Note on validation of the baseline passenger terminal building model for the purpose of performing a capacity assessment of Dublin Airport

1 Background

Under Section 8(1) of the Aviation Regulation Act 2001, the Commission for Aviation Regulation (CAR) is the competent authority in Ireland for the purposes of Council Regulation (EEC) No. 95/93. Therefore, the Commission is responsible for determining appropriate parameters for slot allocation. To ensure that optimal parameters are set, the Commission has engaged Helios to carry out a full capacity assessment of Dublin Airport with a view to assisting the Commission in declaring the parameters for slot allocation at Dublin Airport.

The primary aims of this capacity assessment are as follows:

- Assessment of capacity of runways 10 and 28 under a range of parameters.
- Evaluation of stand and apron capacity.
- Identification of pinch points on the taxiway system.
- Assessment of appropriate delay criteria.
- Assessment of the maximum capacity when coordinating to a 10-minute period compared to a 5-minute period.
- Assessment of capacity of terminals 1 and 2.
- High-level assessment of airspace capacity, roads and parking lot capacity.

This document concerns the assessment of capacity of terminals 1 and 2 only.

To understand the situation at Dublin Airport and collect the data required the Helios team conducted a series of stakeholder consultations, via phone/skype and face-to-face meetings, in May 2017. The following stakeholders were consulted:

Organisation	Means	Date of Consultation
British Airways	Meeting	03.05.2017
ACL	Meeting	11.05.2017
Lufthansa	Skype call	12.05.2017
United Airlines	Skype call	12.05.2017
City Jet	Meeting	15.05.2017
daa (security)	Meeting	15.05.2017
daa (airside operations)	Meeting	15.05.2017
daa (passenger terminal operations)	Meeting	15.05.2017
daa (planning and regulation)	Meeting	15.05.2017
Ryanair	Meeting	15.05.2017
Stobart Air	Meeting	16.05.2017
Aer Lingus	Meeting	16.05.2017
IAA	Meeting	16.05.2017
CAR	Meeting	16.05.2017
daa (baggage processing)	Meeting	16.05.2017
Customs	Meeting	17.05.2017
Immigration	Meeting	17.05.2017
Swissport Handling	Meeting	17.05.2017

Table 1: Stakeholder consultations

2 Methodology

Our approach to assessing terminal capacity was to model the existing passenger terminal buildings T1 and T2 as a chain of passenger and baggage processing sub-systems, with each sub-system's maximum capacity being calculated and then compared with the peak demand to determine the weakest link(s) in the whole system. The constraining capacity of the whole system could then be the determinant for the derivation of coordination parameters for future season(s).

Instead of modelling different elements of terminal building infrastructure independently and assessing their respective capacities, we created one complete fast-time model of both T1 and T2 at Dublin Airport. This model is capable of simulating all the key processes in both terminals, such as passenger check-in, passport control, security screening or boarding. The model is also able to simulate Customs and Border Protection (CBP) processes. All elements of the model are interlinked and interact with each other, ensuring that the impact of any potential bottleneck is then appropriately propagated through the whole system.

Before the model can be used for the analysis of the impacts of changes in a future schedule it has to be calibrated. The approach taken involves:

- Development of the baseline model. This is a reference model which allows direct comparison against available historic records. After consultation with the daa it was decided that 23 June 2016 was to be used as the 'peak day' for the purposes of developing the baseline model. This day was identified as a typical peak day in terms of number of movements, passengers, and traffic mix. All flights that operated at the Dublin airport at any time between 23 June 2016 00:00:00 and 23 June 2016 23:59:59 were included into the simulation. The model was built using data and assumptions that were provided by daa and other relevant information which had been disclosed by other parties during the stakeholder consultations.
- Validation and calibration of the baseline model. Early stages of the baseline model performance were discussed with CAR and daa representatives during a model validation meeting held on 28 June 2017 at Dublin Airport. As the model calibration is an iterative process, the aim of this meeting was to identify the areas where the model output showed significant deviations from the observed movements and to suggest corrective actions.
- Post-review actions. The model was updated taking into account the previously identified deviations and the performance of the latest version of the baseline model is now being shared with all coordination committee members via this document.
- Development of reference S17 and S18 model. With the baseline model calibrated against available S16 historic data it will be possible to adjust the existing model for simulation of S17 performance. With the S17 model set-up and running it will be possible to evaluate impact of any changes proposed for the S18 flight schedule, be it changes in flight schedule, fleet mix or terminal buildings infrastructure.

The assessment of both T1 and T2 passenger terminal buildings encompasses the analysis of passenger flows in the following facilities:

- Departure flow:
    - Departure hall.
    - Check-in.
    - Boarding pass check.
    - Security screening.
    - US preclearance area.
    - Boarding.
- Arrival flow:
    - Disembarkation.
    - Immigration.
    - Baggage delivery.
    - Arrival hall.
- Transfer flow:
    - Disembarkation.
    - Transfer passport control.
    - Security screening.

In addition to the dynamic simulation of passenger flows, a static analysis was carried out to determine the capacity of the baggage handling systems (collection, screening and sorting for departing bags and transferring bags, delivery and claim belts).

With the exception of the baggage handling system, all simulations are being conducted in Pedestrian Dynamics (PD) fast-time airport simulation software. This software is dedicated to modelling of passenger terminal building capacities, and has been widely used by various international hubs (e.g. Schiphol and Brisbane). The tool allows dynamic simulations of each passenger flow and integrates individual passenger behaviour and characteristics.

3 Data and assumptions

The following table includes the data and assumptions collected for the baseline model preparation.

Item	Type	Source
CAD drawings of T1 and T2	Data	daa
Detailed flight schedule from 23 June 2016, including number of passengers and allocated resources: - Scheduled and actual times - Operators - Terminals - Gates - Belts, first bag and last bag delivery	Data	daa
Average processing times for each passenger process	Data	daa (verified by Helios)
Process resources, resource allocation, resource opening and closing schedule: - Check in - Security lanes at Terminal 1 & Terminal 2 - CBP and DVO desks at US pre-clearance area (no distinction) - Immigration desks at Terminal 1 & 2 with EU/Non-EU - Baggage belts	Data	daa
Passenger immigration profiles: EU/ non-EU, US / non-US : - At Pier 3 for Long Haul peak - At Pier 1 & 2 for Short Haul peak - At Pier 4 for Short Haul and Long Haul peaks	Assumption	daa
Immigration resource opening/closing schedule (including EU/non-EU): - At Terminal 1 Pier 3 - In the US pre-clearance area for TSA lanes	Assumption	Helios
Check-in mode distribution per airline group: - % of straight to security - % of SSK - % of bag drop-off - % of traditional	Assumption	daa
Transfer matrix (distribution of passengers between their two flights)	Assumption	Helios
Show-up profile at boarding pass scan per passenger type - A set of show-up profiles at Terminal 1 - A set of show-up profiles at Terminal 2	Data	daa
Show-up profile in departure hall: - A set of show-up profiles at Terminal 1 - A set of show-up profiles at Terminal 2	Assumption	Helios (discussed with daa)

Actual 23 June 2016 passenger monitoring data:
- Show-up count at boarding pass scan Terminal 1 & 2
- Waiting time at security on Terminal 1 and Terminal 2
- Waiting time at immigration for EU passengers at:
  o Terminal 1
  o Terminal 2
- Waiting time at immigration for non-EU passengers at:
  o Terminal 1
  o Terminal 2
Waiting time at immigration at Pier 3
- Waiting time at CBP + Triage, at TSA, at DVO, at End-to-End
- Waiting times in the Baggage Hall
Waiting times provided are median values of the last 15-minute period
	Data	daa

Table 2: List of inputs

4 Calibration and validation of FTS results

The calibration of the passenger terminal building model was made possible thanks to the provision of actual passenger flow monitoring data provided by the daa, including:

- the boarding pass scanning report,
- the mobile phone antenna signal captures within each security area and immigration hall (to measure waiting times in these areas).

In order to fully calibrate the model, we would need access to all of the parameters for each of the processes accompanied by a specific time of implementation, which is not possible. However, thanks to an extensive data collection provision, performed by various parties, an intense calibration exercise was made possible incorporating appropriate assumptions (see the table above) when required, to compensate for the missing input data.

For example, data does not exist on the number of actual EU and non-EU passengers on each flight on a specific day, and the allocation schedule is not available at two processes (TSA and Immigration Pier 3). Appropriate assumptions were made, which resulted in minor deviations of performance of the model when compared to the observed performance measured on the design day.

The following sections show the key outputs calculated by our model compared to the observed passenger flows and queue times on the peak day.

Please note that calibration of security processes is still on-going and any results will be shared as soon as they are available.

4.1 Departing passengers at the boarding pass scan in T1 and T2

Departing passengers must pass through the boarding pass scan in both T1 and T2. However, it is important to note that T1 passengers can use the boarding pass scan and security lanes from T2, and vice versa, as there is a common airside facility and passengers can move between all piers once on the airside.

The good match between the Helios and daa graphs is very important to the model calibration. In order to build the model, it was necessary to assume a show-up profile for departing passengers in the public hall (to generate passengers for the modelling of initial processes) while daa provided show-up profiles at the Boarding Pass Scan (BPS) at a later stage. The graphs in sections below show comparable results, which indicates that the model is successfully representing the flow of departing passengers.

4.1.1 Boarding Pass Scan in T1

These two graphs show the simulated and actual show-up at T1 boarding pass scan every5 minutes (Figure 1), and the cumulated values over the S16 Design Day, Figure 2.

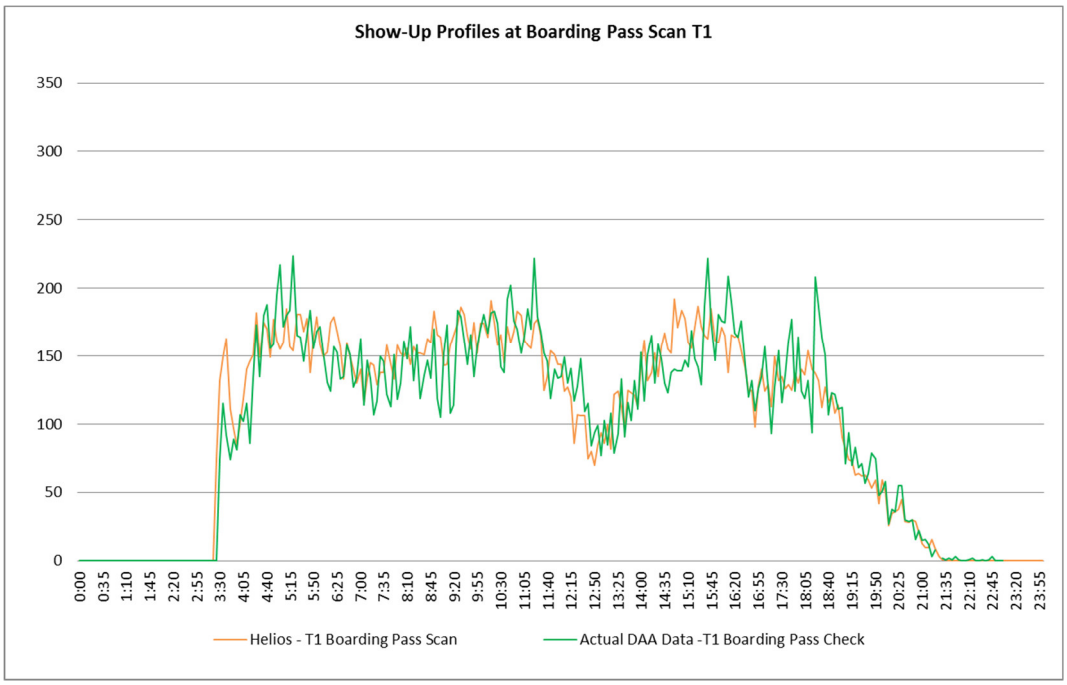

Figure 1: Number of passengers arriving at the boarding pass scan (before Security) per 5 min periods (T1)

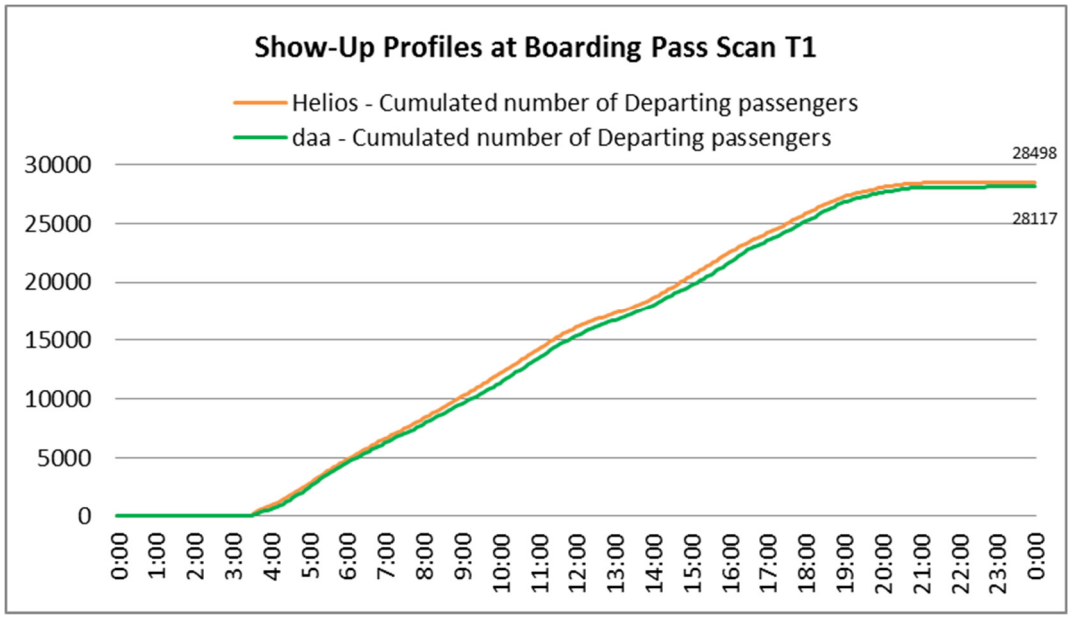

Figure 2: Cumulated number of passengers arriving at the boarding pass scan (T1)

4.1.2 Boarding Pass Scan in T2

These two graphs show the simulated and actual show-up at T2 boarding pass scan every 5 minutes, (Figure 3), and the cumulated values over the S16 Design Day, (Figure 4).

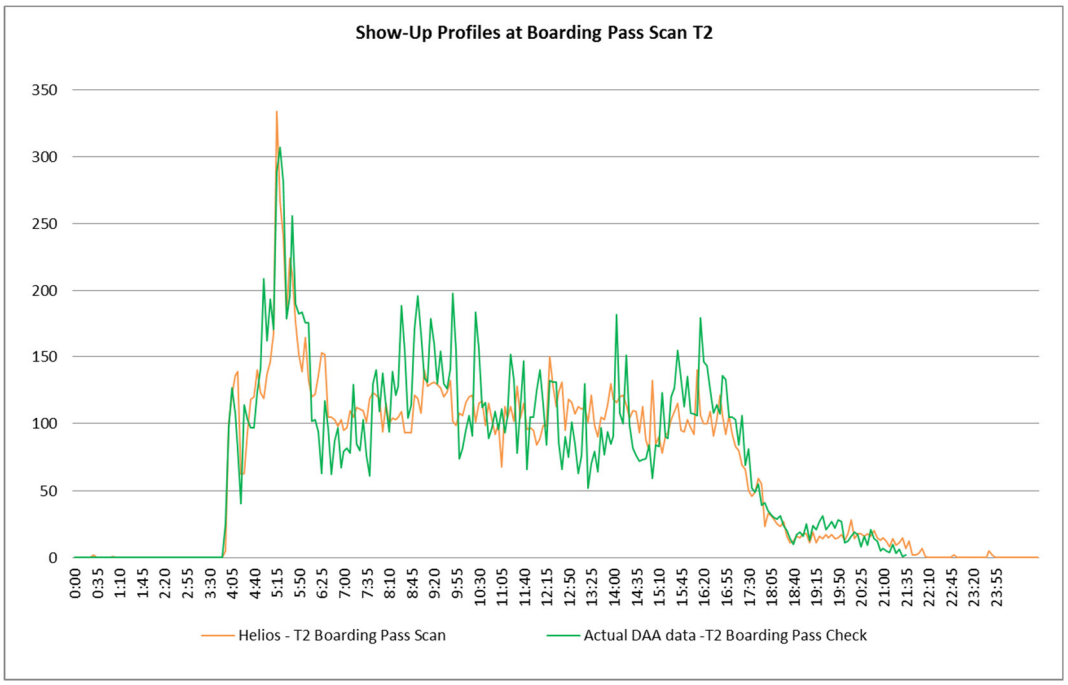

Figure 3: Number of passengers arriving at the boarding pass scan (before Security) per 5 min period (T2, including Transfer Passengers)

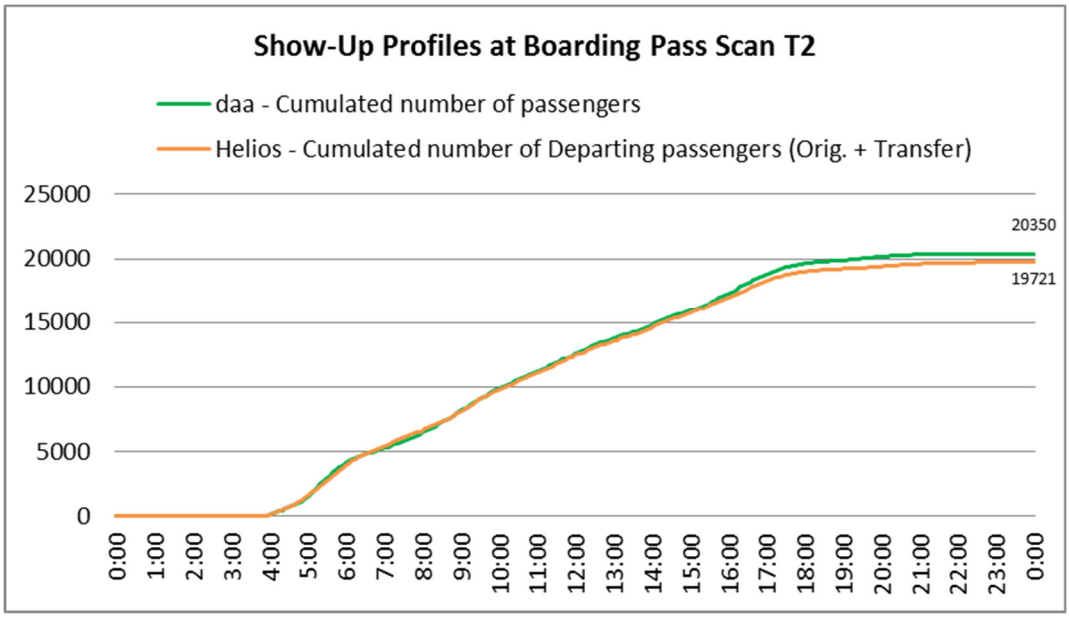

Figure 4: Cumulated number of passengers arriving at the boarding pass scan (T2)(with transfer passengers)

4.1.3 Boarding Pass Scan in T1+T2

The addition of passengers from T1 and T2 Boarding Pass Scan demonstrates the similarity between the model and the daa data. From the flight schedule analysis, a total of 48,247 passengers were originating or transferring passengers.

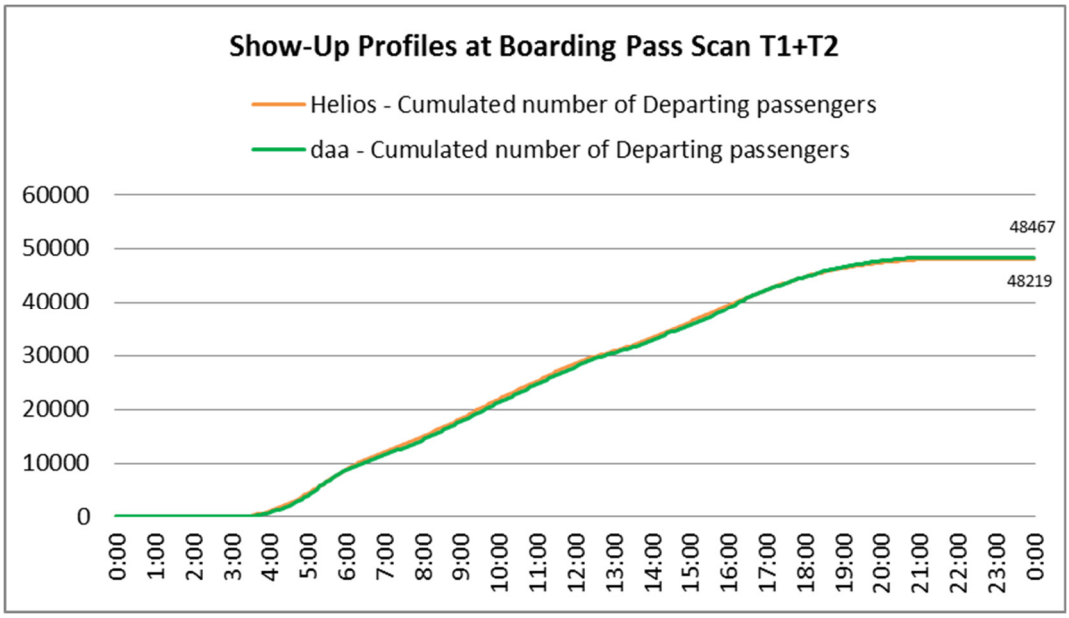

Figure 5: Cumulated number of passengers arriving at the boarding pass scan (T1+T2)

4.2 Waiting times at security

All departing passengers must pass through the security screening process but before reaching this area, all passengers need to go through the boarding pass scan. The boarding pass scan process will smooth the peak demand and will therefore regulate the number of passengers allowed within the security screening area.

The passenger arrival graphs at upstream boarding pass scan are very similar to the actual data, both in profile and in total number of passengers. A small number of passengers have preferred to use the opposite security area (instead of the one allocated in the model) but it is negligible. With these originating passengers entering into the security area, the security lanes allocation planning provided to us has been implemented into the model. Fast-track security lane has not been modelled.

Data	- Number of resources - Opening schedule - Throughput per 15 min period at T1 and T2 - Average processing time

4.2.1 Using the same Opening Schedule

The following figures show the opening schedule for security lanes. This opening schedule has been calculated by daa in advance (so to adjust the staffing), using flight schedule and show-up profiles to determine future daily profiles. During the Design Day S16, the number of actual opened X-ray lanes is significantly below the maximum capacity, in both terminals, as shown on the graphs below.

Therefore, during the capacity assessment analysis a large headroom of capacity will be available because in each case there are 50% more security lanes available to be opened.

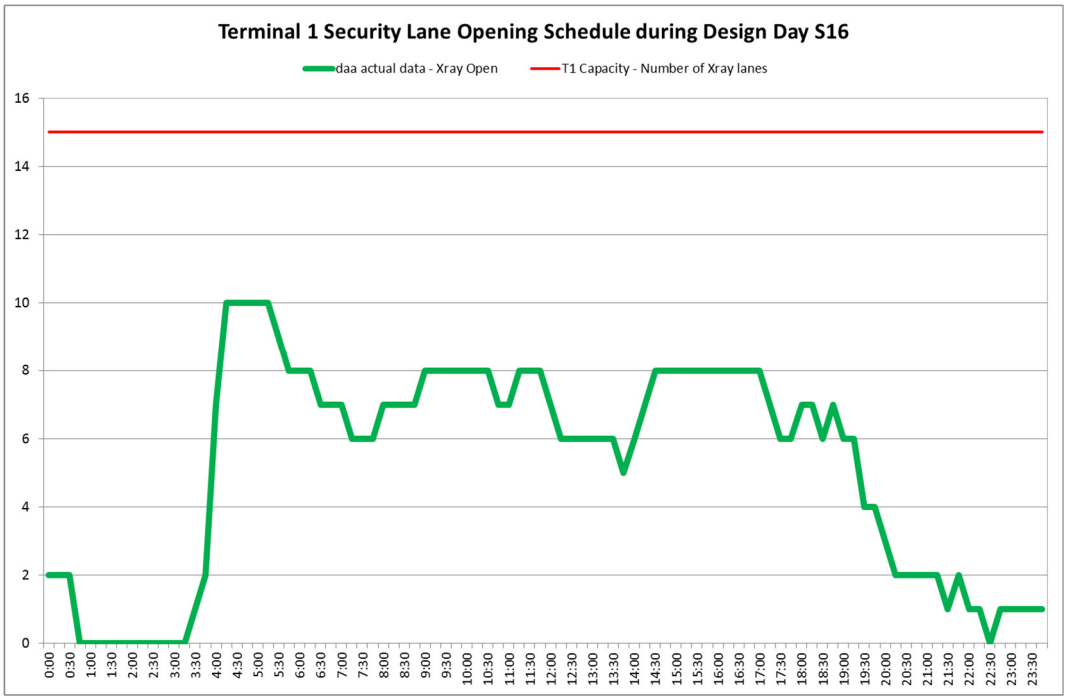

Figure 6: T1 security lane opening schedule

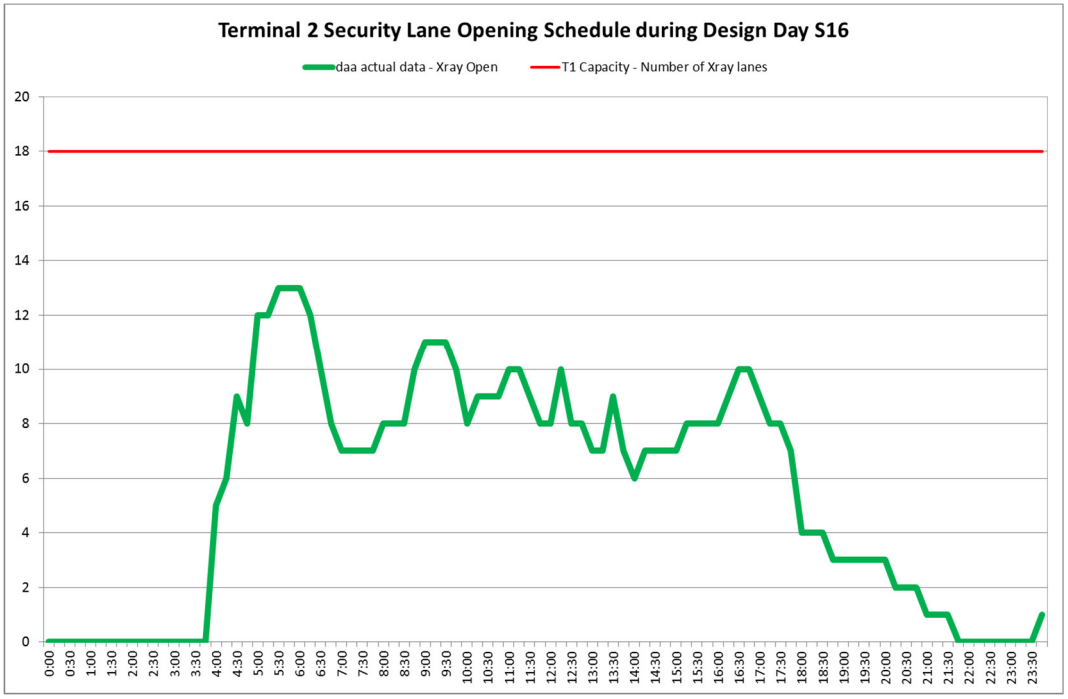

Figure 7: T2 security lane opening schedule

The daa data has a discrepancy in the number of passengers between boarding pass scanning and security. While daa counts a total of 48,467 passengers at T1 and T2 Boarding Pass Scan facilities (in line with the Flight Schedule table), there are only 43,239 passengers being reported from T1 and T2 Security service

whose numbers come from the automated Walk-Through Metal Detector system. The comparison of the throughput at security between the model results and the DAA data is analysed in the following section.

4.2.1.1 Comparison for T1 Security

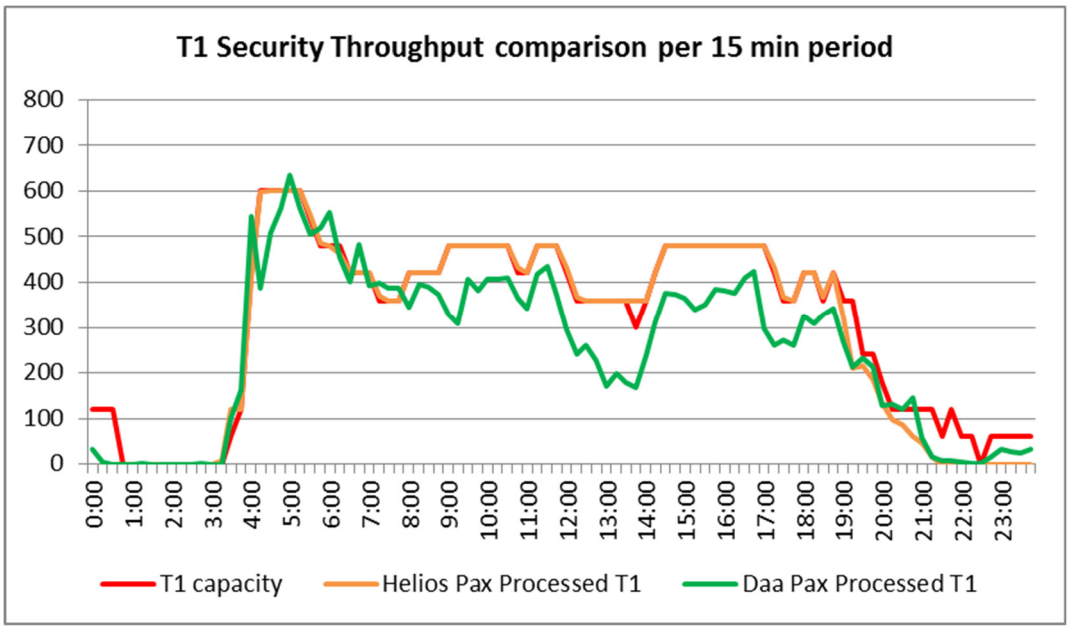

Figure 8: T1 security lane throughput per 15 min period

The comparison of T1 Security model throughput, which is the number of processed passengers per 15min period, with the same opening schedule as the one from the daa data, shows a similar profile over the day. However, there are more T1 passengers being processed in the model than in the DAA data (28,476 against 24,210 as reported), especially in the afternoon period (compared to 28,117 passengers reported from T1 Boarding Pass Scan). Also, the model is processing as many passengers as possible along the 4am – 7pm period of the same day (where throughput equals capacity), which justifies the positive waiting times shown on the graph below for the same period.

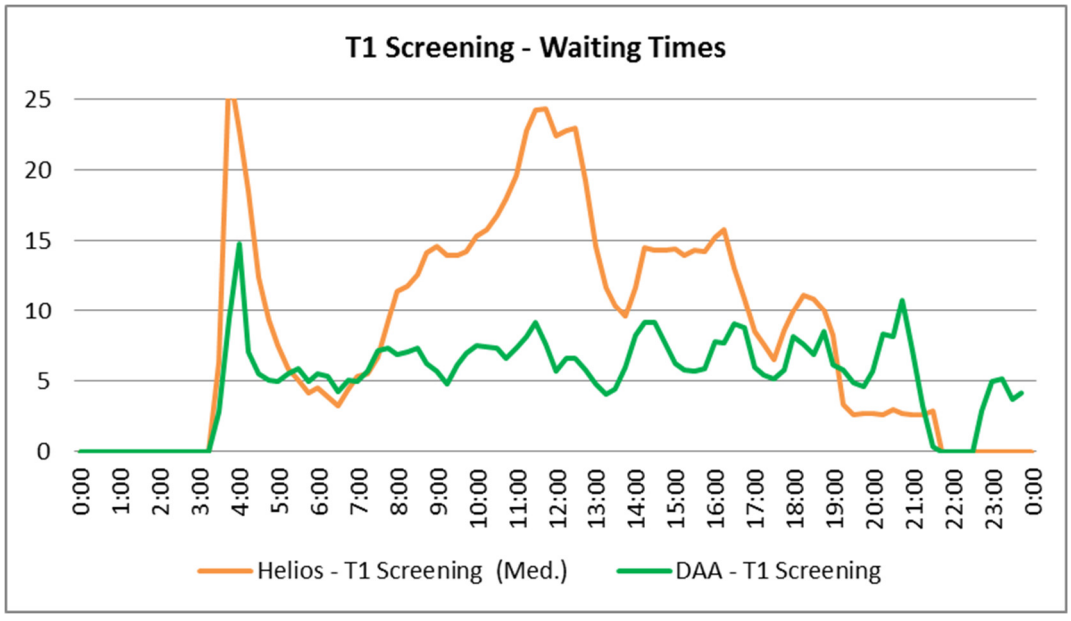

Figure 9: Waiting times before Security. This metric is the median value over all T1 passengers entering the security queue per last 15 min period.

The comparison between the waiting times calculated in the model and the ones from the daa data is showing major differences in the morning peak and around noon.

As an intermediate conclusion, the model is not returning the same Waiting Times profile while using:

- The same waiting time calculation method: from the moment the passenger starts queuing at Boarding Pass Scan till the moment he is processed at Security
- Similar opening schedule
- The average processing time based on the solid assumption that even on that particular busy day the Security process might have been done faster than usual
- A slightly different show-up profile

In order to investigate the differences, another simulation has been ran with the same show-up profile data from daa: the same number of passengers (28,117) is generated in each 5 minute period of the day as being reported from daa BPS count.

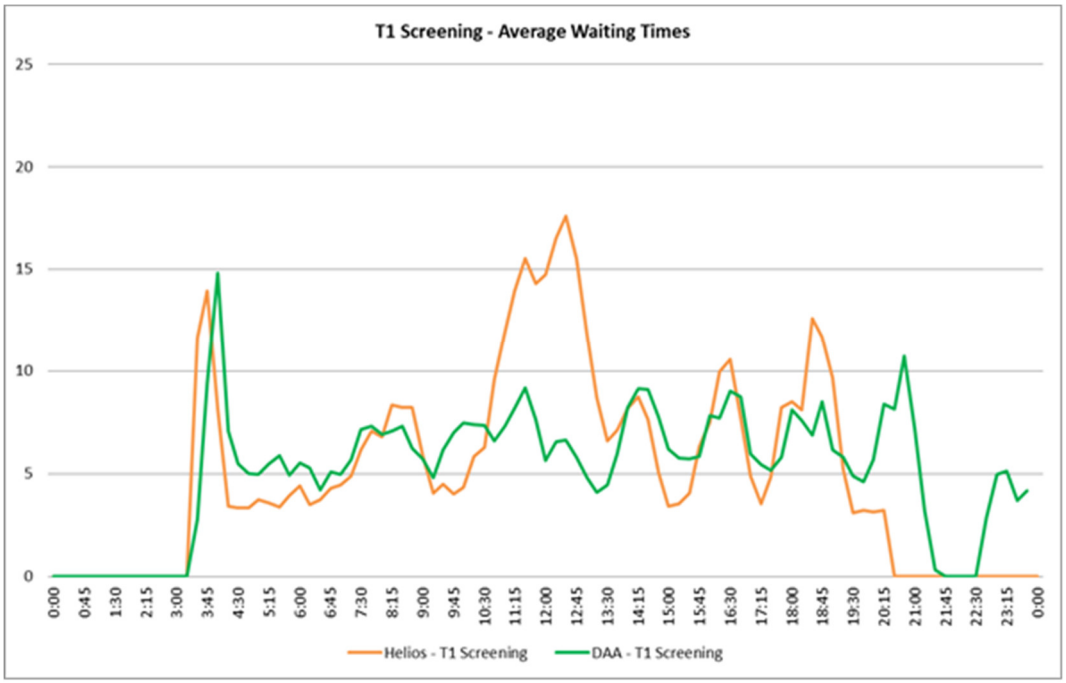

Figure 10: Waiting times before Security. This metric is the value over all T1 passengers entering the security queue per last 15 min period. The same show-up profile from daa has been used in the model to generate passengers before Security.

- The morning peak is well represented here: the show-up profile from Helios assumption was more aggressive at 3.30 (see Figure 1) than the daa data.
- Around noon, the waiting time from the model increases over 15 minutes (median value) while daa data is slightly below 10 minutes. However, the

throughput from the model is maximum and is equal to the available capacity.

- Surprisingly, around 9pm, the waiting times from daa blu-fi system are still reaching 10 minutes, while the show-up is very low (72 passengers after 9pm) and up to two lanes remain opened.

As expected from the model, the dispersion of waiting times around the median and the average values is very limited.

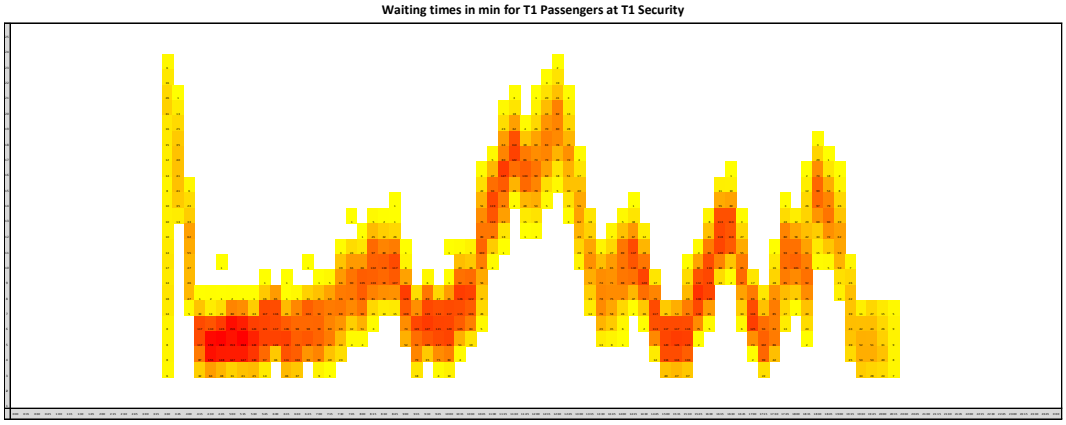

Figure 11: Graph showing the individual passenger waiting time classification at T1 Security during the S16 Design Day

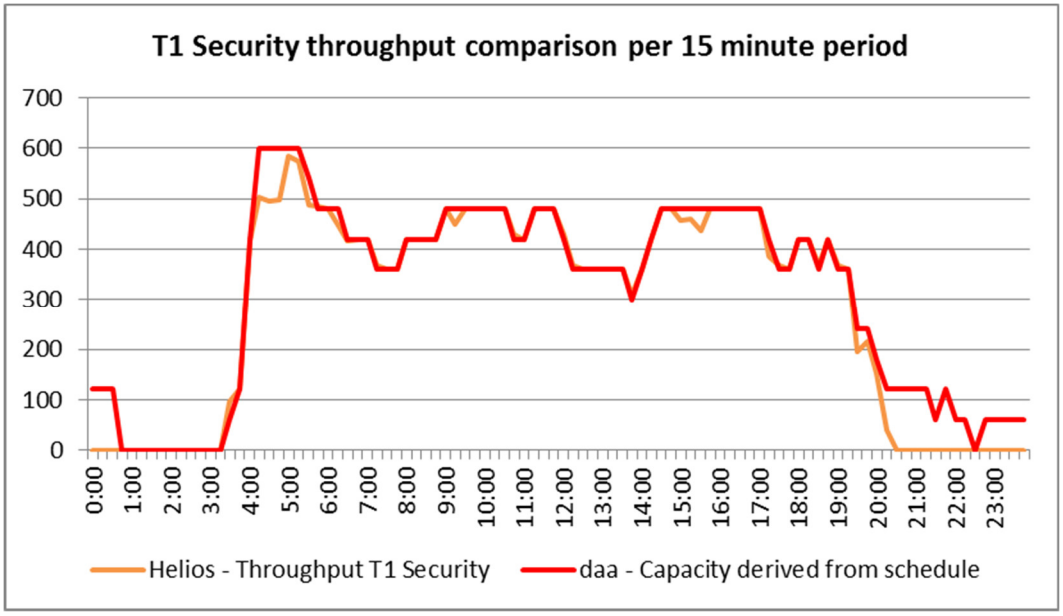

Figure 12: Throughput at T1 Security. The same show-up profile from daa has been used in the model to generate passengers before Security. The capacity is calculated every 15 minutes from the number of opened lanes (240 pax/h/lane).

4.2.1.2 Comparison at T2 Security

The comparison of T2 Security model throughput, with the same opening schedule as the one from the daa data, shows a similar profile over the day but less T2 passengers are being processed in the model than shown by the daa data (17,827 against 19,029 as reported). This is happening especially in the late afternoon period. Also, the model is processing as many passengers as possible from 11am to 2pm and after 5pm, and therefore the waiting times will be positive during these periods.

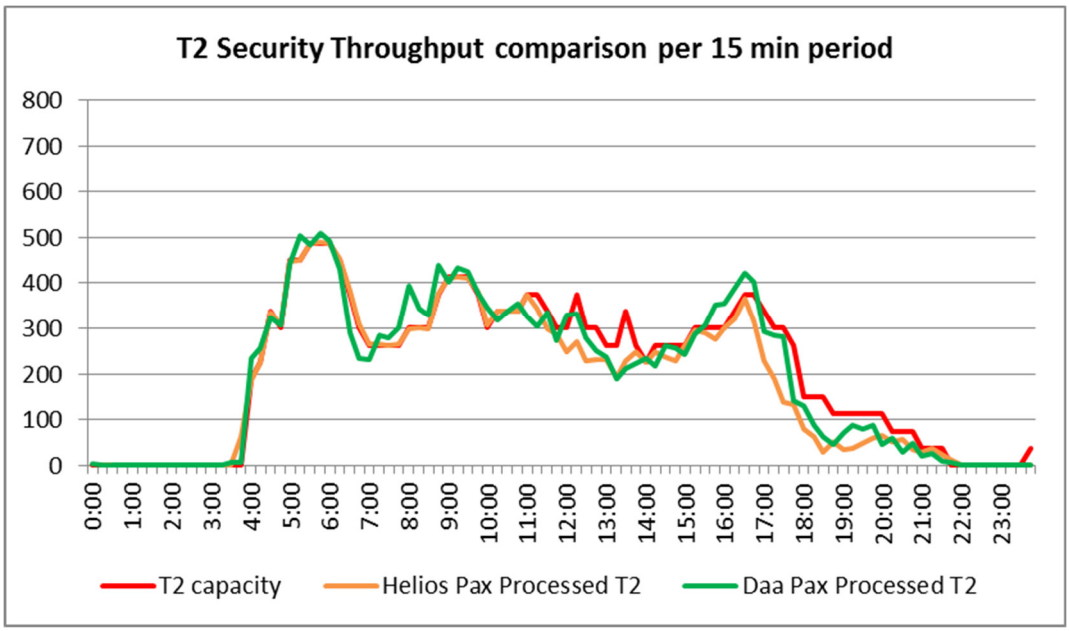

Figure 13: T2 security lane throughput per 15 min period. The capacity is calculated every 15 minutes from the number of opened lanes (150 pax/h/lane).

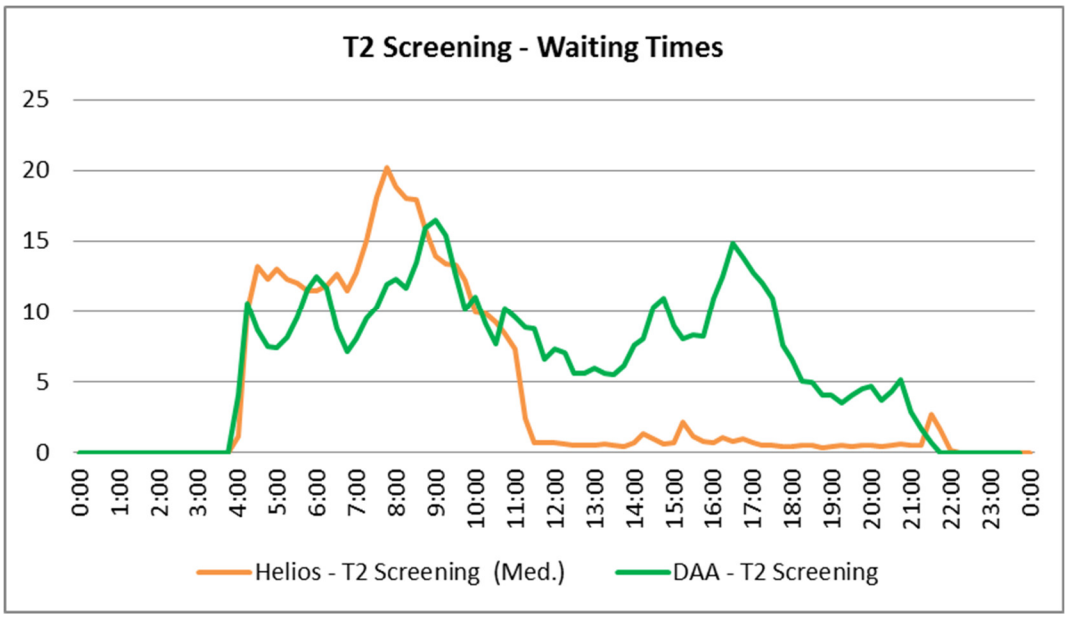

Figure 14: Waiting times before Security. This metric is the median value over all T2 passengers entering the Security queue per last 15 min period.

The comparison between the waiting times calculated in the model and the ones from the daa data is showing major differences in the afternoon.

As an intermediate conclusion, the model is not returning the same Waiting Times profile when using:

- The same waiting time calculation method: from the moment the passenger starts queuing at Boarding Pass Scan till the moment he is processed at Security
- Similar opening schedule
- The average processing time based on the solid assumption that even on that particular busy day the Security process might have been done faster than usual
- A slightly different show-up profile.

Without a separate reporting between Originating and Transferring passengers showing-up at T2 BPS, it was not possible to repeat the test from T1.

4.2.2 Using a different Opening Schedule

It was possible to run a few other simulations with an adjusted Opening Schedule, at both terminals to show similar waiting time profiles.

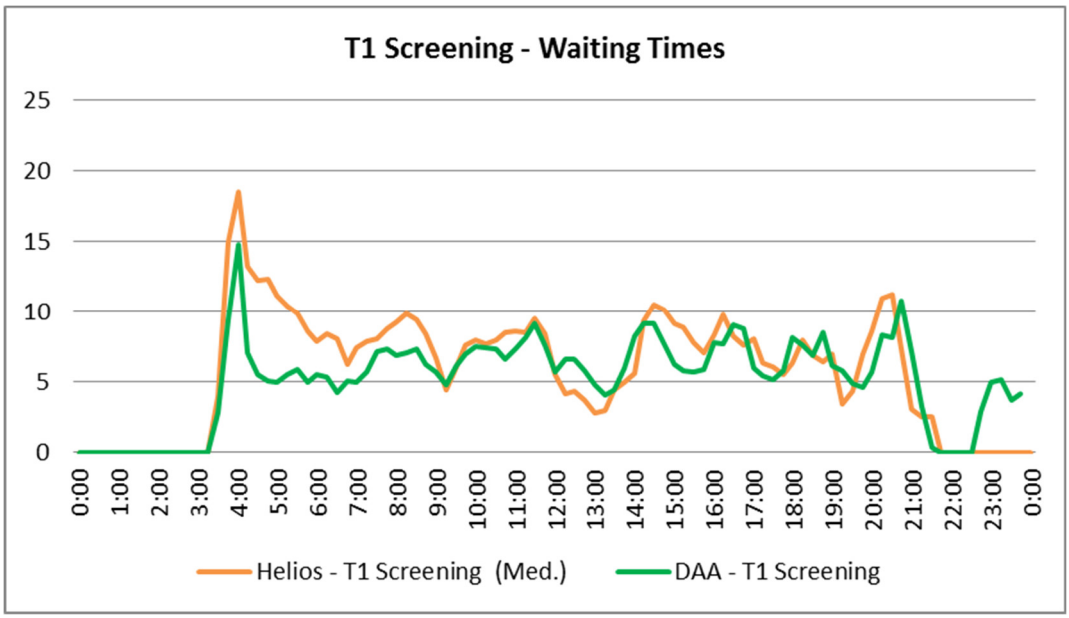

Figure 15: Waiting times before T1 Security. This metric is the median value over all T1 passengers entering the security queue per last 15 min period. The Opening Schedule has been adjusted.

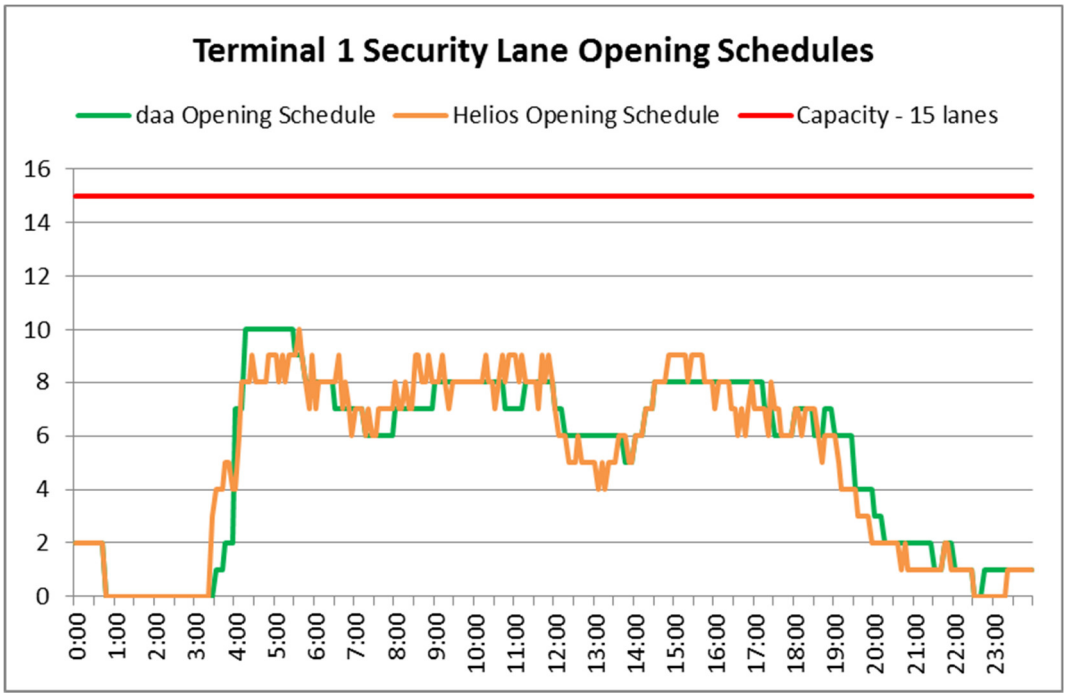

Figure 16: T1 Security Lane Opening Schedules (DAA and adjusted Helios schedules)

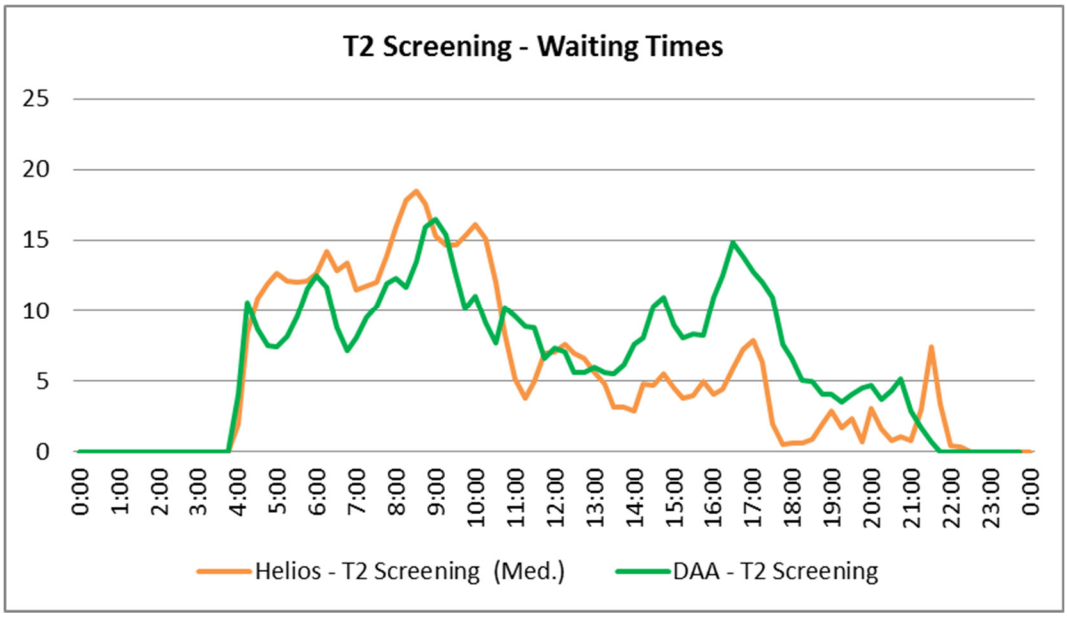

Figure 17: Waiting times before T2 Security. This metric is the median value over all T2 passengers entering the security queue per last 15 min period. The Opening Schedule has been adjusted.

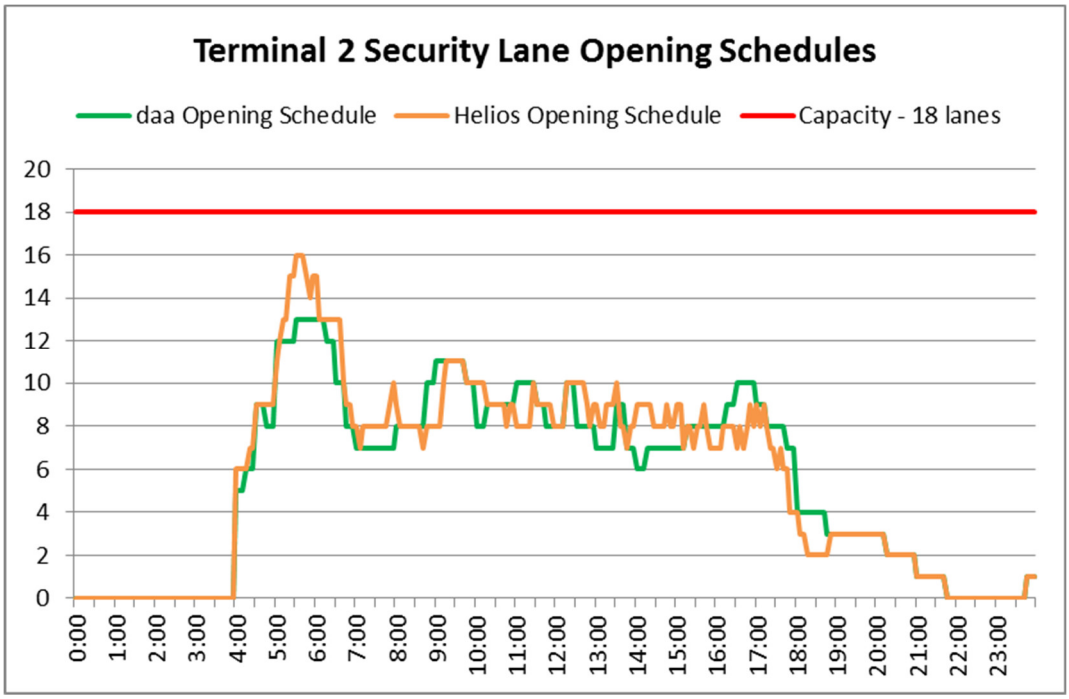

Figure 18: T2 Security Lane Opening Schedules (DAA and adjusted Helios schedules)

4.2.3 Conclusion on the model calibration for the Security Process

A long analysis has been made to understand the operations at Security and to handle the data provided by the daa. The calibration exercise has involved multiple adjustments to the model and multiple runs of the simulation to obtain the results shown above.

Despite this effort, the waiting times calculated from the blu-fi system from the S16 Design Day monitoring data have not been replicated exactly.

In addition to the clarifications from above, other factors can explain the differences from reality:

- The 16th fast-track (and staff) security lane at T1 has not been modelled. In general, the fast-track option for late or premium passengers has not been considered.
- The dispersion between real passengers and modelled passengers (see below)
- Blu-fi system data post-processing algorithm

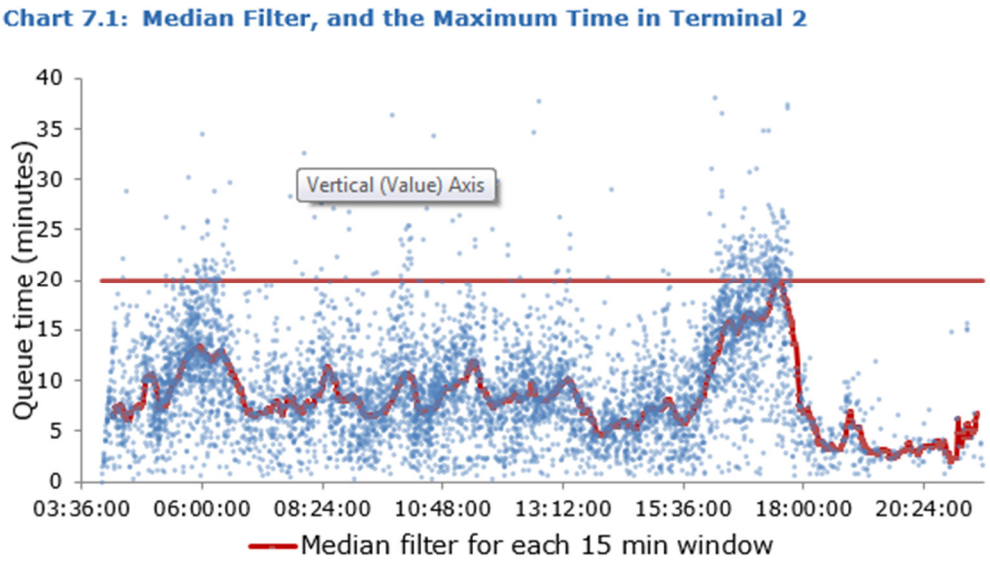

Figure 19: Illustration graph showing raw data and median value of passenger waiting times at T2 Security (not during the S16 Design Day) (source: CAR/daa)

4.2.4 Validity of the modelled performance at security processes

The Security Process is an important process within the Passenger Terminal Buildings. The T1 and T2 departure declared capacities are set in such a manner that the Security process capacity can accommodate all the passengers.

Although there are some discrepancies between the model and the recorded data in the actual waiting time, the model has proven its consistency. The calculated throughput and calculated waiting times are responding well to the changes of the opening schedule and to the passenger show-up daily profile.

The security waiting times will not be a limiting factor in the overall capacity assessment as, in each terminal, during the Design Day S16, the number of actual opened X-ray lanes is significantly below the maximum capacity of the two terminals. An additional 50% of the security lanes are still available to be opened.

The future schedules to be investigated in this study are far below this increase in traffic. Therefore, during the S17 and S18 capacity assessment analysis, a large headroom of capacity will be available.

4.3 Departure US pre-clearance processes: Transportation Security Administration check

This specific process is carried out as a part of the US pre-clearance processes located on the ground floor of Pier 4.

The flow of passengers in the model going to the TSA security lanes is regulated by the Document Check controls. The opening of resources is dependent of US administration.

It is understood that the TSA opens at 06:30 and the queue that is observed from daa's results prior to 06:00 comprises of passengers who are choosing to wait at a facility that is closed before perhaps returning back to the retail area. It should be noted that the daa recorded figures are the average of all the samples in the blu-fi

system but the samples can be as small as one person. So, the early morning discrepancy could be caused by a single passenger choosing to wait at that area.

The magnitude of the subsequent wait time and that observed in the middle of the day is most likely attributable to variations in the number of lanes than are being operated – information that is not known.

The impact of having more resources open in the upstream process could also potentially manifest itself downstream (at DVO and CBP & Triage) showing more delay. This shows the interconnected nature of the processes, meaning that variations in the results of one will cause variations in the results of another.

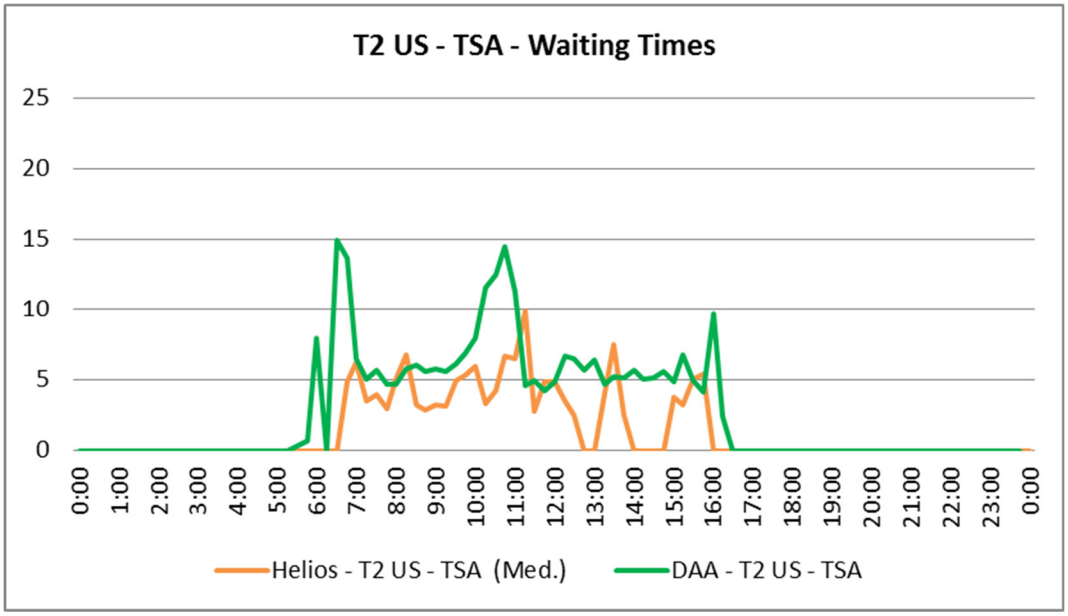

Figure 20: Waiting times between entrance of Document Check queue and before TSA Security Check. This metric is the median value over all US departing passengers presenting at pre-clearance area per last 15 min period.

Data	- Number of resources - Average processing time
Assumption	- Opening schedule of Document Check desks and TSA search lanes

4.4 Departure US pre-clearance processes: Document Verification Office

This specific process is carried out as a part of the US pre-clearance processes in the Pier 4 ground floor.

Document verification offices are provided for US citizen or registered foreign passengers after they received an entry approval receipt from an Automated Passport Control kiosk. Opening of resources is dependent on US administration.

The initial model performance is good and the afternoon peak is well represented.

The two model generated peaks in the mid-afternoon and the observed build up to the final peak implies that the model is assuming that passengers will proceed to the TSA and the DVO only when required, rather than perhaps a long time in advance of their respective STD.

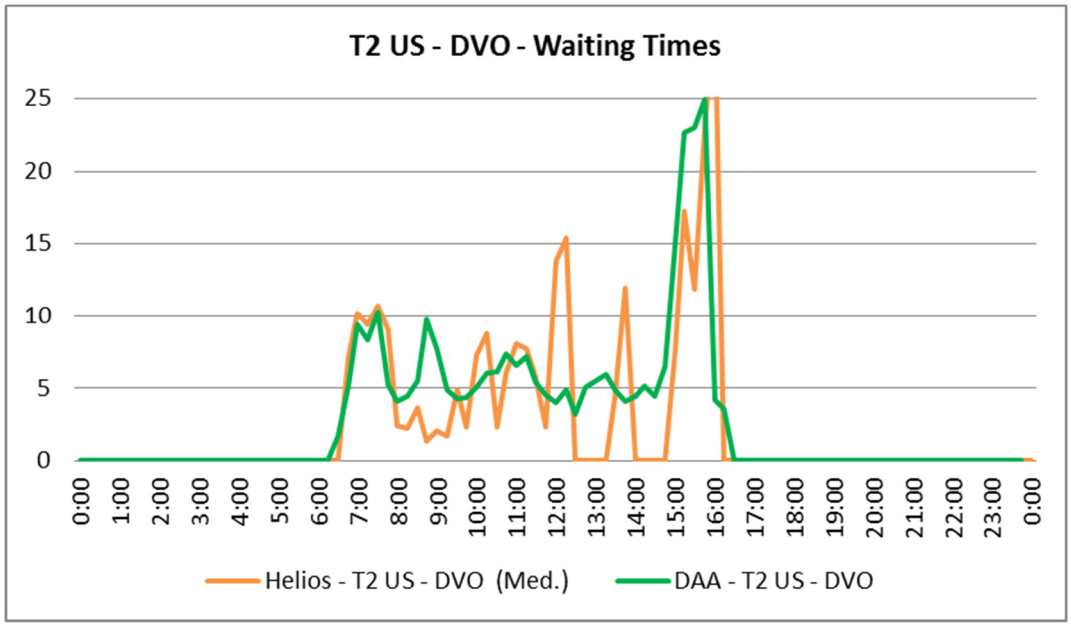

Figure 21: Waiting times at document verification office. This metric is the median value over all US departing passengers using document verification office per 15 min period.

Data	- Number of resources - Average processing time
Assumption	- % of passengers allowed from the APC kiosks to the DVO officer

4.5 Departure US pre-clearance processes: US Customs and Border Protection

This specific process is carried out as a part of the US pre-clearance processes in the Pier 4 ground floor. The queue is common for CBP (passengers who do not use Automated Passport Control kiosks) and Triage (passengers rejected after APC use) desks.

It should be noted that the actual number of passengers using these desks during the peak day is not known, which resulted in the modelling of an assumed distribution of US-departing passengers and explains some of the discrepancies in the graph.

The more conservative results of the Helios model are perhaps more reflective of the upstream process, especially in the early morning. Specifically, the model has optimised flow through the upstream TSA (where daa shows greater queues in the morning) and this has resulted in the model projecting a downstream queue.

In consequence in terms of the objective of this assessment, there is a reasonable comparison between the potential throughput of the TSA and the CBP & Triage from both the model and the observed data.

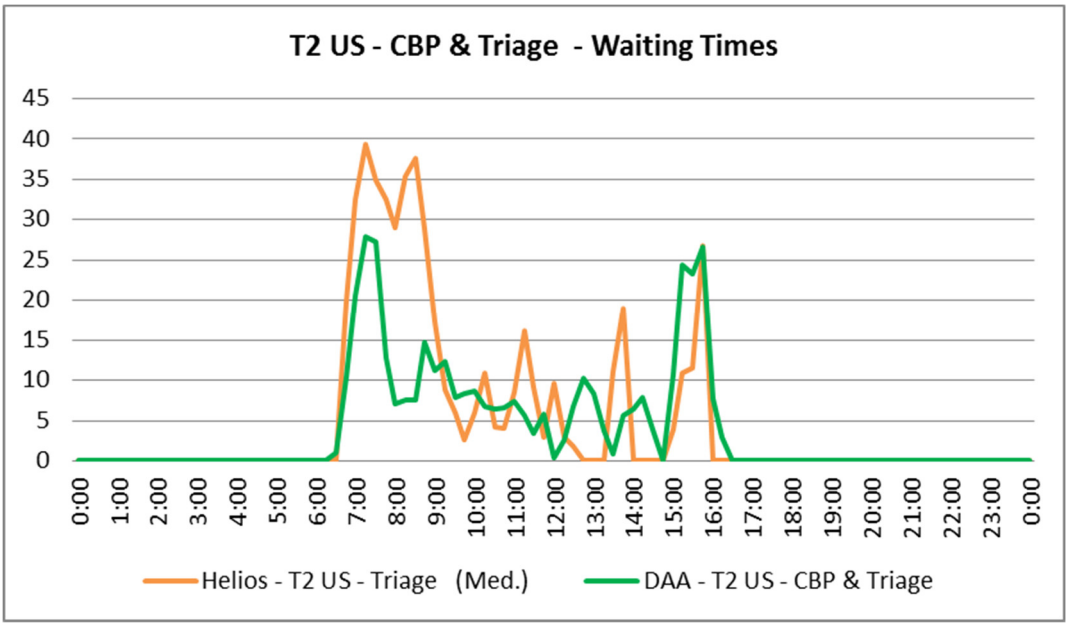

Figure 22: Waiting times at Customs and Border Protection (CBP) / Triage processes. This metric is the median value over all US departing passengers using CBP / Triage desks per last 15 min period.

Data	- Number of resources - Opening schedule - Average processing times
Assumption	- % of passenger rejected at APC and going to triage - % of passenger going directly to CBP

4.6 Departure US pre-clearance processes: End-To-End

Finally, daa provided end-to-end waiting times of passengers: it is measured from the moment the passenger arrives to the first process (Document Check) till the moment the passenger exits the Inspection Desks (CBP or Triage or DVO processes).

The distribution of passengers over the different processes (APC or non-APC, then CBP or Triage or DVO) is not available for the actual Design Day so the assumption made for the model impacts the results. Moreover, the impact of the upstream processes (Document Check and TSA) has consequences over the downstream waiting times.

In general, the graph below shows comparable results particularly during peak periods. Some of the differences in individual processes seen earlier are removed. The differences observed are caused by the different model assumptions, but for the purpose of the S17 and S18 Capacity Assessment, the resource allocation schedule will be adjusted up to the maximum capacity so to confirm whether the PTB can accommodate the anticipated passengers with the appropriate level of service.

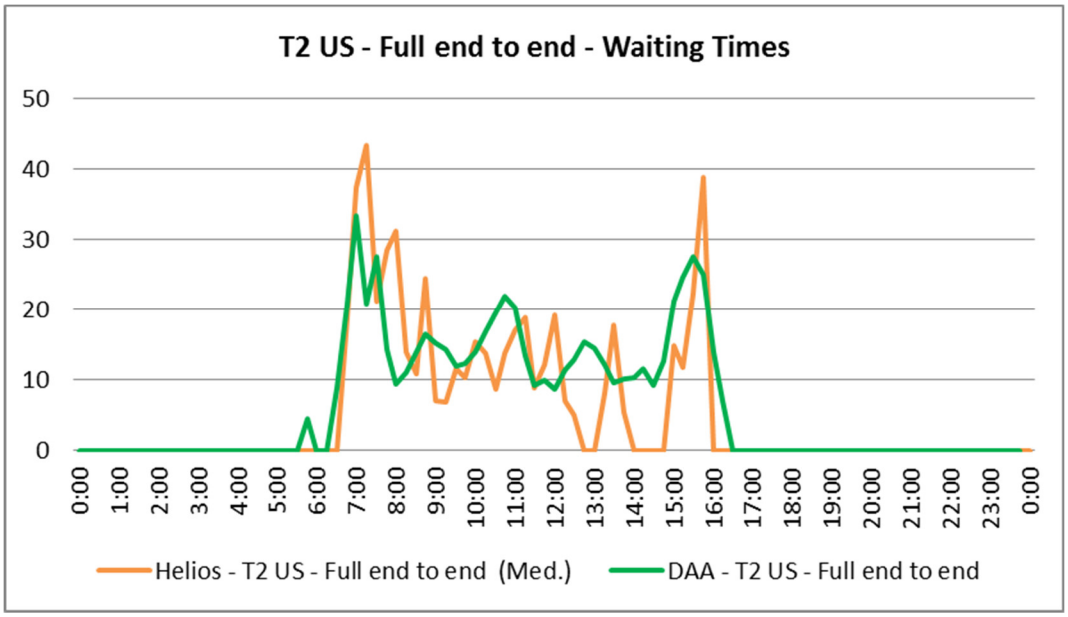

Figure 23: Waiting times cumulated in the US Pre-clearance Area. This metric is the median value over all US departing passengers entering the area per last 15 min period.

Data	- Number of resources - Opening schedule - Average processing times
Assumption	- % of passenger rejected at APC and going to triage - % of passenger going directly to CBP - % of passengers allowed from the APC kiosks to the DVO officer - Opening schedule of Document Check desks and TSA search lanes

4.7 Waiting times at immigration

Arriving passengers must pass through the Immigration Control in three different areas: T1 Piers 1/2, T1 Pier 3 and T2.

daa has provided measured waiting times from the blu-fi monitoring system. Mobile phone antenna signal are captured on each side on each immigration hall and then reconciled to estimate waiting times. From the model, a metric is calculated from the entrance time and the exit time of each arriving passenger in immigration halls. Comparative graphs and histograms for T1, Piers 1/2 and 3 and T2 Pier 4 are presented in the following pages.

Local discrepancies between simulated and actual waiting times at immigration as shown on the daily profile graphs can be explained by

(i) Unavailability of information on the number of EU/Non-EU booths opened across the day for Pier 3 and;

(ii) Unavailability of information on distribution of EU/non-EU passengers on each flight arriving on the design day.

This lack of data will limit the possible accuracy of the model but even with this level of uncertainty, most of the immigration charts show reasonable correlation with actual waiting times.

4.7.1 Terminal 1 Piers 1&2 Immigration

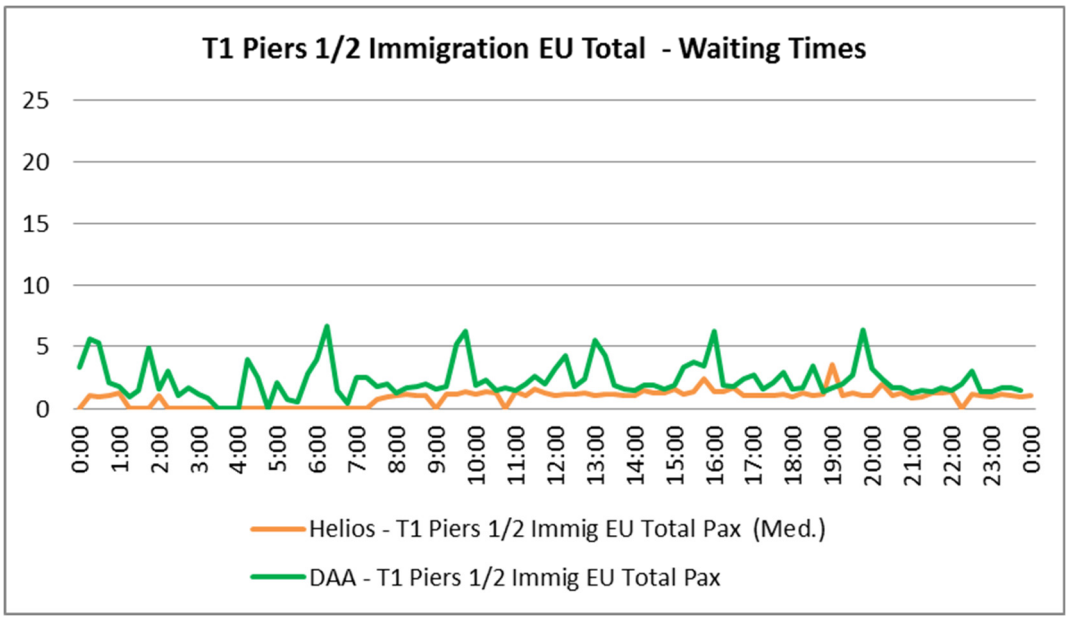

Figure 24: Waiting time (minutes) between the entrance and the exit of the EU immigration queue. This metric is the median value over all EU passengers entering the T1 Piers 1/2 immigration queues per last 15 min period.

Data	- Number of resources - Average processing times
Assumption	- Data on the opening schedule and also the EU / Non-EU allocation was received on 27 July and so was not considered in this assessment.

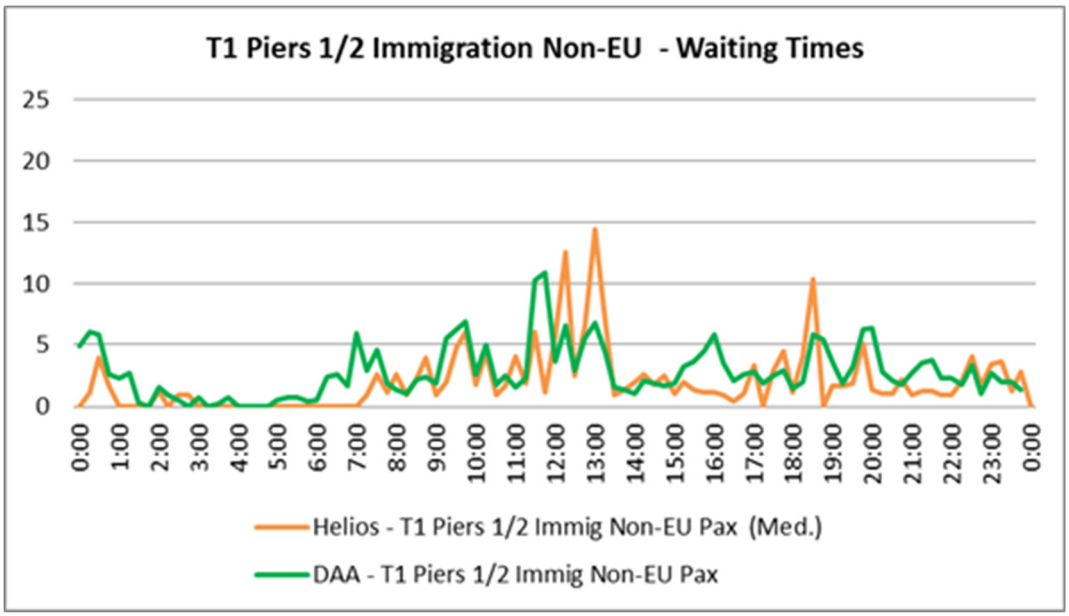

Figure 25: Waiting time (minutes) between the entrance and the exit of the non-EU immigration queue. This metric is the median value over all Non-EU passengers entering the T1 Piers 1/2 immigration queues per last 15 min period.

Data	- Number of resources - Average processing times
Assumption	- Data on the opening schedule and also the EU / Non-EU allocation was received on 27th July and so was not considered in this assessment.

4.7.2 Terminal 1 Pier 3 Immigration

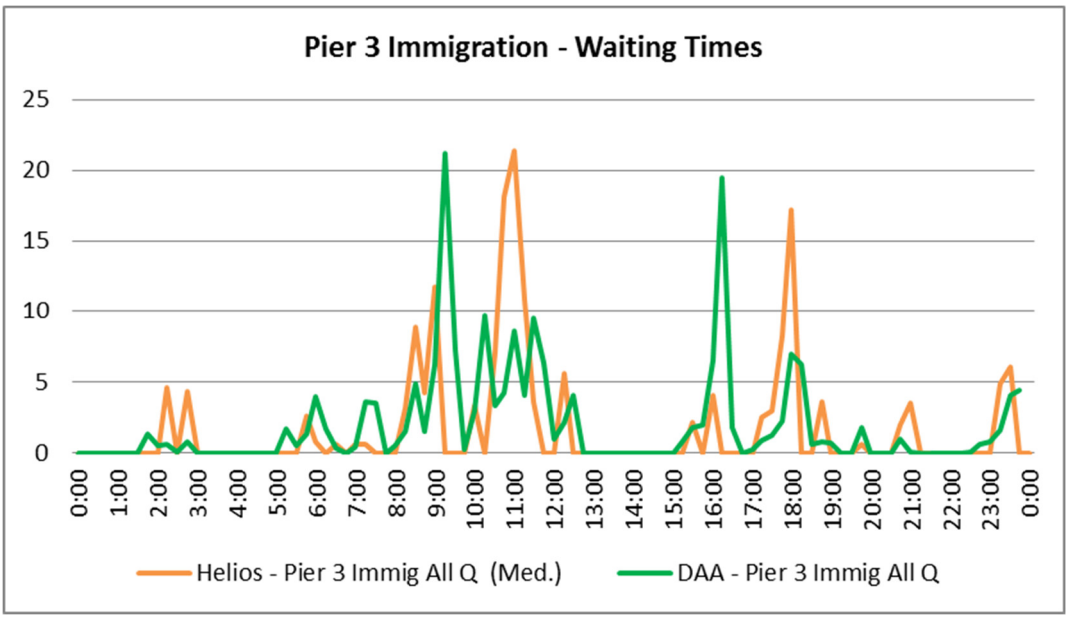

Figure 26: Waiting time (minutes) between the entrance and the exit of the immigration queue. This metric is the median value over all passengers entering the T1 Pier 3 immigration queues per last 15 min period.

Data	- Number of resources - Average processing times
Assumption	- Opening schedule - Allocation between EU and non-EU desks

Whilst the profiles are broadly comparable, the different timings of the four noticeable spikes requires further explanation.

In the morning, the daa spike appears to capture the two smaller Helios spikes and the large Helios spike appears to capture the three daa spikes. In both instances this is attributable to variations in the assumptions of the number of immigration desks that are opened.

In the afternoon, it was noted that at the time of the daa spike a flight from Istanbul was included in the schedule. It is inevitable that on such occasion a longer processing rate per passenger would apply. Similarly, the Helios spike was comprised of only flights to the UK and one to Madrid which are able to be processed at a much faster rate.

These differences, when combined with the assumption of a constant EU/Non-EU passenger distribution would suggest how such variations can occur.

Although the peaks occur in different places, all of the modelled spikes are of similar magnitude thereby generating similar amounts of delay.

4.7.3 Terminal 2 Immigration

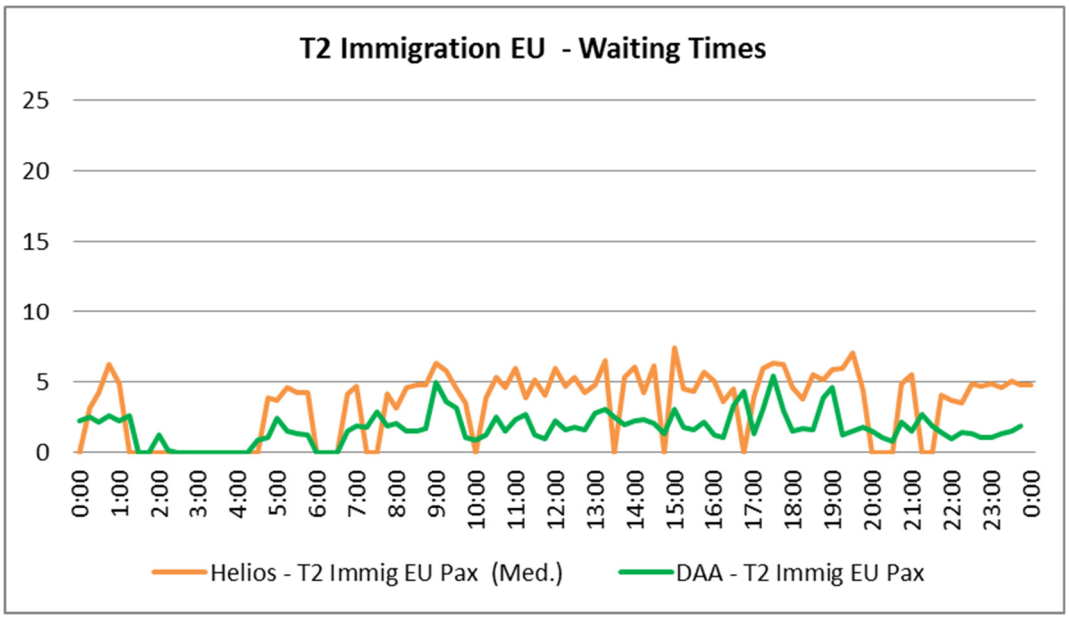

Figure 27: Waiting time (mins) between the entrance and the exit of the EU immigration queue. The metric is the median value over all passengers entering the T2 immigration queues per last 15 min period.

Data	- Number of resources - Opening schedule - Average processing time
Assumption	- Data on the opening schedule and also the EU / Non-EU allocation was received on 27th July and so was not considered in this assessment.

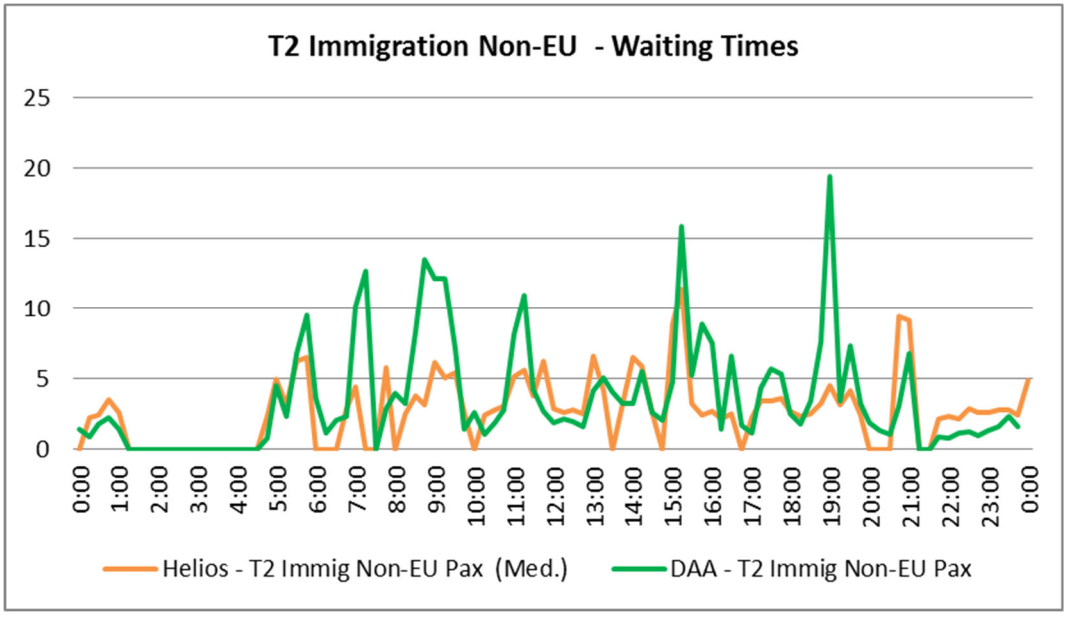

Figure 28: Waiting time (mins) between the entrance and the exit of the non-EU immigration queue. The metric is the median value over all passengers entering the T2 immigration queues per last 15 min period.

Data	- Number of resources - Opening schedule - Average processing time
Assumption	- Data on the opening schedule and also the EU / Non-EU allocation was received on 27th July and so was not considered in this assessment.

The comparison of immigration in T2 suggests that there is an overestimation of EU passengers in the EU/Non-EU passengers in the initial assumption. This would result in more extreme delays in non-EU waiting times due to the exponential nature of delay brought about by the application of longer processing times.

4.8 Waiting times in the Baggage Hall

Finally, there are two baggage halls in the terminals where arriving passengers pick up their hold bags.

daa has provided measured waiting times from the blu-fi monitoring system. From the model, a metric is calculated from the entrance time and the exit time of each arriving passenger. Comparative graphs and histograms for T1 and T2 are presented on the following pages.

Differences along the day between simulated and actual waiting times at Baggage Hall T1 can be explained by:

(i) The number of passengers with hold bags has been estimated: from the daa statistics on the number of checked bags that day; a ratio was defined for T1 and T2 passengers with hold bags (respectively 44% and 69%). The variation from one flight to another has not been taken into account.

(ii) Actual first-bag and last-bag delivery times (from daa database) and actual delivery belt allocated to each flight of the day was used in the model, with complementary assumptions when the information was missing.

(iii) The passenger actions in the baggage hall have been simplified (if hold bag, then wait in front of the allocated belt for its bags and leave the hall immediately): no dwell time, individual behaviour. But the passenger-baggage reconciliation takes into account a random distribution as in reality.

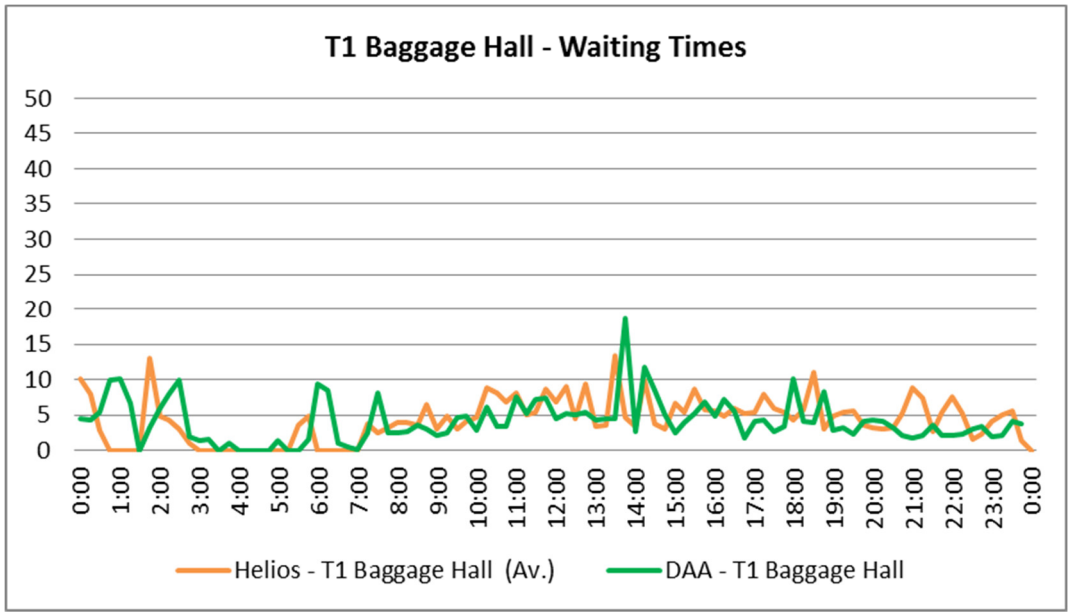

Figure 29: Waiting time (mins) between the entrance and the exit of the baggage delivery hall. The metric is the average value over all passengers entering the T1 baggage delivery hall per last 15 min period. The median value was returning a lower level if all passengers without hold bags are taken into account

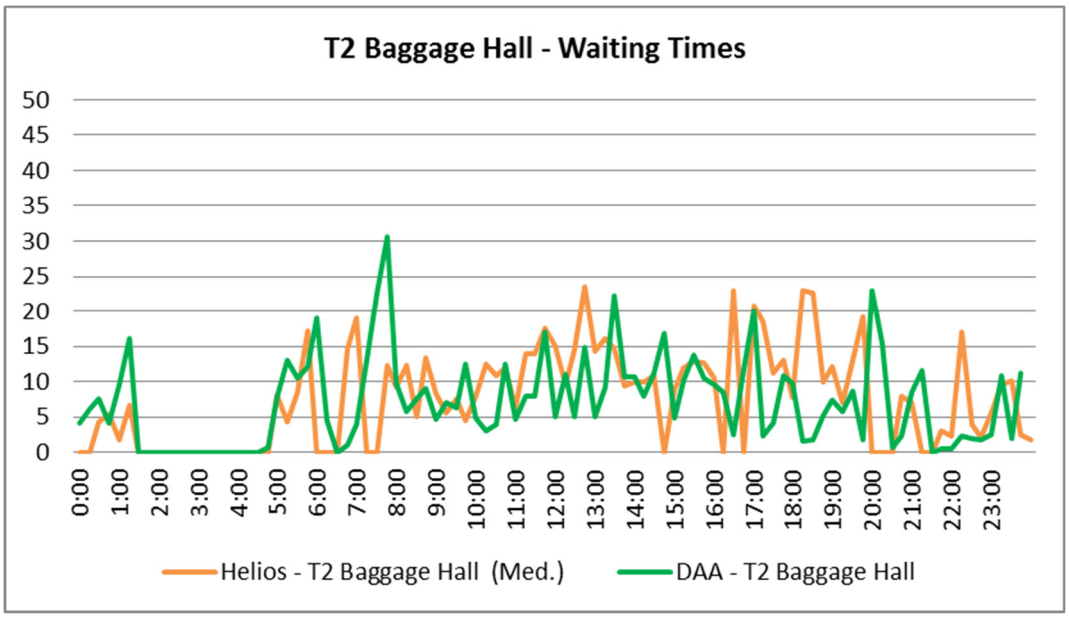

Figure 30: Waiting time (mins) between the entrance and the exit of the baggage delivery hall. The metric is the median over all passengers entering the T1 baggage delivery hall per last 15 min period.

The T1 comparison representation shows a good fit whilst the T2 comparison is generally of the correct magnitude with the exception of one spike that occurred at 07:45. The most probable reason for this would be an operational delay in transporting the bags from the aircraft to the baggage hall. The model would not be able to reflect this.

From IATA's Optimum Level of Service recommendations, the most important criteria is for the first bag to be delivered to the first passenger in less than 15 min

(25 min for long haul), which is the case according to daa monitoring data. The capacity of the baggage hall is firstly assessed from the number of belts available through the day and from the capacity to deliver the baggage in due time.

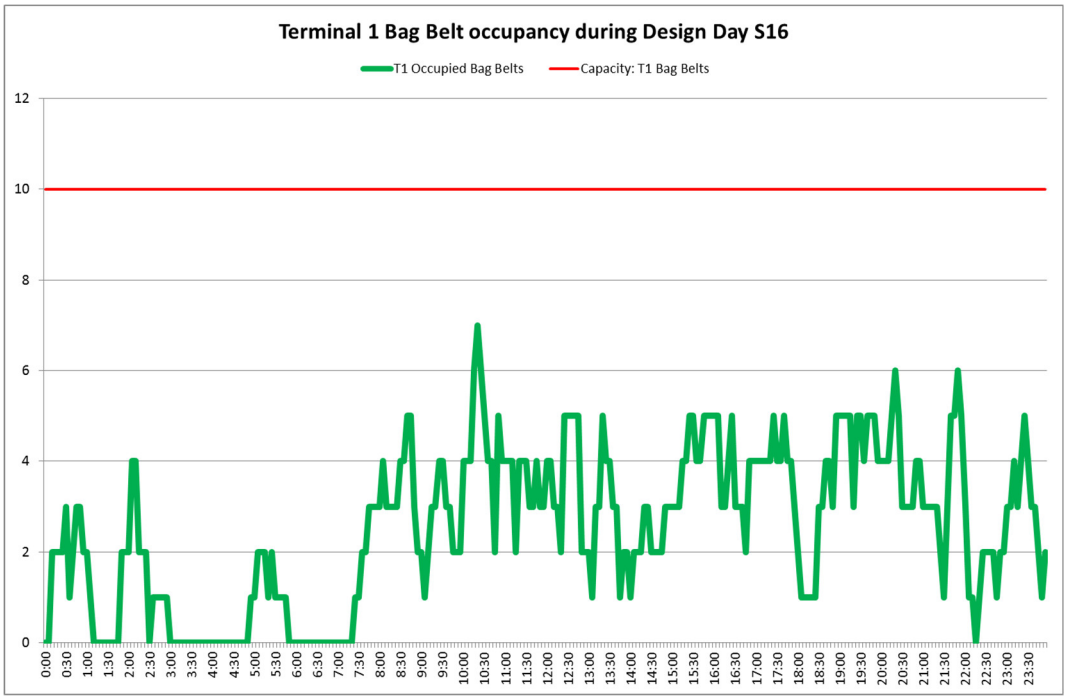

Figure 31: Occupancy of the T1 bag delivery belts through the Design Day. Metric calculated with the flight schedule information and belt allocation schedule from daa.

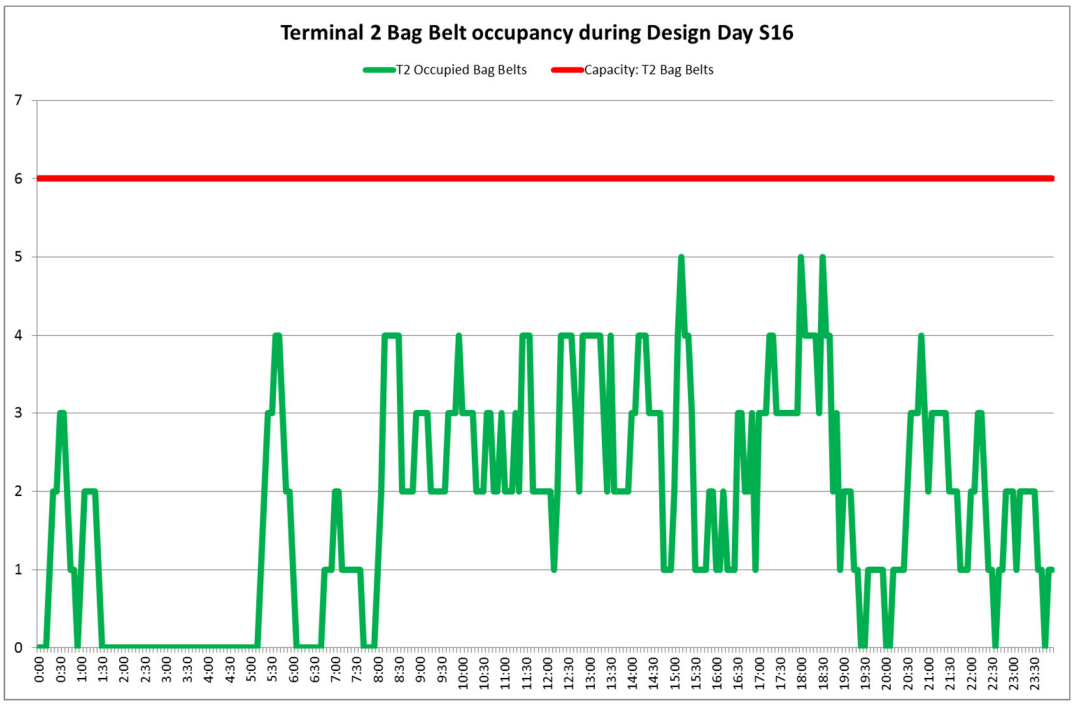

Figure 32: Occupancy of the T2 bag delivery belts through the Design Day. Metric calculated with the flight schedule information and belt allocation schedule from daa.

It is apparent that in both T1 and T2 there is spare capacity (at least 40% for T1 and 20% for T2).

5 Conclusions and next steps

The modelling exercise required collection of a comprehensive data set. Despite the large amount of information collected with the invaluable collaboration of daa, certain assumptions had to be made to align the model's performance with the actual observed performance on the design day. The key data that was not available included:

- The passenger dwell-time between each process.
- The number of staffed immigration booths in Pier 3.
- The distribution of EU and non-EU passengers on each flight.

Although this data was not available in S16, this doesn't matter for S17 and S18 since the data is re-calculated for these schedules anyway. These missing inputs will therefore not affect S17 and S18.

In addition, the technology used to collect passenger waiting times (blu-fi) does not capture all passengers travelling through the terminal(s) and a median waiting time (as reported) could have been generated by a single passenger or by many queuing passengers. The primary objective of the terminal capacity assessment which will be conducted using the model is to assess the maximum hourly capacity of both terminals to be declared. In the S17 and S18 scenarios the number of available resources at each process will be maximised in order to ascertain whether the available infrastructure capacity can process additional passengers whilst maintaining an acceptable level of service. Where daa is not able to adjust the resource staffing (at Immigration and in the US pre-clearance area) the resources will be assumed as fully staffed first to check there is overall capacity available. After this, the simulation will be re-run with similar staffing pattern as in the Design Day S16 to see if current staffing levels would be sufficient.

It should be noted that there are considerable free resources in the terminal to cope with small increases in the flight schedule, eg:

- At least 50% more security lanes can be opened at any time (T1 and T2)
- At least 20% increase in bag belt capacity.
- Most of the collected data show available spare capacity, e.g. T2 EU immigration data show waiting peaks of 5 minutes, half of the 10 minute service level target.

As the correlation between metrics calculated through the model and those based on the observations during the design day show similarities both in terms of the magnitude and the shape of profile throughout the day, the baseline model can be considered as a satisfactorily representation of the existing terminal for the purpose of evaluating the impact of changes in flight schedules.

The baseline model will be updated with traffic schedules for the S17 design day (11 August 2017) and the passenger terminal building operational performance on this day will be simulated and recorded as a reference scenario.

Subsequently, this S17 design day will be adjusted with anticipated S18 changes in the flight schedule and any anticipated changes in passenger terminal building infrastructure will be modelled (Pier 1 Extension; Pier 2 Segregation; Piers 1&2 Immigration Area; T1 Check-in Hall refurbishment; Pre-Boarding Zone and Shuttle Service).

Results from this comparison will be presented on 17 August 2017 during the Coordination Committee pre-meeting to better inform stakeholders' voting decision. The remainder of the capacity analysis will be completed and shared with all stakeholders on 25 September 2017.