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Capacity assessment at Dublin Airport for the purpose of setting slot coordination parameters

Draft final report for the Commission for Aviation Regulation

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Document information

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Approval

Date	Name	Signature	Role
13 October 2017	S.J.Leighton		Project Director

Executive summary

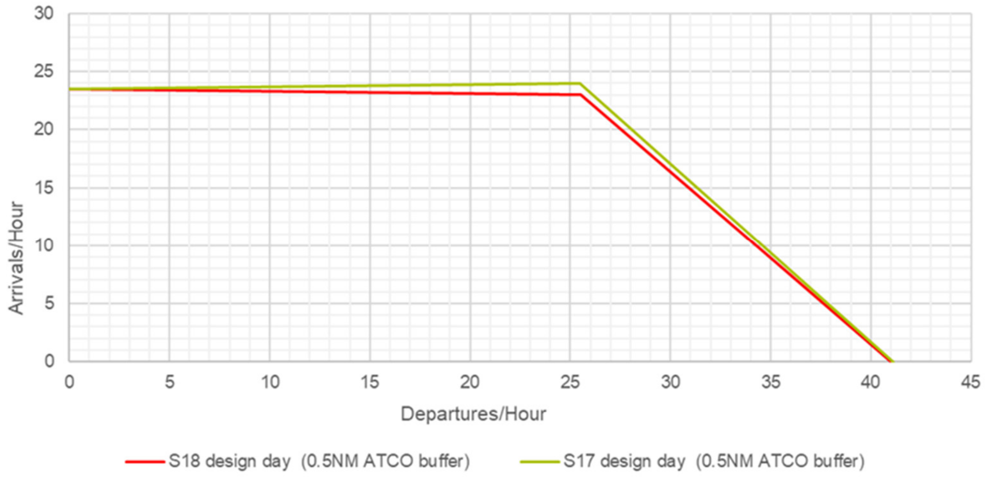
Helios was contracted by the Commission for Aviation Regulation to undertake an independent assessment of the current capacity of Dublin Airport. This report provides a summary of our findings.

Approach

Our approach to the study was to analyse capacity through the use of airside and passenger terminal building fast time simulation models. This approach was based on the assumption that all elements of the airport system are dependent on each other, therefore the optimum approach to evaluate available capacity is through an approach that encompasses the interactions between all elements of the airport's infrastructure and services. A reference summer season model for 2016 was validated against real data from the day of operations, with all stakeholders being offered several opportunities to provide comments on the model's performance. The validated model was then updated to reflect the S17 and expected S18 schedule and infrastructure.

Runway and airspace capacity

The analysis shows that the maximum achievable runway throughput on Runway 10-28 is 24 arrivals in arrivals mode, 41 departures in departures mode and 48 flights in mixed mode (assuming S18 design day fleet mix). These limits are sensitive to operating fleet mix and reduce by approximately 2 movements (in mixed mode) for every 15% increase in the share of heavy aircraft in the fleet mix. Runway hourly throughput for different traffic mixes can be investigated using the following chart, which shows the relationship between various combinations of arrivals and departures scheduled in one hour. It should be noted this chart assumes constant fleet mix.



The arrivals capacity declaration in 2200 UTC exceeds the simulated runway throughput envelope. This does not mean the declaration is incorrect. It just indicates that scheduled arrivals above the maximum arrivals throughput will be accommodated with delay.

All declared departures limits are within the simulated runway throughput envelope. However, adding extra flights into hours which are at, or close to the declared limits will incur extra delay for flights operating in these hours. Sensitivity analysis with the morning departures wave indicates that adding a flight into this period will lead to an increase in departure ground delays between two and three and half minutes, depending on whether the added flight is an arrival or departure and whether it is a narrow body or wide body aircraft. Similarly, removing a flight from this period will lead to a reduction of between one and two minutes.

Airspace capacity has not been quantified in detail, but the analysis undertaken identified that the structure of the airspace around Dublin does not accentuate airport delays. With the Point-Merge system in place the Dublin TMA is likely to be able to handle increases in traffic in the next few years.

Taxiway and stand capacity

With the exception of peak periods, the taxiways can serve the traffic without delay.

Overall stand capacity is at the capacity limits during the morning peak period. Although additional flights could be accommodated this would result in either a reduced number of resilience stands, or increased towing.

The number of wide body contact stands is close to capacity limits during the morning wide body peak period. If traffic continues to grow additional flights could be accommodated, but would likely result in increased towing. These aircraft will typically have to be towed north, in a direction opposite to aircraft taxiing for departure.

Passenger terminal capacity

The declared capacity parameters for Terminal 1 and Terminal 2 are not the limiting parameters for the airport as a whole when compared to the runway and stand limits. This is consistent with ACL reports that indicate terminal building capacity values are minor reasons for slot adjustments.

Terminal 1 and Terminal 2 departure throughputs are limited by the security process. Similarly, Terminal 1 and Terminal 2 arrival throughputs are limited by the immigration processes.

The following table summarise our capacity findings by terminal process for departures:

Process	Terminal 1	Terminal 2
Check-in	Capacity well in excess of current peak hour demand.	The number of T2 check-in desks does not match the current demand and justifies the need for the Advisory Flag. Throughput estimated at 3,000 passengers/hour.
Boarding pass presentation	Substantial 6000 passengers per hour capacity.	Substantial 7,200 passengers per hour capacity.
Security	The T1 security control, performed with 15 modern ATRS lanes, could theoretically process up to 3,600 passengers per hour. This constitutes the limiting departure process in the terminal.	The T2 security control, performed with 18 classical lanes, could theoretically process 2,700 passengers per hour. This constitutes the limiting departure process for the terminal. US Pre-clearance processes can handle around 1,100 passengers per hour.
Boarding	The estimate of T1 boarding capacity is 6,150 passengers per hour (Piers 1,2 and 3).	T2 can serve up to 4,650 passengers per hour (including coaching gates, pre-boarding zone gates and pier 4 gates)

For arrivals, the following table summarises our capacity findings by terminal process:

Process	Terminal 1	Terminal 2
Immigration	We propose a combined capacity parameter of 4,100 passengers per hour for T1 Arrivals.	We propose a combined capacity parameter of 3,000 passengers per hour for T2 arrivals.
Baggage delivery	Capable of supporting 6,000 passengers per hour.	Capable of supporting 4,950 passengers per hour.

Both T1 and T2 Baggage Handling Systems (BHS) have sufficient capacity and can handle a substantial traffic increase:

In Terminal 1, the baggage screening system can globally accept twice as many bags then currently experienced, despite temporary saturation being observed on collecting belt 13. The sorting and make-up area is constrained during the first morning departure peak.

In Terminal 2, the screening, handling and sorting systems provide significant capacity. Double the number of departing bags per hour could be handled. However, at the moment insufficient check-in desks in T2 limits that potential.

Scheduling limits and criteria

Runway holding delay, whilst the main source of airfield departure delay, does not capture all sources of delay that occur to aircraft on departure from Dublin. We have proposed that a broader additional departure taxi-time metric be adopted that includes all delays from pushback to runway entry. On the basis of the departure ground delays observed from simulating S18 forecast schedule applying an18-minute criteria using this metric would look appropriate. The acceptability of this metric or of continuing to rely on runway holding delay criteria should be discussed and agreed with stakeholders and the delay criteria.

The assessment of the passenger terminal building capacity and operational issues led us to conclude that the following scheduling criteria should be applied for the passenger terminals:

- Our results for T2 are consistent with the limits set for S18:
  - 3,700 passengers per rolling hour for T2 Departures.
  - 3,000 against 3,050 for T2 Arrivals.
- However, our results for T1 support a higher capacity being declared:
  - 4,800 passengers per rolling hour vs. 3,700 for departures.
  - 4,100 passengers per rolling hour vs. 3,550 for arrivals, assuming that the distribution of these passengers over both Piers 1/2 and Pier 3 immigration hall is consistent with their respective capacity.

The number of T2 check-in desks does not meet the current demand and justifies the need for the Advisory Flag.

The T2 Advisory Flag on US CBP departures is also justified and should be maintained.

Firebreaks

There are currently two firebreaks at Dublin Airport. The first one, between 0700 UTC and 0759 UTC helps in mitigating delays incurred during the morning departures peak. The second one, between 1300 UTC and 1359 UTC helps mitigate any morning delays which either persist through the first firebreak, or which occur after it. The first fire-break can ameliorate all simulated delays (up to 60 minutes), while the second fire-break can reasonably ameliorate delays of up to 30 minutes.

A short third fire-break should be considered within one hour in the afternoon period between 1400 and 1900 UTC. The need for and protection of fire-breaks should be discussed with stakeholders and formalised in the capacity declaration.

5-minute scheduling

A transition to 5-minute scheduling limits has the potential to streamline the flow of aircraft through reduced bunching, especially during peak periods. This has the potential to lead to decreased ground and runway delays. Further exploration is recommended before any decision on a transition towards 5-minute scheduling limits is made.

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1 Introduction

1.1 General

Helios was contracted by the Commission for Aviation Regulation (the Commission, CAR) to undertake an independent assessment of the current capacity of Dublin Airport (the Airport). This report provides a summary of our findings.

Background

Section 8(1) of the Aviation Regulation Act, 2001, states that the Commission is the competent authority in Ireland for the purposes of Council Regulation (EEC) No. 95/93, as amended by Regulation (EC) No 793/2004 ("the Slot Allocation Regulations").

Dublin had the status of being an uncoordinated airport until 1 September 2000 from which point it was designated as schedule facilitated[1] by the Minister for Public Enterprise. ACL was subsequently appointed as the slot coordinator to facilitate voluntary schedule adjustments. Even though it was not a legal requirement, a Coordination Committee was established, consisting of representatives of all the key stakeholders present at Dublin Airport.

A review of airport slot coordination status was carried out in late 2002 and it was concluded that no change of coordination status was required. However, a further review, which was carried out in early 2004, identified that potential increases in transatlantic flights and the number of airlines refusing to adjust their schedules upon request could form a solid ground for the Airport to become coordinated[2].

In summer 2005, the level of refusals increased by over 100% when compared to summer 2004. Consequently, the Commission announced its decision to designate Dublin Airport as coordinated in April 2005, which came into effect in summer 2006. Following a Judicial Review, the High Court decided that the April 2005 decision was insufficiently supported by the 2004 capacity analysis and the airport slot coordination status returned to schedule facilitated.

In light of the decision made by the High Court, the Commission engaged consultants to carry out another capacity study in the latter half of 2006. Following this analysis, the Commission designated Dublin Airport as coordinated from March 2007 onwards.

Since then, the Airport is required to follow the slot coordination process as described in EEC 95/93. The Commission is therefore required to ensure the declaration of parameters for each IATA slot season.

Following the Summer 2017 Dublin Airport Coordination Committee meeting, during which all airline participants voted against the proposed capacity increases, the Commission decided that a full capacity analysis of the Airport was required in order to assist in the determination of coordination parameters beyond Summer 2017. The Commission engaged Helios to carry out a full capacity assessment of the Airport and to make recommendations as to the appropriate parameters.

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[1] A schedule facilitated airport is an airport where a coordinator has been appointed to facilitate the operations of air carriers operating or intending to operate at that airport. At a coordinated airport, as distinct from a fully coordinated airport, an air carrier need not have a slot allocated to it by the coordinator in order to take off or land.

[2] Fully coordinated airports are those where slots are allocated by a coordinator, and an airline may not operate unless in possession of a slot.

The Helios study consisted of two main activities:

- Evaluation of the impact of forecast changes in the summer 2018 flight schedule, and
- A full capacity assessment of the Airport.

The evaluation of the impact of forecast changes in the summer 2018 flight schedule was carried out and shared with all Coordination Committee members in advance of the Summer 2018 Coordination Committee meeting and is also publicly available on the Commission's website.

Slot coordination parameters

Capacity is declared at Dublin Airport separately for every Summer and Winter season. The S18 capacity declaration (see Annex B) indicates that the maximum hourly number of movements that can be achieved between 1600-1700 UTC is 48. The departures peak is declared between 0500-0600 UTC as 36 departures per hour and the arrivals peak of 30 arrivals per hour is between 2100-2200 UTC.

In parallel with the hourly runway capacity constraints, all flights need to adhere to 10-minute scheduling limits which limit the total number of planned movements per 10-minute period to 9. At the same time, there are limits imposed on the maximum number of arrivals (6 arrivals) and departures (6 departures[3]) in the same 10-minute period.

Where demand for stands exceeds supply based on the coordinator's allocation, flights are referred to the Airport for detailed assessment.

For terminal buildings, the following coordination parameters apply:

- T1 Departures: 3,700 enplaned passengers in a rolling 60-min period.
- T2 Departures: 3,700 enplaned passengers in a rolling 60-min period.
- T1 Arrivals: 3,550 deplaned passengers in a rolling 60-min period.
- T2 Arrivals: 3,050 deplaned passengers in a rolling 60-min period.

Rolling periods are counted every 10 minutes and load factors of 85% and 95% applied to scheduled and charter services respectively. There is no longer a parameter related to 120-minute rolling peaks, as was the case in previous declarations.

These limits were set to reflect the limiting capacities of the departure screening areas (T1 and T2), and in the immigration halls (Piers 1/2, Pier 3, Pier 4).

In addition to these parameters two "Advisory Flags" have been issued to alert the coordinator and airport on elements of the terminals that are close to their operational capacity:

- T2 Check-in Hall South: due to the high desk demand in the morning peak.
- US Pre-clearance: in order to adapt the flight schedule to the capacity of the US TSA and Immigration processes (both resources and staffing).

With the exception of the flag for Dublin-specific US pre-clearance processes the structure of the capacity declaration looks similar to capacity declarations of other airports of comparable size.

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[3] Maximum departure limit for flights scheduled between 0500-0600 UTC is 7 departures in any 10-minute window.

1.2 Scope

The Commission asked for a report that would:

- Quantify capacities of all infrastructure elements at the Airport,
- Allow assessment of runway 10-28 hourly capacity with different mixes of arrivals and departures to allow declaration of runway hourly limits (see section 3.3),
- Provide insight into the optimum number and duration of firebreaks (see section 5),
- Allow determination of runway capacity under various delay criteria (see section 3.4),
- Assess capacity implications when coordinating to 5-minute periods (see section 6),
- Identify pinch-points across the Airport as a whole together with high level solutions or options to alleviate these pinch points.

1.3 Structure of this report

As per the scope of work defined in the Request for Tender number 113298 this report provides an assessment of all major infrastructure elements at the Airport, namely:

- Airside elements:
    - Runway 10-28[4] (section 3)
    - Taxiways (section 4)
    - Aprons and stands (section 4.4)
- Terminal building elements:
    - Check-in (section 7.2)
    - Security (section 7.4)
    - US pre-clearance processes (section 7.7)
    - Immigration (section 7.6)

This report also provides a high-level assessment of baggage processing systems, access roads and airspace around the Airport (sections 7.10, 8 and 3 respectively). All results are interpreted in section 9 and the key findings are summarised in section 10.

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[4] Runway 16-34 is not in scope of this report

2 Study methodology

2.1 Consultation

In order to understand the operation at Dublin Airport and to collect the data required for the project, the study commenced with a series of stakeholder consultations. Our team sought to engage all of the key airport stakeholders. These consultations took place in May 2017:

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

Table 1: Stakeholders consulted

A familiarisation visit to the airside and both passenger terminals was facilitated by daa. The consultations and the site visit provided the Helios team with a better insight into the specific operations of each stakeholder and disclosed important views on various aspects of the airport operations.

2.2 Modelling approach

On the basis of our understanding of the key aims of this study (defined in section 1.2) we chose to achieve them through the use of airside and passenger terminal building (PTB) fast time simulation (FTS) models. These models were developed using the data collected during the site visit and consultations and, where needed, were complemented with information from the public domain. A full list of data/assumptions used in both models is provided later in this document, see Annex H.

Although the detailed methodology for design/validation/use of both airside and PTB models is provided in the appropriate sections below, there are several similarities that both the airside and PTB methodologies share.

Firstly, both models were based on data from real-world measurements wherever possible. Where such data was not available to us, expert assumptions were made and consulted with appropriate stakeholders before use.

Secondly, both models were calibrated against available historic records and offered for review to all stakeholders.

Finally, a set of alternative scenarios were created to help answer the key questions posed in section 1.2.

The methodology we used for both airside and PTB modelling is in line with recognised airport modelling best practices and consists of the following steps:

- Development of the baseline model. This is a reference model which allows direct comparison against available historic performance. It was decided that 23 June 2016 would be used as the ‘design day’ for the purpose of the baseline model development. This day was identified as typical in terms of number of movements, traffic mix and stand usage. All flights that operated at Dublin Airport at any time between 23 June 2016 00:00:00 and 23 June 2016 23:59:59 were included in the simulation model. Both airfield and PTB models were built using data and assumptions collated from daa, IAA and any other relevant information disclosed by other parties during the stakeholder consultation period.
- Validation and calibration of the baseline models. The baseline model performance when compared to historic performance was discussed with CAR, daa and IAA representatives during a model validation meeting held on the 27th June 2017 at Dublin Airport. Updated versions of both models were then shared with all Coordination Committee members and were subject to two additional review cycles.
- Post-review actions. Both models were updated taking into account any specific issues identified during the review and the performance of the latest version of the baseline model was shared with all Coordination Committee members. As the validation demonstrated a close match between simulation and observed performance on a design day in Summer 2016, these versions of both airside and PTB models were considered by Helios and by the Commission as fit for the purpose of the capacity assessment of the Airport.
- Development of reference S17 model. With the baseline models calibrated against available S16 historic data it was possible to then tailor and use them for simulation of S17 performance. A flight schedule from the Summer 2017 design day (the 11th August 2017) was used as a basis for the S17 model. As the actual stand usage data from 11 August 2017 was not available at the time of S17 model design, a set of rules[5] was created for stand allocation. Airside and terminal building layouts were also updated to be reflective of the actual situation on the S17 design day.
- Development of S18 forecast model. For the purpose of assessing the impact of the additional services forecast for S18, the S17 flight schedule was enlarged by an extra 37 flights. These were identified as the best representation of what the S18 season could look like with the information available at that point in the seasonal slot allocation process.

An overview of the models produced is provided in Table 2 below:

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[5] Based on historic use of stands by narrow body and wide body aircraft of each airline during the full S16 season.

Model	S16 baseline	S17 reference	S18 forecast
Day modelled	23-Jun-16	11-Aug-17	11 August 2017 + forecast S18 additions to the flight schedule
Airside and terminal layouts	As of 23 June 2016	As of 11 August 2017	As of 11 August 2017, with immigration e-gates and pre-boarding zone as of S18 conditions.
Stand allocation	Historic allocations as they happened on 23 June 2016	Rule based allocations. (rules based on historic use of stands by NB/WB aircraft of each airline during the full S16 season)	
Separations	A-A: 3.5NM D-D: 84 seconds A-D-A: 5.5NM WVC minimum separations apply		

Table 2: Overview of airside models

Finally, it should be noted that sections 7.10 and 8 (Baggage handling and roads access) were not analysed using dynamic simulation.

2.3 Derivation of flight schedules

Three different flight schedules were applied to both models: The S16 design day flight schedule, the S17 design day flight schedule and the S18 forecast.

The S16 design day (23 June 2016) flight schedule was used in the S16 baseline model its only purpose was to provide actual data on airfield performance that would allow for calibration of the model behaviour.

A flight schedule from the Summer 2017 design day (11 August 2017) was used as a basis for the S17 model. This day was identified as a typical day in terms of number of movements, traffic mix and stand usage. At the time of model design (prior to 11 August 2017), no actual data on airfield performance was available, therefore a set of rules was implemented based upon historic trends in the S16 season.

In order to assess airport performance during the S18 season it was necessary to create a S18 flight schedule. To achieve this, the S17 design day flight schedule was extended by 37 additional flights. These were identified by individual airlines as likely to be operated during the S18 season. In periods where the S18 schedule exceeded the declared capacity a minimum number of flights were moved to adjacent hours. Similarly, 10-minute movement limits were also taken into account. Figure 1 indicates the number of additional S18 arrivals and departures added in each hour on top of the S17 design day schedule. For a more detailed break-down please refer to Annex C.

It should be noted that for the purpose of PTB capacity testing, it was assumed that all resources within the terminal building are available and that all aircraft operate with 100% seat load factor. This approach is in line with the IATA World Slot Guidelines which state, that when assessing the capacity of airport facilities "the analysis should assume that the airport facilities are being managed efficiently and are fully staffed”. As the S18 flight schedule contains significantly more flights and passengers than the S17 or S16 design day, it was considered appropriate to use the S18 flight schedule for both airside and PTB capacity testing purposes.

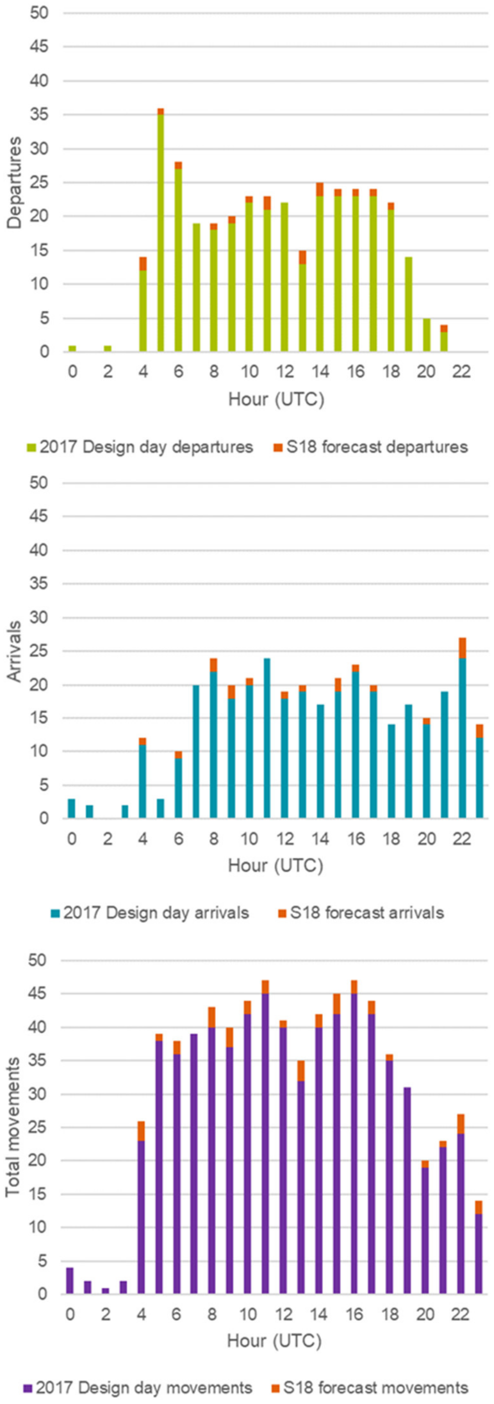

Figure 1: S18 flight schedule

2.4 Modelling the runway, apron, stands and airspace

As all elements of the airport airside system are dependent on each other, the optimum approach to evaluate available capacity is through a unified approach that encompasses the interactions between all elements of infrastructure and services. The most suitable approach is based upon a fast time simulation model.

Instead of modelling different elements of airside infrastructure independently and then assessing their capacities, we created one complete airside model of Dublin Airport. This model simulates operations on the runway, in the airspace immediately around Dublin Airport as well as operations on ground (and their interactions with each other) at the same time. The ability to model all airside elements ensures that the overall capacity assessment takes into account all interactions between aircraft, airspace and ground infrastructure.

The fast-time simulation tool used for assessment of all elements of airside capacity is AirTOp. AirTOp has been used worldwide by air navigation service providers, airports and civil aviation authorities for several years, and it has been also used by Eurocontrol and the US Federal Aviation Administration (FAA) for airspace analysis.

The AirTOp rule-based engine allows the user to define all of the typical airport controller tasks, such as runway entry/exit selection and usage, runway crossing procedures, runway line-up procedures, allocation of gates/parking positions/stand-off positions/hangars, flight plan connections and turnaround management, re-routing, stop-and-wait, runway departure/arrival separations, etc. Additionally, the rules, conditions and other parameters set up by the user can be applied to different traffic samples if needed, without the need to pre-process this sample (e.g. stand allocation can be performed via rules instead of by manual allocation).

Whilst AirTOp can be applied to Ground Service Equipment (GSE) such as belt-loaders, airside buses[6], catering vehicles, etc. for the runway and airfield capacity assessment these have not been considered. Resourcing and management of ground operations (e.g. the turnaround process, airside transportation and baggage transport) are assumed to be sufficient so as to not impact the throughput achieved by the runway or ground infrastructure.

Further details on the assumptions used in the modelling are contained in Annex H.

2.5 Modelling the passenger terminal building

The existing passenger terminal buildings T1 and T2 were modelled as a chain of inter-related passenger and baggage processing sub-systems. Each sub-system's maximum capacity was calculated and then compared with the peak demand to determine the weakest link(s) in the whole system. The limiting capacity constraints could then be used to assess the coordination parameters for future seasons.

One complete fast-time model of both T1 and T2 at Dublin Airport was created. 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 US Preclearance (CBP) processes. All elements of the model are interlinked and

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[6] Busses must give way to crossing aircraft and as such have no impact on aircraft taxi times, and therefore we do not believe that it is necessary to model bussing as part of this exercise. We understand that a bus which gets delayed due to a crossing aircraft may deliver passengers to the flight late, possibly causing late departure, however, this is an operational planning issue rather than airside capacity issue.

interact with each other. This ensures that the impact of each potential bottleneck is appropriately propagated through the whole system.

With the exception of baggage handling, all capacity assessments were carried out using Pedestrian Dynamics fast time simulation software. This software is dedicated to the modelling of passenger terminal buildings and is currently being used at several international airports including Amsterdam Schiphol and Brisbane. The tool considers the dynamic simulation of each passenger with individual behaviour characteristics assigned to each.

For baggage handling assessments, a static spreadsheet analysis was carried out using Microsoft Excel. A dynamic simulation of the baggage handling system would require significant details of all system configurations and software parameters in each Terminal, as well as a number of assumptions regarding baggage check-in, screening, sorting and collection. Furthermore, it is very unlikely that the baggage handling system could limit passenger throughput since there are less constraints and more flexibility (e.g. in desk allocation, belt speed, sorting point sharing, etc.). On this basis, a static capacity analysis based on peak hour data is considered sufficient to assess the level of use of the systems.

Further details on the assumptions used in the modelling are contained in Annex H.

3 Analysis of runway and airspace capacity

3.1 General

The following section provides a detailed quantitative assessment of the current capacity of the runway as well as a higher-level assessment of airspace capacity. For reference, the ground layout of Dublin Airport is provided in Annex E.

The capacity implications of the findings in this section are discussed in more detail in Section 9.

There are two operational runways at Dublin Airport: runway 10-28 and runway 16-34.

The main runway is 10-28, which is also the runway used to derive the declared capacity limits. Runway 28 was used approximately 70% of the time over the S16 period[7]. Runway 16-34 is used during cross-wind conditions and occasionally during the morning peak periods of runway 10-28 operations.

Runways 10 or 28 are the required runways between 0600 and 2300 local time when the crosswind component is 20KT (Knots) or less. Runway 28 is the preferential runway when the tailwind component is 10KT or less and braking action is assessed as good. Aircraft are required to use runways 10 or 28 except when operational reasons dictate otherwise.

If the crosswind component on Runway 10 or Runway 28 is greater than 20KT, Runway 16 or Runway 34 may become the active runway but the use of Runway 16-34 will be kept to an absolute minimum subject to operational conditions.

During the summer 2016 period, the breakdown of runway operating directions at Dublin was as follows:

Month Runway	10	28	16	34
April	32%	63%	1%	4%
May	44%	51%	4%	2%
June	21%	77%	1%	1%
July	17%	80%	2%	1%
August	26%	73%	1%	1%
September	17%	79%	2%	1%

Table 3: Runway operating directions (S16)

It should be noted that March and October figures are excluded due to a lower number of days falling into S16 season in both months.

3.2 Runway capacity assumptions

Runway capacity is defined as the number of movements (arrivals and/or departures) that can be performed on the runway in one hour.

Maximum hourly runway capacity uses the following assumptions:

- Average runway occupancy time (ROT) is known or can be calculated.
- There is a continuous supply of arrivals and/or departures.
- No two aircraft can be on the runway at the same time.

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[7] Full S17 data was not available at the time of writing this report

- Safe wake vortex separation distances between two flights are ensured.
- Fleet mix remains static (i.e. type of aircraft using the runway do not change over time).
- Approach procedure does not change.

As a consequence, the maximum hourly runway capacity is a theoretical measure of runway capacity and is represented as an average capacity for the runway. Assuming no two aircraft can use the runway at the same time, the theoretical maximum hourly runway capacity would be 3600 / (average runway occupancy time in seconds). However, this approach would be too simplistic. In order to calculate more realistic runway capacity, we took into account assumptions related to fleet mix and aircraft performance. These are summarised in Table 4 below.

	% of S17 design day	% of S18 design day	Weighted average aROT (R28) in seconds	Weighted average aROT (R10) in seconds	Weighted average approach speed (KT)
Turbo Prop	11.8%	11.2%	50.2	58.9	130
Jet – to Code C	77.2%	77.2%	58.6	53.9	135
757	1.7%	1.6%	67.6	71.2	140
Jet - other Code D and above	9.2%	9.9%	75.5	75.2	150

Table 4: Key assumptions related to the fleet mix and aircraft performance

We also considered ATC separations between various classes of aircraft. By default, these were set up to:

- 3NM for Arrival to Arrival (A-A) separation (unless required otherwise due to the wake turbulence category),
- 84 seconds for Departure to Departure (D-D) separation (unless required otherwise due to the wake turbulence category), and
- 2NM for Departure to Arrival (D-A) separation.

On top of the separations above, we considered an average 0.5NM buffer added by ATCOs to arrival separations, effectively bringing the arrival-arrival separation to 3.5NM.

It was also assumed that the runway operates in mixed mode 100% of the time.

3.3 Runway 10/28 capacity analysis

Taking into account the assumptions above, it was possible to calculate the runway capacity using the fleet mix from the S17 and S18 design days. The methodology for calculation of runway capacity in departures, arrivals and mixed mode included:

- Calculation of arrival to arrival minimum separations based on fleet mix averages, approach speeds, minimum separation behind specific aircraft, and operating buffers.
- Calculation of arrivals capacity based on average arrival to arrival separation times.
- Calculation of departure to departure minimum separations based on fleet mix averages, separation behind specific aircraft, and operating buffers.
- Calculation of departures capacity based on fleet mix averages and separation behind specific aircraft.

- Calculation of minimum time requirement to introduce departures between a pair of arrivals based on runway occupancy times, minimum arrival to departure spacing, and approach speeds.
- Calculation of mixed mode capacity based on average arrival to arrival separation and interleaved departure time requirements.

The maximum number of arrivals per hour decreased from 24 to 23 between the S17 and S18 design days. This decrease can be explained by the increase in the share of heavy aircraft in the fleet mix between the S17 and S18 design days with their need for larger separations. The maximum number of departures remained the same at 41 departures per hour. The difference between the maximum runway capacity during S17 and S18 design days is provided in Figure 2 below.

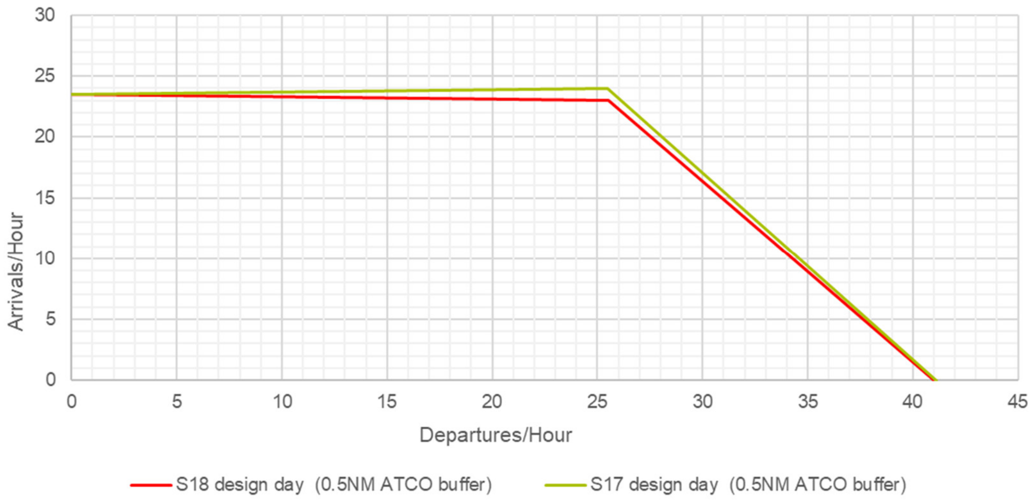

Figure 2: Maximum runway capacity based on S17 and S18 fleet mix

As the share of heavy aircraft in the fleet mix can significantly influence the runway capacity, a series of test were carried out with variations in % share of heavy aircraft in the fleet mix. Only proportions of narrow body jets and heavy aircraft were changed to reflect the trend of replacing smaller aircraft with larger ones on the most popular routes. Proportions of all the other aircraft types remained the same.

Figure 3 and Table 5 below show the impact of an increased share of heavy aircraft in the fleet mix. The decrease in capacity is clearly visible up to the point where heavy aircraft account for 30% of the fleet mix. After reaching this saturation level, the further increase in the share of heavy aircraft does not have a significant influence on arrivals or departure capacity.

Fleet mix				**Capacity**		
Heavy	**757s**	**Narrow body jets**	**Turbo-props**	**Arr**	**Dep**	**Total**
0.0%	3.7%	94.2%	2.1%	24.0	42.2	48.4
15.0%	3.7%	79.2%	2.1%	23.0	40.1	46.2
30.0%	3.7%	64.2%	2.1%	22.0	38.9	44.4
45.0%	3.7%	49.2%	2.1%	22.0	38.4	44.0
60.0%	3.7%	34.2%	2.1%	22.0	38.6	43.8

Table 5: Impact of heavy aircraft on capacity of runway 10/28

The maximum achievable runway throughput on runway 10-28 is 24 arrivals in arrivals mode, 41 departures in departures mode and 48 flights in mixed mode. These limits are sensitive to operating fleet mix and reduce by approximately 2 movements (in mixed mode) for every 15% increase in the share of heavy (Code E/F) aircraft in the fleet mix (see Table 5 above).

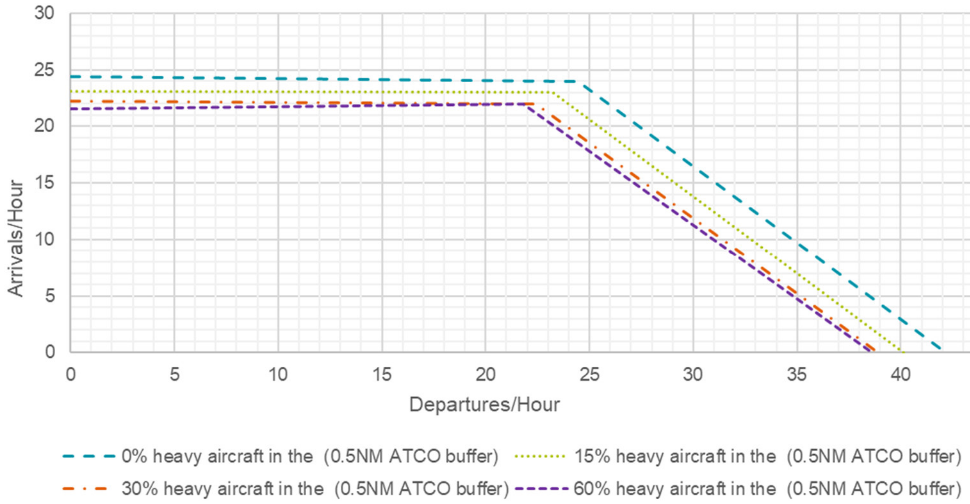

Figure 3: Impact of heavy aircraft on capacity of runway 10/28

In order to assess the suitability of existing declared runway capacity limits, we plotted both arrivals[8] and departures[9] from the S18 capacity declaration against the capacity frontier based on the S18 design day.

In Figure 4 below we plotted arrivals from the S18 capacity declaration against the S18 design day runway throughput. As many of the plots were above the capacity limit, we also tested the impact of removing the 0.5NM ATCO buffer. This resulted in a closer match with the throughput envelope. However, it should be noted that this scenario is unrealistic as ATCOs do not sequence aircraft without including buffers. Although Figure 4 suggests that the arrivals capacity limits are above the arrivals runway throughput in certain hours, it should be noted that the fleet mix in those hours can be substantially different to the average daily fleet mix, thus allowing more arrivals to be accommodated in a given hour.

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[8] In order to plot maximum number of arrivals in each hour of the declaration we subtracted the declared arrivals limits from the total limit in each hour to identify the number of departures corresponding to the maximum number of arrivals in a given hour.

[9] In order to plot maximum number of departures in each hour of the declaration we subtracted the declared departures limits from the total limit in each hour to identify the number of arrivals corresponding to the maximum number of departures in a given hour.

The arrivals capacity declaration in some hours (notably the evening peak) exceeds the simulated runway throughput envelope. This does not mean the present declaration is incorrect, it just indicates that arrivals above the maximum arrivals throughput will be accommodated with delay.

In Figure 5 below we plotted departures from the S18 capacity declaration against the S18 design day runway capacity. Unlike the arrivals data, no plots exist outside the capacity envelope (regardless of whether the 0.5NM ATCO buffer was included).

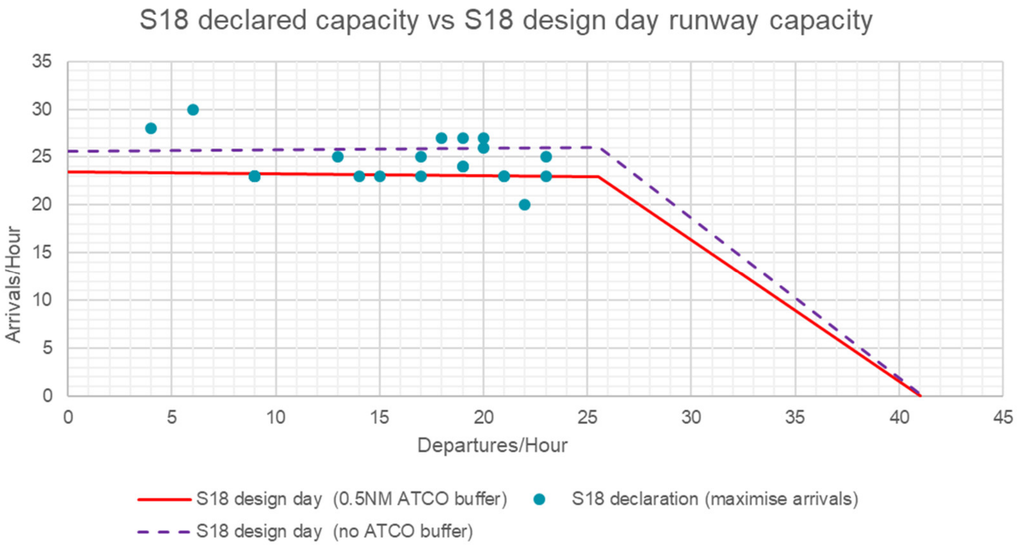

Figure 4: S18 declared capacity vs S18 design day capacity (Arrivals)

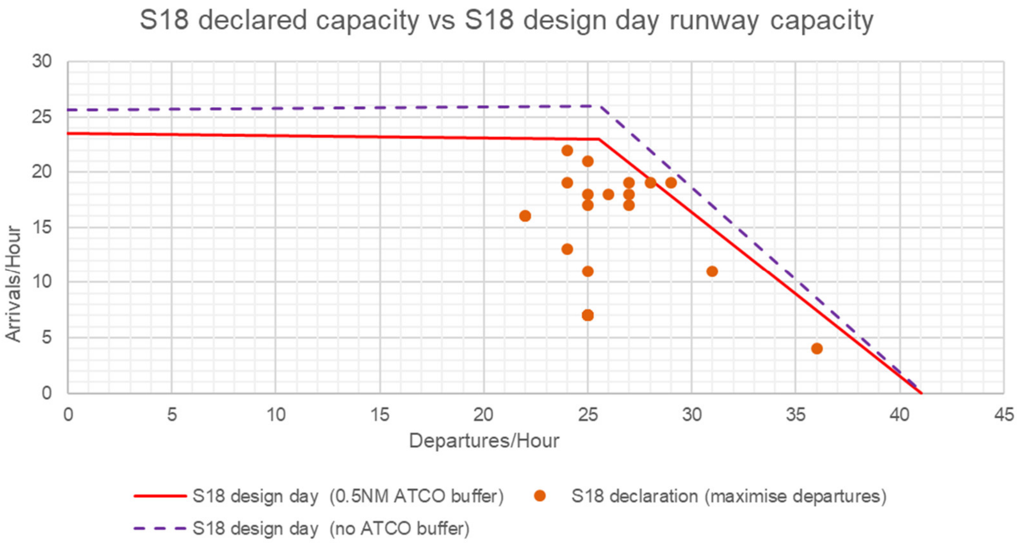

Figure 5: S18 declared capacity vs S18 design day capacity (Departures)

All declared departures limits in the capacity declaration are within the simulated runway throughput envelope. However, adding extra flights into hours which are at, or close to the declared limits will incur extra delay for flights operating in these hours.

The graphs presented above show maximum number of arrivals/departures from S18 capacity declaration plotted against the runway throughput. However, not all hours in S18 are scheduled up to the declared limits. To understand what the S18 forecast schedule looks like when compared to runway throughput we plotted forecast number of arrivals and departures in each hour of S18 forecast against the runway 10-28 frontier. This is presented in Figure 6 below.

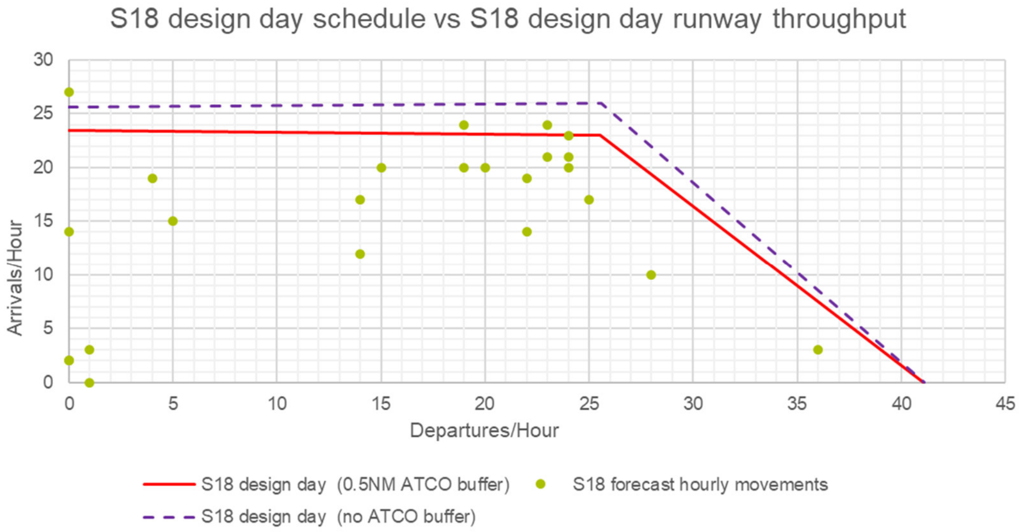

Figure 6: S18 design day schedule vs S18 design day throughput

All the hours in S18 design day forecast are within the capacity frontier, with the exception of 0800, 1100 and 2200 hour (all UTC). As the capacity frontier was constructed using average daily fleet mix, it is safe to assume that all of these three hours would fall into the capacity frontier if recalculated using the specific fleet mix observed during these hours.

3.4 Runway 28 sensitivity to changes in peak period

Dublin Airport experiences its first and biggest traffic peak between 0530 and 0630 UTC in a morning departures wave. Different patterns of activity can arise on different days of the week but the number of movements in the first morning wave is (almost) always close to or at the scheduling limits. Despite this, airlines would still like to open additional services during this time period. As the runway is operating close to its capacity during the morning departure wave, we tested the impact of various changes in the fleet mix on three metrics: runway delay, departure ground delay and departure taxi duration.

Summary of the impact is provided in Figure 7, Table 6 and Table 7 overleaf.

To increase precision of the calculation, these metrics were averaged in 1-minute intervals. It should be noted all results in this section are dependent on the assumption on type of aircraft, operator and parking position.

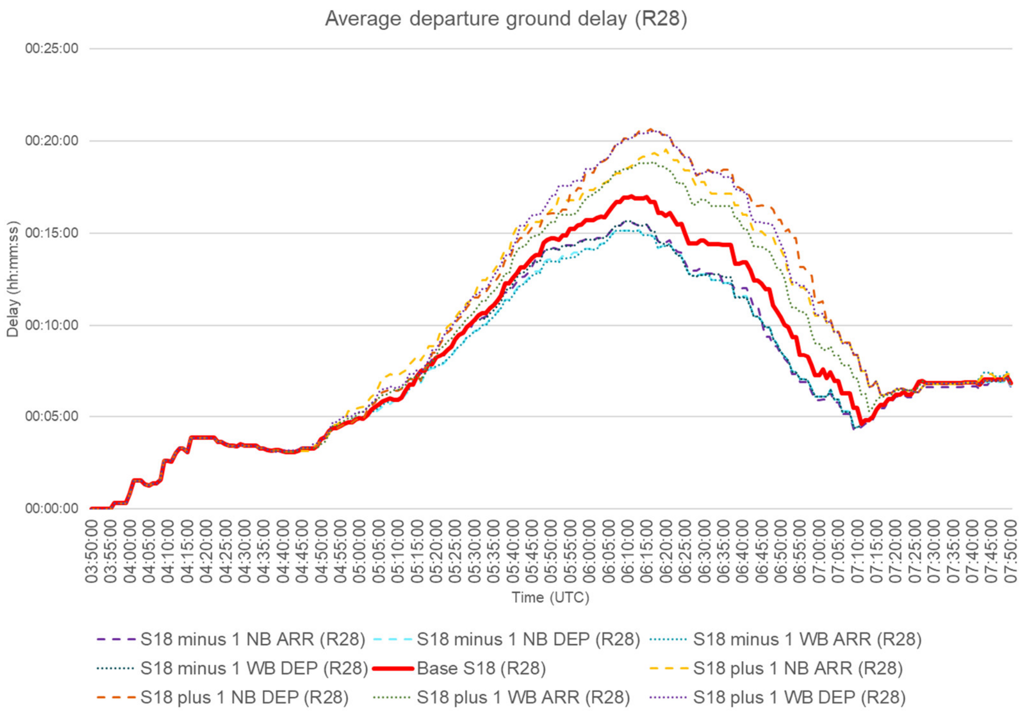

Figure 7: Sensitivity of R28 departure ground delay to changes in fleet mix and movements

Peak maximum	Runway delay	Departure ground delay	Departure taxi duration
S18 minus 1 NB ARR (R28)	00:13:54	00:15:36	00:24:35
S18 minus 1 NB DEP (R28)	00:14:00	00:15:10	00:24:11
S18 minus 1 WB ARR (R28)	00:13:59	00:15:09	00:24:11
S18 minus 1 WB DEP (R28)	00:14:26	00:15:38	00:24:59
Base S18 (R28)	**00:15:29**	**00:16:59**	**00:25:55**
S18 plus 1 NB ARR (R28)	00:18:02	00:19:32	00:28:23
S18 plus 1 NB DEP (R28)	00:17:59	00:20:39	00:29:33
S18 plus 1 WB ARR (R28)	00:16:49	00:18:53	00:27:30
S18 plus 1 WB DEP (R28)	00:18:53	00:20:35	00:29:16

Table 6: Runway 28 sensitivity to changes in peak period (peak values)[10]

Difference against S18 baseline	Runway delay	Departure ground delay	Departure taxi duration
S18 minus 1 NB ARR (R28)	- 00:01:35	- 00:01:23	- 00:01:20
S18 minus 1 NB DEP (R28)	- 00:01:29	- 00:01:49	- 00:01:44
S18 minus 1 WB ARR (R28)	- 00:01:30	- 00:01:50	- 00:01:44
S18 minus 1 WB DEP (R28)	- 00:01:03	- 00:01:21	- 00:00:56
Base S18 (R28)	**00:00:00**	**00:00:00**	**00:00:00**
S18 plus 1 NB ARR (R28)	00:02:33	00:02:33	00:02:28
S18 plus 1 NB DEP (R28)	00:02:30	00:03:40	00:03:38
S18 plus 1 WB ARR (R28)	00:01:20	00:01:54	00:01:35
S18 plus 1 WB DEP (R28)	00:03:24	00:03:36	00:03:21

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[10] Definition of the three metrics provided in this table is available in Annex I

Table 7: Runway 28 sensitivity to changes in peak period (differences)

3.5 Runway 10 sensitivity to changes in peak period

Akin to section 3.4, we tested also the sensitivity of Runway 10 to changes in fleet mix during the peak period. A summary of the impact is provided in Figure 8, Table 8 and Table 9 below. To increase the precision of the calculation, these metrics were averaged over 1-minute intervals. It should be noted all results in this section are dependent on the assumption on type of aircraft, operator and parking position.

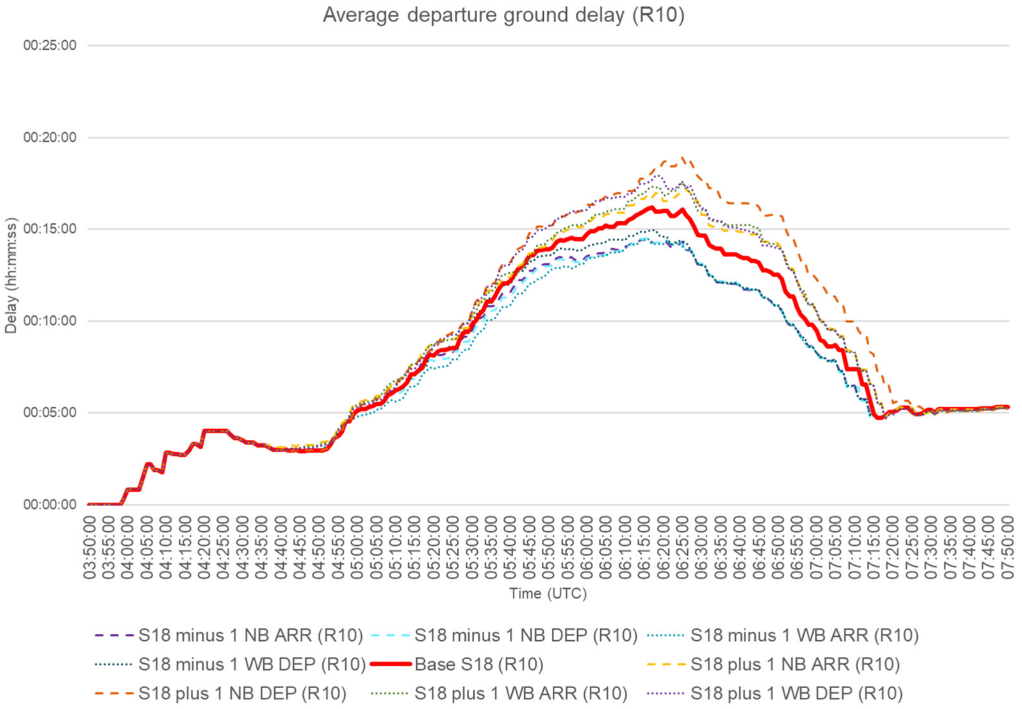

Figure 8: Sensitivity of R10 departure ground delay to changes in fleet mix

Peak maximum	Runway delay	Departure ground delay	Departure taxi duration
S18 minus 1 NB ARR (R10)	00:13:18	00:14:34	00:28:09
S18 minus 1 NB DEP (R10)	00:13:22	00:14:32	00:28:05
S18 minus 1 WB ARR (R10)	00:13:19	00:14:29	00:28:02
S18 minus 1 WB DEP (R10)	00:13:41	00:14:57	00:28:29
Base S18 (R10)	**00:14:58**	**00:16:13**	**00:29:53**
S18 plus 1 NB ARR (R10)	00:15:46	00:17:09	00:30:48
S18 plus 1 NB DEP (R10)	00:17:47	00:18:54	00:32:46
S18 plus 1 WB ARR (R10)	00:16:25	00:17:33	00:31:17
S18 plus 1 WB DEP (R10)	00:16:42	00:17:56	00:31:43

Table 8: Runway 28 sensitivity to changes in peak period (peak values)[11]

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[11] Definition of the three metrics provided in this table is available in Annex I

Difference against S18 baseline	Runway delay	Departure ground delay	Departure taxi duration
S18 minus 1 NB ARR (R10)	- 00:01:40	- 00:01:39	- 00:01:44
S18 minus 1 NB DEP (R10)	- 00:01:36	- 00:01:41	- 00:01:48
S18 minus 1 WB ARR (R10)	- 00:01:39	- 00:01:44	- 00:01:51
S18 minus 1 WB DEP (R10)	- 00:01:17	- 00:01:16	- 00:01:24
Base S18 (R10)	**00:00:00**	**00:00:00**	**00:00:00**
S18 plus 1 NB ARR (R10)	00:00:48	00:00:56	00:00:55
S18 plus 1 NB DEP (R10)	00:02:49	00:02:41	00:02:53
S18 plus 1 WB ARR (R10)	00:01:27	00:01:20	00:01:24
S18 plus 1 WB DEP (R10)	00:01:44	00:01:43	00:01:50

Table 9: Runway 28 sensitivity to changes in peak period (differences)

Sensitivity analysis with the S18 morning departures wave indicates that adding a flight into this period on top of S18 forecast will lead to an increase in departure ground delays of between two and three and half minutes, depending on whether the added flight is an arrival or departure and whether it is narrow body or wide body aircraft.

3.6 Airspace capacity

The airside model would not be complete without appropriate simulation of flows of arriving and departing traffic. However, the main aim for modelling the Dublin Terminal Manoeuvring Area (TMA) was to ensure that the flow and separation of arriving and departing aircraft is as accurate as reasonably possible to ensure the modelled runway capacity/throughput is not impaired by inaccuracies in the surrounding airspace. The focus of this study is on the capacity of ground infrastructure. Therefore, the airspace assessment provided in this section is high-level only

The airspace around Dublin features a Point Merge system. Point Merge is a structured technique for merging arrival flows. It is based on a specific route structure that is made of a merge point with pre-defined legs (the sequencing legs) equidistant from this point for path stretching/shortening. The operating method for ATC comprises two main steps:

- Create the spacing by a “direct-to” instruction to the merge point issued for each aircraft at the appropriate time while on a leg
- Maintain the spacing by speed control after leaving a leg

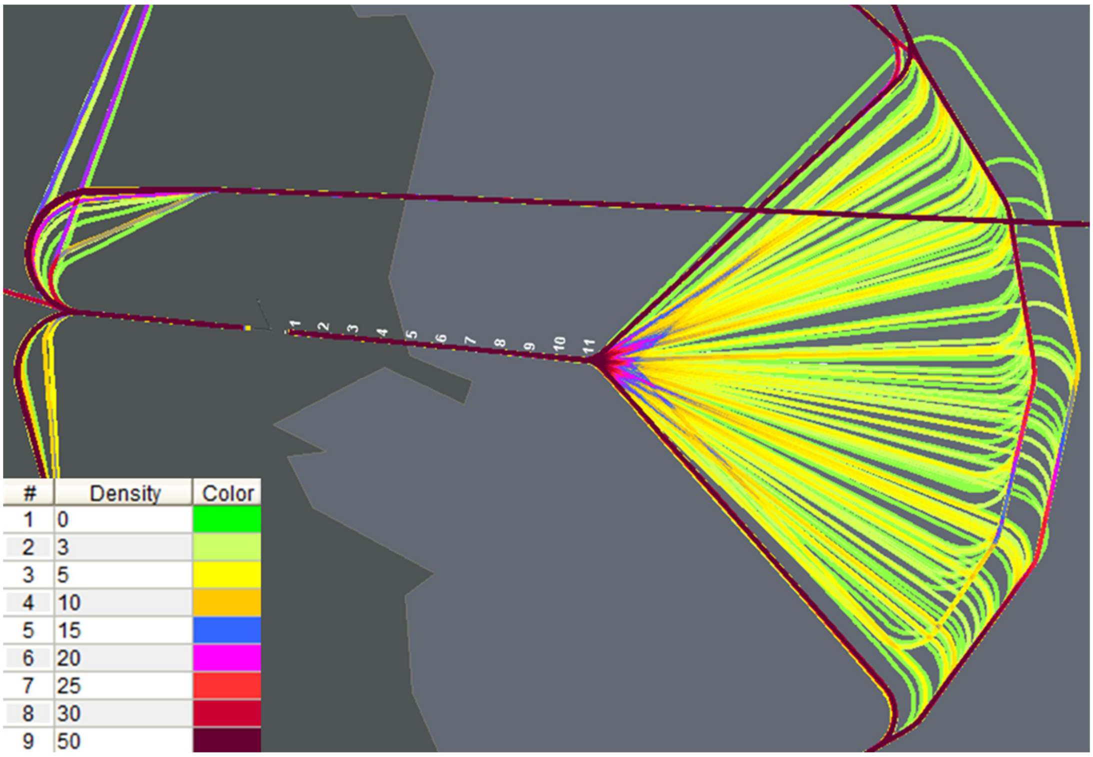
The descent may be given when leaving a leg (and clear of traffic on the other leg). It should be a continuous descent as the distance to go is then known by the aircraft flight management system (FMS). The equidistance property is key for the air traffic controller to easily and intuitively assess the spacing between an aircraft on the leg and the preceding aircraft (on course to the merge point).

Point Merge, can provide predictable and optimised routeings within the terminal airspace without the controller having to intervene with radar vectoring, thus providing the ability to carry out continuous descent approaches (CDAs) and so optimise descent profiles and cockpit workload. This can be achieved, even with high traffic load. The use of the Point Merge technique may also have some limitations: once the aircraft sequence is decided and the aircraft put on direct route to the merging point, only speed adjustments can be used to maintain the sequence. Any subsequent sequence change requires temporarily reverting to open-loop vectoring, losing the benefit of the system for a certain time. Hence the importance of an optimised arrival sequence, continuously adjusted to runway demand.

Information from the IAA[12] established that by using Point Merge, airlines landing at Dublin Airport reduced their arrival fuel requirement by 19.1% per flight. It also found that aircraft reduced the length of the flight by 11.3 miles, a 17% saving, compared to arrival routes prior to the implementation.

Density maps in Figure 9 and Figure 10 extracted from our simulation model revealed that the vast majority of arrivals to both runway 28 and runway 10 flew the shortest leg of the point merge, directly to the merge point. This is in line with the current operational practice. Only a few flights flew the outer arcs and most of these turned towards the merge point before reaching one third of the outer arc length. Further analyses of airborne arrival delays did not identify any significant peaks during the day.

It can therefore be concluded that the airspace structures around Dublin do not pose a significant capacity constraint and thanks to the Point Merge system should be able to efficiently handle potential increases in traffic.



#	Density	Color
1	0	🟩
2	3	🟩
3	5	🟨
4	10	🟧
5	15	🟦
6	20	🟪
7	25	🟥
8	30	🟥
9	50	🟫

Figure 9: Trajectories of simulated flights (runway 28, S18 design day)

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[12] https://www.iaa.ie/air-traffic-management/innovation/dublin-point-merge

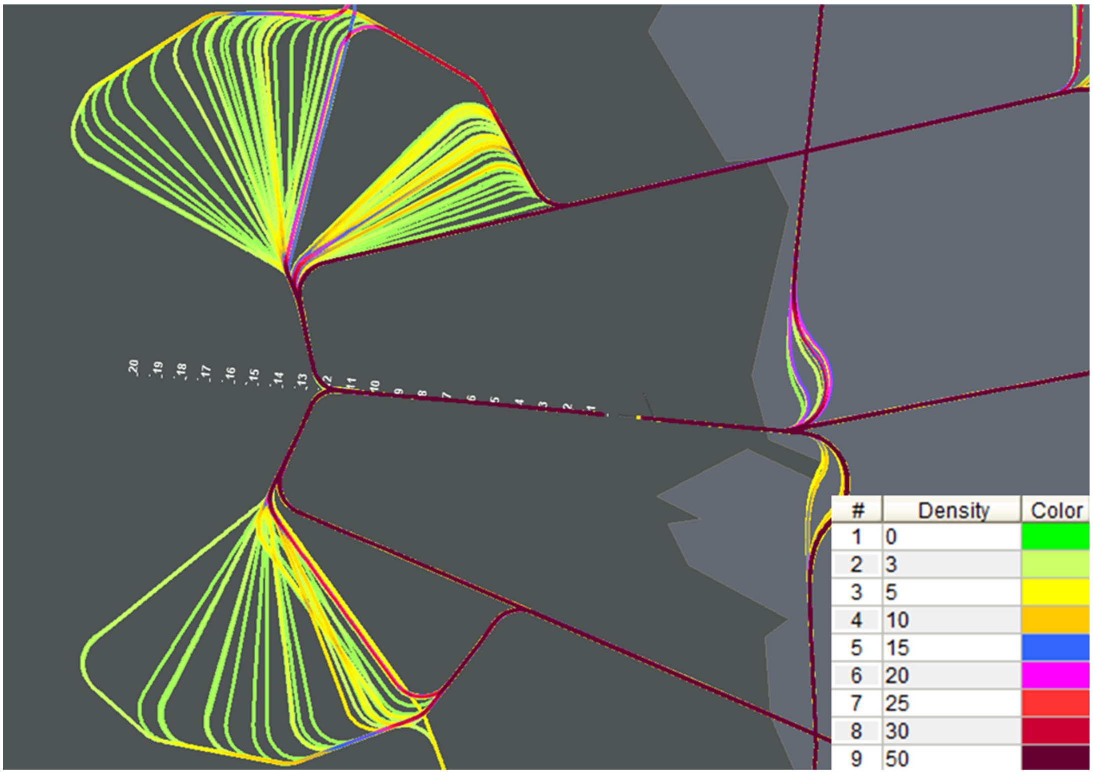

Figure 10: Trajectories of simulated flights (runway 10, S18 design day)

4 Analysis of taxiway and stand capacity

4.1 General

The following section provides a detailed quantitative assessment of the current capacity of the taxiway system and stands. For reference, the ground layout of Dublin Airport is provided in Annex E.

The capacity implications of the findings in this section are discussed in more detail in Section 9.

The taxiway system at Dublin Airport consists of taxiway Bravo parallel to Runway 10-28, taxiway Foxtrot, parallel to Runway 16-34, taxiways Mike and Papa that allow access to the West Apron and a series of shorter taxiways allowing access to/ exit from each runway.

4.2 Taxiway capacity

A key operational concern is the taxiway congestion experienced by arrivals flights in the early morning peak (0600-0800 hours UTC) as these are impeded by aircraft queuing at the line up points. This applies both to operations on R28 and R10. Further congestion can be introduced by early arrivals, which often have to wait on a taxiway or other hold position before a stand becomes vacant. This applies to both early US and Canadian flights, where the flight times can vary depending on the wind conditions en-route and track used and to early UK and European flights.

Another specific operational factor at Dublin Airport relates to the number and direction of tows in the morning period. This can slow down the traffic taxiing for departure and complicates the flow of traffic on the ground as the towed aircraft are moving in the opposite direction to those aircraft taxiing for departure.

Several cul-de-sacs stand arrangements are in place at Dublin – these operate according to a “one in, one out” rule, preventing nose-to-nose conflict, but adding extra delay to arriving aircraft which may need to wait before the departing one has left the cul-de-sac area. Moreover, aircraft waiting outside the cul-de-sac area complicate the flow of other traffic, limiting access to the runway.

Taxiway capacity is a difficult metric to measure and cannot be quantified by a single figure. In order to assess whether the taxiways at Dublin Airport pose a capacity bottleneck, we have simulated the design day and observed the delay accumulated on taxiway segments and the number of aircraft that had to be stopped on each taxiway segment. These metrics were then visualised on the airport map (See Figure 11 below).

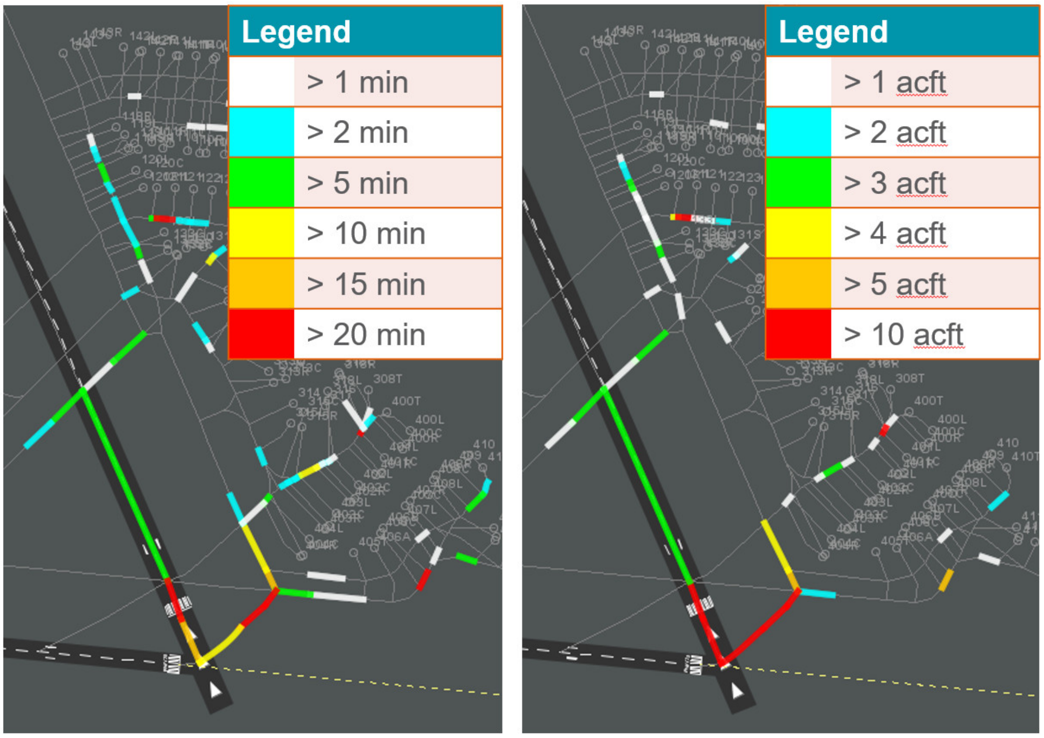

Figure 11: Delay accumulated (left) and aircraft stopped (right) on taxiways (S18 forecast)

As expected, the simulation confirmed the existence of a hotspot in the area where Runway 28 joins Runway 34. This area is busy due to multiple runway entry points and converging taxiways. Another potentially congested area is Link 4 – junction between taxiways H1 (used by runway 28 arrivals going to Pier 1, Pier 2 or Apron 5G), F-inner (used by departures coming from Apron 5G, Triangle and Pier 1 stands), F-outer (used by arrivals to Pier 1 or Apron 5G) and F3 (used by aircraft being towed north).

With the exception of peak periods, the taxiways can serve the traffic reasonably well. During the morning peak period on Runway 28 operations, queues of departing aircraft may complicate traffic flow around Pier 3 South and Pier 4.

Cul-de-sac stand arrangements add delay to arriving aircraft when another aircraft is departing from cul-de-sac area. The arriving aircraft, which is waiting outside the cul-de-sac also complicates taxiing of other aircraft.

4.3 Consideration of options to improve capacity

Link 6 to R16-34

Although not shown significantly in the simulation, there is a risk that aircraft coming from various directions will meet at Link 4 (especially during busy morning period, when the first narrow bodied aircraft are taxiing from Pier 1 towards Runway 28, early morning long haul arrivals start coming in and on some days there are other aircraft being towed to/from their hangar. Such a situation has the potential to lead to increased taxi times/delays as some aircraft will have to give way to others. At the same time, this area will require more ATCO attention and planning, especially as the traffic grows from S18 onwards.

We considered adjustments to the taxiway system to alleviate this pinch point. One possible option could be to re-route a significant portion of traffic through different taxiways. For example, arrivals going to Pier 1 North/Apron 5G could continue north via Runway 16-34 and then turn east to join Link 6. This would allow departures from and arrivals to the Pier 1 and Apron 5G stands to bypass the area between F-Inner, F-outer, Link 4 and Link 6 as needed. The proposed taxiway could also serve as a runway exit during Runway 16-34 operations.

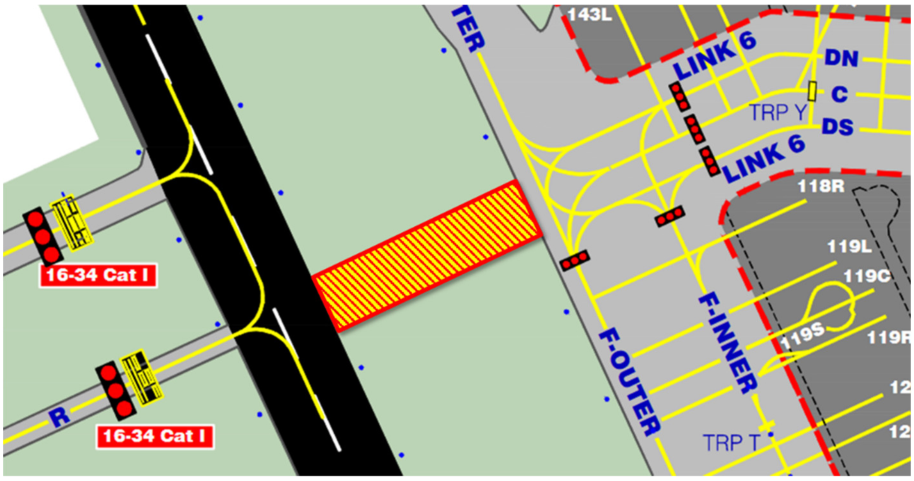

Figure 12: Taxiway joining Link 6 and Runway 16-34

Simulation of this option using the design day flight schedule revealed that the daily average departure taxi-out time decreased by 29 seconds with the taxiway joining Link 6 and Runway 16-34 implemented. In case of the morning peak period, we observed a decrease in departure taxi out time duration by up to one minute per flight on average. A reduction of over one minute was observed between 1400 and 1800 UTC. The impact on the remainder of the day was not as significant, however on average, departure taxi out times decreased throughout the whole day. The impact of this option on taxi out times for Runway 28 departures is provided in Figure 13 below.

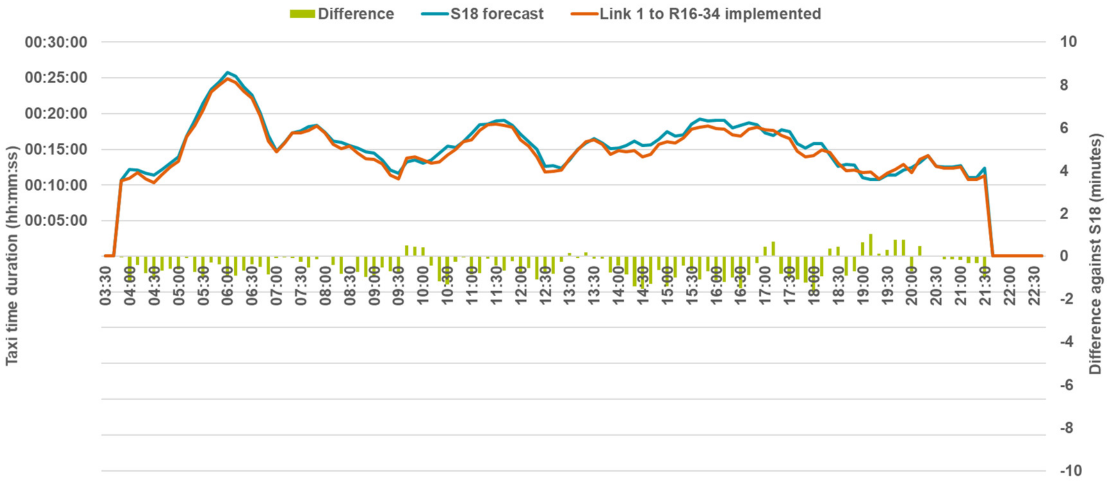

Figure 13: Impact of taxiway joining Link 6 and R16-34 on taxi out times (R28)

Assessment of the same option during operations in the Runway 10 direction returned similar results. However, the average benefit from implementation of this infrastructure change seems to be smaller. This is most likely due to the fact that any delays incurred around the Pier 1 North or Apron 5G can be mitigated by faster taxiing speeds to Runway 10 threshold so that part of the delay can be absorbed during the departure taxi procedure. The impact of a taxiway joining Link 6 and Runway 16-34 on taxi out times when in Runway 10 operating direction is presented in Figure 14 below.

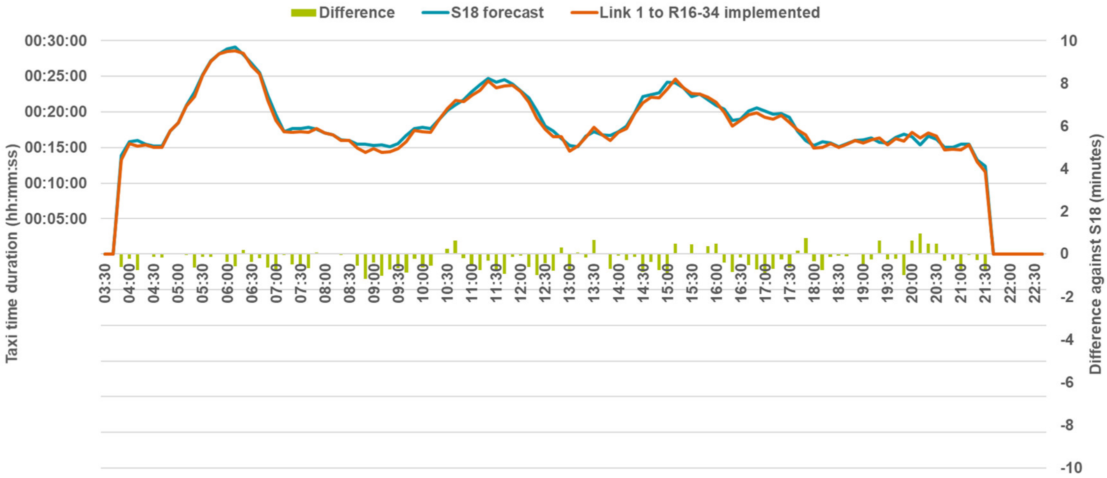

Figure 14: Impact of taxiway joining Link 6 and R16-34 on taxi out times (R10)

Link 3 to R16-34

A solution similar to that in the preceding section could also be implemented near Link 3. A taxiway between the Link 3 junction and the Runway 16-34 could help in a similar fashion as that between Link 6 and Runway 16-34; it would allow traffic to/from Pier 3 and Pier 2 South to avoid Link 4 and Link 2 junctions. Again, this should lead to a smoother flow of traffic on the ground, potentially leading to a decrease in departure taxi times and improvement in arrival OTP (through reduced arrival taxi in times.) Additionally, this taxiway could also serve as a runway entry/exit during Runway 16-34 operations. This option is presented in Figure 15 below. This infrastructure change was not modelled.

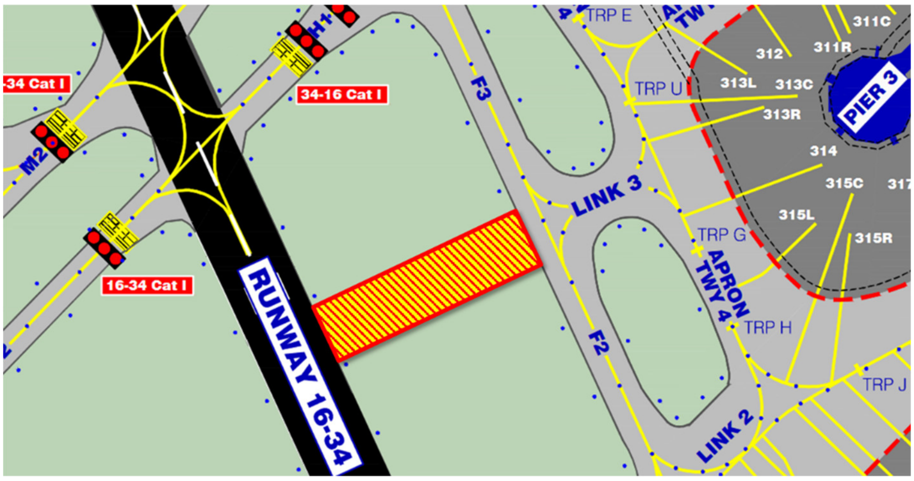

Figure 15: Taxiway joining Link 3 and Runway 16-34

The two extra taxiways proposed above may be sufficient to help facilitate short-term increases in traffic. However, the airport is likely to need a major improvement of its taxiway system if it wants to provide the same quality of service with ever-increasing traffic levels (especially with the view of the new runway being operational by 2020) is elaborated below.

Parallel taxiway

The use of dual taxiways F-Inner and F-Outer helps to manage the traffic around the Pier 1 and the Triangle. A similar concept could help with the Pier 3 and Pier 4 traffic, when a new taxiway, parallel with F3/F2/F1 would be built (assuming it will have the same aircraft ICAO Code capacity as F-Inner/F-Outer). This would provide additional towing routes and it would also enable smoother push-backs, as other taxiing aircraft could use the new taxiway instead of waiting for the other aircraft to complete its pushback. It is likely that with growing traffic the queue of aircraft departing from Runway 28 will shortly reach the Link 4 area. Additional available taxiways would allow more aircraft to wait for departure in the second queue, on the taxiway, instead of waiting on stand, thereby blocking it from other use. An additional taxiway would also open more options for ATC when it comes to organising the departure sequence flow on the ground.

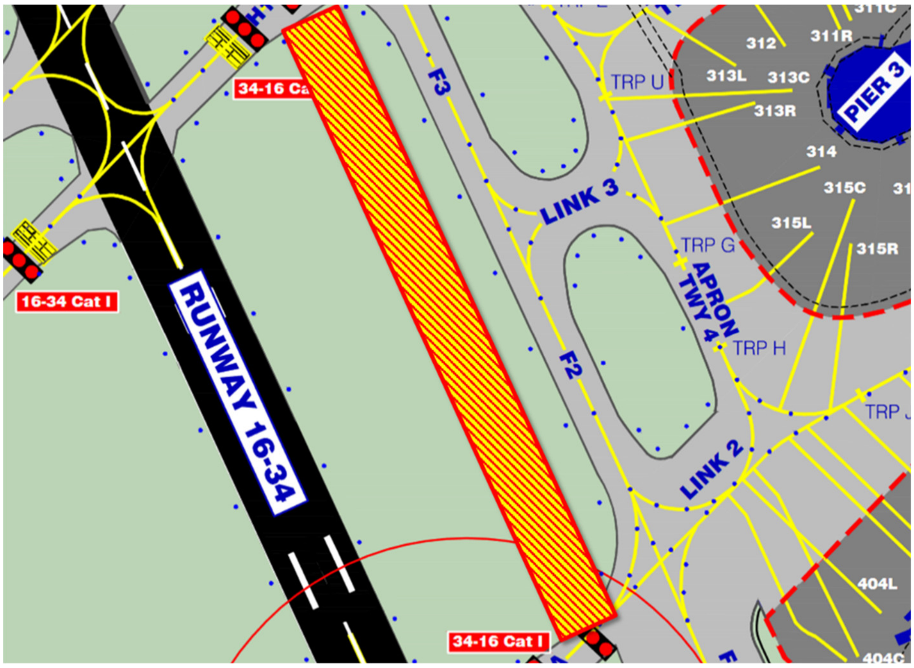

Figure 16: Parallel taxiway

This option was also simulated in both Runway 28 and Runway 10 directions using S18 design day traffic. Figure 17 shows that daily profile for departure taxi out time (with the parallel taxiway implemented) when runway 28 is in operations is smaller than the same metric measured without the additional taxiway. The difference is the most pronounced during peak periods, with reductions of taxi times as high as 2 minutes on average, between 1500 and 1700 UTC. The overall impact of this change measured across the full day results in a 17 seconds reduction in taxi out times.

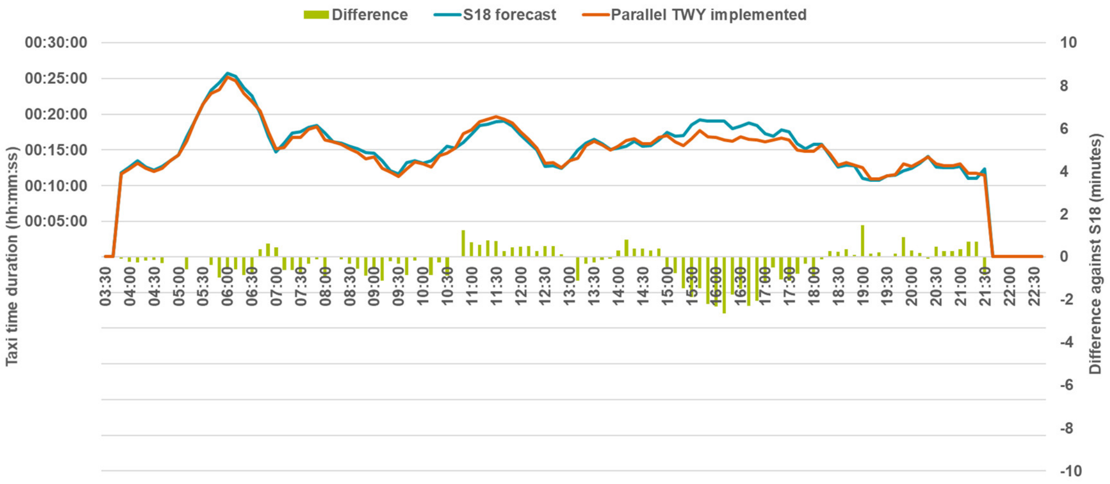

Figure 17: Impact of taxiway parallel to taxiway F on taxi-out times (R28)

The impact on taxi out times in the Runway 10 operating direction is negligible because it is mostly taxiway H and taxiway B which are used during R10 operations. That being said, another taxiway parallel to TWY F could be used by towed aircraft to decrease their impact on airfield operations.

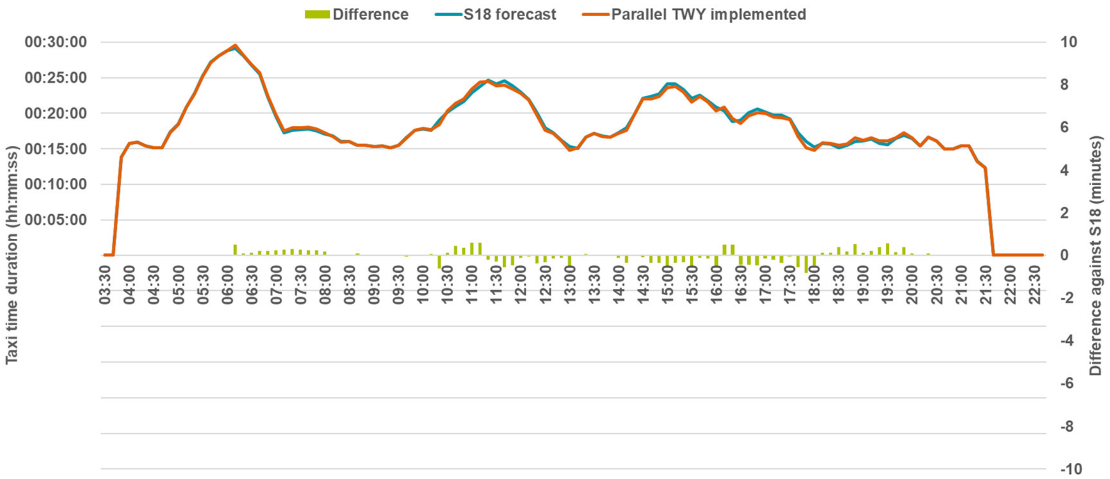

Figure 18: Impact of taxiway parallel to taxiway F on taxi-out times (R10)

4.4 Stand capacity

Aircraft at Dublin Airport can be parked on stands around four piers (Pier 1 to 4) or at one of the 5 aprons (North, South, West, Central and 5G). Whilst the West Apron is primarily used for long term parking, APC (aircraft park C) can be used for overnight parking or minor maintenance of aircraft up to code C. General aviation parks in one common area – light aircraft parking Bravo, while cargo aircraft and technical stopovers use the West Apron. Stands at West Apron and APC are not used for commercial passenger operations.

Assuming that one wide body aircraft can (e.g. at stands in Multi Aircraft Ramp System – MARS - configuration) effectively block two adjacent narrow body parking positions, it is possible to express the stand capacity in a narrow body equivalent number of parking positions. The maximum number of aircraft that can be simultaneously parked at these aprons (narrow body equivalents) as of Summer 2017 is provided in Table 10 below. As there are no new stands proposed for S18 period, figures presented in Table 10 are valid also for S18.

	GA	Non-turnaround			Turnaround stands								All
	LAB	APC	W.A.	Total	5G	P1	P2	P3	P4	S.A.	Central	Total	Total
Contact	-	-	-	**-**	-	21	10	11	19	-	-	**61**	**61**
Remote	12	13	23	**36**	14	2	-	-	1	9	5	**31**	**79**
All	12	13	23	**36**	14	23	10	11	20	9	5	**92**	**140**

Table 10: Available parking positions

Analysis of turnaround stands utilisation from the historic S17 busy day data[13] revealed that at any time, no more than 73 commercial aircraft sought to use a turnaround stand. During the peak turnaround stand demand period (around 0540 UTC) these 73 aircraft occupied 79 narrow-body equivalent turnaround parking positions, effectively using 86% of the total available turnaround stand capacity.

It should be noted that the total number of aircraft parked overnight at Dublin Airport is much higher than 73 and includes additional cargo, technical transit or general aviation aircraft. However, these aircraft can be parked also on non-turnaround stands and as such were not included into this analysis. There are also five additional stand-by aircraft operated by various carriers which contribute to the total number of aircraft parked overnight at Dublin Airport. After factoring in all of the above, the total number of overnight parked aircraft exceeds one hundred aircraft.

The remainder of this section deals with turnaround stands only.

It is common industry practice that a certain number of stands should be kept free at all times as a contingency for diverted flights, emergencies, or stands temporarily out of service (e.g. due to maintenance). This contingency should be in the order of at least 10% - 15% of the stand demand.

After factoring in the contingency requirement into stand capacity calculations it can be concluded that during the early morning peak period the airport is effectively operating at its stand capacity limits and further stand capacity may be required in order to facilitate continued traffic growth during the morning period. Daily stand occupancy profile (expressed in narrow-body equivalent parking positions demand) is provided in Figure 19 on page 40, while the same demand, broken down by individual airport area (e.g. Apron 5G, Central apron etc.) is provided in Annex D.

The daily stand occupation profile remains fairly constant from 0200 UTC, when all the late-night arrivals have already returned back to Dublin. Stand demand increases from around 0430 UTC to 0600 UTC when the first morning arrivals start to come in and when the departing aircraft which have been parked on non-turnaround stands and in hangars start being towed to turnaround stands. After the morning departures are gone, the stand demand drops to 25 narrow-body equivalent stands before starting to rise again as a wave of long haul aircraft start to arrive. The stand demand then gradually declines throughout the day until 2120 UTC, when the Dublin-based aircraft start to return to be parked overnight.

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[13] S18 historic data was not yet available at the time of writing this report.

The maximum number of narrow body aircraft on stand occurs overnight and consists primarily of base carriers' aircraft. The wide-bodied peak occurs between 0900 UTC and 1000 UTC when long-haul aircraft are typically on the ground. This peak occurs predominantly after the first wave of morning departures, however late departures of both short and long-haul aircraft coupled with early arrivals of additional long-haul aircraft can cause stand allocation challenges.

Usually, if an aircraft arrives before its scheduled arrival time and its allocated stand is still occupied, the arriving aircraft may be offered an alternative stand or requested to hold for their dedicated stand to become available. If the aircraft needs to wait for its stand on taxiway, the taxiway cannot be used by other traffic which needs to be re-routed. If the aircraft arrived late, and allocating it to its preferred stand bears a risk of consequential stand allocation problems, it is usually allocated to a different stand with less risk of causing alterations to the daily stand plan.

In order to accommodate other operations during the day, some aircraft arriving during the morning period are towed off from contact stands and later towed back for their scheduled departures. This is especially true for narrow body aircraft with a scheduled turnaround time greater than two hours, or wide body aircraft with a scheduled turnaround time greater than three hours. Wide bodies are usually towed off 60 minutes after arrival and towed back 90 minutes before departure, effectively freeing up their stand for another aircraft. Wide body aircraft are usually towed either to their hangar (Aer Lingus), or to wide body stands on apron 5G, or to the West Apron. Narrow body aircraft can be towed to remote stands or APC stands. The majority of towing operations occur overnight, however, any tows during the busy morning period cause departure taxi out delays and complicates the flow of traffic on the ground as the towed aircraft are moving in the opposite direction to aircraft taxiing for departure.

Overall stand capacity is at its limits during the morning peak period. Although additional flights could be accommodated in this period, it would result in either a reduced number of resilience stands, or increased towing.

The number of wide body contact stands is close to the capacity limits during the morning wide body peak period. Additional flights could be accommodated, but would result in increased towing. As these aircraft will have to be towed north, in a direction opposite to the direction of aircraft taxiing for departure, any extra towing operations between 0600 and 0800 UTC are likely to complicate ground movements and possibly add to the overall ground delays.

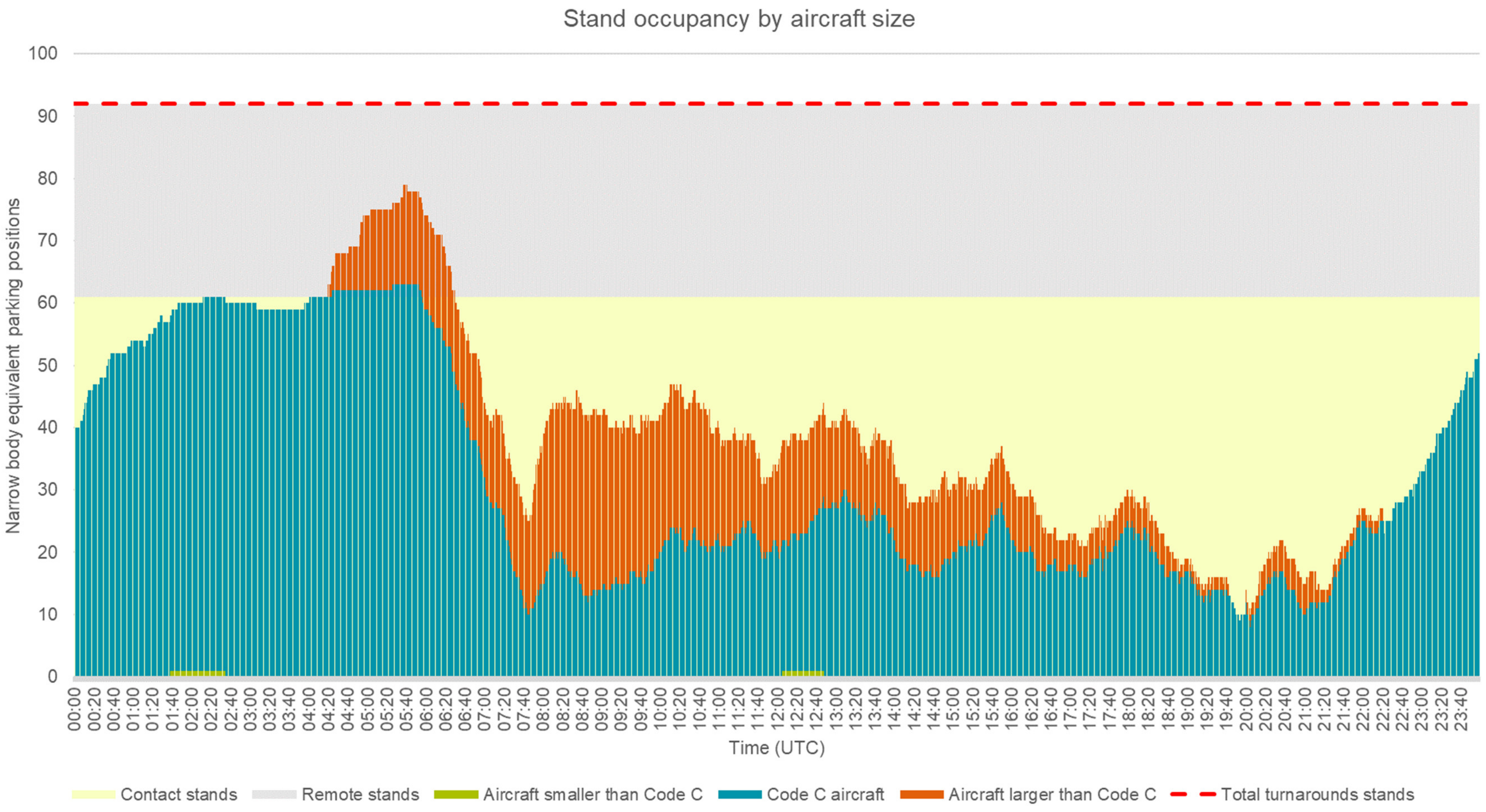

Figure 19: Stand occupancy by aircraft size (S17, turnaround stands only[14])

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[14] It should be noted that the total number of aircraft parked overnight at Dublin Airport is much higher than indicated in the graph and includes additional cargo, technical transit or general aviation aircraft. However, these aircraft can be parked also on non-turnaround stands and as such were not included into this graph. There are also five additional stand-by aircraft operated by various carriers which contribute to the total number of aircraft parked overnight at Dublin Airport. After factoring in all of the above, the total number of overnight parked aircraft exceeds one hundred aircraft.

5 Analysis of fire-breaks

5.1 General

The typical daily operating profile of any airport consists of several traffic peaks, usually early morning departures peak, evening arrivals peak and one or more peaks in between depending on the operating models of the airlines serving the airport. An increased number of flights during these peak periods leads to higher system utilisation, be it runway, taxiway or airspace. If the periods with high utilisation are long, or if any unforeseen circumstance causes additional delays, recovery from such situation is usually only possible when utilisation drops low enough to allow delays to be absorbed. Such periods are called fire-breaks.

There are no formally defined fire-breaks in the Capacity Declaration of Dublin Airport. As such, nothing in the runway parameters prevent operators filling all hours in the declaration to the maximum applicable limits. However, closer analysis of the number of flights per hour operated against the maximum number of flights potentially scheduled indicates that the 0700 UTC hour and 1300 UTC hour could be considered as fire-breaks. The hourly runway utilisation is depicted in Figure 20 below.

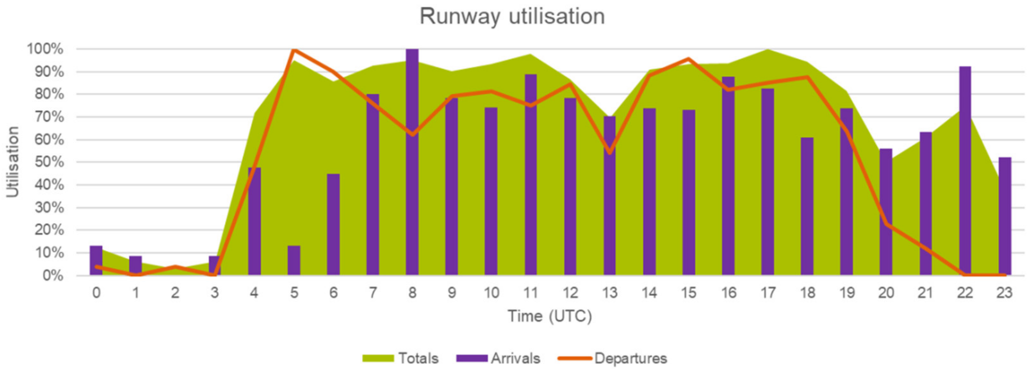

Figure 20: Runway utilisation

The 0700 UTC hour features a significant drop in the scheduled number of departing aircraft (19 departures in 0700 UTC compared to 35 and 27 departures in the 0500 UTC and 0600 UTC respectively). Moreover, the 0700 UTC hour features a fairly balanced fleet mix – 19 departures and 20 arrivals – which allows a more balanced A-D-A sequencing. All previous simulations indicated that delays accumulated during the first morning wave start to dissipate or disappear completely around 0730-0800 UTC.

The 1300 UTC hour could be considered the second fire break, helping to mitigate any delays experienced during the first half of the day. Compared to 1200 UTC and 1400 UTC, this hour has significantly fewer movements scheduled inside the 1300-1359 period.

5.2 Modelling of fire-break performance

As there are two fire-breaks identified during the day, we set-up and ran two distinct series of simulations to assess the capability of both to handle additional delay. The S18 forecast flight schedule was used in the simulation to account for increased number of flights. Only runway 28 operations were modelled.

The first case focussed on delays incurred during the first morning wave (e.g. operational constraints, emergency etc.) and the ability of the 0700 UTC firebreak to absorb these. All flights scheduled between 0400 UTC and 0559 UTC were delayed by a random value from a pre-set range. We simulated the impact of random delays of up to 10, 20, 30, 40, 50 and 60 minutes. Figure 21 below shows daily profile of randomised departure ground delay. Simulations confirmed that the first fire-break is able to reasonably absorb all of the simulated delays before the second peak (noon) starts.

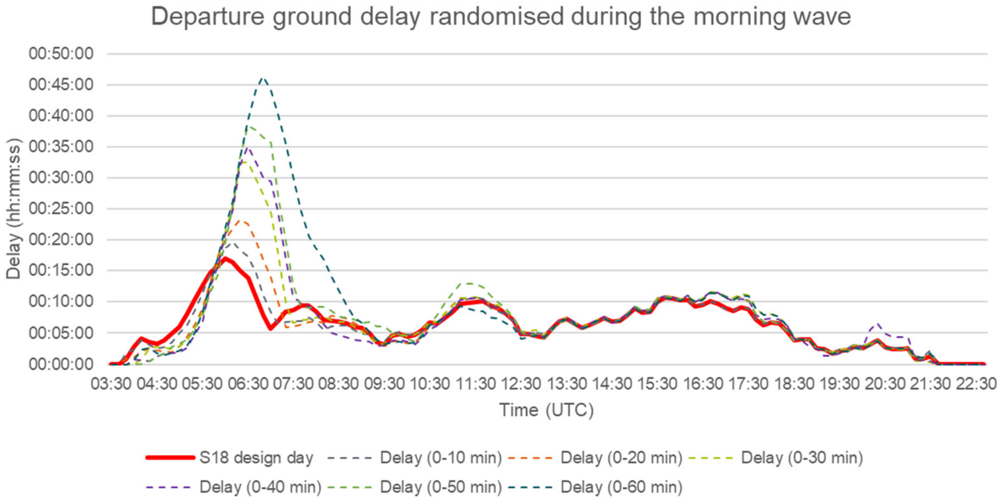

Figure 21: Departure ground delay randomised during the morning wave

The second case modelled focussed on delays lasting longer than a few hours, such as an increased number of outbound flow restrictions (Controlled Time of Take-off, CTOT), airspace closures, ATC strikes etc. To mirror this situation, all flights scheduled between 0400 UTC and 1159 UTC were delayed by a random value from a pre-set range. Similar to the previous scenario, we simulated the impact of random delays of up to 10, 20, 30, 40, 50 and 60 minutes.

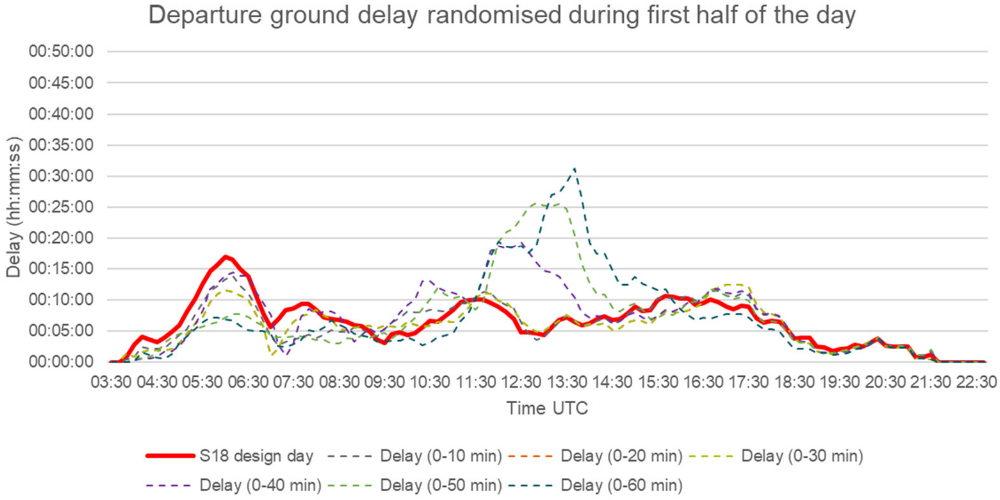

Figure 22: Departure ground delay randomised during the first half of the day

With delays being assigned to flights over a longer period it is likely that many flights scheduled to operate in the first morning wave ended up operating outside of this wave, i.e. they were delayed into the post-morning-peak period. This explains why the departure ground delay in Figure 22 is below the S18 design day delay. Part of the delay accumulated during the morning wave gets absorbed during the first firebreak, but as more flights continue to be delayed after the first fire-break, some of them end up operating at or close to the second peak period (noon). The simulation indicates that the second fire-break is able to handle delays of up to 30 minutes, but as the delay increases, the time required for the airport to recover from such situations increases too. In the worst-case scenario, where we simulated up to 60 minutes delay, the departure ground delays returned back to S18 baseline levels only after 16:00, four hours after the last flight was delayed (delays applied to flights scheduled between 0400 and 1159).

5.3 Summary

Additional delay analysis would be required, ideally using a full season of data, in order to identify in full the frequency, duration and daily profile of typical delays at Dublin Airport. Such information could then inform the decision on the need for additional fire-breaks during the afternoon hours, as well as their duration and magnitude. Currently, all hours between 1400 UTC and 1859 UTC are scheduled very close to the maximum limits, with spare capacity never more than 2 flights per hour. In case of unforeseen circumstances during the afternoon period, the airport is likely to struggle to recover before 19:00 UTC.

It should be noted that this analysis is a theoretical exercise aimed to evaluate the sensitivity of fire-breaks to changes in delays. It is not a simulation of actual performance during a “bad day”.

Both existing firebreaks should be protected to ensure operational resilience. However, there is no firebreak in the afternoon period. Creation of a short fire-break during a particular afternoon hour between 1400 and 1900 may help to reduce any delays incurred during this period.

6 Analysis of 5-minute schedule coordination periods

6.1 General

In accordance with the S17 capacity declaration, all flights at Dublin Airport need to adhere to 10-minute scheduling limits which limit the total number of scheduled movements per 10-minute period to 9 movements. At the same time, there are limits imposed on the maximum number of arrivals (6 arrivals) and departures (6 departures[15]) in the same 10-minute period.

Maximum number of movements per 10-minute period (S17)	
Maximum Total	9
Maximum Arrivals	6
Maximum Departures	6*
*Exception: Maximum departure limit is 7 movements at 0500, 0510, 0520, 0530, 0540 and 0550 UTC.	

Table 11: 10-minute scheduling limits (S17)

6.2 Modelling of 5-minute schedule coordination

There is interest in considering the benefits of shorter coordination periods, e.g. 5 minutes. The hypothesis is that a smoother hourly distribution of flights should decrease bunching at the runway entry, which in turn leads to shorter runway delays (and thus overall departure ground delays). In theory, the coordination periods could be as short as one minute. However, due to practical reasons related to the maintenance of such system (and delays), there are no airports that currently impose limits on number of movements per minute.

Whilst limits on the number of movements per 10-minute period are not unusual at Level 3 coordinated airports, few airports have defined these limits for 5-minute intervals. The key aim of the assessment carried out in this section is to identify the impact on airport performance if all flights were scheduled according to 5-minute coordination limits.

In order to assess the impact of 5-minute coordination windows at Dublin Airport it was necessary to impose new limits on the number of movements. These were derived from the original 10-minute limits and rounded up to:

Maximum number of movements	10-minute limits	5-minute limits
Maximum Total	9	5
Maximum Arrivals	6	3
Maximum Departures (0500-0559)	7	4
Maximum Departures (rest of the day)	6	3

Table 12: 5-minute coordination limits

The S18 flight schedule was then compared against these 5-minute limits and flights in periods which exceeded these limits were re-scheduled to the closest available 5-minute period. Where possible, every attempt was made to keep the same number of flights within the hour. Re-scheduling affected 6% of arrivals and 13% of departures, resulting in

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[15] Maximum departure limit for flights scheduled between 0500-0600 UTC is 7 departures in any 10-minute window.

almost one out of every ten flights (9.5%) having to be re-scheduled. It should be noted that the vast majority (80%) of these changes could be accommodated in the prior or subsequent 5-minute window. Only 16% of re-scheduled flights had to be moved by ten minutes and only three flights (4%) had to be moved by fifteen minutes.


Arrivals re-scheduled for 5-minute coordination periods

Departures re-scheduled for 5-minute coordination periods

Figure 23: Flights moved due to 5-minute coordination

Changes in scheduled time (minutes)	-15	-10	-5	0	5	10	15
Arrival (flights)	0	2	3	345	13	3	1
Departure (flights)	1	4	11	316	28	2	1
Total	**1**	**6**	**14**	**661**	**41**	**5**	**2**
Arrival (%)	0.0	0.3	0.4	47.3	1.8	0.4	0.1
Departure (%)	0.1	0.6	1.5	43.3	3.8	0.3	0.1

Table 13: Flights moved due to 5-minute coordination

6.3 Results

With the S18 schedule re-planned to 5-minute limits, it was possible to compare the original schedule against the re-planned in terms of number of arrivals, departures and total movements within every period of the day. As the theory behind the transition to 5-minute limits is that there should be less bunching compared to 10-minute limits, it was necessary to assess overall smoothness of both daily profiles. This was achieved through calculation of differences between every pair of successive points and subsequent calculation of the standard deviation (SD) from these series. Results of this statistical examination are provided in the Table 14 below.

S18 daily profile (standard deviation of differences in subsequent coordination periods)	Arrivals	Departures	Totals
10-minute coordination periods	1.65	1.68	2.14
5-minute coordination periods	1.21	1.08	1.44

Table 14: S18 - daily profile smoothness

As smoothness of a series increases with decreasing standard deviation, it is obvious that a transition towards 5-minute coordination periods has the potential to smoothen daily runway demand, which should result in decreased delays during the peak periods. To verify this idea, we ran the S18 schedule, coordinated to 5-minute limits, through our airside model. We then compared results in three key metrics (departure taxi out time, ground delay and runway delay) against the same metrics calculated from S18 flight schedule coordinated to 10-minute limits. The results of this comparison are provided in Figure 24 below.

Figure 24: Comparison of airfield performance under 5- and 10-minute coordination periods

6.4 Summary

The key findings visible in these graphs are:

- Transition to 5-minute scheduling limits has a potential to streamline the flow of aircraft, especially during peak periods. This is likely to lead to decreased ground and runway delays.
- Decrease in delays is likely to improve OTP performance
- The maximum decrease in runway delay observed during the morning peak was 00:05:20 at 0720 UTC.
- The maximum decrease in runway delay observed during the afternoon peak was 00:03:50 at 1720 UTC.

It should be noted that this assessment was carried out as a high-level informative exercise only. As such, it assumes that all airlines will be willing to change their flight schedules as required. It also assumes that all aircraft operate on time – in other words, random variations of block times from the schedule could impact these benefits if bunching re-occurs.

The benefits listed above should be treated as indicative only and before a transition to 5-minute coordination period can be recommended more detailed analysis is required.

Transition to 5-minute scheduling limits has the potential to streamline the flow of aircraft, especially during peak periods. This is likely to lead to decreased ground and runway delays.

7 Analysis of passenger terminal capacity

7.1 General

7.1.1 Passenger throughput

For the purposes of passenger terminal capacity assessment, it is typical to define capacity as a throughput rate, expressed in terms of passengers per hour (pax/hr). The smooth flow of passengers from the kerbside to the aircraft (and vice versa) is interrupted by a series of essential processes as illustrated below.

Terminal capacity is therefore defined by the operational effectiveness of the most constraining process. For the purposes of this capacity assessment, only the processing ability of the infrastructure is considered, and subsequent references relate only to the maximum waiting times.

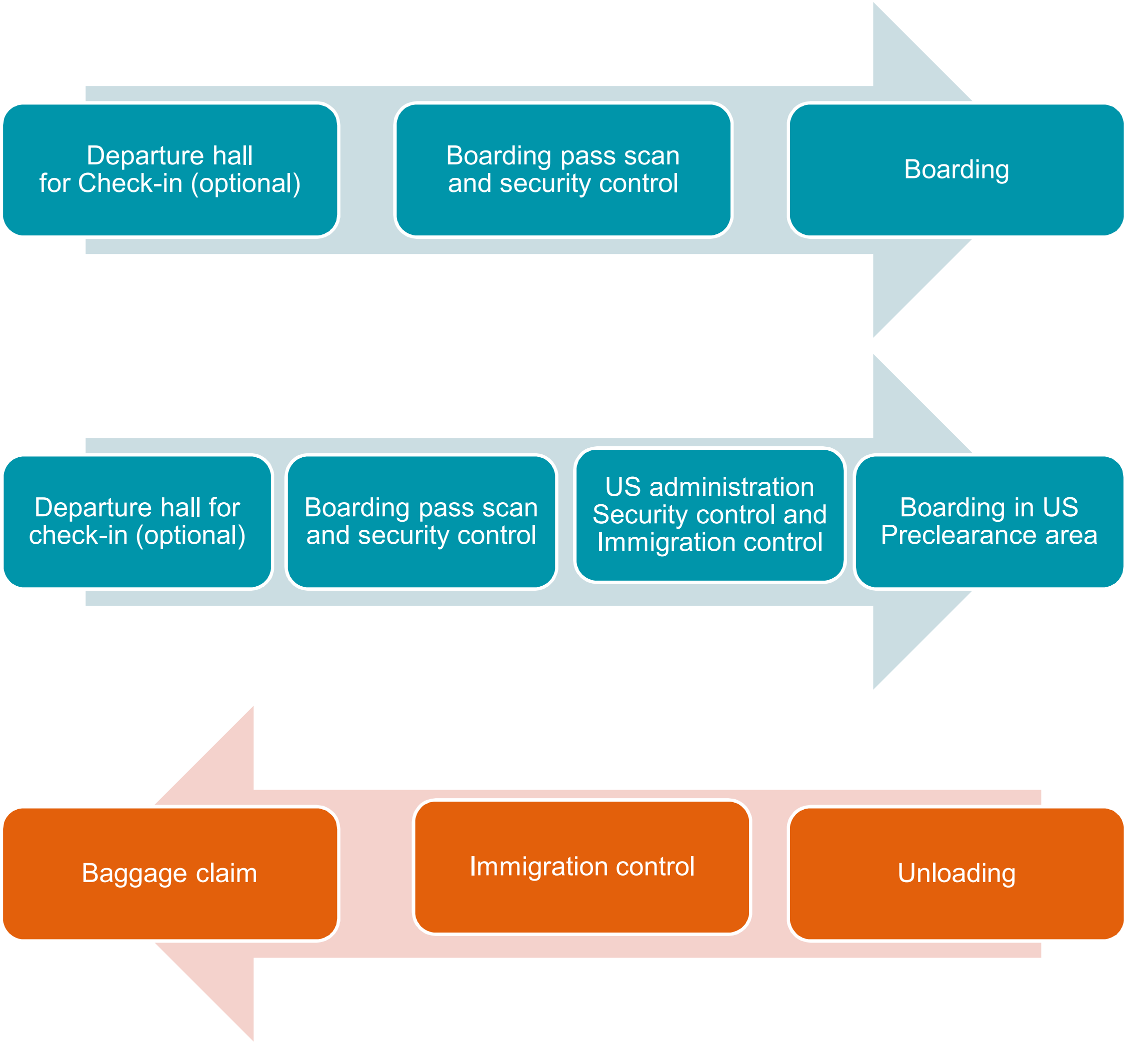

Figure 25: Flow diagrams: Departures, Departures on US CBP flights, Arrivals

The degree to which the effectiveness of each process can be enhanced is dependent upon the ability of the airport to improve its infrastructure provision, staffing levels, optimisation of the process steps or all three. Whilst there are no near-term plans to make enhancements to the provision of infrastructure within the terminal building, it is reasonable to consider that optimisations could be made to the staffing levels or to the efficiency of the process. It is acknowledged that the airport only has the control of the staffing levels at security.

Although there is limited interaction between T1 & T2, it was determined that for ease of reporting the two terminals would be considered separately. A calibration exercise was carried out using actual data and was reviewed prior to the analysis of the Summer 2017 and 2018 peak day schedules to assess the performance of both terminals.

7.1.2 Capacity vs Level of Service

The Level of Service (LoS) concept was introduced into passenger terminal capacity guidelines by the International Air Transport Association (IATA). IATA originally retained the Level of Service A to F notation and the guidelines focused almost exclusively on the density of passengers within a certain defined area, for example at a queue area in front of check-in desks.

More recently, as published in the 2014 Airport Development Reference Manual (ADRM) 10th edition, IATA introduced three more generic classifications, superseding the notation of the 9th edition, namely:

- Over Design
- Optimum
- Sub Optimum

thereby proposing clear recommendations.

Of perhaps greater significance is the introduction of maximum queue times, which had previously been guidelines and not specifically tied to LoS. For the first time, queue (waiting) time is specifically referenced to the LoS concept and the upper and lower limits of "optimum" are interpreted as the recommended standard.

IATA states in ADRM 10 that level of service may be expressed in terms of:

- Waiting time per passenger for processing facilities, either as a maximum waiting time during the planning busy hour or as a percentage (i.e. 90 percent of the design Peak Hour Passenger queue for less than 7 minutes);
- Unit area per occupant for holding facilities; and
- Available cross-sectional area and availability of movement-assisted devices (i.e.: moving walkways, automated people movers, etc.) for circulation facilities.

7.1.3 Minimum / Maximum waiting times

A summary of the relevant minimum and maximum waiting times is set out below.

These guidelines are applied to a design Peak Hour Passenger (PHP) demand, which IATA recommends be defined as the peak hourly profile of the 2nd busiest day of the average week of the peak month.

The purpose of selecting a design peak hour that is not the absolute peak hour is to avoid the over provisioning of facilities. The derivation of a design hour that may be for example the 95th percentile of the absolute peak hour implies that a lower level of service on peak days and peak hours is considered tolerable.

Although airports may in conjunction with their respective regulator choose to adopt their own methods of assessment, (eg 95th percentile), the key point is that it is universally acknowledged that in all cases it is tolerable to accept levels of delay and crowding that would accompany the absolute peak days of every design year.

		Minimum Wait Time (mins)	Maximum Wait Time (mins)	Minimum Wait Time (mins)	Maximum Wait Time (mins)
		Economy Class		Business / First Class	
Check In	Self Service Boarding Pass / Tagging	1	2	1	2
	Bag Drop Desk	1	5	1	3
	Check-in Desk	10	20	3	5
Security	Checkpoint	5	10	1	3
Emigration	Passport Control	5	10	1	3
Immigration	Passport Control	5	10	1	5
Baggage Claim Area	Narrow Body	1	15	1	5
	Wide Body	1	25	1	15

Table 15: IATA 'Optimum' Level of Service Guidelines for Processing Facilities (ADRM 10)

7.1.4 Processing time

Check-in to departure gate process time

Each airline has indicated to daa its preferred check-in desk opening and closing time relative to the Scheduled Time of Departure (STD). Opening times range from STD-240 minutes to STD-120 minutes, whilst closing times can vary from STD-75 minutes to STD-30 minutes.

It is ultimately the passenger's responsibility to ensure that they get to the departure gate on time, however by virtue of the fact that a check-in desk for a dedicated flight can remain open up to 30 minutes prior to the STD suggests that it must be physically possible for the passenger to get to the gate within the allotted time and prior to the closure of the boarding gate.

Typically, it can be assumed that for a passenger checking in at STD-35 minutes, and with a 10-minute walk to their boarding gate, 25 minutes should be considered the maximum permissible waiting and processing time at the security facilities.

It is also noted that all flights to the USA require additional processes in connection with US Preclearance prior to departure from Dublin. In a similar fashion, additional time is required and this is reflected in the earlier closure of the check-in desks (e.g. STD-75 mins or STD-60 mins). The combined processing capacity of security screening and US preclearance must be such that all processes are completed within a maximum of 55 minutes (check-in closure = STD-65mins, less 10 minutes walking time).

Arrival process time

Whilst a delay in the arrivals process (excluding transfer) will inconvenience the passenger, it will not directly inconvenience the airline. The principal determinant of arrival capacity at the terminal is based upon both the maximum waiting time and the number of desks in operation at immigration. The relationship between immigration and the capacity of the baggage reclaim hall is worthy of note. An increased capacity the immigration process will result in greater numbers of passengers waiting for their bags in the arrival hall. Conversely, reduced immigration capacity will result in increased queuing at immigration and less of a build-up of passengers in the reclaim hall.

Transfer process time

Nearly all transfer movements take place in T2 and the vast majority of these are with Aer Lingus. T2 has its own dedicated facilities and there is a minimum connection time of 45 minutes to permit the movement of passengers and the baggage to the departing aircraft. Additional time is allowed for transatlantic flights, 60 minutes to connect a short-haul flight with a transatlantic and 75 minutes to connect a transatlantic flight with a short-haul flight.

7.2 Check in process

The capacity of the check-in process cannot be used directly to set the declared departure capacity of the terminals, because the share of originating passengers using the airport check-in resources (traditional check-in desk, self-service kiosks and drop-off desks) varies by type of flight, time of day, day of week and time of year.

Two approaches are considered:

1) The maximum capacity of the check-in resources. This is derived by multiplying the number of resources by their hourly throughput. This leads to a maximum potential throughput which does not take into account any of the allocation preferences that are generated by airlines wanting a number of desks in the same location or their preference for dedicated flight check-in or common check-in.
2) The availability of the resources during a busy day can be assessed to evaluate the throughput potential with similar allocation preferences.

Terminal 1

The first approach is not presented hereafter for Terminal 1. With as many as 119 desks in T1 Hall and 24 desks in the reserved Area 14, the absolute maximum throughput of T1 check-in resources exceeds demand. More important is the occupancy of the check-in desks during the busy days, and the possibility of accommodating additional departures movements during peak times. The second approach was used to determine the saturation level of the T1 check-in resources.

In Terminal 1, there are only a limited number of wide-body long-haul flights, and most narrow-body flights are operated by low-cost airlines, mainly Ryanair. So, the number of hold bags per passenger is low.

The distribution of airlines from check-in islands 3 to 13 groups airlines from the same airline alliance (Skyteam, Oneworld, Star Alliance) and allocates different islands to different airline groups. Ryanair, for example, with a continuous offering of flights in a day, is served at check-in islands 12 and 13, combining both common and dedicated facilities. In addition, around 30 self-bag-tag kiosks have been installed in the same area to optimise the usage of the collecting belt (when passengers drop their hold bags).

The throughput of these 29 desks in Areas 12 and 13 associated with the kiosks is presently sufficient to accommodate the departure peaks. A change in the operator's policy to rebalance between hold bag and cabin bag (a reduction of hold bag fee for instance) could quickly increase the saturation of check-in resources. There is a concern that the capacity of the collector belt 13, and the capacity of the downstream hold baggage screening machines, may not be sufficient if the number of hold bags increases.

A change in the check-in desk allocation, for example to extend Ryanair's allocation to include Area 11, could potentially solve this issue.

All other T1 airlines operate a smaller number of flights per day. Some airlines open the same desks for the whole day (Air France area 9, Lufthansa area 5), while charter airlines and other regular operators tend to be allocated desks according to their needs and the availability of desks.

The detailed check-in desk allocation for the Summer S16 Design Day was used to produce the following graph. Over the day, the number of check-in desks in use peaks at 60, just before 10am.

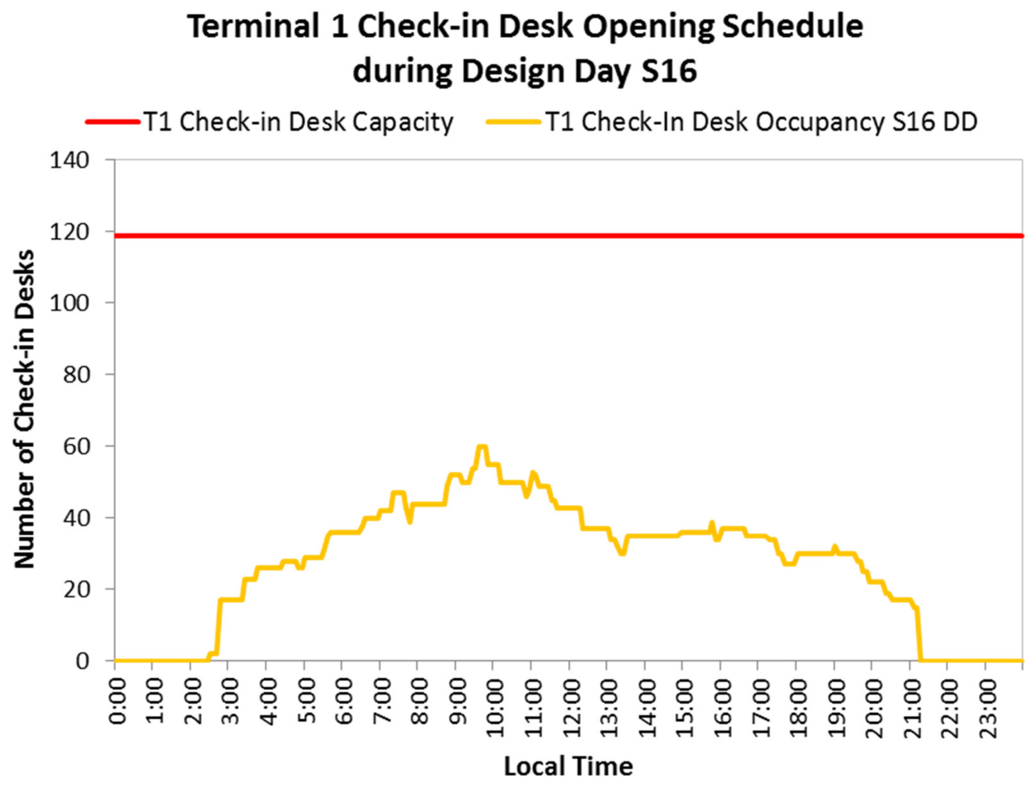

Figure 26: T1 Check-in desk occupancy during S16 Design Day

A 100% occupancy is not desirable as typically:

- some desks are unavailable due to maintenance,
- spare desks are scattered across the various check-in islands and are not in one usable block,
- some desks are reserved for later flights that need to open before an earlier flight would be ready to close.

For flexibility, a reserve of 15% would be preferable so a maximum of 100 check-in desks should be considered as the operational capacity in the T1 main check-in hall. Area 14 provides additional capacity of 24 check-in desks.

It can be concluded that the T1 check-in capacity is in excess of the current peak hour demand and could accept a significant increase of peak hour traffic assuming a similar passenger mix.

The capacity of the downstream bag screening and sorting areas is assessed separately later in the report.

Terminal 2

Terminal 2 has 56 check-in desks and a number of additional self-service check-in kiosks (dedicated to American Airlines, United Airlines and Aer Lingus passengers only).

With the exception of the Ethiopian Airlines flight to Los Angeles, all US destinations are serviced from Terminal 2 as it provides the facility for passengers to clear US immigrations prior to departure, and the growth of the US market is therefore increasing pressure on T2 check-in facilities.

The analysis of the Summer 16 Design Day desk allocation schedule reveals that all desks are allocated during the morning peak:

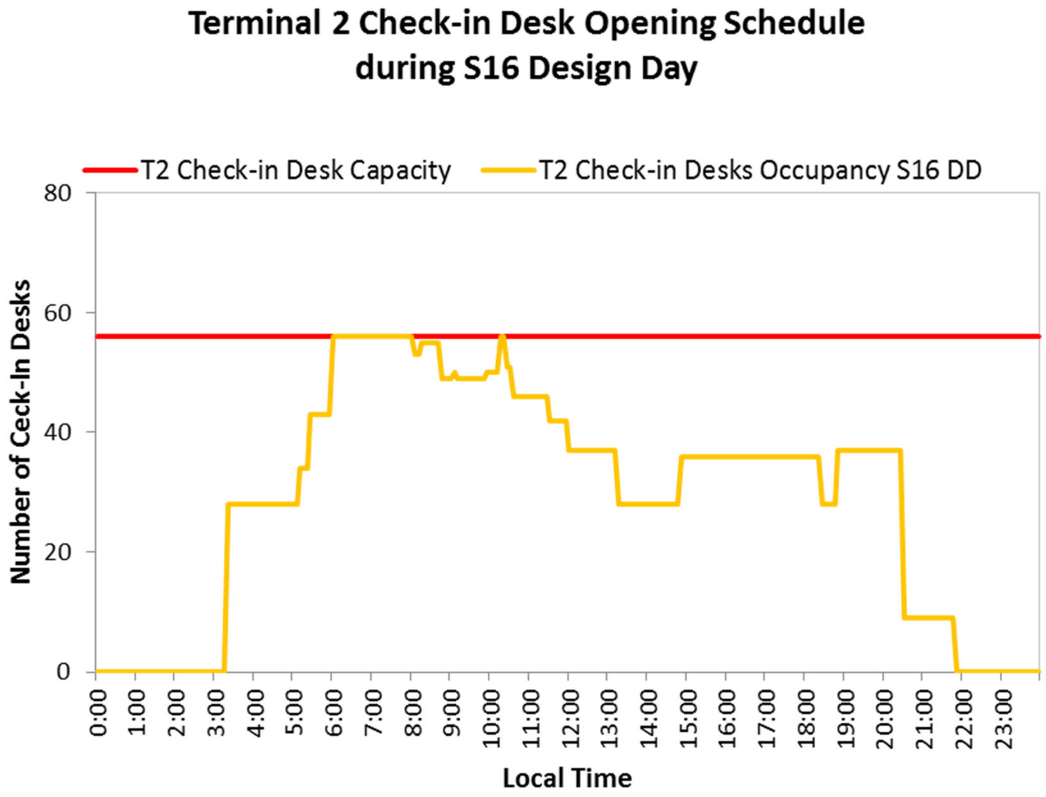

Figure 27: T2 Check-in desk occupancy during S16 Design Day

The T2 check-in hall is divided into two zones, East and West. The western zone of the check-in hall offers 28 desks and one out-of-gauge (OOG) facility and is occupied in the west by Aer Lingus (and its franchise partner Stobart Air). With the installation of around 30 self-service kiosks (64 seconds per passenger) and the opening of 12 automated bag drop desks (10 seconds per passenger), in addition to 16 traditional check-in desks to serve the remaining passengers, the throughput can be estimated to:

- Around 1700 passengers at kiosks with immediate access to one of the 12 drop off desks. The passengers are mainly directed to the kiosks, especially if they have no hold bag.

- Around 800 passengers at check-in desks during short-haul peaks. Check-in process is longer for passenger on transatlantic flights (130 sec/pax) and the maximum throughput decreases to 450 pax/h during the morning peak.

During the Aer Lingus operating peaks, allowing for both passengers without a hold bag(s) and transfer passengers, the simulation shows there is sufficient capacity to handle the current traffic levels. Outside of the peak periods there is considerable spare capacity in the western zone of the check-in hall.

The eastern check-in islands (28 desks and 1 OOG desk) are shared between other carriers operating to the US and Emirates. The number of occupied belts during the morning transatlantic peak reaches the maximum available, 28. Assuming 120 seconds per passenger, with no 'dead-time' between passengers being served, the throughput of this section of the hall is estimated as 840 passengers/hour.

daa has confirmed that these airlines had to accept a smaller number of check-in desks than they originally requested: some traditional airlines are willing to open a larger number of desks (generally 5 to 10 for a long-haul flight) in order to differentiate the service quality between their first, business and economy passengers. Airlines recommend to their passengers flying to the US, to arrive at check-in 3 hours before their flight. daa manages the excess demand for and allocation of these 28 desks, which justifies the advisory flag for T2 morning departure flights.

The growth potential of the US market is constrained by the unavailability of desks. Other high service international airlines (such as Emirates) also have a demand for desks in the modern T2 halls.

The number of T2 check-in desks does not match the current demand and justifies the need for the Advisory Flag. Our estimate of the global throughput from the 56 check-in and drop-off desks is around 3,000 passengers/hour, which is more than the rolling 60-min peaks. Waiting times could however be higher than acceptable during morning peaks due to the lack of supplementary counters for certain busy flights. With the share of passengers that are going directly to the security process and the dilution effect coming from the passengers arriving early at check-in before the departure, the theoretical throughput is not the subject of concern but the insufficient number of check-in desks will penalise the level of service and will constrain the growth of transatlantic routes.

7.3 Boarding pass presentation

All T1 originating passengers (starting their journey in Dublin) have to present their boarding pass at automated scanning gates. There is flexibility in which boarding pass presentation gates a passenger uses as some T2 passengers (mainly Aer Lingus passengers) can choose to use T1 boarding pass presentation gates, and likewise, some T1 passenger can access their boarding gates via the T2 boarding card presentation facility.

The boarding pass presentation process is automated and is assisted by daa staff when necessary, on average it takes 6 seconds per passenger.

The objective is to act as a security control and ensure that only passengers with a valid boarding pass enter into the security restricted area. The scan is the first contact point between the passenger and the daa, as check-in is operated by handling agents on behalf of the airlines. The data gathered by the daa at boarding pass presentation allows the daa to define different passenger reporting profiles, and therefore to more accurately forecast the security manning levels.

There are currently 10 boarding pass presentation gates in T1 with space available to increase the number of gates; there are also 2 manual positions available. The maximum theoretically throughput of the T1 board pass presentation gates is 6,000 passengers per hour.

To regulate the flow of passengers into the security control area, at peak times, the daa open and close some of the board pass presentation gates. In T1 the space between the boarding pass presentation gates and the security processing area is limited (850m²) and does not offer an acceptable level of comfort to more than 850 passengers at any one time. For that reason, the maximum capacity of the security control area is more important than that of the boarding pass presentation.

The T1 boarding pass scan process has a very large capacity (6,000 passengers per hour).

In T2 boarding pass presentation is a manual process with up to 12 positions spread across 6 doors, providing a theoretically capacity of 7,200 passengers per hour. In practice, daa usually operates 3 to 4 positions, including one reserved for fast-track passengers.

During peak periods, flow management at the boarding pass presentation positions limits the number of queuing passengers in the security control area. In T2, the space between both processes is limited (circa 500m²) and would not offer an acceptable comfort to more than 500 passengers. The large public area prior to boarding pass presentation is over 1,000m^2 and is therefore used as a holding area prior to security. As with T1, the maximum capacity of the security control area is more important than that of boarding pass presentation.

The T2 boarding pass scan process has a very large capacity (7,200 passengers per hour).

7.4 Security process

While there is the possibility for T2 passengers to go through T1 security area, and vice versa, the cross-over between terminals is minor. Connecting passengers arriving in T1 Piers 1, 2, or 3 join the T1 originating passengers prior to security.

The security process is subject to the changing national and international security regulations and is largely supported by high-tech devices (screening machines, walk-through metal detector, special detectors, conveyors, IT solutions…). Operational practices are regularly evolving to increase or maintain the passenger throughput. In T1 daa has installed an automated tray-return system (ATRS) and has extended the preparation stage area and the collecting area. In T2, the lanes are shorter delivering a less efficient process.

7.4.1 Terminal 1

In T1, daa assumes a processing rate of 240 passengers per hour per lane or 15 seconds per passenger. This is consistent with industry figures for equivalent optimised security layouts. From experience, it would not be reasonable to assume a greater throughput. 15

ATRS lanes are installed, excluding the lane reserved for staff screening. The throughput of the T1 security area is therefore 3,600 passengers per hour (15 lanes at 240 passengers per lane per hour).

The T1 security control, performed with the 15 modern ATRS lanes, could theoretically process up to 3,600 passengers per hour and constitutes the limiting departure process in the terminal.

It has been noted by the daa that potential regulation changes relating to more stringent cabin bag and passenger searches (e.g. liquids and gels) could decrease the observed throughput. Whilst this consideration may be valid it could potentially be countered with the development of new technologies through the next generation machines, which would be able to match the existing throughput, although daa have no plans to replace the machines in the near future. However, without a more detailed view on these future developments, we have proposed to retain the 3,600 passengers per hour rate as the maximum hourly throughput.

7.4.2 Terminal 2

daa assumes a throughput rate of 150 passengers per hour per lane in T2, which is equivalent to 24 seconds per passenger. The layout and the level of equipment enable this with reasonable efficiency, in line with our experience and benchmarking.

With 18 passenger lanes the calculated throughput is 2,700 passengers per hour (18 lanes at 150 passengers per hour).

With all the security lanes in operation, to preserve a maximum waiting time lower than 10 minutes during the peaks, the queue should not be longer than 450 passengers in the available queuing area of around 500m^2.

The T2 security control, performed with 18 classical lanes, could theoretically process 2,700 passengers per hour and constitutes the limiting departure process for the terminal.

7.4.3 Link between Security Throughput and Declared Departure Capacity

To understand how the theoretical throughput at T1 or T2 Security impacts the current coordination parameters, it is necessary to consider the passenger show-up profiles. The simulations carried out used 24 of the 600 available show-up profiles, which were provided by the daa, to reflect the distribution of departing passengers within the PTB model. These show-up profiles were useful to the calibration of the baseline model and the model was successful in closely replicating the actual arrival of originating passengers at the boarding pass scan and at security. Departing passengers can show up at the boarding pass scan and security processes up to 4 hours before their scheduled time of departure (STD) and at the latest around 30 minutes before. This distribution will reduce the impact of a strong departure peak on the relevant processes (check-in, boarding pass scan and security).

From the calculations undertaken and the typical S17 and S18 flight schedules, the rolling 60-min peak at T1 security constitutes around 78% of the rolling 60-min departure peak, or (for example) when 100 passengers are boarding in a peak 60 minutes period, a concentration of no more than 78 will show up at Security in any preceding 60-min window. That calculation is valid when the preceding and the subsequent hours are not as busy as the peak hour, which is the case at Dublin Airport. 71% was derived at T2, in the same fashion.

The 78% assumption for T1 (71% for T2) also means that the declared departure capacity (sum of departing passengers, in 60 minutes) could theoretically be increased by up to 128% (respectively 137%) from the theoretical throughput of the most constraining process, which is at security.

A more conservative uplift could be more appropriate. That reduced uplift would take into account the possible unfavourable regulation changes, the cumulative effect during long peaks and the system inefficiency to provide the theoretical throughput during the peaks. 50% of the relative increase to obtain the recommended enplanement throughput was considered appropriate.

With the assumption of all security lanes in operation and a maximum waiting time of 10 minutes, the system could accept more passengers in one hour. 4,200 passengers could be processed in 70 minutes at T1 for instance, and we could accept that up to 5% of passengers wait more than 10 minutes to increase further the acceptable volume. However, the cumulative effect of a large peak period (over 60 minutes) could generate a situation where the queuing area is saturated during short periods. Therefore, we have proposed to select 4,200 as the maximum acceptable volume of passengers per rolling hour. Using the approach outlined we recommend the increase of this security throughput by 14% to obtain our estimated departure capacity parameter. From 4,200 passengers per rolling hour at security we obtain around 4,800 enplanements in one hour. Such an increase may need to be phased in to allow recruitment of staff, etc.

At T2, with the assumption of all security lanes in operation and a maximum waiting time of 10 minutes, the system could process 3,150 passengers in 70 minutes for instance. As for T1, it is proposed to select that value (3,150) as the maximum acceptable volume of passengers per rolling hour. With the same approach to derive departure capacity from the acceptable volume at T2 security, the recommended enplanement limit at T2 is 3,150*1.18 = 3,717, rounded to 3,700 passengers per hour.

7.5 Boarding process

After security, all T1 or T2 departing passengers can proceed directly to their boarding gates or spend their available dwell time, prior to boarding, making use of the commercial area and amenities.

The capacity of the boarding gates to process departing flights and the boarding of passengers has used the gate allocation plan for the design days. The capacity to accommodate flights at contact stands with passenger boarding bridges or walk-in walk-out (WIWO) procedures is important to a number of the airlines. Pier 1 and Pier 2 are well adapted to WIWO operations for aircraft types such as the B737 or A320, whilst Pier 3 and Pier 4 provide many passenger boarding bridges to serve wide-body and narrow-body aircraft types.

The use of coaching gates and remote stands is necessary because there are insufficient contact stands. Preferred coaching gates are in T2 and in the former terminal building (OCTB gates 217-220). These gates are typically used for the boarding of flights with lower passenger numbers (short-haul flights to secondary UK and Irish airports for instance) and to serve aircraft with long turn-around times, which are usually parked on remote stands. Coaching operations can be serviced from other locations if necessary. In recent years the number of coaching operations has increased due to the frequent saturation of contact stands.

- T1 Pier 1 has 19 WIWO gates, including the 6 new gates provided by the Pier 1 Extension works carried out in early 2017
- T1 Pier 2 has 10 gates and serves stands 200-207. 4 gates are within the OCTB Building and are used to as coaching gates to serve remote stands
- T1 Pier 3 has 8 gates and serves the stands 311-318
- 6 bus boarding gates are located in the ground floor area between Pier 3 and Pier 4 (gates 332-337). From this area a shuttle service will depart to the future Pre-Boarding Zone located near the former cargo apron.
- Pier 4 has 6 gates on the ground floor (401-406) that are reserved for US CBP departures. On the first floor gates 423-426 at the end of the concourse are sometimes allocated to US CBP flights, but once the transatlantic peak is over, all 407-426 gates can be allocated to the non-CBP flights.
- Finally, in the Pre-Boarding Zone which is currently under construction, a total of 5 boarding gates will serve 9 WIWO stands.

To initiate the calculation, it was assumed that each gate on Pier 1, 2, and 3 can service one code C aircraft, and 150 passengers, in one hour. This assumption is simplistic and does not take into account the space provision in airside commercial areas, boarding halls and concourses.

- Pier 1 with 19 gates would enable the boarding of 2,850 passengers per hour
- Pier 2 and OCTB: 2,100 passengers per hour
- Pier 3: 1,200 passengers per hour
- Gates 332-337: 900 passengers per hour
- The same assumption is made for the 5 Pre-Boarding Zone gates: 750 passengers/hour.
- In a narrow-body configuration, Pier 4 could potentially serve up to 20 B737 or A320 simultaneously, or a gross estimate of 3,000 passengers per hour.

An estimated total boarding capacity of 10,800 passengers per hour for these 70+ gates is derived. It is much more than the combined T1 and T2 current departure capacity.

The estimate of Terminal 1 boarding capacity is 6,150 passengers per hour (Piers 1,2 and 3) while the Terminal 2 can serve up to 4,650 passengers per hour (including coaching gates, pre-boarding zone gates and pier 4 gates). The space within the concourses is not seen as a constraint to the throughput except in some limited areas:

- Pier 4 ground floor is usually congested during US CBP peaks.
- Pier 3 and Pier 2 ends have limited floor space.
- The extended end of Pier 1 would most probably be congested if all gates were in use simultaneously.

This simple estimation of the boarding gate maximum throughput, confirms that the T1 and/or T2 declared departure capacities are not limited by the number of gates.

The boarding gates located in Pier 1, Pier 2 and Pier 3 could theoretically process 6,000 passengers per hour. The comfort within the boarding hall and in each concourse, would however limit the practical boarding throughput. The boarding gates located in Pier 4 could theoretically process more than 4,000 passengers per hour.

7.6 Immigration process

The immigration process is performed by the Irish Naturalisation and Immigration Service (INIS).

The processing time depends on the passenger’s origin, with the expectation that Irish citizens being quicker than non-Irish, and European citizens quicker than non-European. The processing time for EU passengers has increased recently after the implementation of the mandatory scan of passports. INIS officers can also decide to increase their scrutiny of certain flights. The mix of passengers varies from one flight to another. Therefore, certain assumptions were made to estimate the profile of arriving passengers:

- 90% EU citizens and 10% non-EU on Piers 1, 2
- 50% EU citizens and 50% Non-EU on Pier 3
- During the "Short haul peak" on Pier 4, 80% EU citizens and 20% non-EU
- During the "Long haul peak" on Pier 4, 50% EU citizens and 50% North American citizens

In Summer 2017 the available resources were the following:

- Pier 1 and Pier 2 Immigration Hall offers 12 manned desks and has recently been renovated to extend the queuing area and improve the flow management. 4 e-gates were installed for trial in 2016, these were not utilised during Summer 2017.
- All T2 passengers arriving on Pier 3 are directed to the Pier 3 Immigration hall which has 8 desks available.
- The Terminal 2 Immigration Hall accommodates all terminating passengers from Pier 4 and those from Aer Lingus arriving at Pier 3 gates. 16 desks are available.

By Summer 2018, 20 e-gates will be installed by INIS (10 in Piers 1/2 Hall and 10 in T2) with the following procedure: only EU citizens can use e-gates, 1 INIS agent will monitor up to 5 e-gates, and the processing time is expected to be around 20 seconds per passenger. The following resources have been assumed in the capacity assessment study:

- Pier 1 and Pier 2 Immigration Hall: 10 desks and 10 e-gates
- Pier 3: 8 desks
- Pier 4: 12 desks and 10 e-gates

The assumptions for the processing times are as follows:

- 10 seconds for EU citizens at a desk
- 20 seconds for EU citizens at a e-gate
- 65 seconds for Non-EU and Non-US/Canadian
- 30 seconds for a Canadian or a US citizen

Acceptable waiting time is an important criterion: it is proposed to set the limit so that 95% of the passengers during the maximum rolling hour do not wait more than 10 minutes. For comparison, 15 minutes has also been considered. The mathematical evaluation of the acceptable throughput leads to the following results:

Passengers/hour	95% wait less than 10 min	95% wait less than 15 min
Piers 1/2	3,965	4,100
Pier 3	835	845
Pier 4 during short-haul peak	3,350	3,440
Pier 4 during long haul peak	3,050	3,250

Table 16: Immigration process passenger throughput

The full staffing of available desks and the opening of all e-gates are required conditions to support peak throughput of passengers.

The transferring passengers, not showing-up at immigration desks, are not considered in this section but are part of the evaluation of capacity parameters later.

The available space within the immigration halls Piers 1/2 (around 950sqm) and Pier 3 (around 290sqm) is a constraint to the flow management and to the comfort of queuing passengers. An increase to the size of the immigration hall in Piers 1/2 would assist in queue management and feeding of passengers to the appropriate desks / kiosks. The situation in Pier 3 ground floor depends on the gate allocation since T2 airlines do not direct their passengers to the Pier 3 immigration desks. Finally, the space before Pier 4 immigration is large enough to allow an efficient flow of passengers to the various desks and e-gates.

Terminal 1 arrivals

The review of the T1 Arrival processes concluded that immigration throughput is the limiting element at T1, even if the situation can be improved with the installation of 10 e-gates by Summer S18. The declared capacity of T1 Arrivals should not be solely dependent upon the assumptions that were stated previously. The calculated theoretical throughput of the Immigration Halls Piers 1/2 and Pier 3 (4,800 passengers/hour for 10-minutes as maximum waiting time for 95% of peak passengers) is calculated with an assumption on the passenger origins, the processing times, the full staffing of INIS desks and the intensive use of desks and e-gates. The limited queuing space does not permit any shortage in staff lest queues exceed the space. Similarly, a change to the processing times or a variation of the passenger origins could also generate unacceptable waiting times. It is therefore recommended to preserve a margin from this theoretical figure (15%) on which basis we propose a combined capacity parameter of 4,100 passengers per hour for T1 Arrivals.

Terminal 2 arrivals

Immigration throughput is also the limiting component for T2 arrivals. Long-haul arrivals are unloading passengers from both sides of the Atlantic Ocean while short-haul arrivals, representing 70% of the declared seats during a typical busy day, are carrying mostly European passengers. It is proposed to set the capacity parameter from the superior throughput results of the short-haul model since long-haul passengers are inclined to accept longer waiting times than short-haul passengers. With the 10-min waiting time assumption for 95% of short-haul passengers, the estimated throughput reaches 3,350 passengers/hour.

A minor share of passengers is transferring. Around 5% of arriving passengers do not show-up at the immigration desks. Therefore, it is proposed to increase by 5% the maximum acceptable volume of arriving passengers at T2 immigration.

In the same conservative manner as performed for T1, in order to cover for the sensitivity of our assumptions, it is proposed to retain the same 15% margin. The calculation leads to 3,350 * 1.05 / 0.85 = 2,990, rounded up to 3,000 passengers per hour.

7.7 US Preclearance

7.7.1 US Preclearance: Document Check

Passengers travelling on US-bound CBP flights must pass through the CBP area located on the ground floor in Pier 4. There, they must first proceed to a Document Check, where daa employees check their boarding pass and travel documents. This check is quick (typically around 6 seconds) and is performed manually at one of 6 positions after the snake queue.

The absolute maximum throughput of the Document Check step is therefore 3,600 passengers per hour, much greater than the observed 60-min rolling peaks. However, all positions are not necessarily always staffed - and the actual throughput is regulated. This is controlled by the daa employees with the objective of limiting the number of passengers in the queue prior to the next step, Transportation Security Administration (TSA) Security Control. There is more space for queuing prior to the Document Check than between the Document Check and the TSA Security Control.

7.7.2 US TSA Security Control

All passengers for US CBP flights must go through an additional security check to comply with TSA screening standards.

daa is not responsible for the staffing and the procedures at the TSA control. Long waiting times have been observed and regular coordination meetings are organised between daa, the US TSA and CBP offices, and airline representatives in order to smooth the flight schedule and adjust staff planning.

The throughput is about 180 passengers per lane per hour, or around 20 seconds per passenger. 6 lanes are installed which sets a maximum throughput of 1,080 passengers in 60 minutes.

With the variable US terrorism threat advisory scale, maintaining sufficient throughput at the TSA Security Control without impacting airline punctuality will remain an on-going challenge.

7.7.3 US Immigration processes

US CBP-flight passengers carrying out their US iCustoms and Border Protection process in Dublin so they can travel as domestic passengers when they arrive at their US destination. Depending on their citizenship and status, they will use one or more of the following processes:

- Automated Passport Control kiosks (APC): a US citizen or an appropriately registered citizen of another country, can scan their passport and use their ESTA registration at one of the APC kiosks located in the first floor of Pier 4 (US citizens only) or in the ground floor area. If the check is ok, the passenger receives a waiver to present at the Document Verification Officer (DVO). If the check fails, they must attend one of the Triage desks for further documentation examination. On average, a US citizen takes 61 seconds in this activity whilst a non-US citizen takes 97 seconds. There are 22 APC kiosks in total, the number of which is sufficient. Passengers are invited to use these kiosks, in order to reduce the flow at manned desks.
- Document Verification Office desks (DVO): There are 7 DVO desks located on the right end of the immigration area. The desks are used by passengers who successfully received a waiver, hence the DVO control is quick (around 29 seconds per passenger).
- Customs and Border Protection (CBP) primary inspection booths: US citizens not using the APC kiosks, and non-US citizens must attend the CBP desks that are manned by US CBP officers. Processing takes between 45 seconds (US citizen) and 94 seconds (Non-US passenger). There are up to 16 desks, shared with the Triage function.
- Triage desks: for those passengers whose checks were rejected by the APC control, the CBP officers then undertake further verification, taking around 100 seconds per passenger.
- Secondary Control: for passengers requiring additional inspection after the CBP or Triage inspection, the US officers can decide to guide them to the secondary inspection area. Here other officers will undertake further examination of the passengers right to enter the US. This exceptional process is not considered in the capacity assessment.

To assess the throughput capacity of the US Immigration area, an assumption related to the distribution of passengers over the different processes is necessary:

- 60% of US CBP passengers go to an APC kiosk; 40% to a CBP desk.
- From the APC kiosk, 20% are redirected to the Triage desk, 80% are forwarded to the DVO desk.

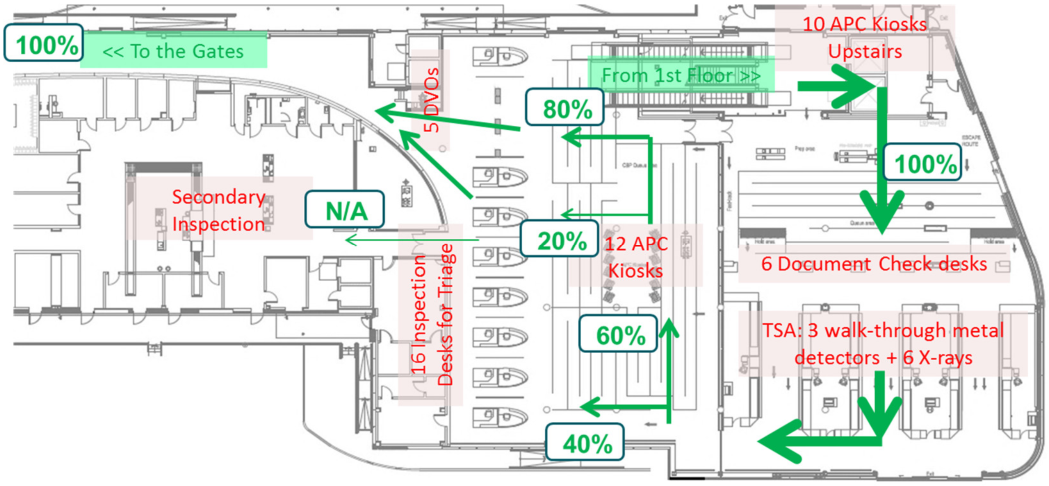

Figure 28: T2 Pier 4 US preclearance area and passenger flow diagram through resources

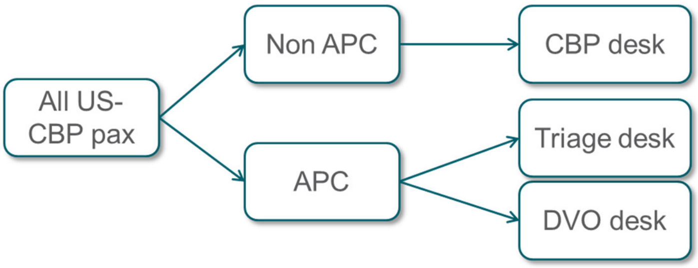

Figure 29: Immigration processes for US Preclearance passengers

As the proportion of US citizens among the US-bound passengers varies from one flight to another, a conservative assumption on the maximum combined throughput of the longest processing times (non-US citizens) were adopted:

- 97 seconds per passenger at the APC kiosk.
- 94 seconds per passenger at the CBP desk.

With these assumptions, the limiting element in the process is the number of CBP/Triage desks (16 currently) which, when fully staffed, provide a theoretical throughput of 1,160 passengers per hour. The APC kiosks and the DVO desks would theoretically accept up to 1,300 passengers/hour.

This assumes all desks are manned and that daa and the US administration are working together to ensure a reasonable waiting time, by adapting the opening schedule to the forecast demand.

In addition to the waiting times, the available queuing space is limited prior to the immigration desks. In difficult situations, the queue could build to the TSA exit area and block the flow. However, we assume that the upstream processes (TSA and before Document Check) would adapt their actual throughput to avoid congestion downstream.

7.7.4 US Preclearance Boarding

All passengers departing through the US CBP area are directed to the boarding gates on the Pier 4 ground floor and first floor. The number of boarding gates available to US CBP flights is limited: 6 gates on the ground floor (401-406), and 4 additional gates (423-426) at the end of the first-floor concourse. Swing Gates are used to separate these passengers from non-CBP departing passengers on the first floor, so additional gates could be counted on first floor but in practice serve the same aircraft stand. The boarding space on the ground floor is limited during peaks but is not considered as a constraint to the throughput. With the assumption of 250 departing passengers per wide-body flight, the gate provision would allow the boarding of 2,500 passengers. The long turn-around times and the schedule preferences do not facilitate maximisation of the actual throughput, and more importantly the US CBP peak traffic is effectively capped by the prior TSA and Immigration processes.

Terminal 2 US Preclearance flights

Terminal 2 at Dublin accommodates US Preclearance flights. The security and immigration processes have been assessed separately:

- the TSA security control could process up to 1,080 passengers per hour.
- the Immigration control is performed with a mix of solutions: APC, CBP, DVO and Triage. The global maximum throughput is estimated to be 1,160 passengers/hour.

The TSA security control is the limiting process in the US Preclearance area. The comfort in that area is limited and an incomplete staffing of resources (from the US administrations) would immediately generate long waiting times and queues. The Advisory Flag applied is justified to adjust the flight schedule so the rolling 60-min period does not exceed that maximum throughput.

A coordination parameter could be created to impose a declared US-bound departure capacity. However, the utilisation of the US Preclearance facility is validated by daa and the US Administration, and a flight to the US could also be served separately in the terminals without the facilitation of the CBP process. Therefore, it is recommended to preserve the same simplified way of arranging the flight schedules through the Advisory Flag procedure.

7.8 Transfer processes

As the hub airport for Aer Lingus' network, the capacity of the terminals to facilitate the passenger transfer from one aircraft to another is crucial. Most transferring passengers are currently travelling with the carrier or with associated partner airlines. Over the S16 busy day, transfer passengers comprised 4% of all passenger movements.

A small share of passengers will have different connections and there will also be an unknown number of passengers, who have chosen to pass from one flight to another without using the transferring facilities.

The flow of transfer passengers therefore considers the transfer facilities in T2:

- Two immigration desks are provided to process the incoming passengers. All passengers are controlled. The distribution of passenger origin is not known. With the assumption of 50% EU Citizens and 50% Canadian/US Citizens (10 seconds processing time per passenger and 30 seconds processing time per passenger), our estimate of the maximum throughput is 360 passengers/hour. Only passengers transferring onto other flights within the common travel area need to be seen by immigration.

- Three security lanes are installed to screen the transferring passengers but that process is not mandatory: passengers arriving from a number of destinations can benefit from the one-stop-security (OSS) agreement, which means that only passengers from non-OSS states need to go through security or those that have mixed with non-OSS arrivals. This excludes US/Canadian flights. When passengers are de-boarding from a non-OSS origin, they are mixed with OSS-origin passengers and at this point the screening installation has to be activated. On the basis of a similar throughput to the main T2 security area, 450 passengers could be processed in an hour.

daa need to continue to facilitate the transfer processes in order to meet Aer Lingus' connecting time objective. With the observed passenger flows from the S16 and S17 flight schedules, transfer capacity is a subject of concern during the morning long-haul and short-haul waves.

daa is in the process of implementing a new transfer facility, which would increase the acceptable throughput and shorten the walking distance.

In T1, transfer passengers use the same immigration resources and are later directed to the common T1 security lanes. This is sufficient for the current level of connecting traffic in T1 but the possibility that a T1 airline, like Ryanair, were to start offering connecting services via Dublin T1 should be anticipated.

It is not possible to apply capacity parameters on transfer passengers due to the wide variety in transfer passengers between individual flights and the commercial nature of such passenger information.

7.9 Baggage delivery process

7.9.1 Terminal 1

In Terminal 1, all arriving and transferring passengers are gathered in a single baggage reclaim hall, which is equipped with 10 bag claim belts. Transferring passengers are directed to the departure security control upstairs, while the majority of passengers without hold bags generally exit quickly via the Customs Control area.

It was assumed that 44% of T1 arriving passengers have a hold bag, a proportion which varies greatly from one airline to another: low-cost airlines such as Ryanair carry less hold bags than long-haul non-European carriers (Turkish, Etihad for instance). The delivery of all bags from one flight generally takes between 5 and 15 minutes, and the belt length is not a constraint.

In certain situations where passengers are still waiting at the immigration desks prior to baggage reclaim, the belts have the potential to be saturated by early delivered bags. From interviews with daa staff, the limiting arrival process is immigration control, and severe congestion rarely occurs in the baggage hall.

For the purpose of the capacity assessment, the bag claim belt allocation schedule of the S16 busy day was analysed. Based upon information provided on the time of first bag/last bag delivery, the actual occupancy of each belt has been estimated across the day. We observe that the baggage hall has adequate capacity and could accommodate additional flights.

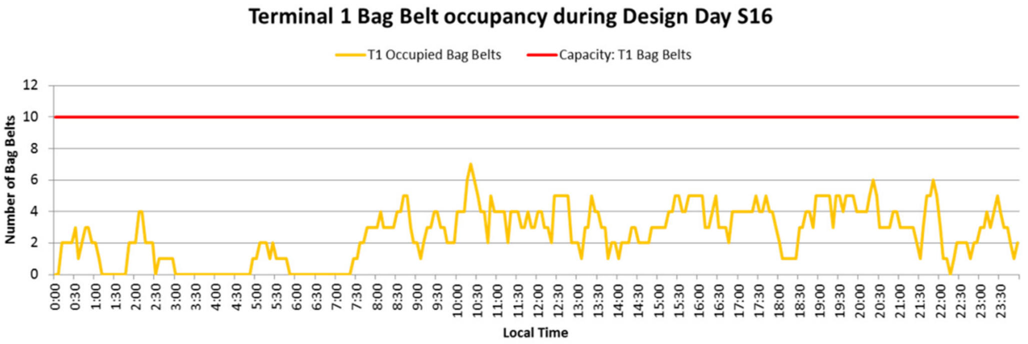

Figure 30: T1 Bag Claim belt occupancy during S16 Design Day

Theoretically, with an occupancy time of around 15 minutes per flight on each belt, an individual belt could serve around 4 flights an hour. The average load of a T1 aircraft is around 150 passengers. With 10 belts available a peak hour of 6,000 arriving passengers could theoretically be accommodated in the baggage hall.

7.9.2 Terminal 2

Similarly, in Terminal 2 the baggage claim hall is equipped with 6 belts, including 5 long belts and 1 shorter belt. Terminal 2 receives many long-haul flights, which have a higher proportion of hold bags. A calculated ratio of 0.69 bags per passenger was assumed. The belt allocation schedule of the S16 busy day was analysed. The results show that during the main peaks of the day there can be times when only one belt remains available.

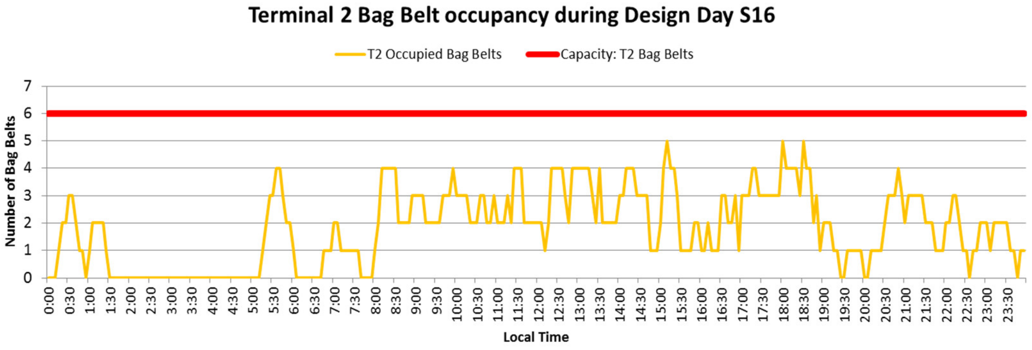

Figure 31: T2 Bag Claim belt occupancy graph during S16 Design Day

The typical belt occupancy for a flight is longer in T2 than in T1 since there are generally more bags to deliver: 20 minutes per flight would be a reasonable assumption. T2 belts are longer and are fed by two delivery belts in the underground level. Therefore, two separate narrow-body flights, with around 150 passengers, could be delivered simultaneously on the same long belts. With this assumption, each of the 5 longer belts could serve 6 narrow-body flights per hour and the sixth belt would serve only 3 flights, leading to a theoretical capacity of 4,950 arriving passengers.

7.10 Baggage handling system

A comprehensive analysis of the full airport baggage handling system (BHS) is presented in Annex G. This section presents the summary of that analysis.

On the basis of the analysis of the BHS related to the check-in, screening and sorting in T1 and in T2, we believe that both T1 and T2 BHS have sufficient capacity and can handle a substantial traffic increase. However, at the moment the insufficient number of check-in desks (as outlined above) in T2 limits that potential (for that terminal).

Local and temporary congestion is frequent in the T1 northern section during the morning departure peak and extension of the make-up capacity should be considered.

The replacement of EDS standard 2 by CT-EDS standard 3, by 2020 due to EU regulation, is a significant undertaking could present implications especially in T1 because:

- The replacement of the current machines by longer and heavier ones could require significant infrastructure works.
- The short Level 2 time-out could lead to an increased number of rejected bags to the Level 3.

When the proposed modifications are implemented, a connection between T1 and T2 might be considered.

The arrival BHS in T1 and T2 is correctly sized to handle the bag flow and could support an increase in peak hour traffic.

In Terminal 1, the baggage screening system can globally accept twice as many bags than currently experienced, despite temporary saturation being observed on collecting belt #13 before the EDS screening machine. The sorting and make-up area is constrained during the first morning departure peak.

In Terminal 2, the screening, handling and sorting systems provide significant capacity. Double the number of departing bags per hour could be handled. However, at the moment the insufficient number of check-in desks (as outlined above) in T2 limits that potential (for that terminal).

Both T1 and T2 BHS have sufficient capacity and can handle a substantial traffic increase.

7.11 Terminal slot coordination parameters

On the basis of our analysis we recommend the following coordination capacity parameters:

- T1 Departure: 4,800 enplaned passengers/hour
- T2 Departure: 3,700 enplaned passengers/hour
- T1 Arrivals: 4,100 deplaned passengers/hour
- T2 Arrivals: 3,000 deplaned passengers/hour

The load factor hypotheses for Scheduled and Charter services are important. The analysis of S16 Design Day shows that the actual load factor was around 93% that day, more than the 85% assumption. That 8% difference represents 8,000 passengers on a day like the S16 Design Day, or 200-300 passengers in peak hours. We are not sure however that this assumption should be changed since it seems that the daa is using historic data on load factors in the staff planning at security. For immigration, the 8% difference could further increase the waiting times. However, a larger margin has already been recommended on the maximum theoretical throughput.

The use of 120-min rolling periods is not recommended. Whilst it can provide an additional safeguard against the cumulative effect of two successive peaky departure hours in the morning wave (for instance), the flight schedule analysis showed that the departure peaks are shorter than 120 minutes in T1 or T2, and generate evident passenger flow “firebreaks”.

The existing Advisory Flags for the US Preclearance flights and for T2 check-in desks should be maintained. The flag on T2 morning arrivals is no longer necessary.

Future challenges for daa

We outline below a number of optimisations that could serve to improve the terminal capacity and/or the level of service, which would also require cooperation from the airlines.

In Terminal 1

- Maintain and possibly improve the throughput at T1 Security through consideration of layout, technology solutions, staffing, queue management and passenger sorting.
- Develop the capacity to handle Transfer bags between T1 and T2 and within T1.
- Consider a different check-in allocation in the T1 Hall if the number of checked bags on collecting belt #13 increases, and to improve the use of the make-up capacity during the first morning peak.
- Facilitate the installation of passport control e-gates and optimise their use. Optimise the comfort in the Immigration Hall and expand it if possible.
- Adjust gate allocation over Piers 1/2/3 to reduce pressure on immigration during the late evening peak.
- Optimise the use of bus boarding gates and remote stands, possibly with the OCTB gates.
- Anticipate a possible increase in the number of transferring passengers and adapt their flow path.

In Terminal 2

- Increase the check-in capacity, providing more desks and optimising their use along the day. Focus on the check-in capacity for US CBP flights.
- Maintain and possibly increase the throughput at T2 Security.
- Consider projects to expand the Preclearance area (US TSA control and US Immigration process) and the boarding capacity and space allocated to the US-bound flights.
- Facilitate the bus boarding and shuttle service to the Pre-Boarding Zone through signage, boarding processes, bus circulation and bus/driver resources.
- Facilitate the installation of e-gates and optimise their use. Optimise the comfort in the Immigration Hall through queue arrangement, queue management and seating.
- Survey the evolution of the share of transfer passengers within T2 and between T2 and T1 to adapt their processes and maintain an acceptable connecting time. The Transfer Box project which has been briefly presented appears to be necessary.

8 Analysis of road access system

In order to provide a complete view of the airport capacity, landside access to the airport has been briefly assessed and a summary of findings is presented below. More details regarding the assessment is available in Annex F.

Dublin airport benefits from good road access due to its proximity to two motorways. From the M1 the airport can be accessed through a short road leading to a large roundabout at the airport entrance. An extensive parking offering is available near the airport with long term parking lots located alongside the motorways.

Although the modal share of private vehicles dropped in the decade up to 2011, it is still the main mode of access to the airport. Post 2011 there has been high growth in air traffic and road traffic has been increasing fast in real terms on the access road to the airport.

The road access capacity has been estimated on the basis of a straightforward comparison between the observed peak flows and the throughput capacity of each road segment, in order to present the actual situation and to highlight the pinch points of the current road system.

The analysis of the network capacity reveals that residual capacity is limited due to the need for most traffic to route through the roundabout at the airport's entrance. This represents a constraint on the ability of the current road infrastructure to absorb the currently observed growth in road traffic growth. Even though the future Metro North to the airport will satisfy an apparent demand for public transport solutions and relieve the road network, a comprehensive traffic study is recommended to verify the residual road capacity and to evaluate the impact and benefit of proposed solutions.

9 Assessment of results

9.1 Implications for Dublin capacity

Airfield and airspace

The assessment of the capacity of the various elements of airside infrastructure revealed these key points:

- The maximum achievable runway throughput on runway 10-28 is 24 arrivals in arrivals mode, 41 departures in departures mode and 48 flights in mixed mode. These limits are sensitive to operating fleet mix and reduce by approximately 2 movements (in mixed mode) for every 15% increase in the share of heavy (Code E/F) aircraft in the fleet mix.
- The arrivals capacity declaration in some hours (notably the evening peak) exceeds the simulated runway throughput envelope. This does not mean the present declaration is incorrect, it just indicates that arrivals above the maximum arrivals throughput will be accommodated with delay.
- All declared departures limits in the capacity declaration are within the simulated runway throughput envelope. However, adding extra flights into hours which are at, or close to the declared limits will incur extra delay for flights operating in these hours. Sensitivity analysis with the morning departures wave indicates that adding a flight into this period will lead to an increase in departure ground delays of between two and three and half minutes, depending on whether the added flight is an arrival or departure and whether it is narrow body or wide body aircraft.
- With the exception of peak periods, the taxiways can serve the traffic without causing delays. During the morning peak period on Runway 28 operations, queues of departing aircraft may complicate traffic flow around Pier 3 South and Pier 4.
- Cul-de-sac stand arrangements add delay to arriving aircraft when another aircraft is departing from cul-de-sac area. The arriving aircraft, which is waiting outside the cul-de-sac also complicates taxiing of other aircraft.
- Overall stand capacity is at its limits during the morning peak period. Although additional flights could be accommodated in this period, it would result in either a reduced number of resilience stands, or increased towing.
- The number of wide body contact stands is close to the capacity limits during the morning wide body peak period. Additional flights could be accommodated, but would result in increased towing. As these aircraft will have to be towed north, in a direction opposite to the direction of aircraft taxiing for departure, extra towing operations are likely to complicate ground movements and possibly add to the overall ground delays.
- The structure of the airspace around Dublin does not accentuate airport delays. Thanks to the Point-Merge arrangements the Dublin TMA is likely to be able to handle any desired increases in traffic in the next few years.

Passenger terminal buildings

Assessment of the capacity and operational issues related to the passenger terminal building infrastructure revealed these key points:

- The declared capacity parameters for T1 and T2 are not limiting parameters compared to the runway and stand limits. This is confirmed by ACL reports that show terminal building capacity to be minor reasons for slot adjustments.
- Local and temporary congestion (in the immigration halls or US Preclearance area) is reported by the daa and the airlines.
- Our results are consistent with the limits set for S18 in T2:
  - 3,700 passengers per rolling hour for T2 Departures.
  - 3,000 passengers per rolling hour against 3,050 for T2 Arrivals.
- However, our analysis indicates a higher capacity could be declared at T1:
  - 4,800 passengers per rolling hour against 3,700 for T1 Departures. The capacity of T1 security lanes is the main constraint.
  - 4,100 passengers per rolling hour against 3,550 for T1 Arrivals, assuming that the distribution of these passengers over both Piers 1/2 and Pier 3 immigration hall is consistent with their respective capacity.

The results in this study are in line with the information presented at the S18 slot coordination committee meetings.

9.2 Key pinch points

Runway

With the current fleet mix, runway 10-28 is operating close to its throughput limits during several periods of the day. If the fleet mix changes in S18 according to the S18 design day forecast and if all of the forecast new services are operated as planned, the 0800 UTC and 2200 UTC hours will be filled up to the arrivals limits, with the 1600 UTC hour being just two flights short of reaching that limit. Departures in the 0500 UTC hour will be scheduled up to the limit, with several other hours being one or two flights short of reaching the departures hourly limit (1400 UTC, 1500 UTC and 1800 UTC). Limits on the total number of movements will be reached in 0800 UTC, 1100 UTC and 1700 UTC, with several other hours being just one or two flights from reaching the limit (1000 UTC and a period from 1400 UTC to 1800 UTC).

Taxiways

The simulations confirmed the existence of a pinch point in the area where runway 28 joins runway 34. This area is busy due to multiple runway entry points and converging taxiways.

Other congested areas include Link 4 – junction of taxiways H1 (used by runway 28 arrivals going to Pier 1, Pier 2 or apron 5G), F-Inner (used by departures coming from Apron 5G, Triangle and Pier 1 stands), F-Outer (used by arrivals to Pier 1 or Apron 5G) and F3 (used by aircraft being towed north). There is a risk that aircraft coming from various directions will meet at Link 4. This is noticeable during the busy morning period, when there are the first narrow bodies taxiing from Pier 1 towards runway 28, early morning long haul arrivals and on some days other aircraft being towed to/from their hangar.

Stands

Analysis of actual turnaround stand utilisation for the S17 busy day revealed that at any time, no more than 73 commercial aircraft demanded to use a turnaround stand. During the peak turnaround stand demand period (around 0540 UTC) these 73-aircraft occupied 79 narrow-body equivalent turnaround parking positions, effectively using 86% of the total available turnaround stand capacity. On top of these aircraft there were other aircraft, mostly cargo and technical stopovers, parked on non-turnaround stands. It is recognised that a certain number of stands should be kept free at all times as a contingency for diverted flights, emergencies, or stands temporarily out of service (e.g. due to maintenance). A typical stand contingency requirement used by other airports would be in the range of 10% - 15% of the stand demand. After factoring the contingency requirement into the stand capacity calculations, it can be concluded that during the early morning peak period the airport is effectively operating at its current stand capacity limits and further stand capacity may be required in order to facilitate continued traffic growth during the morning period.

PTB

The key pinch-points inside the terminal buildings are the check-in hall in T2, the security control areas in T1 and T2, the US Preclearance area in Pier 4, the immigration desks in T1 and T2. For more information see sections 7.2, 7.4, 7.7 and 7.6 respectively.

The capacity to handle transfer passengers and bags between T1 and T2 and within T1, the baggage make-up capacity in T1, and the boarding space for US-bound flights are secondary constraints.

9.3 Opportunities for capacity growth and resilience enhancement

As the runway throughput is a function of aircraft separation and runway occupancy times, the only way to change runway throughput is to improve performance in one of these areas.

Departure separations

One mechanism to increase runway throughput would be a reduction in separation between a departure followed by another departure. The current separation applied of 84 seconds could be further decreased (subject to approval by the Safety Regulator) to help improve runway throughput, especially during the first morning wave, although the impact of this change would be visible in all hours which are scheduled close to the declared limits.

Arrival time-based separations

Varying winds are a common factor for not delivering the declared arrivals runway throughput. Due to strong wind conditions on the final approach, aircraft separations, whilst the same in distance as during lower winds, are longer in time (as an aircraft's ground speed is reduced by the wind). This results in a lower number of arrivals in any given time period than would be the case with low or no winds. This leads to decreased landing rates and increases in ground delays. A possible option to reduce arrival-arrival separations in strong wind conditions is to transition from distance based separation to time based separation. The concept of time spacing is based on the performance of an aircraft in windy conditions, where wake vortex is quickly dispersed, permitting then to reduce the distance between aircraft, while maintaining safety levels.

RET location

Analysis of the usage of runway exits[16] indicates that while runway 28 is in operation, more than 75% of arrivals vacate the runway via rapid-exit taxiway (RET) E6. However, more than 20% of traffic (mostly turboprop aircraft, smaller jets and business aviation) use exit E5. As this exit is perpendicular to the runway, pilots need to decelerate significantly in order to be able to make a safe turn. If there was another RET constructed near the location of the E5 exit, aircraft types which regularly use E5 could exit the runway faster. Reduction in arrival runway occupancy times lead to an increase in runway throughput. Further analysis would be required to identify the best position of the second RET and its potential to improve runway throughput.

While aircraft separations and arrival runway occupancy times can be influenced by the IAA (reduced separations) and daa (construction of new RET), there are no easy tools for reduction of departure runway occupancy times, as these are largely dependent on individual airline procedures, pilot training, their discipline and reaction time.

Taxiway infrastructure

Although the current taxiway layout is not the predominant source of delays, this situation is likely to change as the traffic grows. The simplest short-term solution would be construction of a new taxiway joining Link 6 with Runway 16-34. This would allow departures from and arrivals to Pier 1 and Apron 5G stands to bypass the area between F-Inner, F-outer, Link 4 and Link 6 as needed. The proposed taxiway could also serve as a runway exit during R16-34 operations.

Another potential improvement of taxiway layout would be construction of a new taxiway parallel to the existing TWY F. This would provide additional towing routes and it would also enable smoother traffic flow as there will be less aircraft queued on the existing F3/F2/F1.

Stands

Assuming the traffic at Dublin Airport continues to grow and assuming the runway will be able to handle the extra traffic, it will be necessary to construct new stands to cope with increasing demand for narrow-body, wide-body and contingency stands.

Firebreaks

The analysis in section 5 (Results of firebreak analysis) identified two fire-breaks in the current schedule. The first, between 0700 UTC and 0800 UTC was able to absorb or significantly reduce impact of any delay up to 60 minutes (please note we have not modelled delays above 60 minutes). The second fire-break, between 1300 and 1400 UTC is able to handle delays of up to 30 minutes, but as the delay increases, the time required for the airport to recover from such situation increases too. Both of these firebreaks should be protected.

There is no firebreak in the afternoon period. In the present situation, all hours between 1400 UTC and 1859 UTC are scheduled very close to the maximum limits, with the spare capacity never being greater than 2 flights per hour. In case of unforeseen circumstances during the afternoon period, the airport is likely to struggle to recover before 1900 UTC.

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[16] Arrivals between 01 May 2016 and 31 September 2016

Creation of a short fire-break prior to 1900 would help to reduce any delays incurred during this period.

5-minute scheduling

Finally, another interesting option for increasing resilience and decreasing delays is related to the transition from the existing 10-minute scheduling limits to a 5-minute limit. Transition to 5-minute scheduling limits has the potential to streamline the flow of aircraft, especially during peak periods. This is likely to lead to decreased ground and runway delays. Decrease in delays is then likely to improve OTP performance.

9.4 Runway and airfield delay criteria

Runway scheduling limits are set for each season taking into consideration the current schedule, a wish list of new or amended services and tolerable levels of runway holding delay. The committee has historically accepted forecast runway holding delays of up to ten minutes (the ‘delay criteria’). However, during consultations it was suggested that overall delays from pushback to runway entry were exceeding those of the forecast runway delay presented in the scheduling process.

The results from our capacity assessment presented at the Committee meeting[17] demonstrate that runway holding delay at peak times exceeds 10 minutes per flight, normally considered to be the limit of holding delay. In addition, whilst runway delay is the majority of outbound delay, there are additional delays incurred taxiing to the runway holding points. These taxi delays can be up to 2 minutes per flight at certain times. Relying upon the existing criteria therefore underestimates total delay. The question is whether to change to a different metric for the delay criteria calculation to reflect all delays or whether to maintain the current metric but increase the level of acceptable delay.

We recommend a total additional taxi time metric that captures all sources of delay that an aircraft experiences from pushback to runway entry so that changes to the airport capacity are made in the presence of the full set of facts regarding operational performance. The specifics of the Dublin Airport layout mean that taxiway congestion is likely to be a factor in the airfield capacity and should therefore be reflected. Our results for Runway 28 in S18 when scheduled to the capacity limits indicate that total departure delay reaches 18 minutes at peak times (when averaged over 10 minutes) and this would therefore reflect an appropriate delay limit.

The current NATS runway delay criteria is equivalent to that used by some other busy coordinated airports. In some cases, a 10-minute runway holding delay criteria is used in full knowledge of additional taxi-delays beyond the 10 minutes. Typically, in many of those cases those airports also promulgate maximum taxi times to airlines for flight scheduling and planning purposes so they can accommodate the expected runway delay and taxi delay in their schedules. We are not aware of any airports operating with a runway holding delay criteria in excess of 10-minutes. However, increasing the runway delay criteria to 17 minutes would accommodate the S18 wishlist schedule at all peak periods of the day. We would suggest that were this increase to take place that daa be requested to provide further detail to airlines regarding reasonable and worst-case expectations on overall taxi

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[17] See the documents supporting the draft decision on S18 coordination parameters here: https://www.aviationreg.ie/news/draft-decision-coordination-parameters-summer-2018-dublin-airport.802.html

times by time of day and that planned block-times reasonably accommodate these expectations.

In order to facilitate the transition to a total additional taxi time metric, we would suggest that for the next equivalent season scheduling activities are informed by both existing and new metrics in parallel allowing a period of familiarity to stakeholders in the transition. Subsequent seasons will therefore have a consistent basis upon which to assess operational performance.

9.5 Implications for scheduling limits

9.5.1 Limits applied to the airside infrastructures

In light of findings presented in this section, our review of airside scheduling limits is as follows.

The airfield operates close to or at declared runway capacity limits during several hours of the day. All of the declared runway limits are realistically achievable on the understanding that there will be delay at certain peak times. However, we would recommend that special attention is paid to periods which are scheduled up to or close to either of the three limits imposed on number of arrivals, departures or total movements in any single hour. Having two subsequent hours scheduled up to the current limits may be operationally feasible during normal operations, but bears a risk of severe delays in case of unforeseen disruption, especially as there is no evident fire-break in the afternoon period.

The need for fire-breaks should be discussed within Coordination Committee members and if agreed could be formalised in the capacity declaration to prevent operators from filling up all hours in the declaration to the maximum applicable limits. In such a case, minor disruptions could have significant impact on delays and OTP.

Current stand capacity criteria are still valid and we recommend no changes due to the stand capacity being very limited during the morning period.

Although we do not propose introduction of any airspace capacity criteria, we think it would be useful to have a part of the Coordination Committee meeting dedicated to discussion of the impact of proposed increases in traffic on airspace capacity and delays. A high-level assessment of e.g. changes in average time spent in linear holding may be a good way to start. The idea is use this information to complement the picture of overall impact of any proposed changes[18].

We do not propose introduction of any new airside scheduling criteria.

All stakeholders should discuss the pros and cons of a transition towards 5-minute coordination periods and conduct a specific feasibility study.

Finally, we would recommend that agreement is made well in advance on the delay criteria against which to assess impact of proposed changes in traffic for the next season.

9.5.2 Limits applied to the passenger terminal buildings

Coordination parameters for Summer 2018 included 60-minute rolling traffic and referral limits (or advisory flags).

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[18] For example, if there is not enough priority given to arriving traffic, ground delays could look good but airborne holding could become excessive

We support the recent removal of 120-min rolling periods for coordination. Whilst it can provide an additional safeguard against the cumulative effect of two successive peaky departure hours in the morning wave (for instance), flight schedule analysis showed that the departure peaks are generally shorter than 120 minutes in T1 or T2, and generate evident passenger flow firebreaks.

The existing Advisory Flags for the US Preclearance flights and for T2 check-in desks should be maintained. The collateral discussions between the daa, the US Administration services and the airlines, to arrange the T2 check-in desk distribution and the flight schedules in the US Preclearance area, had proved its efficiency and we have not been told that this system should be replaced by an independent arbitrage from the coordination service provider (ACL currently).

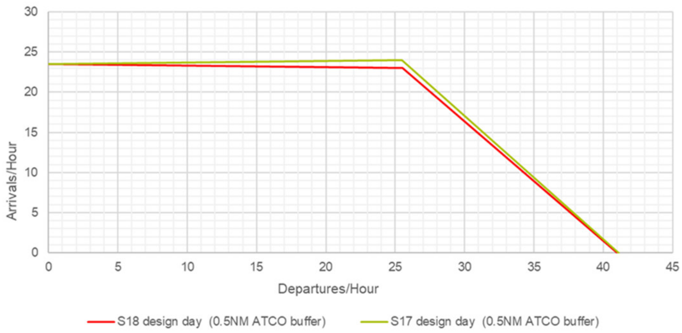
We agree that the flag on T2 morning arrivals is no longer necessary after the present capacity assessment.

10 Conclusions

This section outlines our conclusions relating to each of the high-level questions raised by the Commission in their Request for Tenders on the basis of our analysis. The conclusions are based on our full analysis and we therefore recommend that they are not considered in isolation from it.

The Commission asked for a report that would:

- Quantify capacities of all infrastructure elements at the Airport. The analysis concludes that:
    - The maximum throughput of runway 10-28 is 24 arrivals per hour, or 41 departures per hour or 48 movements if the runway operates in mixed mode.
    - The capacity of taxiways cannot be directly quantified but the existing system is able to serve the existing demand without incurring prolonged delays. This is subject to efficient ATC and stand planning procedures.
    - There are 61 contact and 31 remote turnaround stands that can be used for passenger services. An additional 36 remote stands can be used for long term parking, general aviation or cargo operations. Stand capacity is at its limits during the peak morning period.
    - Airspace capacity has not been quantified in detail, but the analysis undertaken identified that the current airspace structure does not cause any capacity constraints on Dublin Airport.
    - Terminal 1 and Terminal 2 departure throughputs are limited by the security process and our estimates of the appropriate maximum capacity declaration parameters are 4,800 and 3,700 passengers per rolling hour respectively.
    - Similarly, Terminal 1 and Terminal 2 arrival throughputs should be limited to guarantee reasonable waiting times at the constraining immigration processes. Our proposal is to set 4,100 and 3,000 passengers per rolling hour respectively as maximum possibly declared capacity parameters.
    - The US Preclearance Area cannot handle more than 1,080 passengers per hour in our estimate. We recommend maintaining the existing referral limit.
    - The study has not quantified the number of required check-in desks in T2 but insufficient resources in the T2 check-in halls justify the existing referral limit.
- Allow assessment of runway 10-28 hourly capacity with different mixes of arrivals and departures to allow declaration of runway hourly limits,
    - Runway hourly capacity throughput can be investigated using our frontier chart, which shows the relationship between various combinations of arrivals and departures scheduled in one hour. It should be noted this chart assumes constant fleet mix (S18 design day).



  - For more information see section 3.3.

- Provide insight into optimum number and duration of firebreaks,
  - There are currently two firebreaks at Dublin Airport. The first one, between 0700 UTC and 0759 UTC helps in mitigating delays incurred during the morning departures peak. The second one, between 1300 UTC and 1359 UTC helps mitigating any morning delays which persist through the first firebreak, or which occur after it.
  - The first fire-break can ameliorate all simulated delays (up to 60 minutes), while the second fire-break can reasonably ameliorate delays of up to 30 minutes.
  - A third fire-break should be considered in the afternoon period between 1400 and 1900 UTC.
  - The need for fire-breaks should be discussed within the Coordination Committee and any agreed fire-breaks should be formalised in the capacity declaration.
  - For more information see section 5.
- Allow determination of runway capacity under various delay criteria,
  - We have developed a model that allows for detailed sensitivity analysis of runway and airfield capacity under a range of schedules and infrastructures.
  - Assuming the fleet mix remains static (design day), adding a flight into the morning peak period will lead to an increase in departure ground delays of between two and three and half minutes, depending on whether the added flight is an arrival or departure and whether it is a narrow body or wide body aircraft. Similarly, removing a flight from this period will lead to a reduction of between one and two minutes.
  - Acceptability of delay criteria from the previous season for the purpose of assessment of airfield performance in the following season should be discussed during a coordination committee meeting and the delay criteria, against which the forecast performance will be assessed should be agreed before the assessment process begins.
  - Depending on the simulation method (full airport simulation vs. runway only simulation) chosen, the delay criteria may need to be adjusted.
  - For more information see the following sections: 3.4, 3.5 and 9.4.
- Assess capacity implications when coordinating to 5-minute periods,
  - A transition to 5-minute scheduling limits has the potential to streamline the flow of aircraft, especially during peak periods. This has the potential to lead to

decreased ground and runway delays. Decrease in delays is then likely to improve OTP performance.

  - Further exploration is recommended before the decision on a transition towards 5-minute scheduling limits is made.
  - For more information please see section 6.

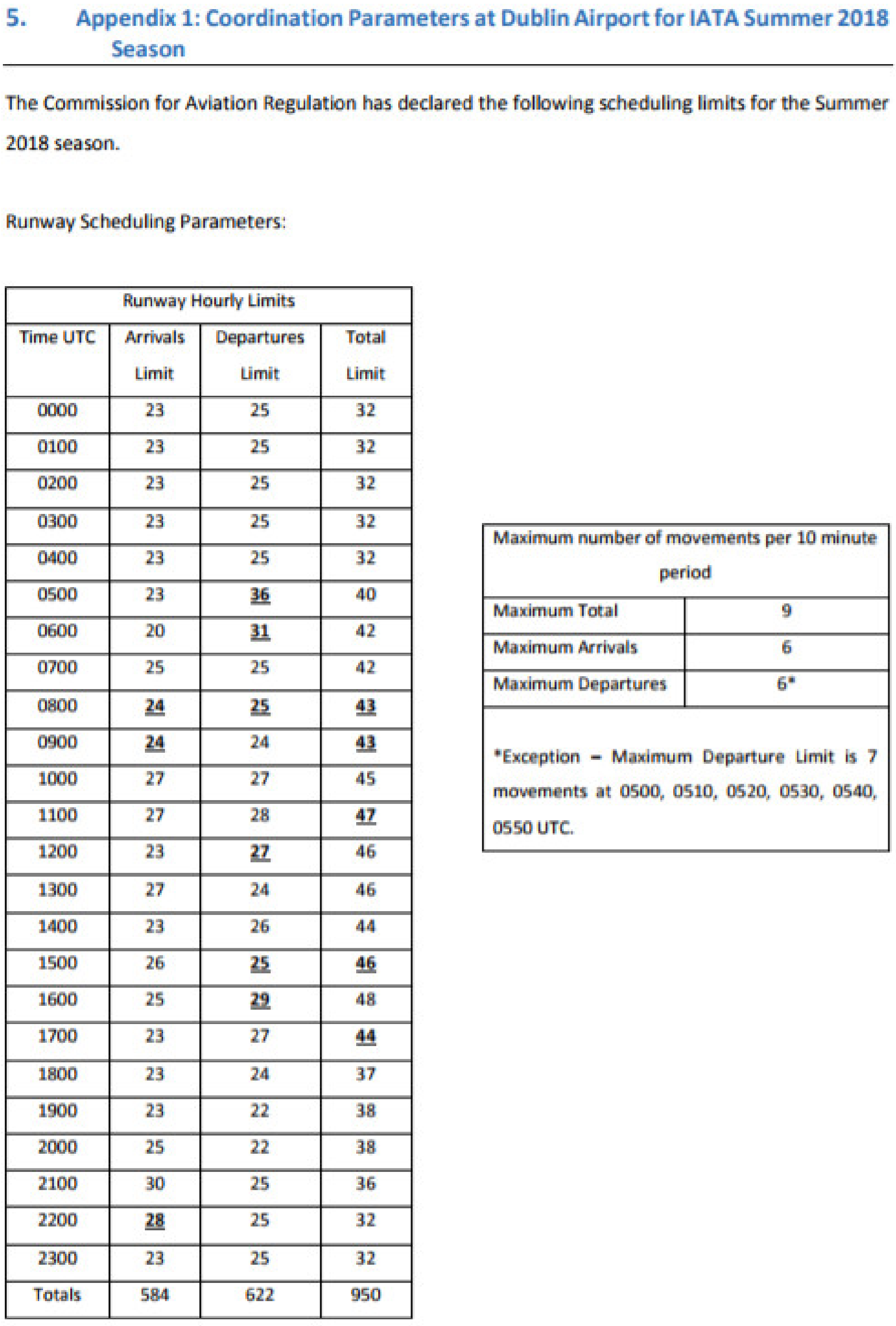
- Identify pinch-points across the Airport, together with high level solutions or options to alleviate these pinch points.
  - The key pinch-points on the airside are the runway 10-28, dual runway threshold with its entry points and stand capacity. For more information on these see sections 4.4 and 9.2.
  - The key pinch-points inside the terminal buildings are the check-in hall in T2, the security control areas in T1 and T2, the US Preclearance area in Pier 4, the immigration desks in T1 and T2, etc. For more information see sections 7.2, 7.4, 7.6 and 7.7

A Acronyms and abbreviations

A-A	Arrival to arrival spacing
A-D-A	Arrival-departure-arrival spacing
ACL	Airport Coordination Ltd
ADRM	Airport Design Reference Manual (ADRM)
AirTOp	Fast Time Simulation tool from AirTOpSoft
APC	Automated Passport Control
ARR	Arrival
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATRS	Automatic Tray Return System
BHS	Baggage Handling System
CAD	Computer Aided Design
CAR	Commission for Aviation Regulation
CBP	Customs and Border Protection
CDA	Continuous Descent Approach
CT-EDS	Computer Tomography Explosive Detection Systems.
D-D	Departure to departure spacing
daa	Dublin Airport
DEP	Departure
DVO	Document Verification Office
EDS	Explosive Detection System
EU	European Union
FMS	Flight Management System
FTS	Fast Time Simulation
GSE	Ground Service Equipment
HBS	Hold Baggage Screening
IAA	Irish Aviation Authority
IATA	International Air Transport Association
INIS	Irish Naturalisation and Immigration Service
KT	Knots
LoS	Level of Service (IATA)
MARS	Multi Aircraft Ramp System
NB	Narrow Body (aircraft)

OCTB	Old Central Terminal Building
OOG	Out Of Gauge (large baggage)
OSS	One Stop Security
OTP	On Time Performance
PHP	Peak Hour Passenger (demand)
PTB	Passenger Terminal Building
RET	Rapid Exit Taxiway
ROT	Runway Occupancy Time
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival Route
STD	Scheduled Time of Departure
TMA	Terminal Manoeuvring Area
TRP	Tug Release Points
TSA	Transportation Security Administration
TWY	Taxiway
ULD	Unit Load Device
US	United States (of America)
UTC	Universal Time Coordinated
WB	Wide Body (aircraft)
WIWO	Walk-in Walk-out
WVC	Wake Vortex Category

B Summer 2018 capacity declaration



5. Appendix 1: Coordination Parameters at Dublin Airport for IATA Summer 2018 Season

The Commission for Aviation Regulation has declared the following scheduling limits for the Summer 2018 season.

Runway Scheduling Parameters:

Runway Hourly Limits			
Time UTC	Arrivals Limit	Departures Limit	Total Limit
0000	23	25	32
0100	23	25	32
0200	23	25	32
0300	23	25	32
0400	23	25	32
0500	23	**36**	40
0600	20	**31**	42
0700	25	25	42
0800	**24**	**25**	**43**
0900	**24**	24	**43**
1000	27	27	45
1100	27	28	**47**
1200	23	**27**	46
1300	27	24	46
1400	23	26	44
1500	26	**25**	**46**
1600	25	**29**	48
1700	23	27	**44**
1800	23	24	37
1900	23	22	38
2000	25	22	38
2100	30	25	36
2200	**28**	25	32
2300	23	25	32
Totals	584	622	950

Maximum number of movements per 10 minute period	
Maximum Total	9
Maximum Arrivals	6
Maximum Departures	6*

*Exception – Maximum Departure Limit is 7 movements at 0500, 0510, 0520, 0530, 0540, 0550 UTC.

Passenger Terminal Parameters:

	Departures Hourly Limit	Arrivals Hourly Limit
Terminal 1	3,700	3,550
Terminal 2	3,700	3,050

Notes:

1) The hourly limit for passengers is rolled every 10 minutes.
2) Load factors of 85% and 95% are applied to Scheduled and Charter services respectively.

Stand Parameters:

	GA	**Non-Turnaround**			**Turnaround Stands**								**All**
	LAB	APC	W.A.	Total	5G	P1	P2	P3	P4	S.A	Triangle	Total	Total
Contact						23	10	11	19			61	61
Remote	12	13	23	36	14				1	9	5	31	79
All	12	13	23	36	14	23	10	11	20	9	5	92	140

Note: Stands defined based on ICAO Code B and C size.

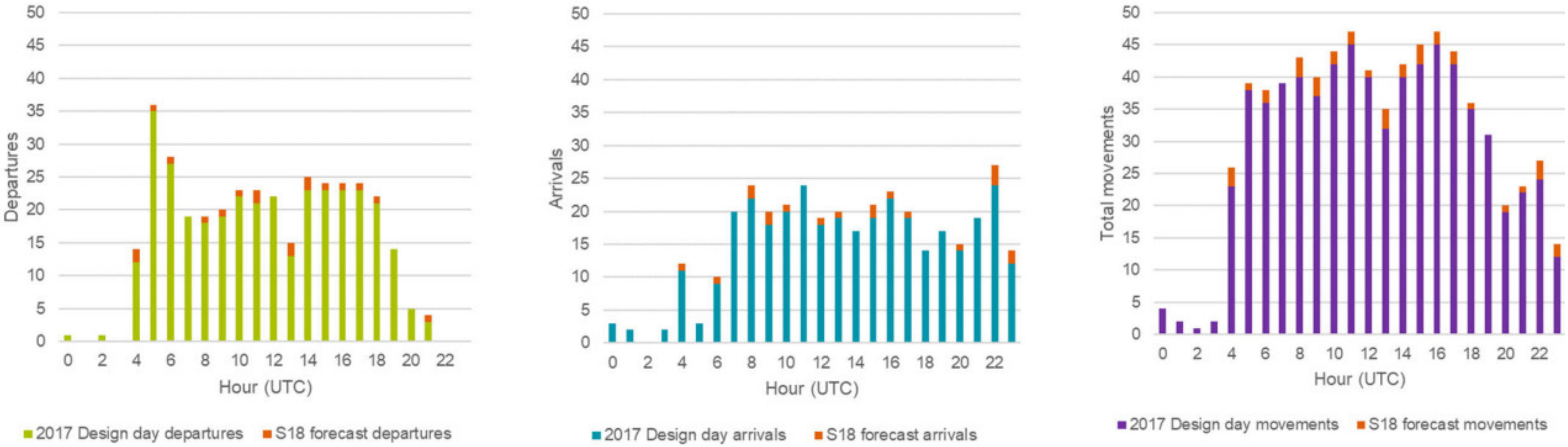
Area	**Constraint**
Stands	Where demand for stands exceeds supply based on coordination allocation, flights to be referred to Dublin Airport for detailed assessment.

Referral Parameters:

Area	**Flag**
T2 Check-in Desks 1-28 (T2 Operators excluding EI)	Demand exceeds 28 desks
US Preclearance	New flights and schedule changes

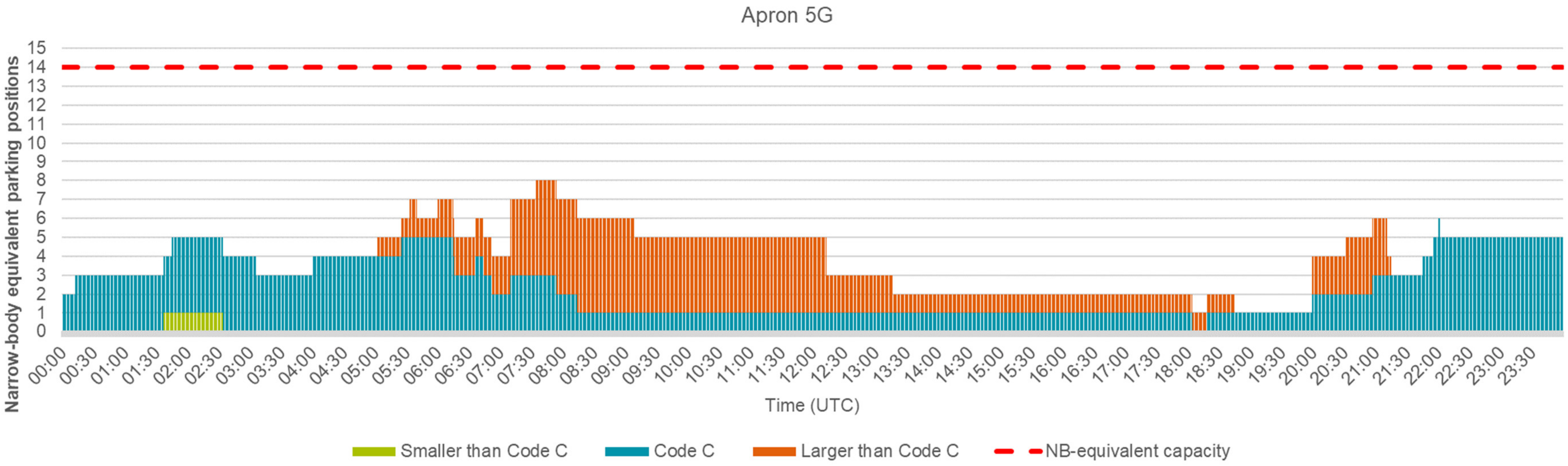
C Hourly number of flights modelled within S17 and S18 design days

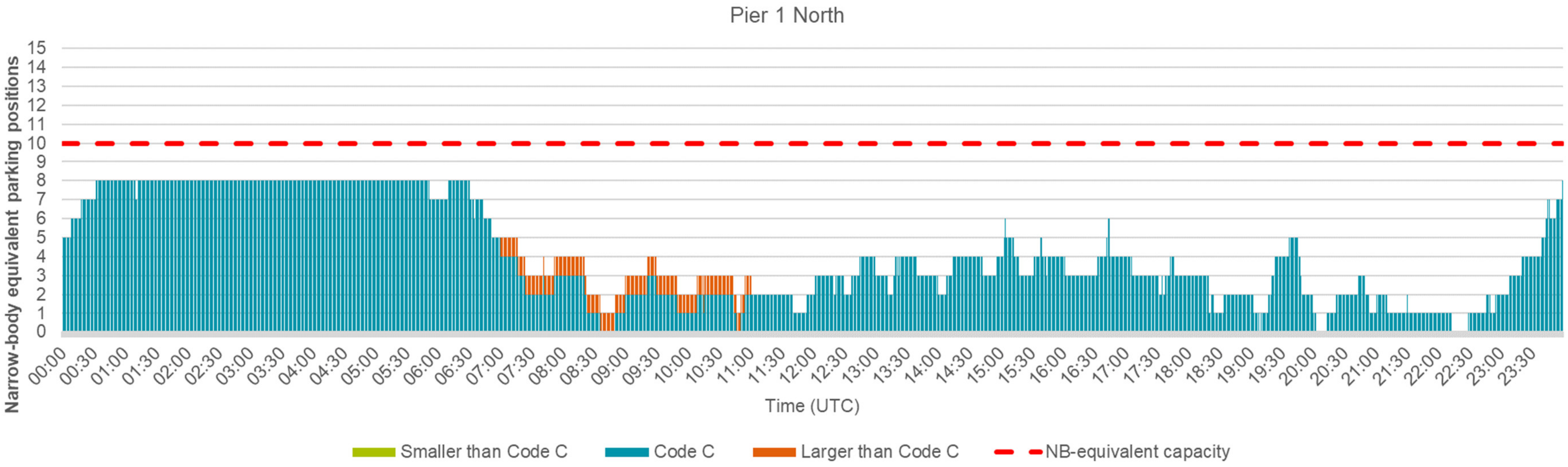
Hourly breakdown of flights modelled in S17 and S18 scenarios:

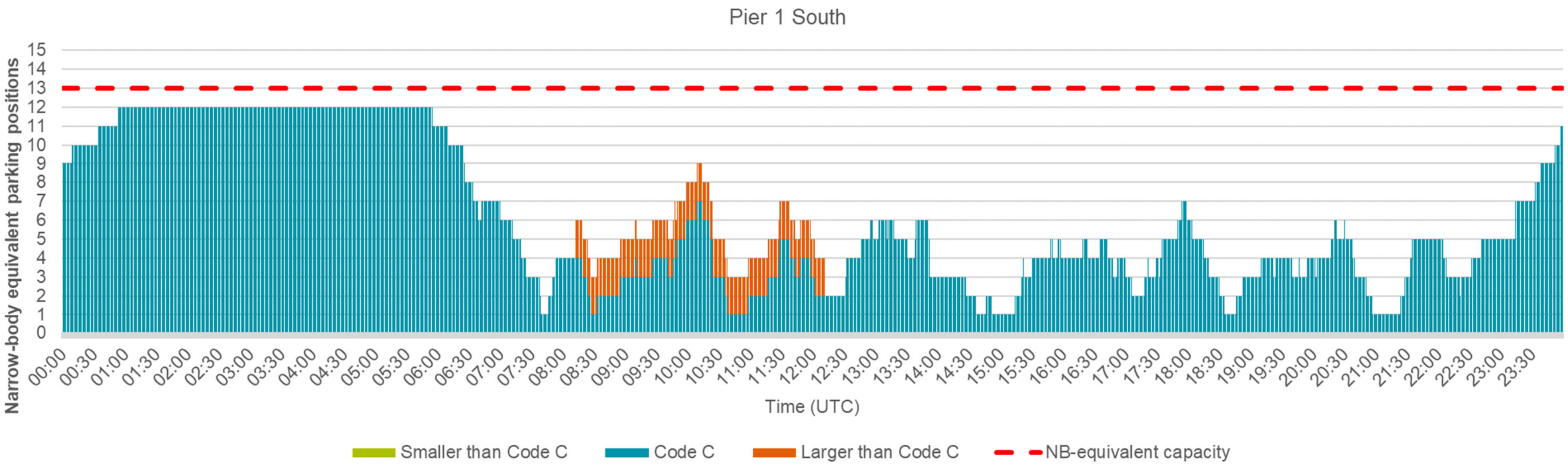


Hour of Day (UTC)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
2017 Design day arrivals	3	2	0	2	11	3	9	20	22	18	20	24	18	19	17	19	22	19	14	17	14	19	24	12	**348**
S18 forecast arrivals	0	0	0	0	+1	0	+1	0	+2	+2	+1	0	+1	+1	0	+2	+1	+1	0	0	+1	0	+3	+2	**+19**
S17 design day + S18 forecast	3	2	0	2	12	3	10	20	24	20	21	24	19	20	17	21	23	20	14	17	15	19	27	14	**367**
2017 Design day departures	1	0	1	0	12	35	27	19	18	19	22	21	22	13	23	23	23	23	21	14	5	3	0	0	**345**
S18 forecast departures	0	0	0	0	+2	+1	+1	0	+1	+1	+1	+2	0	+2	+2	+1	+1	+1	+1	0	0	+1	0	0	**+18**
S17 design day + S18 forecast	1	0	1	0	14	36	28	19	19	20	23	23	22	15	25	24	24	24	22	14	5	4	0	0	**363**
2017 Design day flights	4	2	1	2	23	38	36	39	40	37	42	45	40	32	40	42	45	42	35	31	19	22	24	12	**693**
S18 forecast movements	0	0	0	0	+3	+1	+2	0	+3	+3	+2	+2	+1	+3	+2	+3	+2	+2	+1	0	+1	+1	+3	+2	**+37**
S17 design day + S18 forecast	4	2	1	2	26	39	38	39	43	40	44	47	41	35	42	45	47	44	36	31	20	23	27	14	**730**

D Stand demand by location and aircraft size (S17, turnaround stands only)



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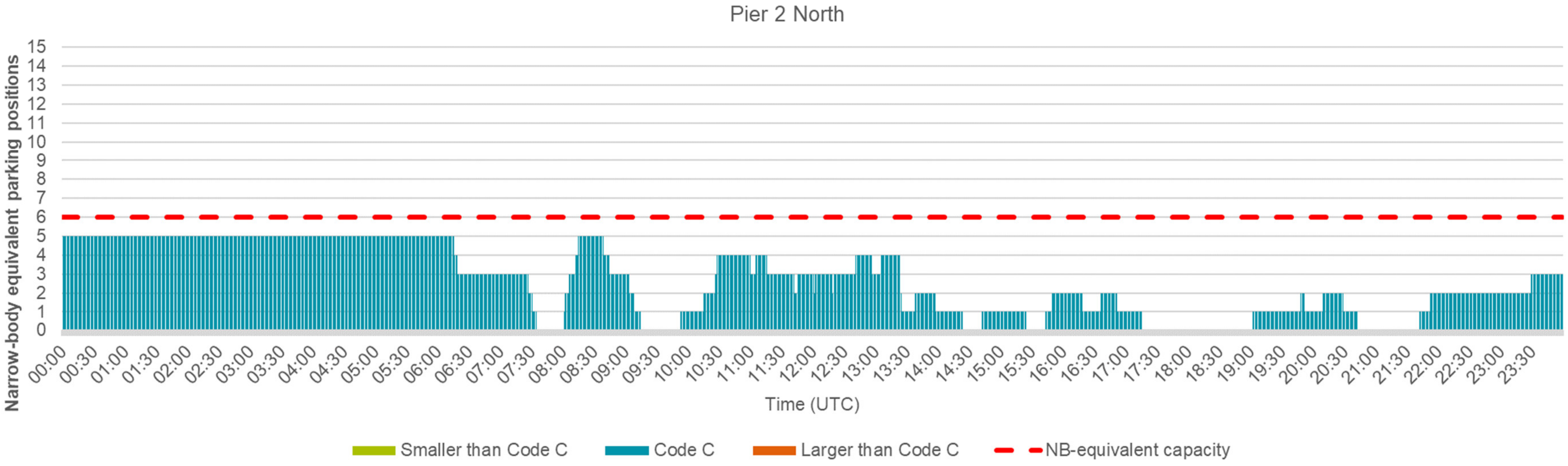
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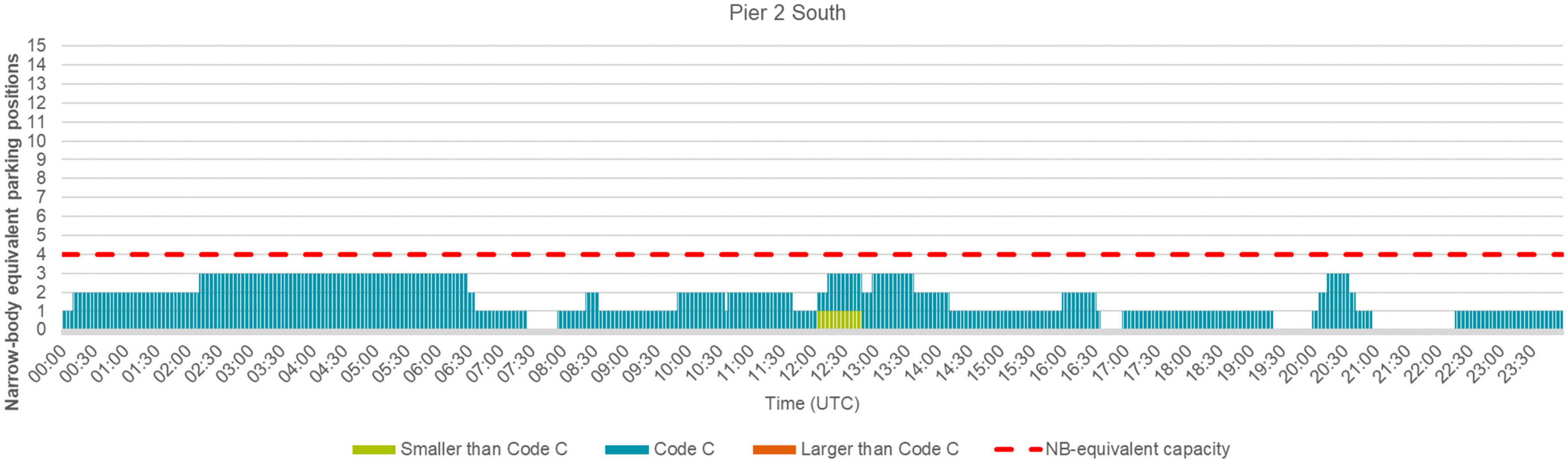
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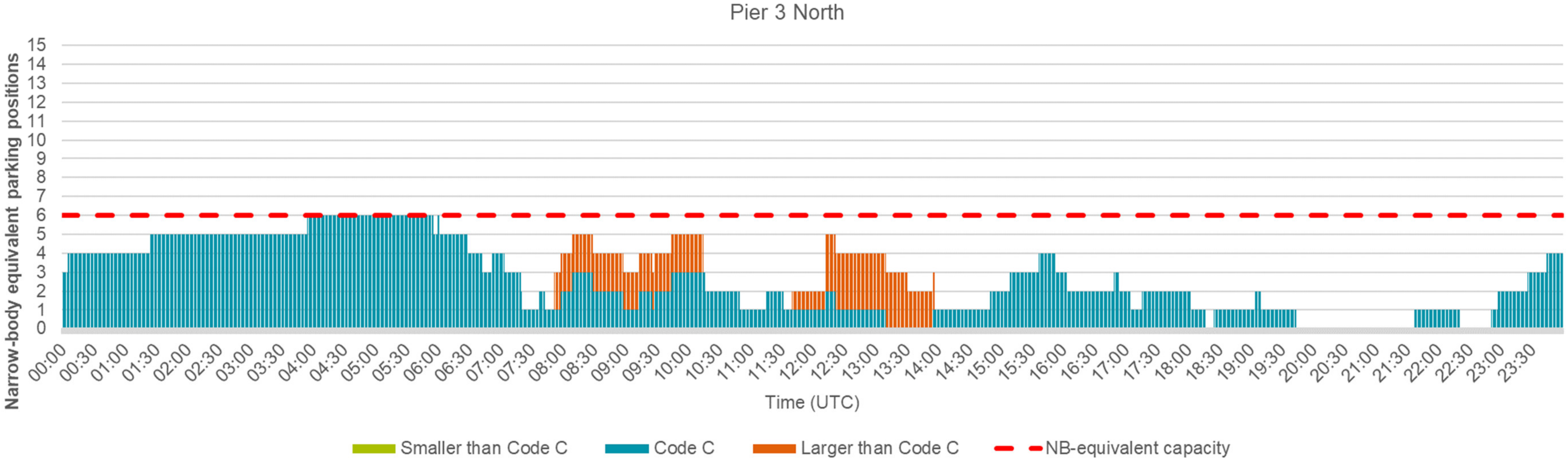
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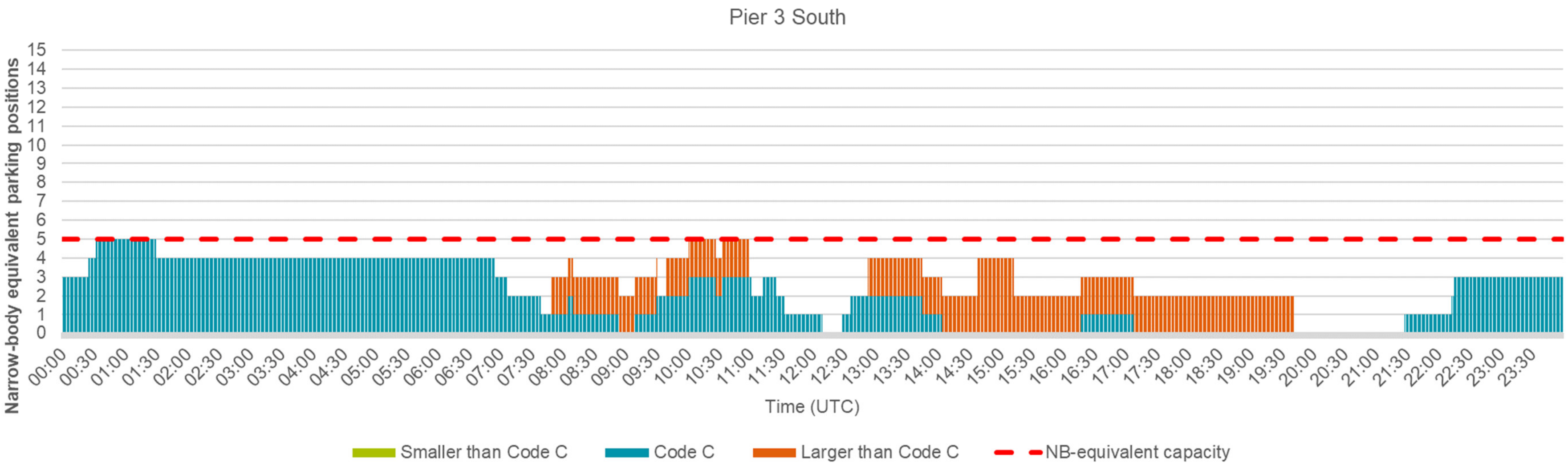
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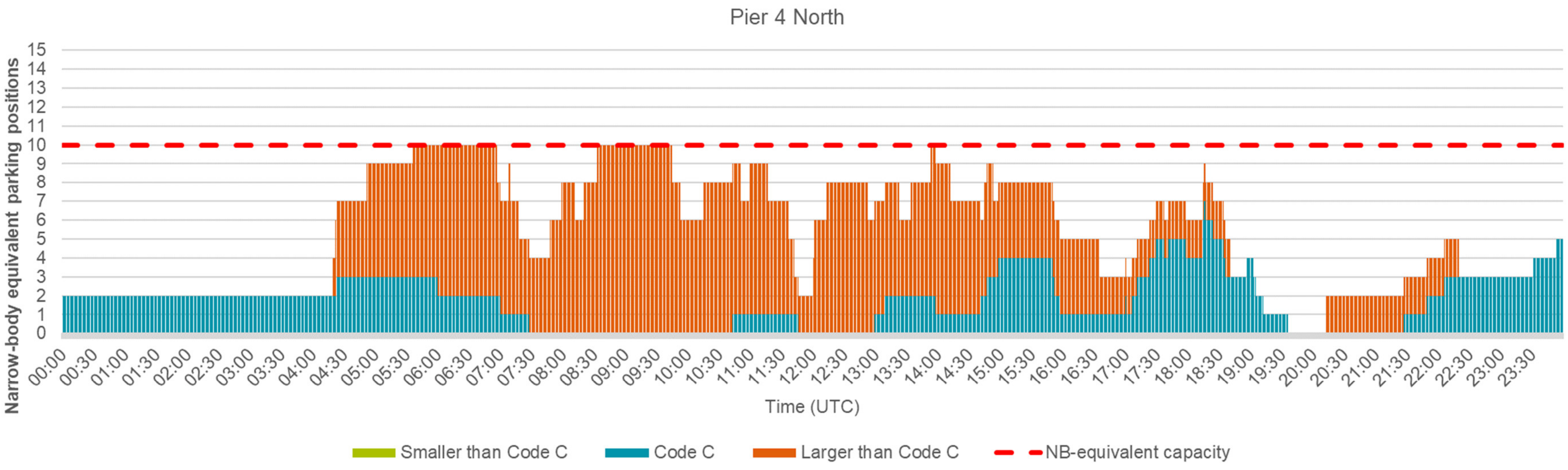
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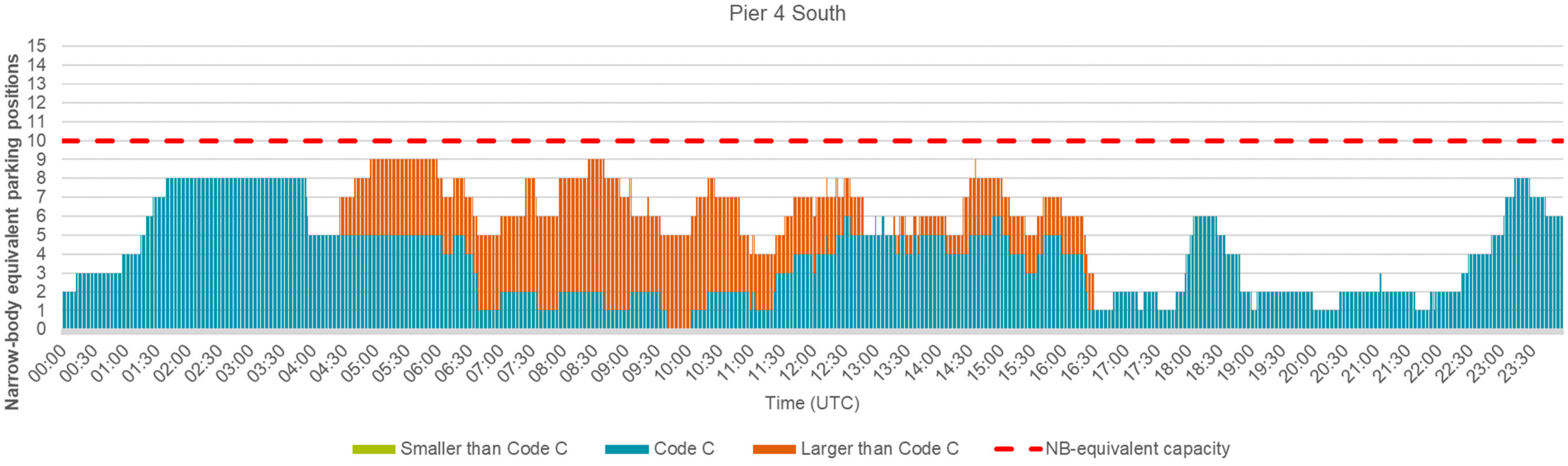
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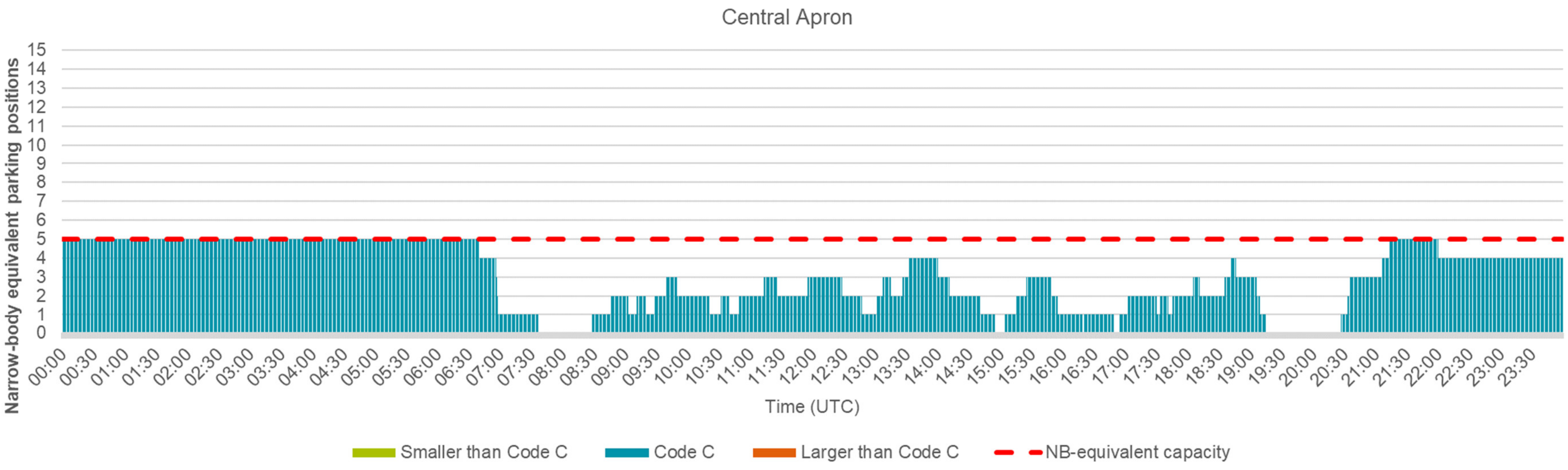
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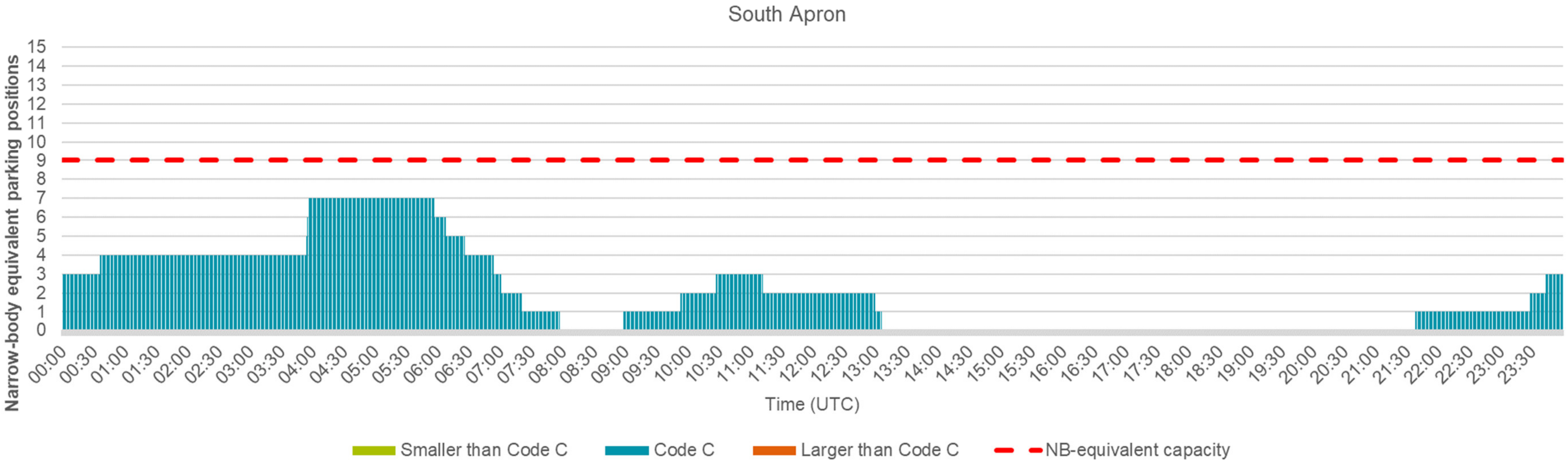
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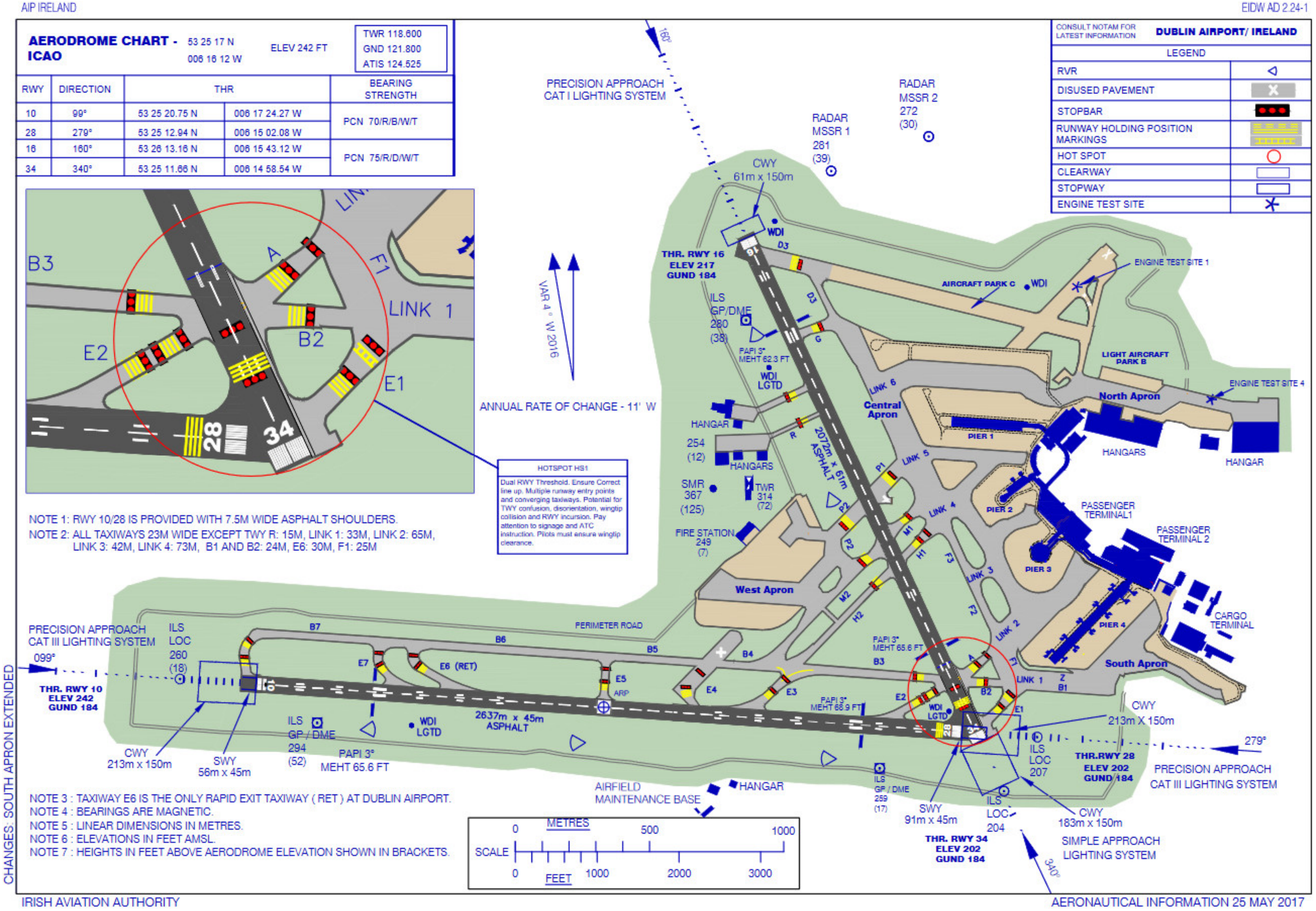
E Dublin Airport ground layout



AIP IRELAND

EIDW AD 2.24-1

AERODROME CHART - ICAO

53 25 17 N
006 16 12 W

ELEV 242 FT

TWR 118.600
GND 121.800
ATIS 124.525

RWY	DIRECTION	THR		BEARING STRENGTH
10	99°	53 25 20.75 N	006 17 24.27 W	PCN 70/R/B/W/T
28	279°	53 25 12.94 N	006 15 02.08 W	
16	160°	53 26 13.16 N	006 15 43.12 W	PCN 75/R/D/W/T
34	340°	53 25 11.66 N	006 14 58.54 W	

CONSULT NOTAM FOR LATEST INFORMATION

DUBLIN AIRPORT/ IRELAND

LEGEND	
RVR	◁
DISUSED PAVEMENT	✕
STOPBAR	●●●
RUNWAY HOLDING POSITION MARKINGS	▤
HOT SPOT	○
CLEARWAY	▭
STOPWAY	▭
ENGINE TEST SITE	✱

HOTSPOT HS1

Dual RWY Threshold. Ensure Correct line up. Multiple runway entry points and converging taxiways. Potential for TWY confusion, disorientation, wingtip collision and RWY incursion. Pay attention to signage and ATC instruction. Pilots must ensure wingtip clearance.

NOTE 1: RWY 10/28 IS PROVIDED WITH 7.5M WIDE ASPHALT SHOULDERS.
NOTE 2: ALL TAXIWAYS 23M WIDE EXCEPT TWY R: 15M, LINK 1: 33M, LINK 2: 65M, LINK 3: 42M, LINK 4: 73M, B1 AND B2: 24M, E6: 30M, F1: 25M

NOTE 3 : TAXIWAY E6 IS THE ONLY RAPID EXIT TAXIWAY (RET) AT DUBLIN AIRPORT.
NOTE 4 : BEARINGS ARE MAGNETIC.
NOTE 5 : LINEAR DIMENSIONS IN METRES.
NOTE 6 : ELEVATIONS IN FEET AMSL.
NOTE 7 : HEIGHTS IN FEET ABOVE AERODROME ELEVATION SHOWN IN BRACKETS.

ANNUAL RATE OF CHANGE - 11' W

CHANGES: SOUTH APRON EXTENDED

IRISH AVIATION AUTHORITY

AERONAUTICAL INFORMATION 25 MAY 2017

F Road networks and parking lots capacity

General

Road access to Dublin Airport consists of the following infrastructure:

- M50 and M1 from the city centre to the airport and continuing towards the UK border,
- M50 bypassing Dublin in the West and South and meeting the M1 just South-West of the airport,
- R132, which complements the road network around the airport,
- M1-R132 link allowing access to the airport from the M1.

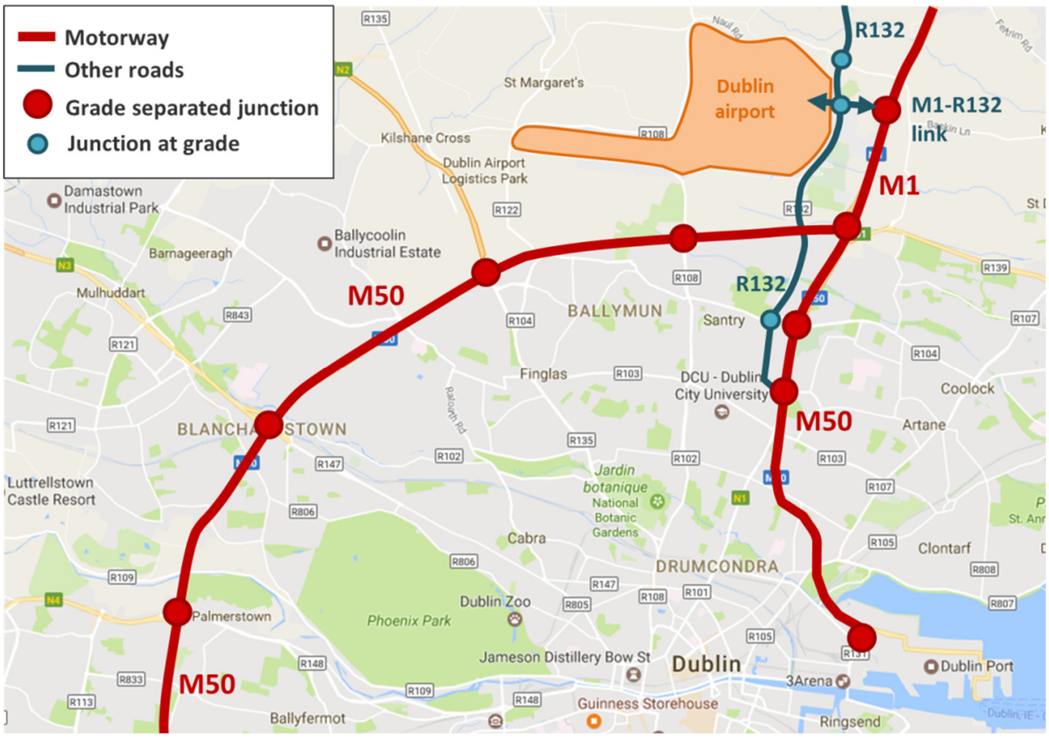


Figure 32: Map of the main access roads from Dublin to Dublin Airport

The main access route is from the M1 through a large roundabout with traffic lights from which traffic is distributed towards the different terminals and parking areas. To optimise capacity, slipways allow bypassing of the roundabout for three of the four left-turns. Inside the airport, flows are unidirectional to optimise capacity and traffic fluidity.

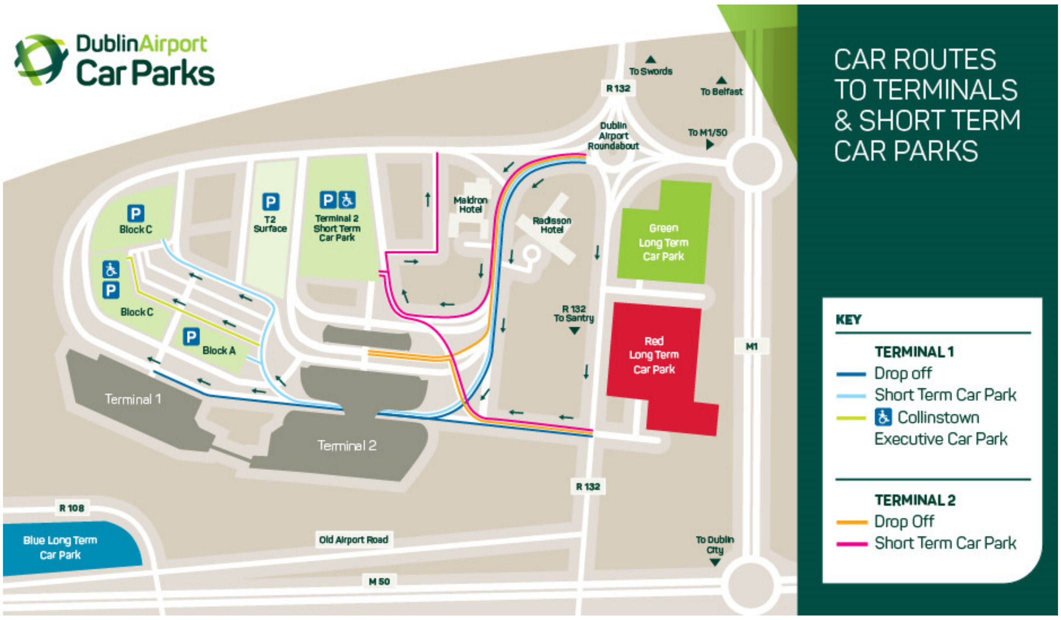


Figure 33: Map of the main roads and car parks within Dublin Airport

Three long term and four short term car parks are available at the airport for a total of 21,000 spaces. Long term car parks, representing 80% of spaces, are logically located further away from the airport and connected to terminals by shuttle bus. Red and Green long-term car parks are situated between the M1 and R132. The Blue long-term car park, along the M50 is the furthest away from the airport.

Duration	Name	Spaces
Long term	Express Red Long-Term Car Parking	7,000
	Express Green Long-Term Car Park	2,000
	Holiday Blue Long Term Car Parking	8,000
	Total long term	17,000
Short term	Short Term Car Park A	450
	Terminal 1 Short Term Car Park C	1,500
	Terminal 2 Multi-Storey Car Park	1,800
	Terminal 2 Short Term Car Park	270
	Total short term	4,020
Total		21,020

Table 17:Car park spaces in the main public car parks at Dublin Airport

The chart below compares the number of annual passengers to the number of parking space for 15 European airports similar to Dublin in their number of passengers. It reveals that Dublin is among the better equipped airports in terms of car parking space provision.

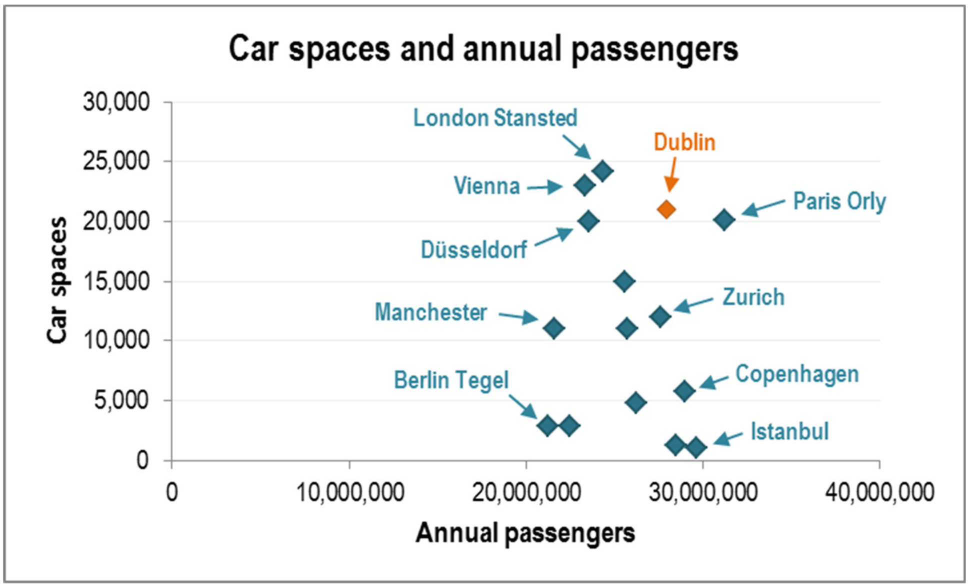


Figure 34: Benchmark of car park spaces and annual passengers

According to Google Maps, the airport can be reached by car from the city centre in around 15 minutes during off-peak hours and up to 50 minutes during peak hours. This access time appears to be in the lower end of access time to airports of similar sized European cities (see table below).

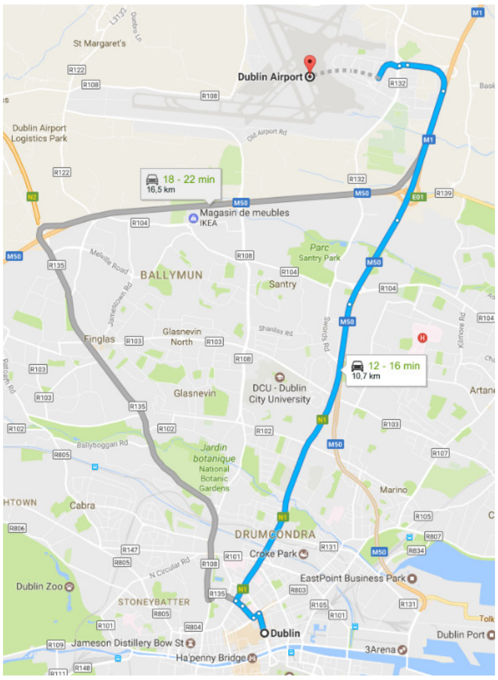
Access time during off-peak hours (12-18min)	**Access time during peak hours (18-50min)**
	

Figure 35: Road access times from Dublin Center to Dublin Airport

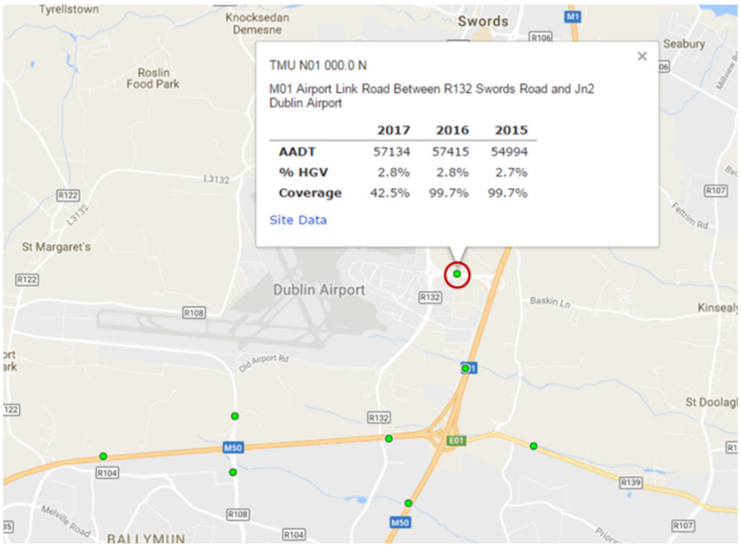
City	Zurich	Dublin	Oslo	Brussels	Glasgow	Lyon	Seville
Inhabitants in urban area (millions)	1.9	1.3	1.0	1.2	1.2	1.3	1.2
Passengers per year (millions)	30	28	26	22	9	9	4
Road distance to city centre (km)	11	11	50	15	17	29	12
Off-peak access time (average, min)	19	15	42	20	16	35	26
Peak hours access time (maximum, min)	35	50	65	60	50	65	40

Table 18:Benchmark of access times at some European airports

Annual traffic

Traffic count data on the road linking the M1 to the airport is available online from 2013 to May 2017[19]. This road constitutes the main, although not the only, access road to the airport and gives a good estimate of the number of vehicles accessing the airport. On average, over 57,000 vehicles are accessing the airport every day on that road. Although the website displays a decrease in road traffic from 57,400 vehicles per day in 2016 to 57,100 in 2017, this is only due to the effect of seasonality as the 2017 summer peak had not been taken into account.

Since there is an observed 3.8% road traffic increase over the first five months of 2017 compared to the same period in 2016, traffic on the access road is approaching an average of 59,800 vehicles per day in 2017.



TMU N01 000.0 N

M01 Airport Link Road Between R132 Swords Road and Jn2 Dublin Airport

	2017	2016	2015
AADT	57134	57415	54994
% HGV	2.8%	2.8%	2.7%
Coverage	42.5%	99.7%	99.7%

Site Data

Figure 36: Road traffic counts

This rise in road traffic is linked to strong growth in air passengers at Dublin Airport which generates road traffic, caused by passengers (accessing the airport in their own car, being

---

[19] Transport Infrastructure Ireland (TII), Traffic Data Site

dropped off by someone else, or riding taxis and buses) and also employees working at the airport.

After a decline in the number of passengers following the economic downturn, growth has been increasing in the last two years with a new record number of passengers at Dublin Airport in 2016 (27.9 million).

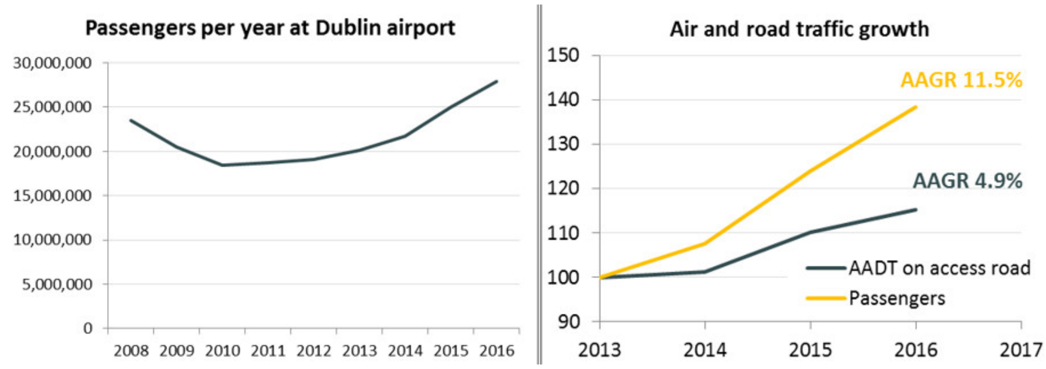


Figure 37: Air traffic and road traffic comparison at Dublin Airport

However, road traffic on the access road to the airport appears to be growing at a much lower rate than air traffic. Comparing passenger growth and road traffic with the help of indices (see chart above) much lower growth rates for road traffic than for airport passenger traffic are being experienced, with average annual growth rates of 4.9% and 11.5% respectively. This suggests a road traffic to airport passenger traffic elasticity of around 0.4, meaning a 4% increase in road traffic for a 10% increase in air passengers.

This decoupling is probably due to the continuing impact of modal shift from cars to buses which was already been observed in the 2001 survey[20] and the 2011 survey[21] conducted via face to face interviews with air passengers at departure gates. Those two surveys reveal a major modal shift in ten years with cars losing 14% modal share to buses and taxis.

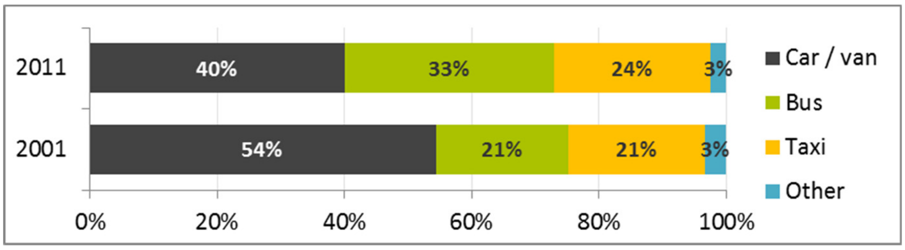


Figure 38: Access mode distribution for Dublin Airport

Hence, although road capacity remains an important issue due to the relatively high growth rates of road traffic, the increasing use of public transport seems to be helping by delaying capacity constraints. Indeed, although a bus uses more than twice the road capacity of a car (since it is larger and slower), it can carry over ten times as many passengers. Buses do remain a low capacity public transport solution which is dependent

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[20] National Transport Authority, DTO Survey at Dublin Airport 2001, 2012 https://www.nationaltransport.ie/wp-content/uploads/2012/04/DTO_Airport_Survey_2001.pdf

[21] National Transport Authority, Survey at Dublin Airport 2011, 2012 https://www.nationaltransport.ie/wp-content/uploads/2012/04/NTA-Survey-at-Dublin-Airport-2011211.pdf

on road traffic conditions to arrive on time. The opening of the Metro North project is planned to be completed by 2026 or 2027. With a 5% annual growth rate, road traffic could increase by up to 60% by the time metro services are introduced.

Traffic seasonality

Due to the very seasonal nature of air traffic, road traffic varies greatly during the year. Traffic is above the average annual daily traffic (AADT) from April to October with peaks in June and September, probably corresponding to a combination of higher numbers of business trips and holidays makers (July and August appear to show slightly lower numbers during peak school vacation time). January is the month with the lowest road traffic observed on the access road to the airport.

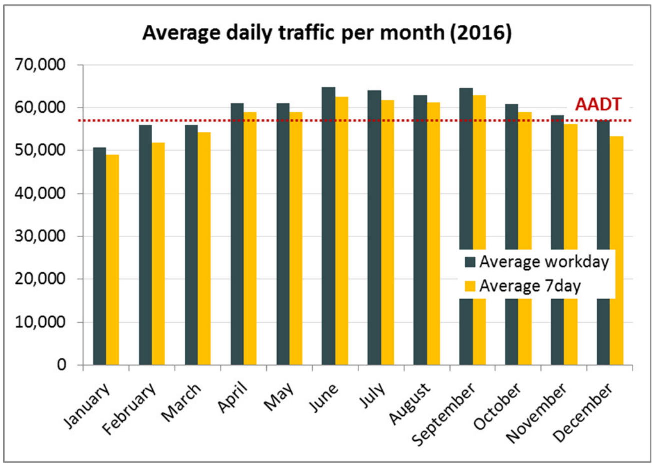


Figure 39: Road traffic data analysis by month

Traffic counts also reveal variations during the week. Traffic is most prevalent on Fridays and, to a lesser extent, Mondays.

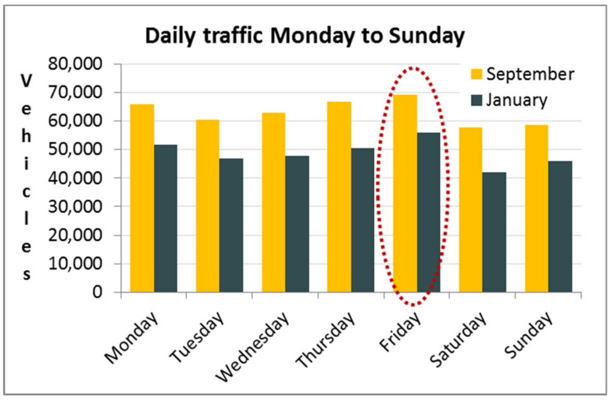


Figure 40: Road traffic data analysis by day

The busiest day of 2016 was Friday 16th September with 69,100 vehicles daily, whereas the busiest hour of the year was Monday September 26th between 10 and 11am with 4,300 vehicles within an hour (64% of which were headed towards the airport) and 65,900 vehicles during the whole day.

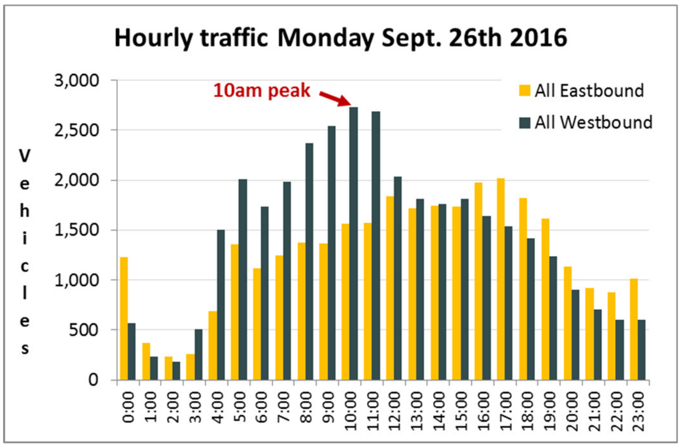


Figure 41: Road traffic data analysis by hour

An alternative busy day identified in the analysis of air traffic was Thursday 23rd June with 66,800 vehicles recorded during the entire day and an hourly two-way peak of 4,000 vehicles at 4pm.

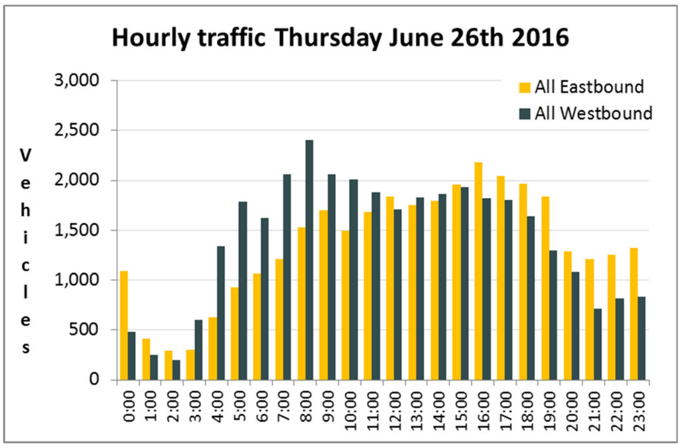


Figure 42: Road traffic data analysis by direction

However, some degree of congestion is unavoidable for those extreme days of traffic and road capacity should typically be designed to accommodate traffic during an average week.

Remaining capacity on the road network

Although the capacity of a road network is mostly determined by the performance of its junctions, it was not possible to evaluate their capacity due to the lack of directional traffic data received. However, linear capacity is also an important indicator. It corresponds to the number of vehicles that can drive on a road section in the absence of a junction. We can estimate the remaining linear capacity for the main access roads on the basis of Transport Infrastructure Ireland traffic data. For each road section we chose to analyse the peak hour with the highest traffic figure for an average workday traffic drawn from October 2016. As shown above, the month of October is slightly higher than, but close to, the annual average daily traffic towards the airport. This allows us to avoid extreme traffic values observed for September or June.

On the basis of a capacity of 2,000 vehicles per lane on motorways and 1,000 vehicles per direction on the R108 - which are commonly accepted values for such infrastructures, we compare road capacity to the highest hourly traffic value observed during October 2016 workdays. Free capacity, indicated by the percentages on the map below, is the remaining capacity not yet used by traffic. Hence, the lower the percentage value the more limited the remaining capacity and the higher the risk of traffic jams.

It appears that capacity is already close to saturation during the peak hours on the road network around the airport, with remaining capacity usually below 30%. Such highly saturated flows would be expected to generate significant delays and conflict points at the junctions.

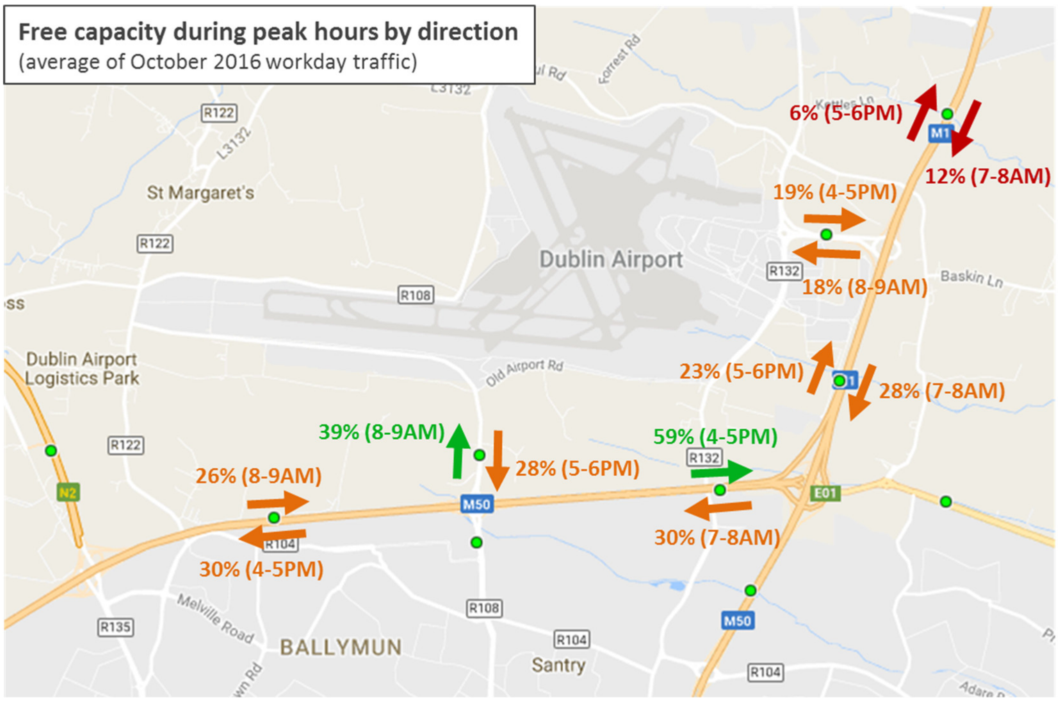


Figure 43: Estimation of free capacity on the main roads

Current traffic conditions

Google records the state of traffic on most roads using data from mobile phone users and displays them in Google Maps. Experience has shown that this data tends to be quite accurate and is a useful tool to identify congestion.

According to Google Maps, current traffic conditions appear to be satisfactory, despite some queues during peak hours, most notably on Fridays. The main limit to capacity appears to be the roundabout at the airport's entrance between the R132 and the road towards the M1. Traffic coming from the long-term parking (between M1 and R132 with 9,000 parking spaces) appears to have difficulties entering the roundabout from the South during Friday afternoons.

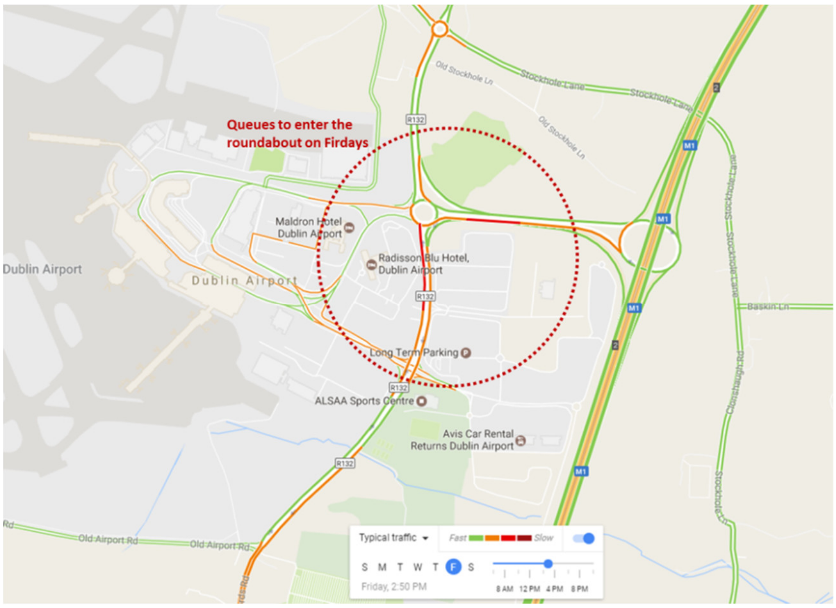


Figure 44: Map of traffic conditions

Traffic conditions on the M50 and M1 between Dublin and the airport appear generally acceptable with no congestion observed by Google during Friday afternoons. This is not the case on the M50 West of the interchange with the M1 where some congestion appears, notably on the M50 section between the junction with the M1 and R135. This seems to be due to some congestion on the slipways at the interchanges.

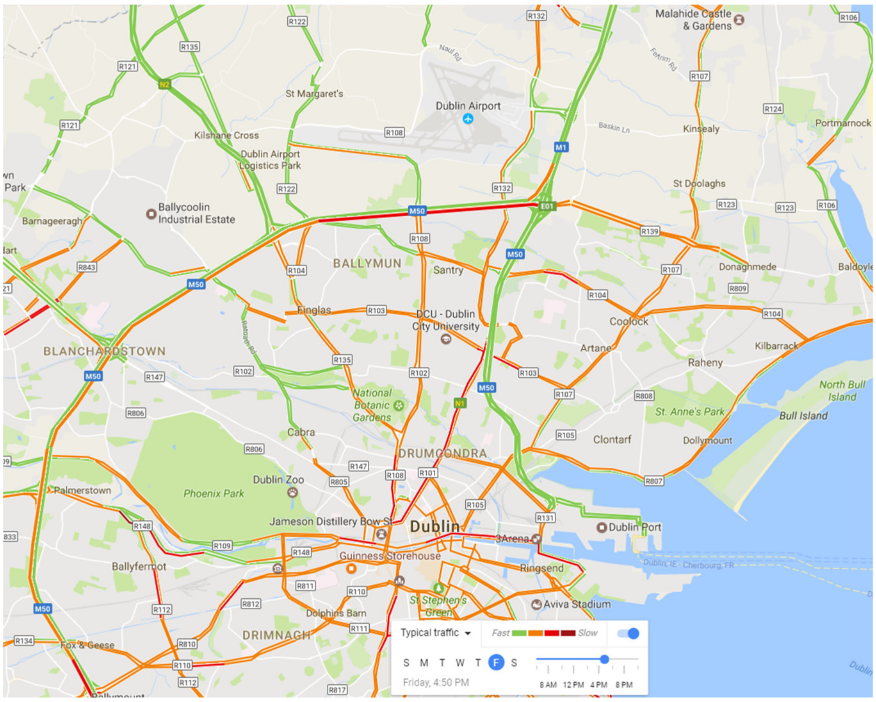


Figure 45: Map of traffic conditions around Dublin

Considering the potential rate of traffic growth, heavy congestion is likely to appear soon on access routes to the airport if solutions are not found to increase the network's capacity.

Potential solutions

Our analysis of the road network has shown that the roundabout on the R132 at the airport entrance is currently the main cause for concern. Although it is already designed to maximise capacity, it creates a bottleneck since all vehicles must drive through it to arrive to or leave the airport. Generally speaking, creating new access routes would need to redirect traffic away from this roundabout and towards alternatives. Three potential solutions to increase capacity have been identified to do so:

- Creating a new exit from M1 directly to the long term parking area; however this does not seem possible for safety reasons due to the proximity of the other 2 interchanges (M1/M50 and M1 to the airport)
- Opening a direct access to the long term parking area before the roundabout; this seems possible at first glance but requires reorganization of the parking area
- Developing access from the old airport road; this seems feasible but would require a road upgrade.

This analysis has been conducted with a limited amount data. A full road capacity analysis is considered necessary to analyse the current traffic state and evaluate the potential solutions.

Taking in to consideration the the rapid traffic growth (around 5% per year) and the required time for implementation, it is recommended that a detailed study (involving the use of a bespoke traffic assignment model) should be conducted as soon as possible to assess the residual capacity and to identify the potential and feasibility of proposed future solutions.

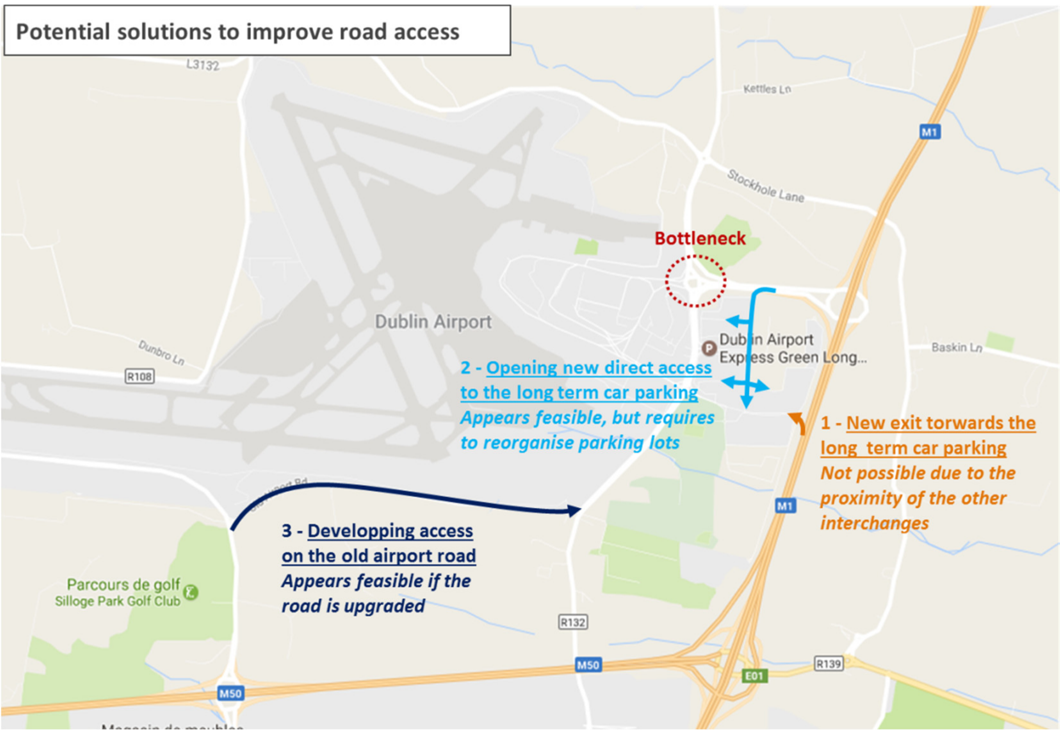


Figure 46: Proposal for road network improvement

The implementation of the Metro North project would of course offer a welcomed non-road based alternative.

Summary

Dublin Airport benefits from good road access due to its proximity to two motorways. From the M1 the airport can be accessed through a short road leading to a large roundabout at the airport entrance. An extensive parking offering is available near the airport with long term parking lots located alongside the motorways.

Although the modal share of private vehicles has dropped in the decade up to 2011, it is still the main mode of access to the airport (40% of air passengers in 2011). Due to the very high growth in air traffic in recent years, road traffic has been increasing fast in real terms on the access road to the airport.

A summary analysis of the network capacity reveals that the residual capacity is limited due to the fact that almost all of the traffic is required to route through the roundabout at the airport's entrance. This raises the question of the ability of the current road infrastructure to absorb the currently observed road traffic growth. Even though the future Metro North to the airport will satisfy an apparent demand for public transport solutions and relieve the road network, a comprehensive traffic study is recommended to to verify the residual road capacity and to evaluate the impact and benefit of proposed solutions.

G Baggage handling system capacity

G.1 Terminal 1

G.1.1 Departure Check-in

The T1 check-in capacity is not causing baggage capacity issues according to the daa. There is no declared capacity limitation or advisory flag for this process.

This section aims to present the check-in facilities and to compare the estimated capacity to the current desk demand and bag volumes to assess this view from the perspective of the baggage handling system.

Check-in Hall description

The T1 check-in hall is composed of the main ground level hall with check-in islands 3-13 and the additional hall Area 14 in the basement level. Traditional desks are used for bag drop-off; there is no automated drop-off system. In addition, there is 1 desk for out-of-gauge (OOG) bags in the main hall, and 1 desk in the basement hall.

Analysis of the T1 check-in desk allocation during peaks demonstrates that more flights could be accepted in the check-in hall. The following section assess whether the collecting, screening and sorting systems could accept more bags.

Check-in theoretical capacity and Design Day bag volume peak demand

The tables below show the theoretical design capacities of the different areas of T1 and the actual peak flows from the Design Day 2016 statistics.

The assumptions used for this calculation are:

- 1 minute to check one bag (daa has suggested different, quicker processing times, 60 seconds is conservative)
- Explosive Detection System (EDS) throughput: 1,200 bags per hour, which is common for standard 2 EDS facilities and conservative for a CT-EDS (typically around 1,400 bags per hour). daa has estimated the practical throughput to be 740 bags per hour, although this appears low given the performance of the common EDS machines. Calculations using both sets of throughput figures are shown in the table below.

South Area analysis

Check-in Areas	8	7	6	5	4	3
Number of Check-in counters	10	10	9	9	9	9
Bag Check-in processing time (sec)	60	60	60	60	60	60
Theoretical Nb/bag/CIC/h	60	60	60	60	60	60
Area total bags/h	600	600	540	540	540	540
Maximum Check-in theoretical throughput	1,200		1,080		1,080	
Max 60-min injected bags per combined area during the Design Day	158	164	97	159	116	100
	274		244		183	
	411				183	
Levels 1/2 screening machines	Connected to EDS 4 & EDS 3 with bi-directional distribution				Connected to EDS 1 & EDS 2 with bi-directional distribution	
Maximum EDS theoretical throughput	1,200 bags per hour per machine > 2400 bags per hour				1,200 bags per hour per machine > 2,400 bags per hour	
EDS declared practical throughput	740 bags per hour > 1,480 bags per hour				740 bags per hour per machine > 1,480 bags per hour	

Table 19: Capacity assessment of T1 BHS – South Area

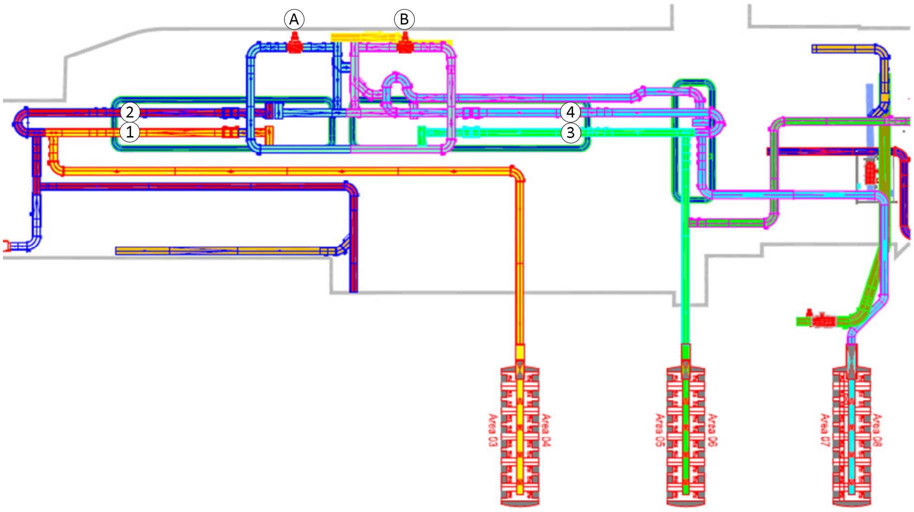


Figure 47: Illustration of southern section of the Terminal 1 baggage handling installation

Conclusion about T1 South Area check-in capacities

During the peak hour of the S16 Design Day, around 519 bags were processed, which is well below the declared or theoretical capacity.

North area analysis

Check-in Areas	13	12	11	10	9
Number of Check-in counters	16	15	15	10	10
Bag Check-in processing time (sec)	60	60	60	60	60
Theoretical Nb/bag/CIC/h	60	60	60	60	60
Area total bags/h	960	900	900	600	600
Maximum Check-in theoretical throughput	960	1,800		1,200	
Max 60-min injected bags per combined area during the Design Day	485	0	156	102	149
	485	156		231	
	485		375		
Levels 1/2 screening machines	Connected to EDS 8 & EDS 7 with bi-directional distribution		Connected to EDS 5 & EDS 6 with bi-directional distribution		
Maximum EDS theoretical throughput	1,200 bags per hour per machine > 2,400bags per hour		1200 bags per hour per machine > 2,400bags per hour		
EDS declared practical throughput	740 bags per hour per machine > 1,480 bags per hour		740 bags per hour per machine > 1,480 bags per hour		

Table 20: Capacity assessment of T1 BHS – North Area

Note: The flow rate of 740 bags per hour declared by the daa appears to be very low according to the rated performance of the common EDS machines.

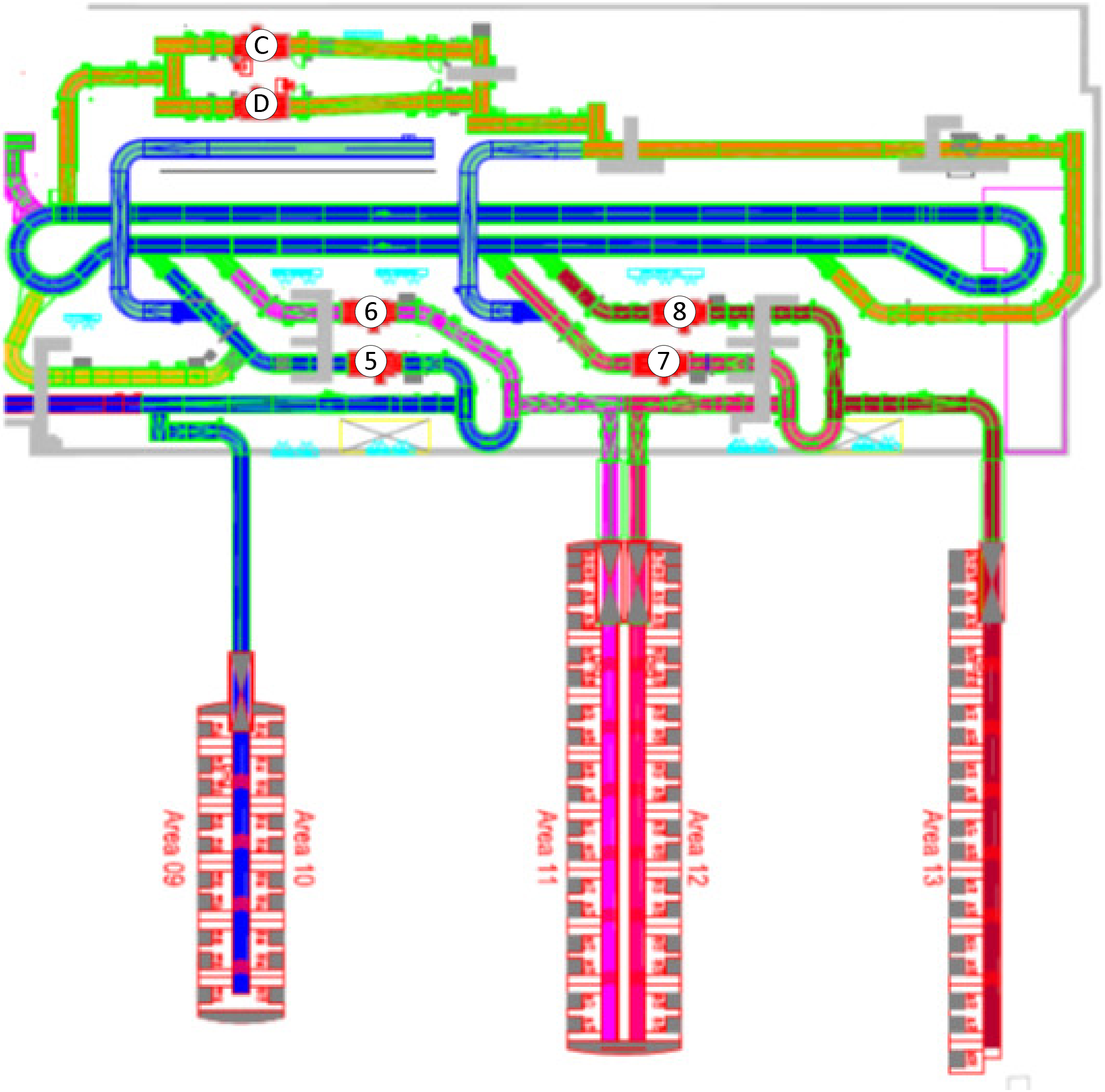


Figure 48: Illustration of northern section of the Terminal 1 baggage handling installation

Conclusion about T1 North Area check-in capacities

During the S16 Design Day peak hour, 667 bags were handled in this area, which is well below the declared or theoretical capacity. However, local congestion has been reported when the short Area 13 collector belt leading to EDS 7/8 fills up and the flow of additional check-in additional bags from the Area 13 check-in desks is interrupted.

Area 14 analysis

Check-in Areas	14
Number of Check-in counters	24
Bag Check-in processing time (sec)	60
Theoretical Nb/bag/CIC/h	60
Area total bags/h	1,440
Maximum Check-in theoretical throughput	1,440
Max 60-min injected bags per combined area during the Design Day	0 – not in use
Levels 1/2 screening machines	Connected to EDS 11 & EDS 12 with bi-directional distribution
Maximum EDS theoretical throughput	1,200 bags per hour per machine > 2,400bags per hour
EDS declared practical throughput	740 bags per hour per machine > 1,480 bags per hour

Table 21: Capacity assessment of T1 BHS – Area 14

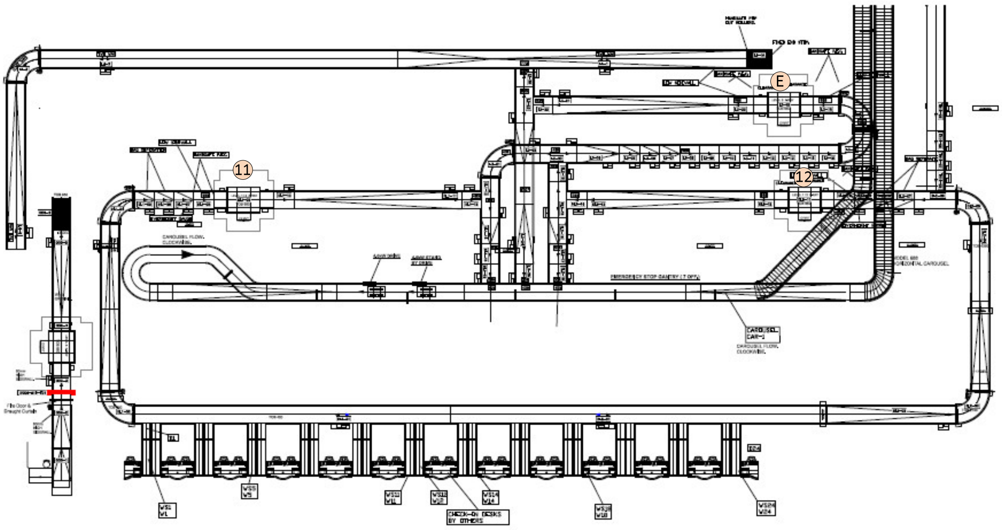


Figure 49: Illustration of Terminal 1 – Area 14 baggage handling installation

Conclusion about T1 Area 14 check-in capacities

Area 14 is generally not in use, but acts as reserve capacity available when civil works temporarily reduce the capacity within the T1 check-in hall. With a design capacity of 1,440 bags per hour and 2 EDS, this area provides a significant and independent back-up capacity.

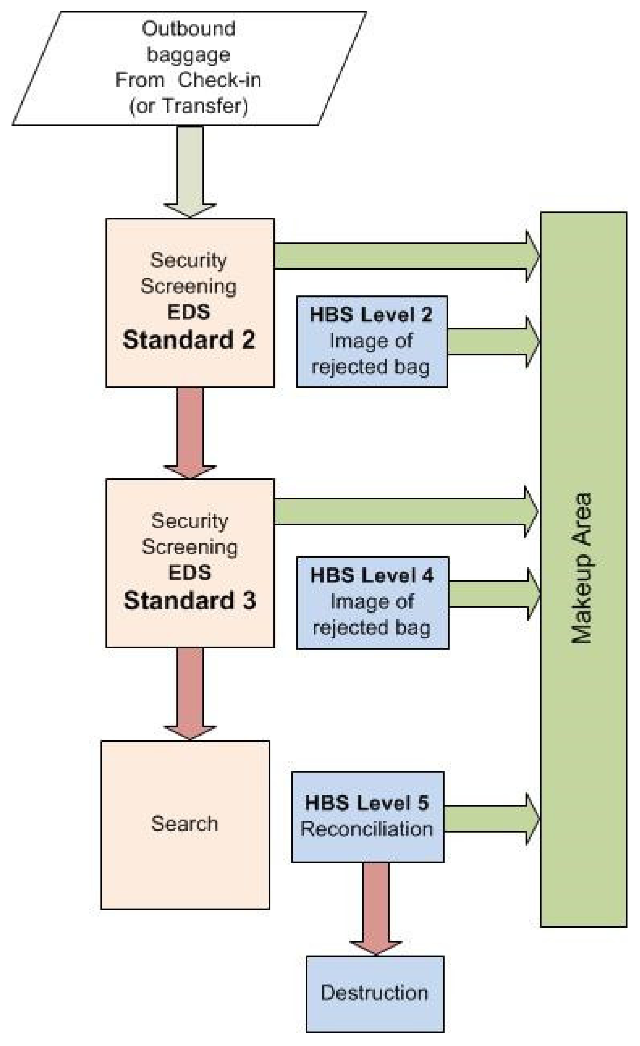
G.1.2 Hold bag Screening

Out-Of-Gauge baggage

The OOG bag screening is performed with an X-ray machine located on the departure level. OOG baggage reconciliation is made next to the machine.

In-gauge baggage

The in-gauge Hold Baggage Screening (HBS) is performed in compliance with the former European regulation, which is still in force until 2020.



Five levels of screening:

1) Level 1: diagnostic by the EDS
2) Level 2: Image of the unclear level 1 baggage checked by an operator. Time out 25 sec for south facility; on the sorter for north facility.
3) Level 3: diagnostic by the CT-EDS,
4) Level 4: Image of the uncleared level 1 baggage checked by an operator.
5) Level 5 : Reconciliation,

Figure 50: Schematic view of Hold baggage screening levels

The HBS facility includes:

- 10 EDS Standard 2 (machines: L3com MVT HR) for Level 1/2 screening:
    - For Areas 3-8: EDS 1-4
    - For Area 9-13: EDS 5-8
    - For Area 14: EDS 11&12
- 4 EDS Standard 3 (machines L3com MVT HR) for Levels 3/4 screening:
- For Areas 3-8, see Figure 31: CT-EDS A & B
- For Areas 9-13, see Figure 32: CT-EDS C & D
- For Area 14: CT-EDS E (there is no redundancy)

There is also an L3com MVT HR for out-of-gauge bags.

Conclusion on the HBS capacity

The T1 HBS installation matches the current requirements and provides sufficient capacity despite temporary congestion in the northern section (Areas 9-13) during morning peak waves.

G.1.3 Departure baggage handling and make-up systems

Make-up facilities

The T1 Make-up is composed of:

Make-up area	Details	Main airlines
1 tilt tray sorter	Approx. 136m length and 114 trays (pitch=1.2m) to serve 53 chutes, Each chute can receive up to 25 bags	Ryanair
Carousel 1	operable length: 66m	Ethiopian, Turkish, British Airways
Carousel 2	operable length: 70m	Lufthansa, SAS
Carousel 3	operable length: 46m	CityJet, Flybe

Table 22: Description of T1 Make-up area

The 53 make-up chutes can manage approximately 50 dollies: this capacity is sufficient to handle the number of bags. However, the chute allocation requirement (2 chutes per departing flight) requires a larger number of chutes to serve the first morning peak. In the first morning departure peak, Ryanair flights require up to 48 chutes of the 53 available. Saturation of the sorter has therefore been reported and the manoeuvring of vehicles within the bag sorting hall around the chutes is difficult due to the number of simultaneous operations and the limited hall size.

Carousels 1, 2 and 3 in the southern section provide sufficient capacity to serve the allocated flights from the less frequent airlines. The 182m operational length of the makeup carousel can manage ~72 dollies or ULD, which is considered more than sufficient to manage the bag flow.

In the current situation, an increase in the number of flights allocated to the northern section would increase the saturation level in the sorting hall. However, in the absence of efficient bag load transfer between both northern and southern sections of the T1 installation, there is no obvious solution to handle more flights, except through the optimisation of operations.

Handling of transfer bags

There are 3 injection points for transfer baggage. However, their location and the space available around the belt, in addition to the stand-alone screening system, are not favourable for operations. An increase in the number of transfer bags will require modification of these systems.

G.1.4 Arrival Delivery system

The baggage claim hall in T1 is a large hall with a total of 10 belts. As demonstrated above the capacity of the baggage claim hall to serve the current peaks is sufficient.

Description and theoretical capacity

The T1 arrival BHS is composed of:

- “In gauge bags”, 9 carousels
- South area (breakdown in the baggage handling airside hall)
- North area (breakdown in the basement baggage handling hall

The delivery belts for baggage handlers are short, but sufficient in most of cases, and the South Area delivery zone is suffering from a lack of space for manoeuvring and circulating.

Belt number	Operable length	North / South bag drop hall	Remarks
Carousel 1	25m	South area	Not used during Design Day
Carousel 2	63m	South area	
Carousel 3	40m	South area	
Carousel 4	40m	South area	
Carousel 5	56m	South area	
Carousel 6	50m	North area	Not used during Design Day
Carousel 7	37m	North area	Not used during Design Day
Carousel 8	37m	North area	
Carousel 9	37m	North area	
Carousel 10	37m	North area	

Table 23: T1 Baggage delivery resources

For OOG bags there is a manual delivery process.

Bag volumes and Belt occupancy during the design day

From the departure baggage counts, it is observed that the number of bags per passenger is generally low (about 0.4 bags per passenger in T1 during the Design Day). Therefore, the operable carousel lengths, from 37m to 63m, are in general sufficient to serve the common Code C flights of about 150-180 passengers. Only two carousels, #1 and #4 would serve wide-body flights or particular narrow-body flights with a larger number of bags.

The belt occupancy chart for the 2016 Design Day is shown in the previous section. With a reclaim area of more than 160m to the north and 190m to the south, the reclaim BHS is suitably sized to handle the current peak periods.

G.1.5 Transfer baggage

Terminal 1 airlines and flights are currently generating a limited number of transfer bags. Interline agreements between Aer Lingus and other airlines are however in place and the absence of inter-connecting transport systems between the T1 and T2 baggage areas is a subject of concern. These bags have to be sorted and transported manually upon arrival, from one area to the other.

Injection belts are located in the middle of T1 make-up area after bags are screened through a stand-alone EDS.

Should a T1 airline consider connecting flights via Dublin Airport, then it would not be possible to handle transfer bag volumes with the current facilities and systems.

G.2 Terminal 2

G.1.6 Departure Check-in

The T2 check-in capacity is a subject of concern since there is an advisory flag for this process. Desk demand from each T2 airline is higher in peaks than the existing resources. This section aims to present the check-in facilities and to compare the estimated capacity to the bag volumes from the perspective of the baggage handling system.

An additional feature of T2 is the US Customs and Border Protection (CBP) process, which requires that all "CBP-flight" hold bags have to be screened in accordance with the US Transportation Security Administration (TSA) procedures within the T2 baggage screening systems.

Check-in hall description

The T2 BHS is composed of 2 check-in islands on the departure level, with 28 desks in each group, and 2 out-of-gauge desks. These desks are collecting bags to be handled in a fully-automated 100%-screening hold baggage screening and sorting system.

The analysis of T2 check-in desk allocation during peak periods demonstrates that there are not enough desks to meet current airline requirements. The following section assess whether the collecting, screening and sorting systems could independently accept more bags.

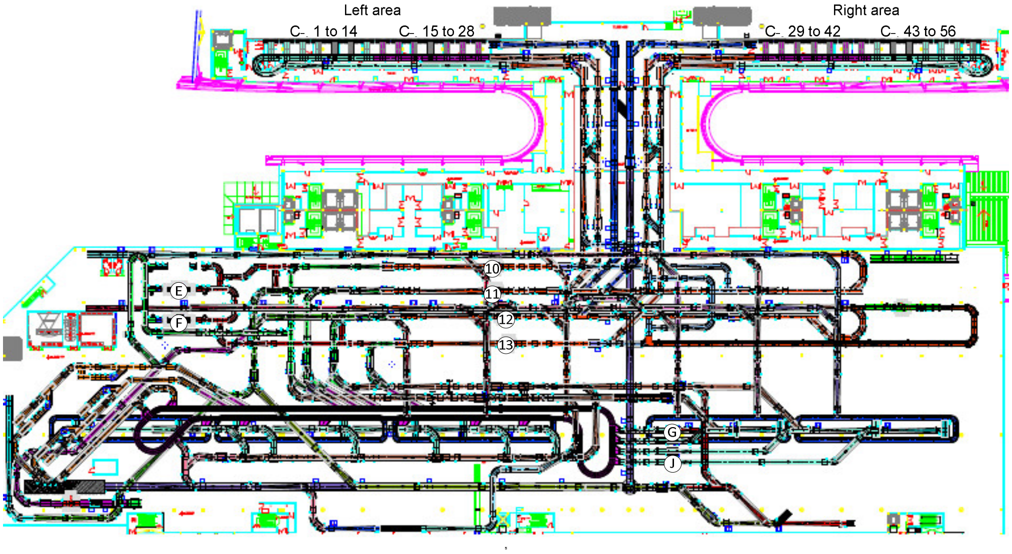


Figure 51: Illustration of Terminal 2 baggage handling installation

Check-in theoretical capacity and Design Day bag volume peak demand

The tables below show the design capacities of the different areas of T2 and the actual peak flows from the 2016 Design Day statistics. The assumptions used for this calculation are the same than for T1.

Check-in Areas	1-14	15-28	29-42	43-56
Airlines	Aer Lingus		American, Delta, US, Emirates Airlines	
Number of Check-in counters	14	14	14	14
Bag Check-in processing time (sec)	60	60	60	60
Theoretical Nb/bag/CIC/h	60	60	60	60
Area total bags/h	840	840	840	840
Maximum Check-in theoretical throughput	1,680		1,680	
Max 60-min injected bags per combined area during the Design Day	626		901	
	1,199			
Transfer bags during the Design Day	About 2,000/day			
Levels 1/2 screening machines	Connected to 4 EDS machines with multi-directional distribution and automated work share			
Maximum EDS theoretical throughput	1,200 bags per hour per machine > 4,800 bags per hour			
EDS declared practical throughput	740 bags per hour per machine > 2,560 per hour			

Table 24: Capacity assessment of T2 BHS

During the peak hour, 1,199 bags were handled in this area (in addition to a few hundred transfer bags), which is well below the declared or theoretical capacity. Sufficient capacity remains available to provide redundancy.

Desk demand during the Design Day

As described above, there is a concern about the number of check-in counters in T2. Even with the current incentives to use self-service kiosks to check-in and then to convert check-in desks into drop-off desks, the demand from the various airlines is not fully satisfied. These full-service carriers open between 4 and 8 desks per flight to differentiate the services between passengers (first, business, premium or economy classes). The pooling with T1 check-in resources is not easy to perform since flights going to the US need to use T2 screening system while Aer Lingus departure waves generate enough originating passengers to occupy half of the check-in hall.

T2 check-in resources are already included in the coordination parameters as a soft constraint, an advisory flag system has been implemented to optimise check-in allocation. The capacity shortage is in the number of desks, not in the capacity of collecting and screening hold bags.

G.1.7 Hold bag Screening (HBS)

Out-Of-Gauge

The OOG bag screening is performed with 2 X-ray machines located on the departure level close behind two OOG check-in desks.

In-gauge bags

The in-gauge HBS is undertaken on the same principle as T1.

The HBS facility includes:

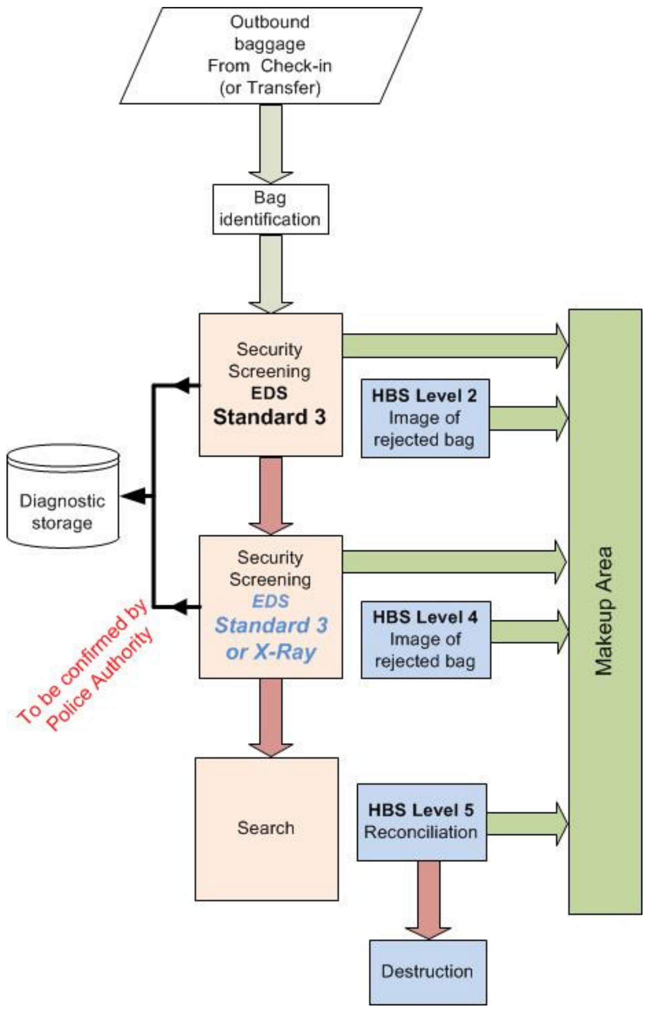
- 4 EDS Standard 2 (L3com MVT HR): EDS 10-13
- 2 EDS Standard 3 (Examiner 3DX9000) and a reservation for a third device: CT-EDS E&F
- 1 L3com PX160 for out-of-gauge.
- Special HBS radiation detection for USA-outgoing bags: see devices G to J.

Conclusion on the HBS capacity

The T2 HBS installation matches the current requirements and provides sufficient capacity. The redundancy of the in-line screening system is optimal.

Hold bag screening: Regulation evolution

For both T1 and T2 installations, the in-gauge HBS is performed in compliance with the former European regulation, currently in force until 2020. However, after 2020, the standard-2 EDS must be replaced by standard-3 CT-EDS to remain compliant.



Bags Identification by reading the bag tag

1) Level 1: diagnostic by the CT-EDS,
2) Level 2: Image 2D of the unclear level 1 bag checked by an operator, time out 40 sec, on the sorter for north facility,
3) Level 3: diagnostic by a screening device
4) Level 4: 3D Image of the unclear level 3 bag checked by an operator,
5) Level 5: Reconciliation

Figure 52: Schematic view of Hold baggage screening levels after 2020 Regulation

In Terminal 1, the replacement of Standard-2 EDS by Standard-3 CT-EDS will create complex works, during operations, in the limited hold bag screening area. This will be a challenge in future years as these new devices are longer and heavier, and the mezzanine location of the current devices will no longer be appropriate.

The T2 HBS system is currently equipped with Level 1/2 L3com MVT-HR devices whose theoretical flow rate is around 1,200 bags per hour. The replacement of these Standard-2 EDS by Standard-3 CT-EDS to respect European regulations will be possible. These new CT-EDS, although longer and heavier, have a similar or even better flow rate capacity. Attention will have to be paid to the structures, access and maintenance facilities.

Performance

The overall performance of the HBSs are not jeopardised by the modification of the regulation, at least for Level 1/2 screening.

Feedback from experience on the installation of CT-EDS on HBS Levels 1/2 shows that around 4% of the bag flow is declared unclear at level 2 and sent to level 3. For each HBS, the theoretical number of rejected bags is the following:

Terminal	Design Capacity	Bags to L3
T1 south	3,360 * 4%	135 bags
T1 north	3,960 * 4%	158 bags
T1 area 14	1,440 * 4%	58 bags
T2	3,360 * 4%	135 bags

Table 25: Capacity assessment of T2 BHS

The capacity to handle Levels 3/4 bag flows needs to be verified. The figures show that, to achieve the overall throughput, the level 3 and 4 control processes should consider the installation of a complementary scanner, reconciliation and/or hand search.

The first option is preferable but the choice of the scanner must be approved by the appropriate regulatory authority. The layout must be submitted to the Authority for approval as soon as possible in the modification process. Nevertheless, the European Civil Aviation Conference (ECAC) tends to consider that manual search is the most efficient process. In the future, the rate of compulsory hand search could be imposed (up to 20%). This will increase the area requirement of the reconciliation rooms and the routing of the passengers to reconciliation.

Level 2 time out

The time-out decision time is the time given to the level 2 operator to take the decision to accept or reject a bag rejected at level 1. Due to mechanical constraints, the current time-out is the following:

Terminal	Conveyor length	Conveyor speed	Time out
T1 south	12m	0.5 m/s	24s
T1 north	On sorter		Limited by software
T1 area 14	13m	0.5 m/s	26s
T2	21m	0.5 m/s	42s

Table 26: Hold baggage screening time-out analysis

This time out is acceptable for standard 2 EDS. The experience shows that for CT-EDS, it is between 30 and 40s. Due to mechanical constraints, the short time-out on T1 south and T1 area 14 could lead to an increased number of rejected bags to level 3 and therefore cause some congestion on the reconciliation area. This disadvantage can be avoided by using certain CT-EDSs having 2D and 3D imaging. The process will have to be validated by the Authority in charge of the security.

General conclusion on HBS regulation evolution impacts

As a conclusion, the impact of the new regulation will affect the Terminal 1 installation, especially on the existing systems. In Terminal 2, impact will be less important.

G.1.8 Departure baggage handling and make-up systems

T2 Make-up facilities

The fully automated baggage handling system is composed of a tilt-tray sorter (with a total of 203 trays on a 240m-lengh sorter) and a total of 5 sorting carousels:

- 3 carousels “all destinations”, with an operable length of 320m.
- 2 carousels only for USA-outbound flights, with an operable length of 125m.

Two injection lines are available from the sorter to each carousel. The sorter has also a number of additional sorting destinations:

- 1 system for non-readable tags with 2 encoding stations, which could also serve as a storage circuit for early bags.
- 2 exits for problematic bags, including one specific to the US flights.
- 1 exit with a roller table for early and/or late bags.
- 1 exit to convey the bag to the CBP additional screening room.

The out-of-gauge system also leads to various destinations: 1 normal out-of-gauge roller table, 1 additional out-of-gauge roller table, and 1 US-flight specific OOG roller table.

Around each carousel, there is the possibility to park 2 dollies or ULD in front of each sorting position. The circulation and manoeuvring area is large and facilitates the work.

The capacity of the handling and sorting system is essential. Even with the degraded situation caused by the preservation of carousels 4 and 5 for the sole US-outbound flights, the capacity is largely sufficient to serve the number of flights and the number of bags. Peak periods occur during the US-outbound departure peak and also during the Aer Lingus connecting periods, but adjusting handling staff helps to reduce temporary congestion.

Handling of transfer bags

There are 3 injection lines for transfer bags, and a baggage piece requires, in the best case, around 7 minutes to perform the processes end-to-end. Therefore, the system is providing the capacity to handle larger volumes of transfer bags, within T2 and with a reasonable connecting time, than the current peak volumes.

G.1.9 Arrival Delivery system

The baggage claim hall in T2 is a very large hall with a total of 6 long belts. As demonstrated previously in the report, the baggage claim capacity is large enough to accommodate the peak demand.

The T2 arrival BHS is composed of:

- “In gauge bags”, 6 carousels
- OOG bags
- 2 OOG breakdown and claim facilities including 1 lift for special OOG.

Belt number	Operable length	Remarks
Carousel 1	50m	1 single injection belt
Carousel 2	90m	2 injection belts
Carousel 3	74m	2 injection belts
Carousel 4	74m	2 injection belts
Carousel 5	74m	2 injection belts
Carousel 6	74m	2 injection belts

Table 27: T2 Baggage delivery resources

The delivery belts for baggage handlers are long and well located in the bag handling hall.

Bag volumes and Belt occupancy during the design day

From the departure baggage counts, it can be observed that the number of bags per passenger is in the usual range with that share of long-haul flights (around 1.4 bags per passenger). The carousel operable lengths, from 50m to 90m, are largely sufficient to serve the common Code C flights of about 150-180 passengers, and sufficient to serve the wide-body 250-350pax flights from the US.

The belt occupancy chart for the 2016 Design Day is shown in the previous section.

With a reclaim length of more than 360m, the reclaim BHS is appropriately sized to handle the peak demand. The length of each belt allows the simultaneous delivery of two flights. The space around the belts is largely sufficient to cope with the passenger volumes.

G.1.10 Transfer baggage

Three injection lines for T2-to-T2 transfer baggage in-line screening and sorting are installed. An important number of transfer bags are generated by the Aer Lingus hub strategy (about 2,000 bags during the Design Day). Transfer bags are screened by the same EDS devices. It was observed that the automated handling system carries a bag in less than 7 minutes from the injection belt to the make-up carousel.

There is however, no connecting system with the T1 area.

G.3 Conclusion about T1 and T2 baggage systems

After analysis of the check-in, screening and sorting systems in T1 and in T2, we believe that both T1 and T2 BHS have a sufficient capacity and can handle a substantial traffic increase. But the insufficient number of check-in desks in T2 limits that potential in T2.

Local and temporary congestion is frequent in the T1 northern section during the morning departure peak and extension of the make-up capacity should be considered.

The replacement of EDS standard 2 by CT-EDS standard 3, by 2020 due to EU regulation, will not cause major issues except in T1 for two reasons:

- The replacement of the current machines by longer and heavier ones could require significant infrastructure works.
- The short Level 2 time-out could lead to an increased number of rejected bags to the Level 3.

When the proposed modifications are implemented, a connection between T1 and T2 might be considered.

The arrival BHS in T1 and T2 is correctly sized to handle the bag flow and could support an increase in peak hour traffic.

H Modelling assumptions

H.1 Airfield and airspace

An extensive exercise was required in order to collect the data needed for detailed model set-up.

The list of key assumptions used to build the airside models is provided in Table 28 below.

Item	Type	Source
CAD drawings of landside layout on the design day	Data	daa
Flight by flight historic data for full S16 season	Data	daa
List of infrastructure changes planned between S16 and S18	Data	daa
List of stands not available for commercial operations	Data	daa
S16 stand allocation guide	Data	daa
S17 stand allocation guide	Data	daa
Approved unescorted towing routes	Data	daa
Flight by flight historic runway occupancy data for full S16 season	Data	IAA
SIDs and STARs used by flights on the design day	Data	IAA
Description of arrival and departure procedures	Data	eAIP
Stand usage restrictions	Data	eAIP
Stand size restrictions	Data	Aeronautical Information Publication
Tug release points (TRP)	Data	Aeronautical Information Publications
Commonly used taxi routes from each runway end to each pier	Assumption	IAA
Taxiway F-inner used mostly for departures	Assumption	IAA
Taxiway F-outer used mostly for arrivals	Assumption	IAA
Cul-de-sacs operational rule: “one in, one out” (code C aircraft only)	Assumption	IAA
Aircraft pushed back from stand and towed to the TRP. From there it continues on its own power.	Assumption	IAA
Parallel operations of two (up to) code C aircraft on taxilanes D-north and D-south possible	Assumption	IAA
Operation of only one code D/E aircraft possible on taxilane C	Assumption	IAA
R28 departures from Pier 1 and Pier 2 queue on R16-34	Assumption	IAA
R28 departures from Pier 3 and Pier 4 queue on taxiway F	Assumption	IAA
Taxiway A closed when R28 is in operations	Assumption	IAA
Aircraft performance as per AirTOp performance tables	Assumption	AirTOp
Departure-departure separation set to minimum of 84 seconds	Assumption	IAA
Arrival-Arrival separation set to minimum of 3.5 NM	Assumption	IAA
If arriving aircraft is closer than 2NM from 28 threshold the departure on the R28 holding point cannot be cleared to enter the rwy/take off	Assumption	IAA
Arriving aircraft needs to be on taxiway B to be clear of runway (no other aircraft can land until then)	Assumption	IAA

Departing aircraft needs to be above the opposite runway threshold before the following aircraft can land	Assumption	IAA
Taxi speeds on long and straight taxiway segments increased to 25kts.	Assumption	Helios
Delay between tug release and the time when aircraft starts moving on its own power set to 3 minutes for narrow body and 4 minutes to wide body aircraft.	Assumption	daa
Speeds in point merge (R28): Outer arc: 230kts Off-arc: 210kts LAPMO: 190kts MAXEV: 165kts	Assumption	IAA

Table 28: Airside modelling assumptions

H.2 Passenger terminal building

An extensive data collection exercise was required in order to collect the data needed for detailed model set-up.

The list of key assumptions used to build the Terminal model is provided in Table 29:

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 T1&T2 CBP and DVO desks at US pre-clearance area (no distinction) Immigration desk at T1&T2 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	Assumption	daa

% of bag drop-off % of traditional		
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 T1&T2	Data	daa
Show-up profile in departure hall: A set of show-up profiles at T1&T2	Assumption	Helios (discussed with daa)
Actual 23 June 2016 passenger monitoring data: Show-up count at boarding pass scan T1&T2 Waiting time at security on T1&T2 Waiting time at immigration for EU passengers at T1&T2 Waiting time at immigration for non-EU passengers at T1&T2 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 29: PTB modelling assumptions

I Airside metrics definitions

Runway delay

The delay experienced while the aircraft is queueing for runway entry. The delay can be caused by other aircraft (being slowed down or stopped) or when waiting at runway stop-bar (because the runway is not free for lining up). This metric is defined to be the time period between joining the back end of the queue and the time the aircraft reaches its stop bar for runway entry.

Departure ground delay

Total delay of departing aircraft accumulated between off-block and entering the runway. It is effectively the sum of runway holding delay and other delays (such as delay due to crossing traffic, pulling delay, towing delay and pushback delay).

Departure taxi-out duration

The time duration the aircraft has been taxiing for departure on the ground of its departure airport. This value is updated every second of simulation time when the aircraft is taxiing for departure even if the aircraft is stopped on ground. This metric is defined to be the time period between off-block and the time the aircraft reaches its stop bar for runway entry.