

## Determinants of technical airport capacity

### Introduction

1. The purpose of this appendix is to describe the various dimensions relevant to the assessment of air transport capacity. Air transport capacity includes the following aspects:

- (a) airport capacity—both landside and airside;
- (b) airspace capacity—both in the vicinity of airports and en route;
- (c) aircraft capacity; and
- (d) surface access capacity.

Whilst recognizing all these aspects, this appendix focuses on technical airport capacity.

2. The determination and allocation of airport capacity involves several parties. In the UK, responsibility for declaring capacity parameters rests with the airport operator. A number of parties might advise the airport operator on how best to meet this responsibility. Where requested by the airport operator, NATS would provide advice, based on its operational expertise and modelling, on runway capacity issues. Other parties might advise on the capacity of ground infrastructure, such as aircraft stands and passenger hourly limits. Slot coordination at major UK airports, including Heathrow, Gatwick, Stansted and Manchester, is the responsibility of ACL, which carries out this role within a framework of EU regulations, national regulations and the IATA Worldwide Scheduling Guidelines. Typically the airport Coordination Committee (or specialist subcommittees)—whose membership includes the airport operator, the airlines, NATS and representatives of general/ business aviation—brings together the coordination parameters used by ACL to produce the detailed departure and arrival schedule for the airport. ACL also attends the meetings of the Coordination Committee as an observer.

### Airport capacity—physical characteristics<sup>1</sup>

3. Airport capacity is generally defined across two dimensions: the number of passengers, and aircraft movements which at BAA's airports primarily consist of ATMs.<sup>2</sup> The number of aircraft movements that can be operated from the airport is mainly derived from the number of runways and taxiways, the availability of stands and airspace capacity.
4. The number of passengers that can be handled by the airport is driven by the size of the terminal, the allocation of terminal space to the processing of passengers and the number of staff allocated to the processing of passengers. It is also driven by the investment of airlines in larger aircraft and the suitability of the airfield (including runways and taxiways) for various sizes of aircraft.

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<sup>1</sup>This section draws heavily on *Airport Design and Operation*, Second Edition, by Antonin Kazda and Robert E Caves and the ICAO Airport Planning Manual.

<sup>2</sup>ATMs are landings or take-offs of aircraft engaged on the transport of passengers, cargo or mail on commercial terms.

5. The capacity of airport infrastructure and facilities is generally considered in terms of hourly flows of passengers or aircraft. These are then translated into annual equivalents using a range of assumptions about the profile of aircraft and passenger demand across the day, week, month and season.

### ***Terminal***

6. The standard method of calculating the amount of space needed is to choose a representative busy hour, accepting that, for the few hours a year for which there will be more traffic, there will be severe congestion in the terminal and unacceptable service standards. It would be uneconomical to match the size of the terminal to peak conditions. To identify a representative busy hour, IATA takes the second busiest day of the average week of the peak month and selects its busiest hour.
7. Another approach is to calculate the Standard Busy Rate (SBR), which may be calculated differently by different airport operators, eg it may be the 30<sup>th</sup> busiest hour in the year, the 20<sup>th</sup> busiest hour (at Amsterdam), or the 40<sup>th</sup> busiest hour (Aéroport de Paris). BAA uses a measure called the Busy Hour Rate (BHR), which is the hourly rate above which 5 per cent of the annual traffic in a given terminal or airport is handled.
8. BAA told us that in adopting a percentile measure for determining its busy hour rate, it had consciously chosen a measure which had a more stable and predictable relationship to annual passenger flow. Alan Stratford Associates, who provided us with technical advice, told us that the adoption by BAA of the 30<sup>th</sup> busy hour would, for the same pattern of passenger flows, result in a larger terminal building, more capital investment, better service standards but no increase in the number of flights serving the terminal. Over a period of traffic growth, the terminal would have a longer design life before expansion would be required.
9. The SBR can be approximated by dividing the mppa by 3,000, although this is a crude rule of thumb which fails to recognize the different peaking patterns of different traffic types and airports at different stages of maturity.
10. The terminal space is allocated between different activities in order to provide customers with a given level of service and it may be possible to reallocate some of that space to increase the passenger-processing capacity of the terminal (eg by reallocating retail space to security or customer seating). Terminal buildings can also sometimes be extended.

### ***Airfield***

11. The physical characteristics of the airfield constrain capacity in two ways:
  - (a) the hourly number of ATMs that can be operated from the runway: this is determined by the number of runways, configuration of the runways, taxiway system and number and size of stands; and
  - (b) the size and mix of aircraft that can land on the runway and can manoeuvre around the airfield.
12. In addition, procedures for managing the flow of aircraft on and off the runway impact on the number of ATMs that the airport can handle.

## Runways

13. The length and width of runway determine the size, type and weight<sup>3</sup> of aircraft that can be accommodated by an airport. In calculating the required runway length, a number of factors relating to the topography of the airport need to be taken into account: elevation of the airport, air temperature, runway gradient, surface wind and condition of the runway surface. There is therefore no hard and fast rule on the required runway length for different types of aircraft, but a runway length of at least 1,800 metres would generally be considered suitable for commercial operations, although some UK airports (eg London City, Southampton) have successfully developed, in spite of a runway falling short of this estimate. For large aircraft, such as Boeing 747 or Boeing 777, the runway length required for take-off is more likely to be over 3,000 metres. [Annex 1](#) shows estimated runway lengths required for key types of commercial aircraft. The standard runway width for most large commercial jet operations is 45 metres, although some airports with runway widths of 30 metres or less can be served by small commercial aircraft such as A320 or Boeing 717.
14. According to ICAO, the number of ATMs that can be handled on a single runway range from 50 to 59 operations an hour.<sup>4</sup> The increase in capacity resulting from adding a runway is not linear and depends on the configuration adopted, the optimal configuration being a set of two runways separated by at least 1,311 metres to enable parallel independent operations, which would result in a capacity of up to 119 operations an hour. Different configurations and resulting capacity ranges estimated by ICAO are shown in [Annex 2](#).

## Taxiways

15. There are rules laid down by ICAO and the CAA as to how wide taxiways need to be and the separations between them in relation to the wingspan of the aircraft using them. In deciding whether to widen taxiways to accommodate larger aircraft, the operator needs to weigh the capital expenditure and cost of disruption against the flexibility of routing larger aircraft around the airfield, which impacts on taxiway capacity.
16. The taxiway system may have a decisive influence on the capacity of the runway system and the operator needs to seek to optimize the layout to provide efficient taxiing without undue expense. The taxiway system needs to fulfil the following objectives:
  - (a) the safe, fluid and expeditious movement of aircraft; and
  - (b) the shortest and most expeditious connection of the runway with the apron and other areas in the airport, in order to minimize time and the fuel consumption of the aircraft.
17. Over time the airfield is developed to increase the capacity of the runway in line with expected demand: in the airports where the number of aircraft movements during the peak hour is relatively small, it is usually sufficient to provide only a short taxiway at right angles to the runway to connect it to the apron. To cope with larger aircraft, it is then usually necessary to provide additional pavement at the end of the runway to

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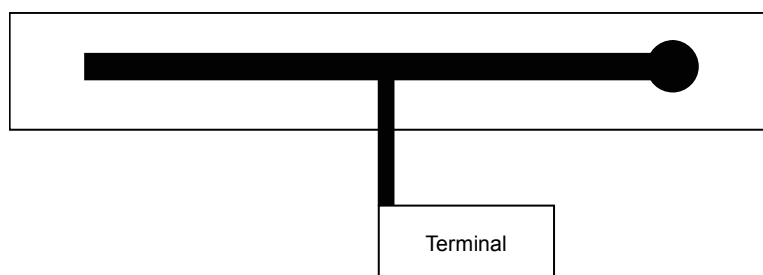
<sup>3</sup>In some cases the length of the runway may be too short for a fully loaded aircraft, but suitable if the same aircraft is partially loaded. For example, a B777-300 can operate at Gatwick Airport, but only if it is not fully loaded.

<sup>4</sup>These ranges are estimated by ICAO. The numbers provided here and in Annex 2 are intended to show the impact on capacity of different runway configurations, absent any other constraints in the airport and airspace system. We discuss further the applicability of ICAO's numbers in paragraphs 97 and 98.

allow the aircraft to turn around. This results in a considerable runway occupancy time. Figure 1 illustrates this type of design.

FIGURE 1

**Runway and apron connected with short right-angle taxiway**

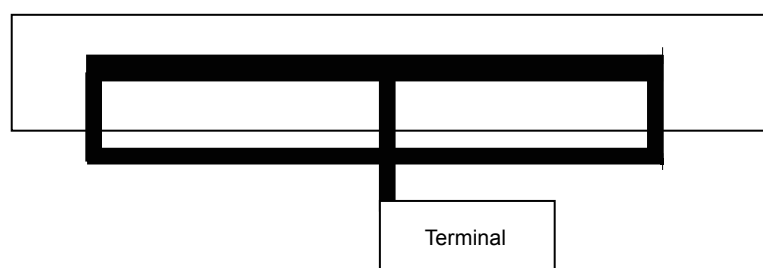


Source: *Airport Design and operation*, Second Edition, Antonin Kazda and Robert E Caves.

18. As the number of movements during the peak hour traffic increases, consideration may have to be given to the construction of a taxiway parallel to the runway, and right-angle connecting taxiways at the end of the runway. In addition, in the event of a longer runway, several right-angle connecting taxiways may be constructed, usually at one-third or one-quarter of the runway length. This configuration is represented in Figure 2.

FIGURE 2

**System of a parallel taxiway with right-angle connections**



Source: *Airport Design and operation*, Second Edition, Antonin Kazda and Robert E Caves

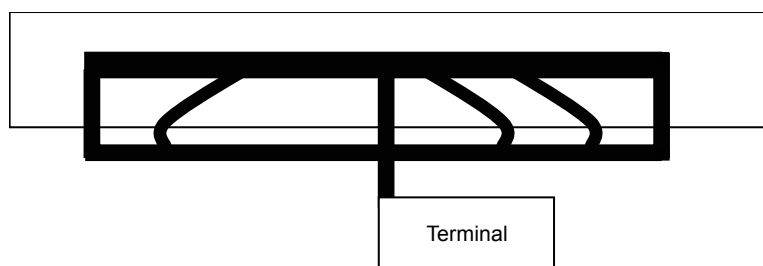
19. To improve the capacity further, it is necessary to construct one or more rapid exit (or high-speed exit) taxiways (RET<sup>5</sup>), whose parameters and location need to correspond to the type of operation on the given runway. Figure 3 illustrates this configuration.

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<sup>5</sup>RETs are exits set at an angle of 30° to the runway, rather than 90°, which is the case with standard exits. First introduced in the 1950s, their main advantage is that pilots do not have to slow down as much prior to leaving the runway.

FIGURE 3

### System of a parallel taxiway with right-angle connections and RETs



Source: *Airport Design and operation*, Second Edition, Antonin Kazda and Robert E Caves.

20. It has been claimed that RETs (when positioned optimally and including associated runway lightings which guide pilots to the earliest possible exit), by reducing runway occupancy, can increase capacity by two to three additional movements an hour,<sup>6</sup> although this is affected by other factors, eg aircraft fleet mix, runway braking action, position, angle and taxiway design. NATS told us that higher capacity gains had been achieved by some airports as a result of the addition of new RETs.
21. Other similar infrastructure enhancements can be made to the airfield to increase capacity, including the construction of Rapid Access Taxiways (RATs), resequencing areas at the end of runways and increased number of hold bars to permit a better sequencing of departing aircraft.

#### *Stands and apron*

22. The apron and associated stands are the bridging point between the runway system and the terminal building. The apron size and the positioning of the stands need to permit the expeditious handling of the airport operation during times of peak hour traffic levels. The appropriate apron and stand sizes depend on the types of aircraft which are intended to use the apron and airports have a mix of stand sizes, as it would be uneconomical to provide all stands at the largest size required.
23. Stands and aprons can constrain capacity, if shortage of stands constrains the flow of traffic and/or the sizes of stands available are not sufficient to handle the volume of larger aircraft using the airport.

#### *Issues linked to the introduction of the Airbus A380<sup>7</sup>*

24. There has been some debate relating to the standards required of aerodromes for the handling the new Code F<sup>8</sup> aircraft.
25. In particular, ICAO has now determined that the minimum runway width for Code F aircraft is 60 metres. This would prevent most aerodromes in the UK, which are

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<sup>6</sup>BAA, quoted in *Horndal at Heathrow?—Co-operation, Learning and Innovation: Investigating the Processes of Runway Capacity Creation at Europe's most Congested Airports*, July 2001, by Bruce S Tether and J Stan Metcalfe ([www.druid.dk/uploads/tx\\_picturedb/ds2001-286.pdf](http://www.druid.dk/uploads/tx_picturedb/ds2001-286.pdf)).

<sup>7</sup>Source: CAA notice to aerodrome licence holders, 2/2003, Requirements for Code F facilities and the introduction of A380 aircraft operations.

<sup>8</sup>Aeroplane with a wingspan of 65 metres up to but not including 80 metres and an outer main gear wheelspan of 14 metres up to but not including 16 metres (eg the new Airbus A380).

designed to Code E<sup>9</sup> standards (including a 45-metre runway width and 25-metre taxiway width), from being served by the new aircraft, as upgrading to ICAO's standards is considered prohibitively costly and disruptive. However, the methodology used by ICAO to determine the Code F requirements has been challenged, and Airbus has stated that the A380 has been designed specifically to operate from runways of Code E standard. The CAA, in collaboration with other stakeholders, has put in place interim arrangements for A380 aircraft operations pending aerodrome developments to Code F standards. BAA told us that this had been achieved largely as a result of significant influencing by BAA.

## **Operational issues and airside system capacity**

26. Airside system capacity is not only the result of the investment made in facilities, but also operational choices.<sup>10</sup> The following are the key operational aspects that affect airside capacity:

(a) the mode of operation of the runways for airports with more than one runway, ie whether each runway is used for both arrivals and departures (this is referred to as 'mixed mode' operation), or just one of these (ie 'segregated mode' operation);<sup>11</sup>

(b) the traffic mix and its management (including the performance of pilots), which influence the average runway occupancy time and the airborne separation between pairs of aircraft;

(c) service standards and associated levels of aircraft delay; and

(d) airspace issues: standard instrument departure, including noise preferential routings and the mix of routes flown by aircraft immediately after departure.

## **Mode of operation**

27. In segregated mode, streams of arriving and departing aircraft have to be comparatively widely spaced, because of aircraft wake vortex. This leads to a potential waste of runway capacity, which can, however, be mitigated by the implementation of measures, such as tactically enhanced arrivals mode<sup>12</sup> (TEAM). In addition, capacity may be unused on one runway whilst excess arrivals or departures on the other runway suffer delays.

28. Mixed mode operation involves operating parallel 'independent' streams of arrivals on each of the runways into which departures are interleaved. The capacity benefit comes from taking advantage of the wake vortex spacing between arrivals to insert departures on the same runway. Additionally, whilst arrival and departure capacity is increased in a 'balanced' way, there is also flexibility to handle traffic surges as priority can be given to arrivals or departures on one or both runways in order to

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<sup>9</sup>Aeroplane with a wingspan of 52 metres up to but not including 65 metres and outer main gear wheelspan of 9 metres up to but not including 14 metres (eg a Boeing 747).

<sup>10</sup>It can also be a function of environmental limits and planning conditions.

<sup>11</sup>Heathrow is the only BAA airport which has more than one runway. Therefore, the discussion on 'mixed mode' and 'segregated mode' applies only to Heathrow.

<sup>12</sup>Procedure applied to boost arrivals capacity temporarily by allowing a proportion of the arriving aircraft to use the departure runway.

reduce delays. Mixed mode operation is not always possible, if the space between the two runways is too narrow<sup>13</sup> or if there are airspace capacity constraints.

### **Mix of traffic, departure routes and management of aircraft flow**

29. Runway capacity depends on aircraft size, speed, manoeuvrability and braking capability as well as human factors such as pilot skills. It also depends on the mix of aircraft using the runway throughout the day. The size of aircraft affects wake vortices and the approach and touchdown speeds. Slower speeds reduce the runway capacity and the generation of wake vortices by larger aircraft creates manoeuvrability problems for smaller aircraft.
30. The standard separation distances required between inbound aircraft varies between 2½ miles (between medium aircraft in certain conditions at Heathrow only), 7 miles (between a heavy aircraft and a following light aircraft) and 20 miles (in certain conditions behind an A380). Departure separations are heavily dependent not only on wake vortex requirements but also on the route to be flown after departure and the capacity of the en-route airspace both within and outside the UK, and sometimes also of the destination airport. These factors have a significant impact on the capacity that each airport can deliver. The following two examples illustrate this point: an airport focusing on the short-haul market will be subject to different pressures and constraints than one focusing on long-haul destinations; in the winter months, the increased numbers of departures from Gatwick Airport heading south to European ski destinations reduces departure capacity compared with a traffic mix more equally spread between north, south, east and west headings.
31. We list below a selection of measures<sup>14</sup> which can be taken to improve the utilization of the runway:
  - (a) Changes in wake vortices criteria have increased capacity over time. However, the introduction of the A380 will result in greater wake vortex separation for the following aircraft until experience shows that it is safe to reduce separation. In the meantime, there will be a loss in ATM capacity.
  - (b) A more proactive management of the queues of aircraft waiting to use the runway can also result in increased capacity by reducing the number of times a light aircraft follows a heavy one in the landing sequence. A similar procedure can be implemented for departures, but is more complex, as the route of the aircraft needs to be taken into account.
  - (c) Runway occupancy time can also be reduced by improving pilots' performance through briefing of pilots and controllers.

### **Service standards**

32. Runway capacity is defined by the CAA as 'the number of aircraft movements that may be scheduled to use a runway such that their average delay during the airport's busy period does not exceed a specified value',<sup>15</sup> as it would not be efficient to assume no delay at all for planning purposes because of the variable nature of

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<sup>13</sup>It is possible for a pair of runways that are spaced by less than the stipulated distance to be operated in 'dependent mixed mode' with a lower overall capacity.

<sup>14</sup>This was explored in a NATS-IATA-BAA study carried out in August 1994, *The Heathrow Airport Runway Capacity Enhancement Study*, and was also discussed in [www.druid.dk/uploads/tx\\_picturedb/ds2001-286.pdf](http://www.druid.dk/uploads/tx_picturedb/ds2001-286.pdf) (*Horndal at Heathrow?* July 2001).

<sup>15</sup>CAP 627.

demand for runway capacity throughout the day. Capacity can be created by increasing the scheduling rate, thus lengthening the average delay, which amounts to a deterioration of service quality. A compromise has therefore to be reached between the scheduling rate and the delay the airlines (and passengers) will tolerate. Increasing the average delay also results in higher costs to airlines and users: anticipating the delays, airlines increase scheduled block times for the turnaround of aircraft. For short-haul routes, this can reduce the utilization of aircraft from four to three trips a day. The longer ground times also require more apron facilities.<sup>16</sup>

33. Although the airport operator has the ultimate responsibility for declaring airport capacity, the declaration process is managed in a collaborative manner, and involves airlines, NATS and ACL. Through a twice-yearly review of runway capacity, the parties involved jointly sign off any changes proposed as a result of these reviews. Decisions about capacity are made jointly by all parties and reflect the joint view about the appropriate trade-off between capacity and delay.

### **Airspace capacity**

34. The airspace is divided into sectors. Air traffic control officers (ATCOs) can handle only a certain amount of traffic at the time and each sector therefore has a sector capacity set by the ATC services provider (NATS in the UK) with the objective of maintaining a safe flow of traffic. The South-East of England has one of the most complex and busiest sectors of airspace in the world. En-route sectors, where aircraft are cruising at more than 20,000 feet, are relatively simple and ATCOs could handle more traffic in them than in very complex sectors like south-east England. We note that complexity can only be considered on a sector by sector basis and that en-route sectors in the South-East of England are complex.
35. In order to maintain safety in the London Terminal Manoeuvring Area (LTMA), NATS would apply minimum departure intervals when necessary. Minimum separation standards (5 miles horizontally, reducing to 3 miles in some circumstances, and 1,000 feet vertically) apply to all aircraft regardless of size. Separation minima are the dominant ATC factor affecting capacity. As noted elsewhere, there are additional factors affecting minimum safe separation between aircraft when using the runway.

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<sup>16</sup>SERAS note: Airside System Service Standard, Halcrow Airports & Air Transport (PDS), 1 September 2000.

## Minimum length required for take-off\* for a selection of aircraft types

*metres*

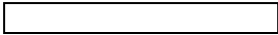
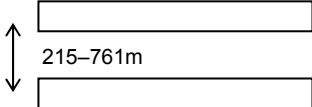
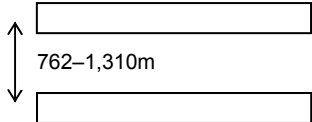
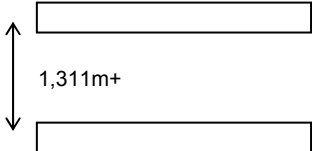
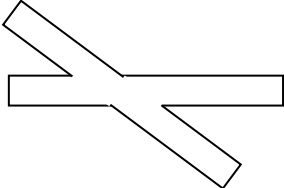
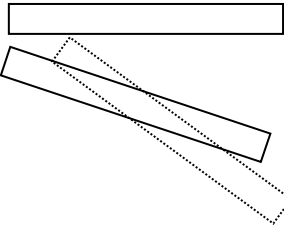
<i>Aircraft make and model</i>	<i>Aeroplane reference field length</i>
Boeing B717-200	1,670
Boeing B737-600	1,690
Boeing B737-700	1,598
Airbus A300 B2	1,676
Airbus A320-200	2,480
Boeing B727-100	2,502
Boeing B727-200	3,176
Boeing B737-100	2,499
Boeing B737-200	2,295
Boeing B737-300	2,160
Boeing B737-400	2,550
Boeing B737-500	2,470
Boeing B737-800	2,090
Boeing B737-900	2,240
Airbus A300 B4	2,605
Airbus A300-600	2,332
Airbus A310	1,845
Boeing B707-300	3,088
Boeing B707-400	3,277
Boeing B720	1,981
Boeing B757-200	1,980
Boeing B757-300	2,400
Boeing B767-200	1,981
Boeing B767-300ER	2,540
Boeing B767-400ER	3,130
Boeing B747-100	3,060
Boeing B747-200	3,150
Boeing B747-300	3,292
Boeing B747-400	2,890
Boeing B747-SR	1,860
Boeing B747-SP	2,710
Boeing B777-200	2,390
Boeing B777-200ER	3,110
Boeing B777-300	3,140
Boeing B777-300ER	3,120
Airbus A380	3,350

*Source:* Based on the ICAO Aerodrome Design Manual—Runways, Appendix 1—Airplane classification by code number and letter.

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\*At maximum certificated take-off mass at sea level, standard atmospheric conditions, still air and zero runway slope.

## Hourly capacity of different runway configurations

Runway use configuration	Operations per hour*
	50–59
	56–60
	62–75
	99–119
	56–60
	56–60

Source: Adapted from Figure 3-13 in *Airport design and operation*, Second Edition, Antonin Kazda and Robert E Caves.

\*Under Instrument Flight Rules (IFR), the rules governing flight in certain limited visibility and cloud conditions. In practice today most commercial flights are carried on under IFRs even in good weather conditions. Although both IFR and Visual Flight Rules (VFR) can operate in Gatwick's air traffic zone, BAA believed that it was unlikely that capacity gains could be made by offering VFR approaches to commercial traffic.