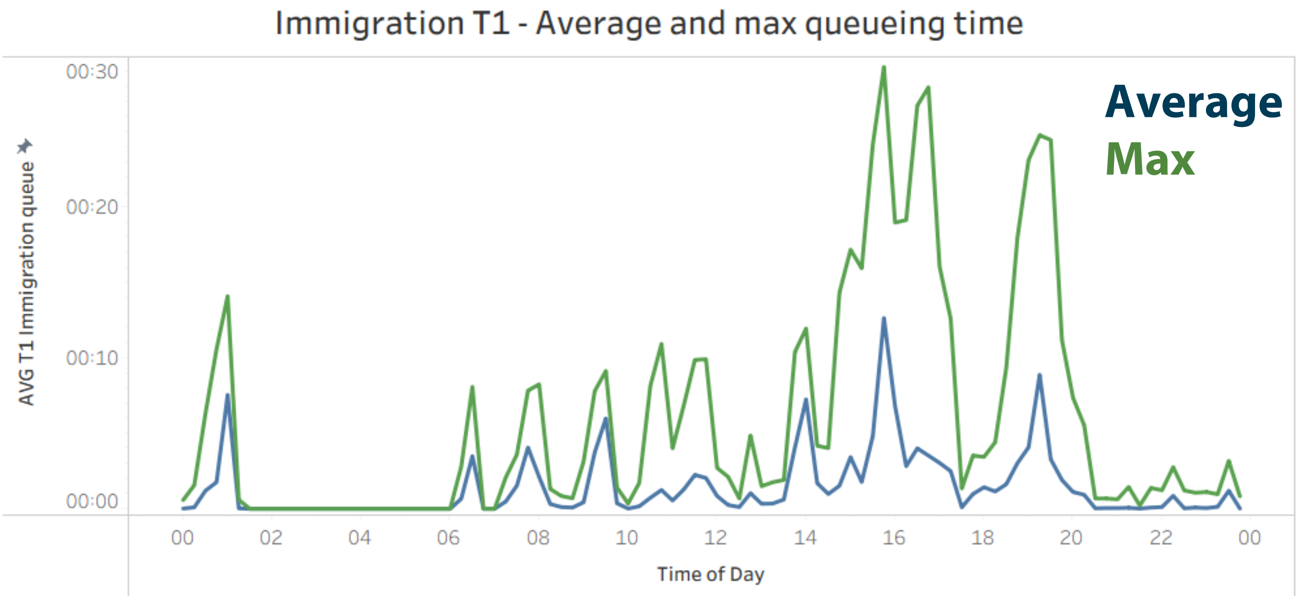


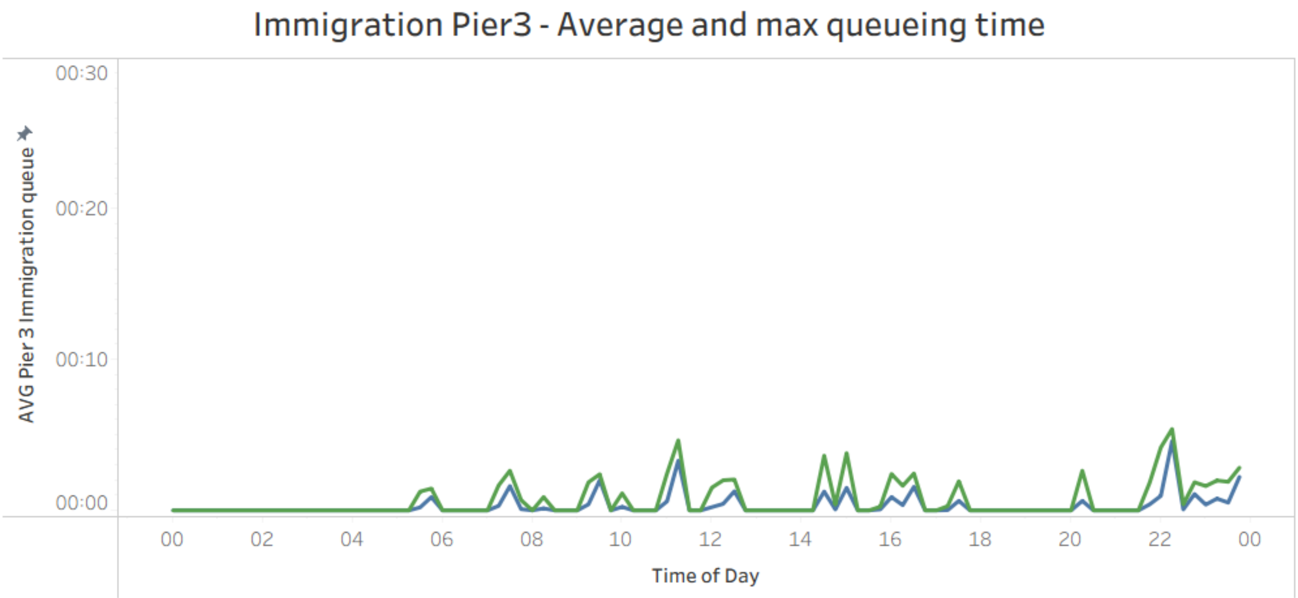
Metric definition:
Number of passengers that scan their documentation before TSA control per 15-minute window. Simulation output vs operational data.



Metric definition:
Time spent queueing at any CBP queue, per 15-minute window. Simulation output vs operational data.

T1 immigration queuing time

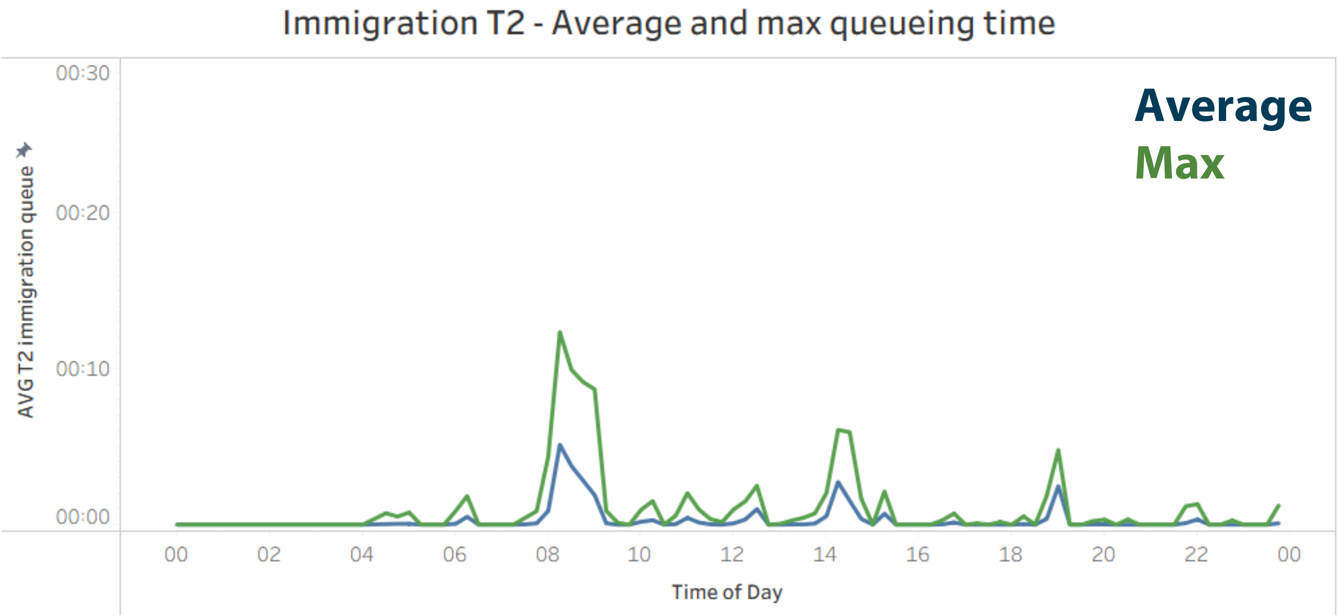




Metric definition:
Time spent queueing at immigration queue, per 15-minute window. Only simulation data available.

- Pier 1 and 2 immigration
- Pier 3 immigration

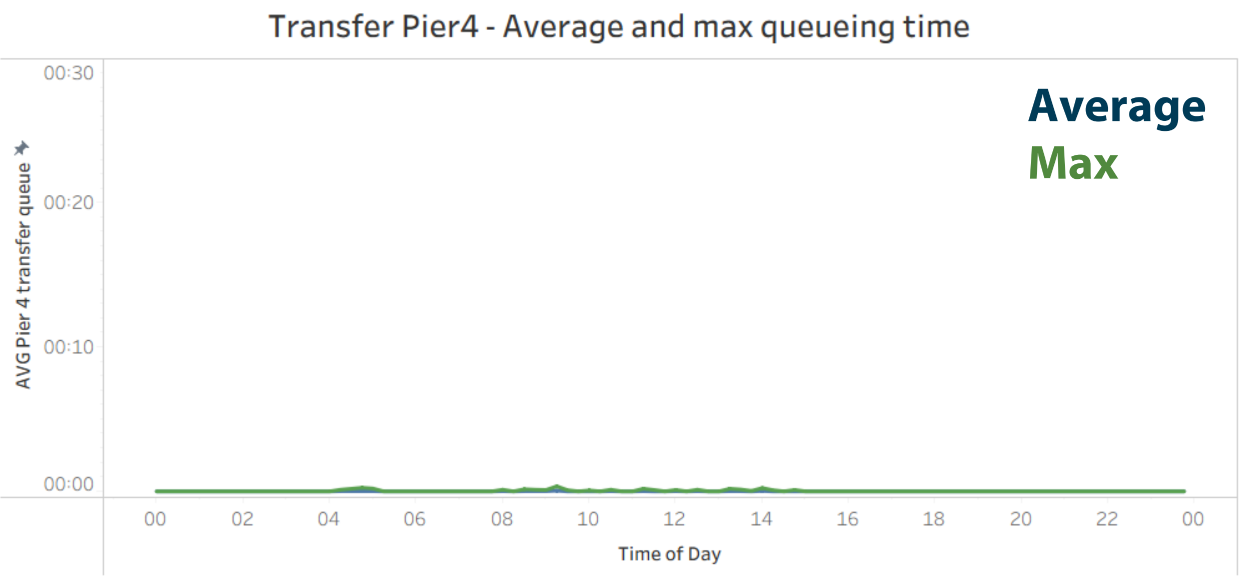
T2 immigration queuing time

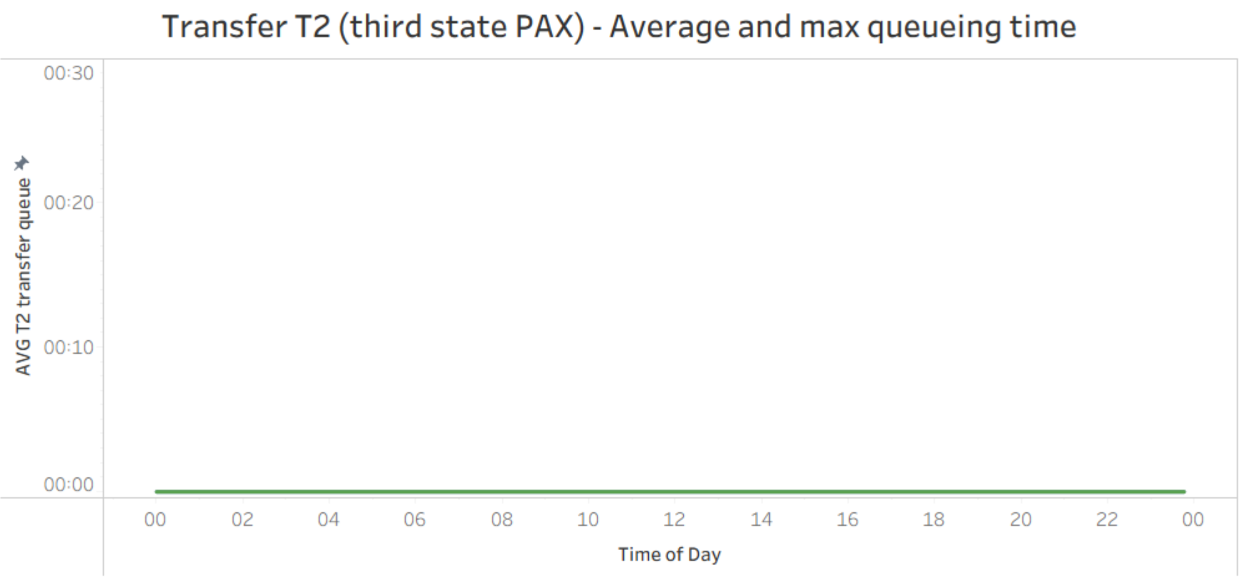


Metric definition:
Time spent queueing at immigration queue, per 15-minute window. Only simulation data available.

- T2 Immigration

Transfer facilities queuing time





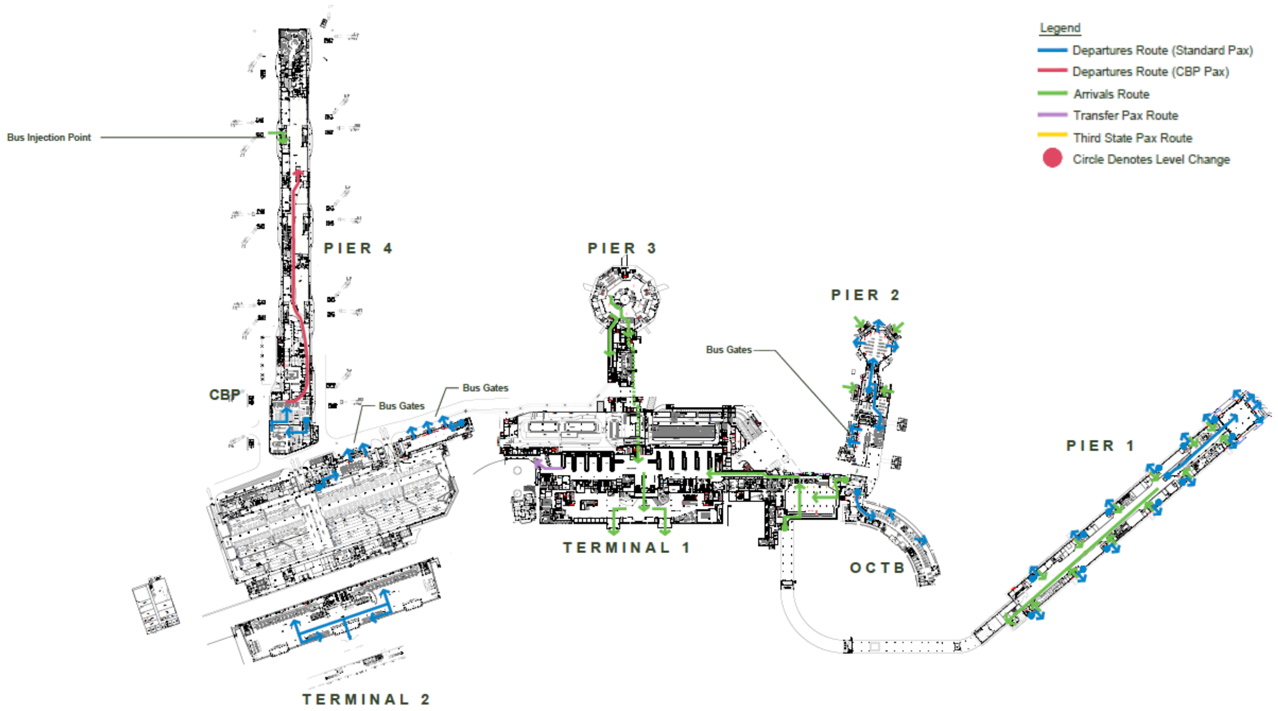
Metric definition:
Time spent queueing at immigration queue, per 15-minute window. Only simulation data available.

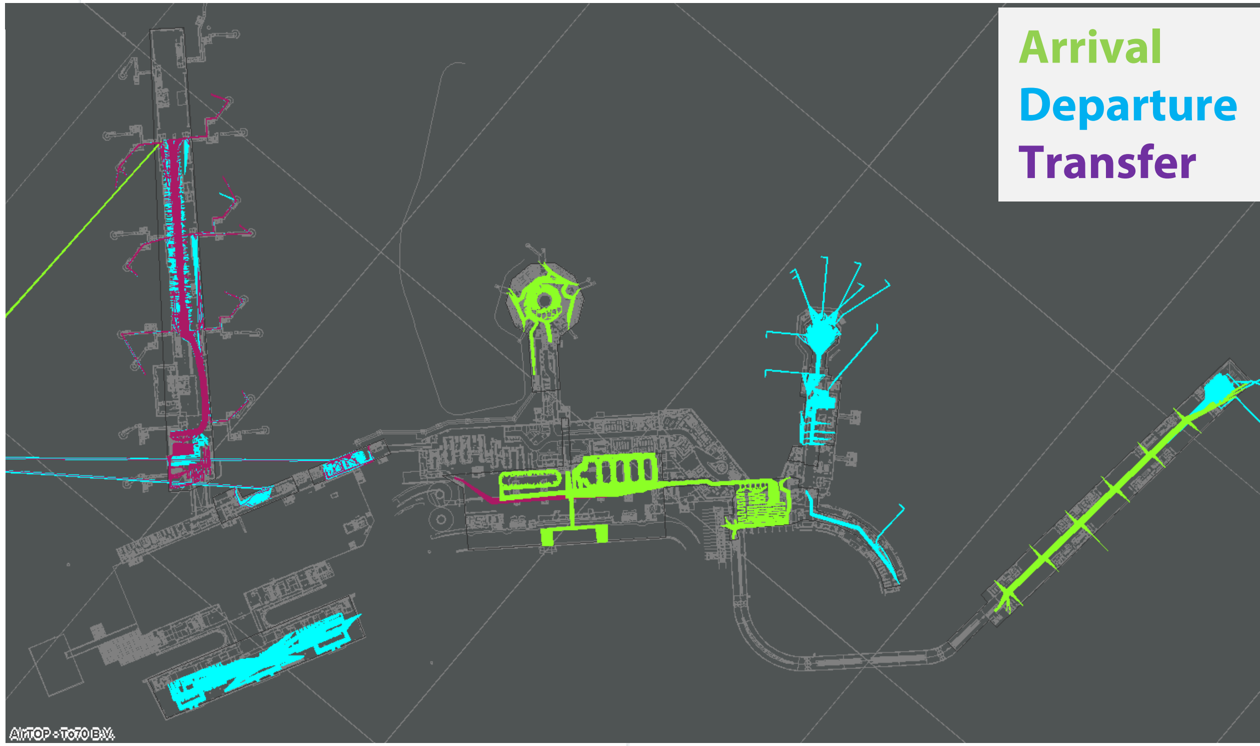
- Pier 4 transfer facility
- T2 transfer facility (third state PAX)

The transfer facility queue at Pier 4 is very small due to a small number of transfer passengers.

At T2 transfer facility there is no queue as the very small number of passengers simulated through this facility is served by 3 processors.

PAX Flow – L1

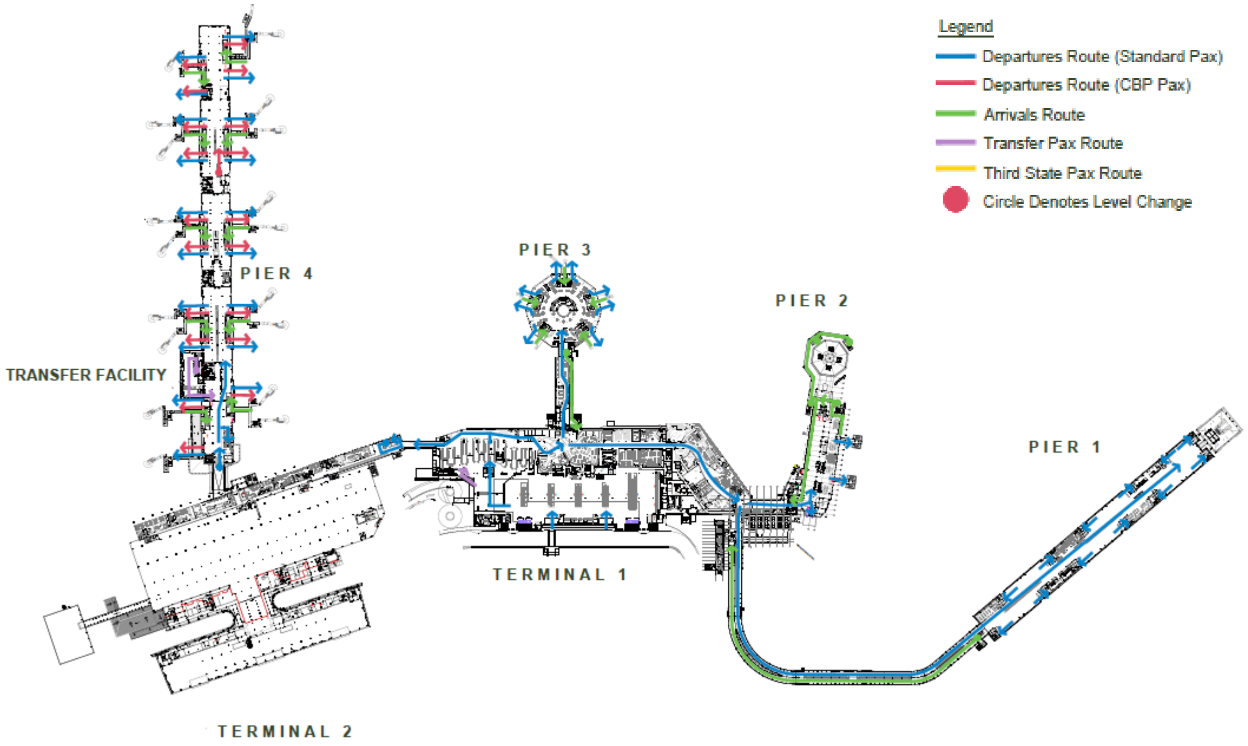


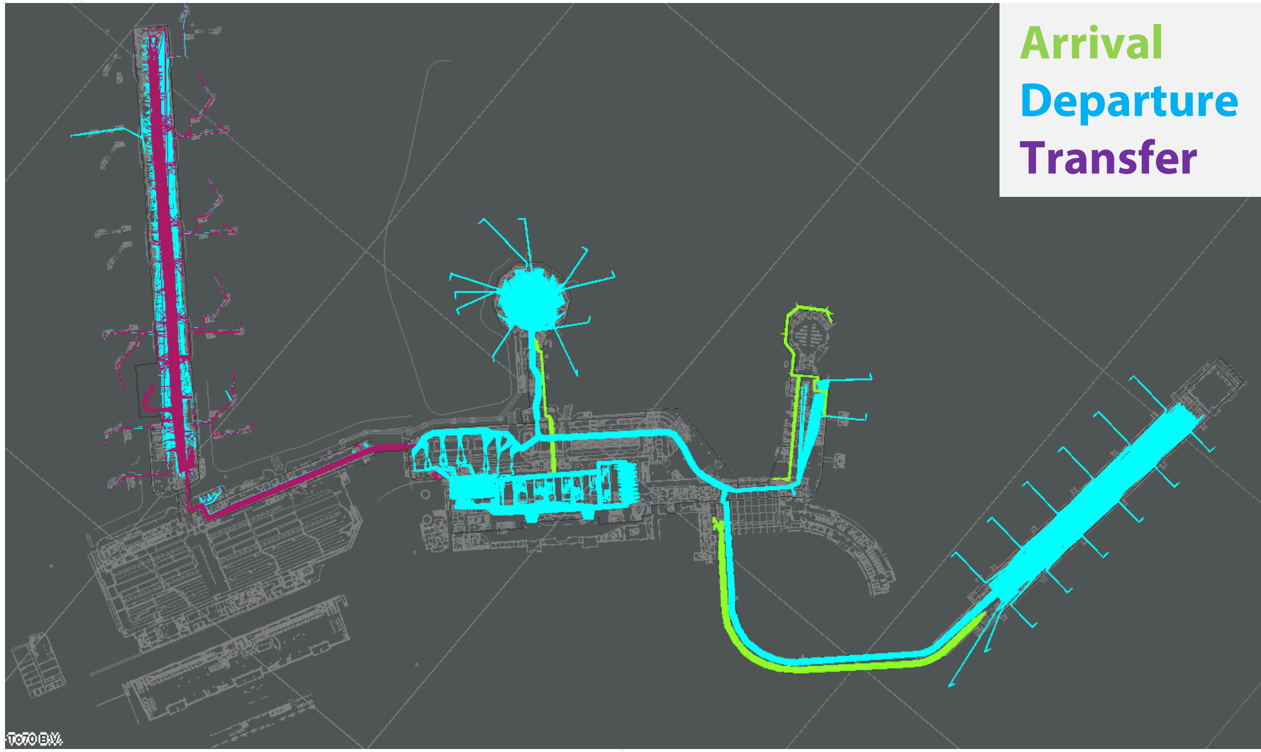


Remarks:

- The image on the right shows the aggregation of all simulated passenger trajectories for the given design day.
- As the GSE module was not opted for, bus gates and bus injection points are simulated by passengers walking faster in a straight line (T2) or with a set transfer time (Pier 2). The different modelling approach ensures ability to simulate the waiting time at the South Apron.
- In Pier 4 simulation snapshot it might seem like in certain areas there are only transfer passengers, but that is not the case (except for their specific TSA line and transfer facilities). It is a visualization artefact where, when zooming out, the magenta colour is drawn over the blue (individual flows are drawn in layers one over another).

PAX Flow – L2

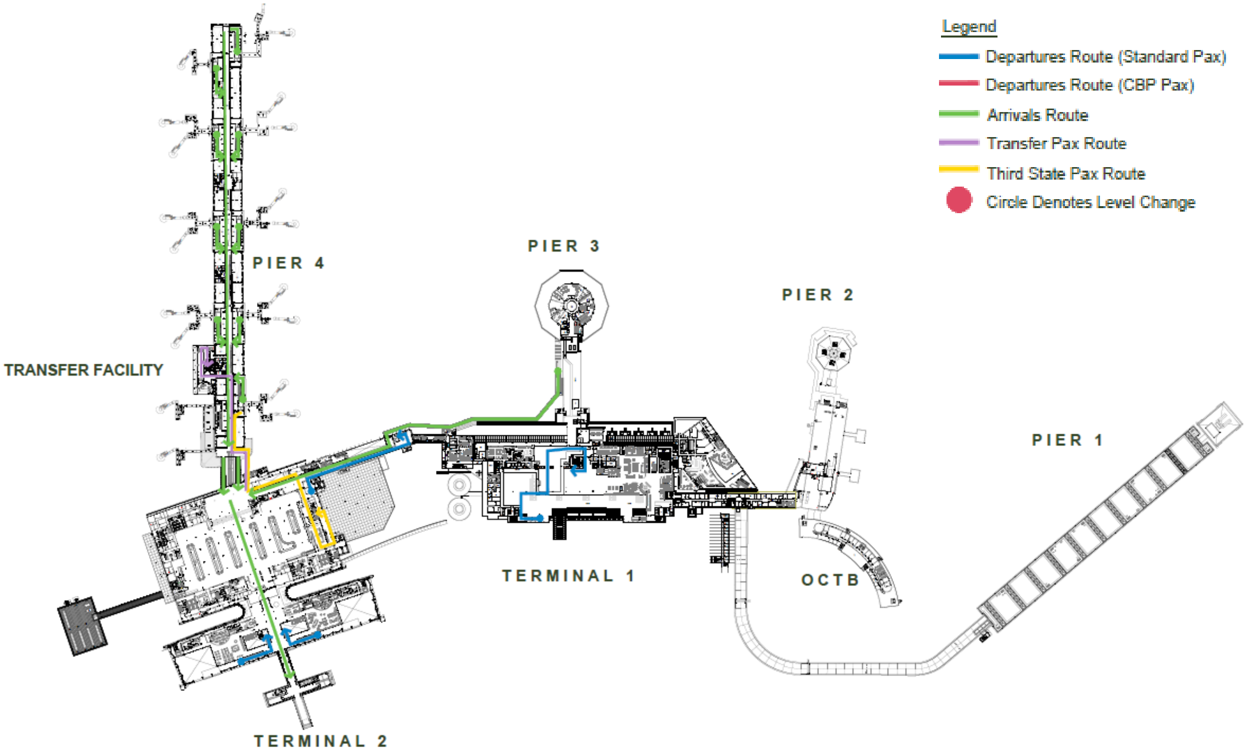


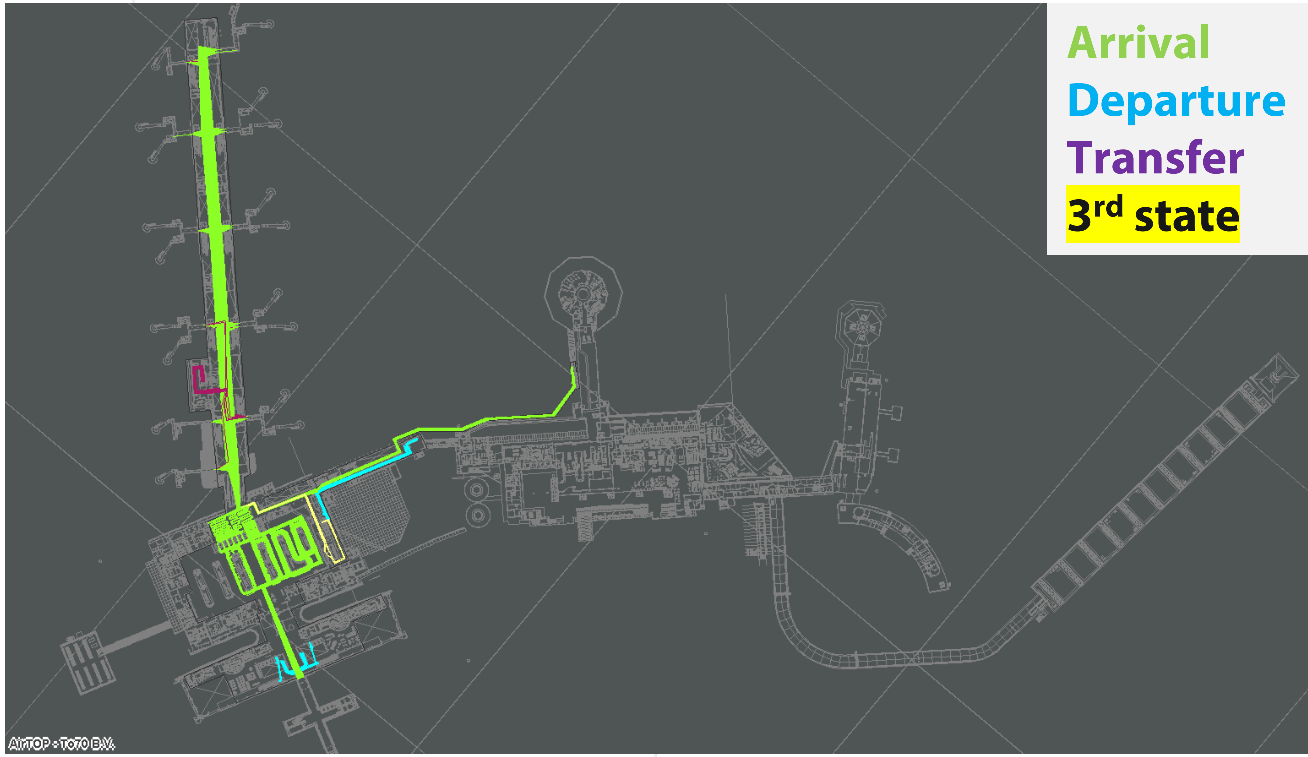


Remarks:

- Depending on the gate assigned, CBP passengers can board via L1 or L2. This is decided based on the stand allocation.

PAX Flow – L3

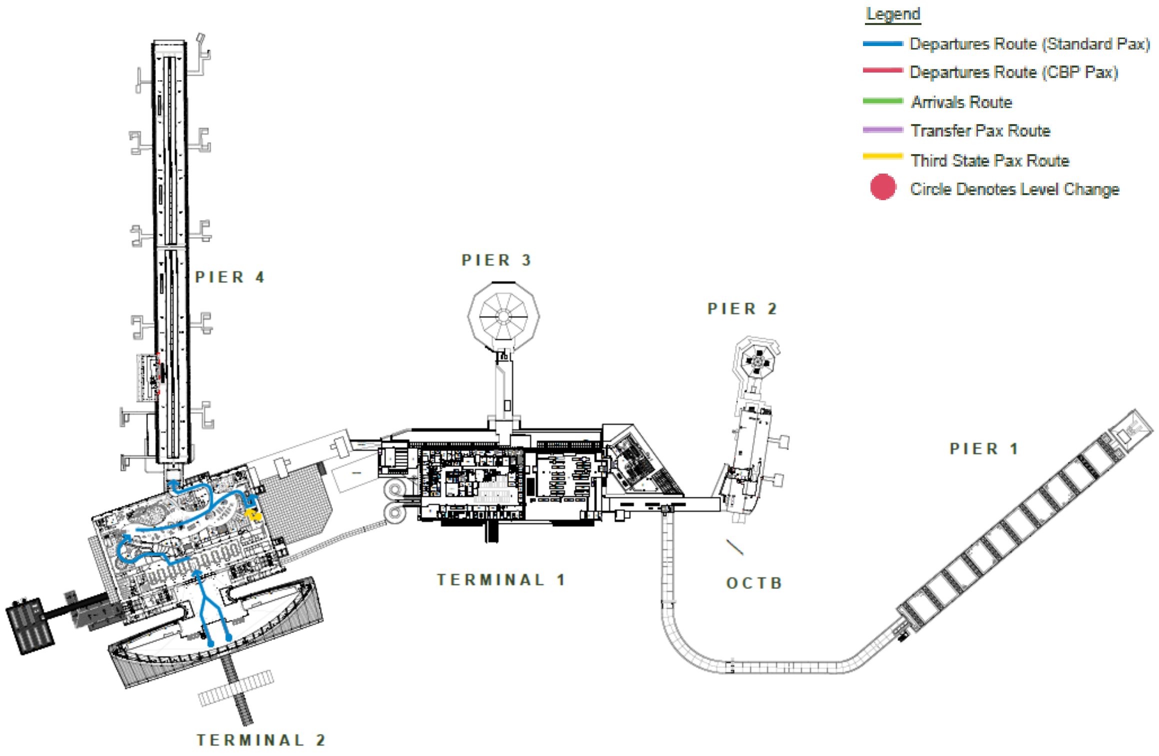


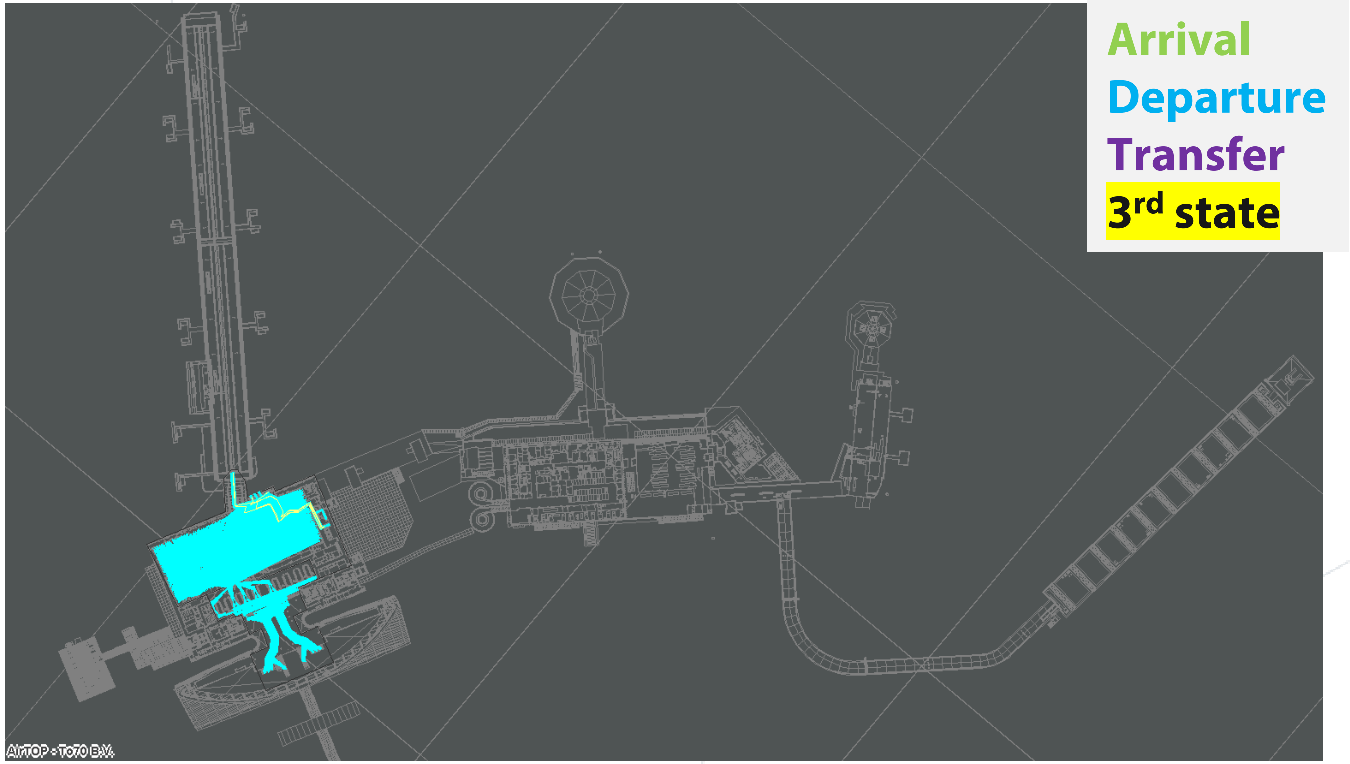


Remarks:

- Third state passengers using the facilities at T2 and then merging with the T2 departure passengers on L4.
- Some arrivals from Pier 3 using T2 immigration facilities.
- T1 L3 security control lanes were not available on the 8th of November, so they are not used for this validation. They will be modelled for the CIP assessment.

PAX Flow - L4



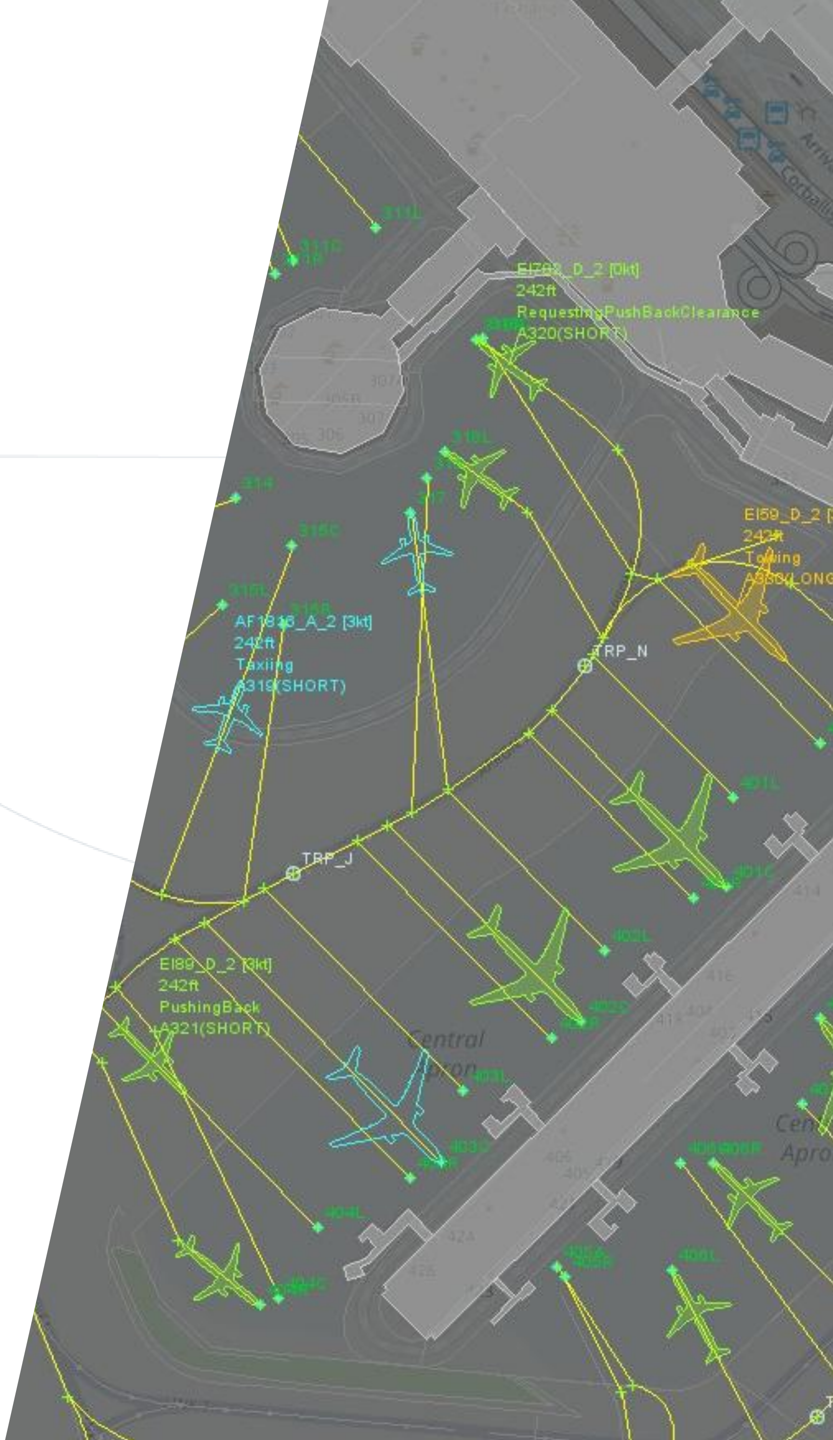


Remarks:

- Third state passengers using the facilities at T2 and then merging with the T2 departure passengers on L4.
- After adding the waiting/idle area and call to gate, it can be seen how T2 departure passengers take more space (instead of simply following standard walking path).

Observations (PTB)

- The updated PTB model is capable of modelling the correct number of passengers entering the processing areas in the correct point in time.
- With regards to queuing, the model can replicate the <u>peak</u> queuing durations when the load at the processor(s) is at its highest. This suggests the combinations of inputs and assumptions used in the model are correct, as their use leads to a comparable “busy hour” performance.
- For the remainder of the simulation day, there are noticeable differences between the real-world off-peak queuing durations and simulated off-peak queuing durations. These differences can be attributed to assumptions on composition of the passenger groups at any point in time, assumptions on the duration of processing a single passenger, human factors (performance of individual security or immigration or airport agents) and, ultimately, on operational irregularities during the day.
- Unlike with airside operations, where aircraft operate according to a strict (and predictable) set of rules, crowd simulation is based on more generic assumptions leading to less options to fine-tune the model performance.
- However, with enough additional data it should be possible to adjust even the off-peak periods to ensure a better match with reality – Nevertheless, there is trade-off between how much extra data/assumptions can be put into the model and how “independent” will such a model be when handling forward-looking projections where no detailed inputs (such as daily security opening schedules) are available.
- Based on the above, we believe that adjusting the model in a way that it returns correct peak performance is more important than having the majority of the daily profile well calibrated albeit with peaks being simulated inaccurately.



Observations (PTB)

- The airside model performs well thanks to much greater availability of operational data, clearer definition of operational rules and years of fine-tuning the model. The current (first) version of the PTB model is considered less accurate than the airside model – although this is expected, it can cause deterioration to the performance of the airside model (less match against the reality) in high-accuracy applications (such as the seasonal assessment). Therefore, we would suggest at least one more validation exercise to be carried out before the joint airside/PTB model can be used as a reliable predictor for seasonal planning purposes.
- Nevertheless, since the PTB model can replicate the main peaks in all the terminal processes accurately, it is safe to assume it will provide an accurate picture of the CIP performance when all processors at both terminal buildings are assumed to be available 24/7. Therefore, the joint airside/PTB model can (and will) be used to generate the quantitative evidence for the CIP simulation report due in the week starting 11th of May 2026.

Observations (combined model)

- The combined PTB/airside/airspace model is capable of providing a holistic view on capacity and efficiency metrics at Dublin airport.
- Development of two-way interactions between airside and PTB modules ensures the potential impact of capacity shortfall in one area (or process) of the airport can manifest as another type of delay in other parts (or processes) of the airport. This provides opportunities for investigation of new (and more complex) dependencies between various actors or processes in the model.
- Given the combined model is still run from the same reference timestamps as the original airside/airspace model, the accuracy of the combined modelling platform remains at a high level – noting the level of detail of assumptions used in the PTB module may need to be improved over the time.
- All the differences between airside model performance simulated in the original model and the expanded model are within reasonable limits and can be sensibly explained through analysis of model results and simulation replay videos.
- The combined model provides a solid basis for future assessments: be it seasonal projections, CIP assessments or expansions with potential additional features (i.e. GSE modelling).

Key data, assumptions and logic used in the model

Data sources

Source	Origin
Stand Allocation Rules	daa
Airline parking position preferences	daa
Aerodrome Manual Part E	daa
Standard taxi routes	daa
Flight schedules data	daa
Airside movements recordings	daa
AD 2.24-2 Aerodrome chart	AirNAV Ireland
AD 2.24-2 Aircraft parking and docking chart	AirNAV Ireland
AD 2 – 1 EIDW AIP	AirNAV Ireland
AD 2.24 Standard departure charts, standard arrival charts and instrument approach charts	AirNAV Ireland
Runway entry and exit data	AirNAV Ireland
Runway occupancy data	AirNAV Ireland
Arrival separation data	AirNAV Ireland
4D aircraft trajectories	FlightAware

Airspace and airside

Airspace

Parameter	Value
Minimum lateral separation	4 NM
Minimum vertical separation	1000 ft
Speeds at IAF	220 – 240 KIAS
Speeds in Point Merge	180 – 220 KIAS
Speeds at final approach	140 – 220 KIAS
Arrival sequencing techniques and priorities	1. Lateral separation (vectoring), 2. Vertical separation, 3. Speed control, 4. Holding pattern.
Runway arrival sequence and AMAN	Sequence re-ordering: max 3 positions backwards. AMAN lookahead horizon: 1 hour before STA.
Departure queue and DMAN	First come first served basis: No departure queue optimisation.
Arrival gaps (if requested)	6NM, 10NM and 16NM gaps in between two arrivals offered if requested.

Runway dependencies

Parameter	Value
Minimum departure after departure separation	87 seconds (or more, depending on WVC combination)
Minimum departure before arrival separation	Arrival no closer than 2NM from the threshold
Minimum arrival after arrival separation	3.5 NM (or more, depending on WVC combination)
Minimum departure after arrival separation	Start take-off after arrival has vacated the runway
A/D priority	Arrivals have a priority over departures – unless overridden by custom rules

Runway entries

Parameter	Value

Distribution of runway entries for easterly operations	• 28R:
	  • Aircraft size categories D or greater use full runway length (N1),
	  • 20% of aircraft size categories C or smaller use full runway length (N1),
	  • 80% of aircraft size categories C or smaller use N2,
	• 28L:
	  • all departures use full runway length.

Distribution of runway entries for westerly operations	10R: All departures use full runway length (S7)
dROT	Calculated from aircraft performance tables (AcType/Acceleration/Haul)

Runway exits and occupancy times

- R28L
  - Size cat A
    - 15% S3 (49s) & 58% S4 (54s) & 27% S5 (70s),
  - Size cat B
    - 8% S3 (50s) & 58% S4 (53s) & 34% S5 (67s),
  - Size cat C
    - 2% S3 (42s) & 22% S4 (50s) & 75% S5 (59s) & 1% S6 (58s),
  - Size cat D
    - 96% S5 (68s) & 4% S6 (67s),
  - Size cat E/F
    - 80% S5 (67s) & 16% S6 (69s) & 4% S7 (100s).
- R28R:
  - Arrivals to 28R not simulated.

Runway exits and occupancy times

- R10R
  - Size cat A
    - 2% S1 (65s) & 88% S2 (59s) & 10% S4 (52s),
  - Size cat B
    - 3% S1 (89s) & 90% S2 (59s) & 10% S4 (52s),
  - Size cat C
    - 4% S1 (68s) & 96% S2 (53s),
  - Size cat D
    - 38% S1 (77s) & 62% S2 (58s),
  - Size cat E/F
    - 60% S1 (79s) & 40% S2 (58s).
- R10L
  - No historical data provided.
  - Standard aircraft type deceleration used.
  - All flights able to vacate via N3 RET.

Taxiways

Parameter	Value
Maximum speeds on long and straight taxiway segments away from complex areas	20 – 30 kts
Maximum speeds on taxiway segments in complex areas	10-15 kts
Maximum speeds for parking in and pushing back	5 kts
Aircraft sizes	AcType size restrictions applied on some taxiway segments (i.e. only sizes C or smaller allowed on DS and DN at North Apron).
Rerouting rules (taxiway flows)	As per the flow diagrams provided by daa.
Taxiway locks	Specific taxiways are "locked" from use by other aircraft if a specific aircraft is using these. This is to prevent ground gridlocks.

Pushback & towing

Parameter	Value
Start one engine time duration	60s
Engine warm up duration	60s
Before taxiing check duration	60s for narrow bodies, 180s for wide bodies
Before tug connection offset	60s
Tug connection duration	60s
Tug disconnection duration	30s
Tug release points	As per the AIP
Max towing speed	15kt
Pushback speed	3kt
Actual tow-on & tow-off times	As per the data provided by daa

Pushback & towing

Parameter	Value
Minimum tow-on time	Driven by timestamps provided by daa. If not available, then: - Size categories A, B, C: 10 minutes before SOBT, - Size categories D, E, F: 20 minutes before SOBT.
Minimum tow-off time	Driven by timestamps provided by daa. If not available, then: - Size categories A, B, C: 10 minutes after AIBT, - Size categories D, E, F: 15 minutes after AIBT.
Towing routes	As per the diagram provided by daa.
Actual long-term parking positions	As per the data provided by daa.
Preferred long-term parking positions	In the absence of data from daa, the preferred LT PPs are assigned in this order of preference: 1. West apron 2. 5H 3. 5G 4. South apron 5. Any available position of suitable size 6. EIN hangars (if EIN aircraft)

Aprons

Parameter	Value
Parking position restrictions	As per the AIP.
Parking position allocation	Initially based on data provided by daa. If not available, a set of parking position allocation rules developed from airline preferences is applied to determine the most suitable PP.
Before push-back traffic check	No opposite traffic, no same heading traffic and no crossing traffic within 60s from the TOBT.
Stand-off positions	On taxiways S and on W1 with maximum stand-off duration of 20 minutes each.
Stand cool-down period	30s

Other

- No randomisation of any parameters.
- No rolling take-offs modelled.
- Default AirTOP aircraft performance dataset with nominal performance values used.

Passenger terminal buildings

Data sources PBT model

Model element	Source or file	Origin
Dublin Airport Terminal layout Number and location of passenger processors	*T-U-00-Combined-ITM.dwg* *T-U-01-Combined-ITM.dwg* *T-U-02-Combined-ITM.dwg* *T-U-03-Combined-ITM.dwg* *T-U-04-Combined-ITM.dwg*	daa
Passenger flows	*Passenger Flow.pdf*	daa
Passenger show up profiles	*Entry Show Up Profiles.xlsx* *Showup Profile.xlsx*	daa
Processing times	*Processing Rates.xlsx* *2018 Facility Requirement Metrics-R1-2026 Update.xlsx* *Appliance Activity Report XX-XXX-260216-260222.xlsx* *First Bag Last Bag Averages 2025 Full Year.xlsx* *SSK and Airware Information.xlsx*	daa
Passenger characteristics and splits	*Checkin Splits Data.xlsx* *2018 Facility Requirement Metrics-R1-2026 Update.xlsx* *2025 Full Year Transfer Splits.xlsx*	daa
Stand-boarding gate mapping	*Gate to Stands relationship with Unused Gates.pdf*	daa
Queue layouts	Several files (PDFs, images) provided by daa	daa
Validation Flight Plan	*Schedule Export 28LR 8th Nov.xlsx*	daa
Description of specific passenger processes such as Transfer, TSA, CBP, etc.	Several email exchanges and video calls with daa	daa

Passenger processing times

Processor	Processing time (seconds)	

Traditional check-in desks	**Terminal 1:**
	• Ryanair – 124 s
	• Other T1 airlines:
	    • Middle East flight – 129 s
	    • Long haul – 75 s
	    • Short haul – 45 s
		Terminal 2:
		
		Aer Lingus – 76 s
		Delta – 90 s
		Emirates – 113 s
		United – 86 s
		American – 86 s
		IAG – 45 s

Self-Service check-in kiosk	Ryanair Airware kiosk – 49 s Ryanair and Aer Lingus Collins kiosk – 86 s Other T1 airlines – 74 s Other T2 airlines – 116 s	
Baggage drop	Ryanair, Aer Lingus, Delta – 15 s Other T1 airlines – 25 s	
Ticket check	6 s	
Security control divesting (4 positions in parallel)	Uniform distribution 10-60 s (10-120 s Fast-track)	
Security control (metal detector)	13 s	

Passenger processing times

Processor	Processing time (seconds)
Immigration booth	NA – 45 s EU – 15 s Non-EU – 40 s
Immigration e-gate	24 s
TSA	Momentum document check – 10 s Emigration e-gate – 15s Custom check – 24s
CBP	Manned booth: • US – 34 s • Non-US – 78s EPP – 20s Global entry - 31s

Other terminal parameters

Parameter	Value
Baggage reclaim belts capacity	T1: 60-90 bags T2: 150 bags
Baggage reclaim belts timing	Two batches of luggage. 2-minute difference between them. First batch appears x min after arrival: Pier 1 and 2: 9 min Pier 3: 7 min Pier 4: 6 min Remote : 21 min

Bangkok, Bengaluru, Brisbane, Brussels, Edinburgh, Geneva, Medellín, Melbourne, Milan, Munich, São Paulo, Singapore, Shanghai, The Hague, Toronto.

www.to70.com

@to70

To70 Aviation