Airside Capacity Management

Prof. Amedeo Odoni

Istanbul Technical University

Air Transportation Management

M.Sc. Program

Airport Planning and Management

Module 11

January 2016

Objective and Topics

Objective:

– To summarize fundamental concepts regarding the definition, estimation, variability and management of airport capacity

Topics:

– On Measuring/Estimating Capacity
– Runway Systems: The Principal Bottleneck
– Capacity of a Single Ruway
– Runway Configurations and their Capacity
– Capacity Envelopes and Capacity Coverage Charts
– Annual Capacity of a Runway System
– Increasing Runway Capacity
– Taxiways and Aprons: A Summary

Outline

- On Measuring/Estimating Capacity
- Landside vs. Airside Capacities
- Runway Systems: The Principal Bottleneck
- Capacity of a Single Ruway
- Runway Configurations and their Capacity
- Capacity Envelopes and Capacity Coverage Charts
- Annual Capacity of a Runway System
- Increasing Runway Capacity
- Taxiways and Aprons: A Summary

How Do We Measure Capacity?

- "Capacity" is associated with the notion of a "maximum" – an "upper limit"
- In many cases, this upper limit can be measured easily and unambiguously
  - "How many cubic centimeters of liquid can a glass hold?"
- But, very often, "capacity" can be measured only after we define the conditions under which we measure it
  - "How many people can fit in a bus?"
  - Note that, to answer this question, we must specify the acceptable "level of stress" or "Level of Service" (LOS)
  - The capacity is like the length of a rubber band
- *The second situation applies often in transportation systems and at airports*

An Important Observation: "Use Specifications"

- "Use Specifications" are rules that specify how a facility or service should be used
  - "Every passenger on a commercial aircraft must have a seat"
- When such "Use Specifications" exist, "capacity" can be measured or computed relatively easily
- In the case of airports,
  - Many "Use Specifications" exist on airside (runways, taxiways, aprons)
  - On landside (passenger terminals, ground access, etc.) more and more "use specifications are being developed, typically in the form of LOS standards

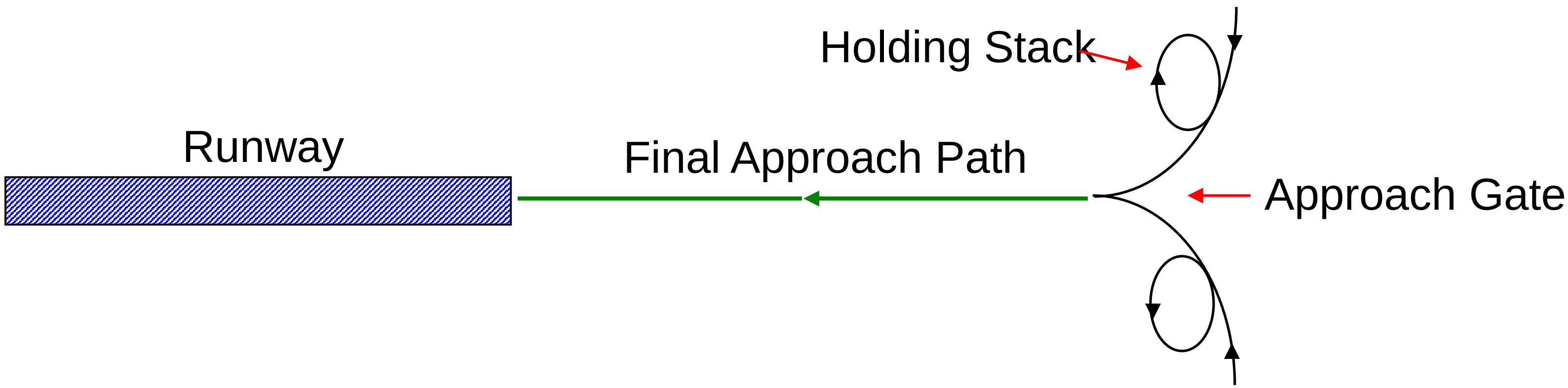
Airside vs. Landside Capacities

- Airside capacities can often be computed with reasonable accuracy because of the presence of well-defined "use specifications" or "rules of the road" (ATC separation requirements, single occupancy of runways, etc.)
- Landside capacities are much less well-defined because they depend on what Level of Service (LOS) one is willing to accept, behavioral characteristics, physical layout of facilities, etc.
- Use specifications, especially if given in terms of LOS standards, can vary greatly across airports
- This has ***very important implications about validity of comparisons*** across airports

Outline

- On Measuring/Estimating Capacity
- Landside vs. Airside Capacities
- **Runway Systems: The Principal Bottleneck**
- **Capacity of a Single Ruway**
- **Runway Configurations and their Capacity**
- Capacity Envelopes and Capacity Coverage Charts
- Annual Capacity of a Runway System
- Increasing Runway Capacity
- Taxiways and Aprons: A Summary

The Principal Bottleneck



- The runway systems of the world's busiest airports act usually as the principal bottlenecks of the air transport system's infrastructure
- While other components of infrastructure may also occasionally act as bottlenecks, the capacity of runway systems is the **most difficult to increase**

Definitions: Runway Capacity*

- *Maximum Throughput (or Saturation) Capacity*

  The expected ("average") number of runway operations (takeoffs and landings) that can be performed in one hour without violating air traffic management (ATM) rules, assuming continuous aircraft demand.

- *Declared Capacity* [tied to *Level of Service* (LOS)]

  The capacity per hour used in specifying the number of slots available for schedule coordination purposes; used extensively outside US; no standard method for its determination; no generally accepted LOS; ***typically set to about 85-90% of saturation capacity***; may be affected by stand/gate capacity, passenger terminal capacity, etc.

** These definitions can be applied to a single runway or to the entire complex of runways at an airport.*

Factors Affecting Runway Capacity

- Number and layout of active runways
- Separation requirements (longitudinal, lateral)
- Weather (ceiling, visibility)
- Wind (direction, strength)
- Mix of aircraft
- Mix and sequencing of operations (landings, takeoffs, mixed)
- Quality and performance of ATM system (including human factor -- pilots and controllers)
- Runway exit locations
- Noise considerations

Role of ATM Separation Requirements

- Runway (and airfield) capacities are constrained by ATM separation requirements
- Typically aircraft are separated into a small number (4 or 5) of classes according to their maximum takeoff weight (MTOW)
- Example: ICAO classification
  - Super Heavy (SH): Airbus 380 [560 tons], Boeing 747-8
  - Heavy (H): 136 tons ≤ MTOW [and <SH]
  - Medium (M): 7 tons ≤ MTOW < 136 tons
  - Light (L): MTOW < 7 tons
- Required separations (in time or in distance) are then specified for every possible pair of aircraft classes and operation types (landing or takeoff)
- Example: "arrival of H followed by arrival of M requires 5 nautical miles of separation on final approach"

ICAO Recommended Separations*: Arrival - Arrival

	TRAILING A/C			
LEADING A/C	Super Heavy	Heavy	Medium	Light
Super Heavy	4	6	7	8
Heavy	4	4	5	6
Medium	3	3	3	5
Light	3	3	3	3

* Separations shown in n. miles (1 n.mile =1.852 km)

- **In addition, leading aircraft must be safely out of runway before the trailing aircraft can touch down on the runway**
- **Separations behind SH and H aircraft are greater because of the “wake vortex” (or “wake turbulence”) effects**

ICAO Recommended Separations*: Departure - Departure

	TRAILING A/C			
LEADING A/C	Super Heavy	Heavy	Medium	Light
Super Heavy	150	150	180	180
Heavy	90	90	120	120
Medium	90	90	90	90
Light	90	90	90	90

*** Approximate separations in seconds (vary according to national practices)**

Variability of Airport Capacity: Airside

- Airside capacity (≈ runway capacity) depends on **runway configuration** in use, which, in turn, depends on weather conditions and wind direction and strength
  - At many airports where weather is variable and/or winds are variable and strong, airside capacity can also be highly variable and difficult to predict even a few hours in advance

The Concept of the "Runway Configuration"

- Multi-runway airports can operate in any one of many possible "runway configurations".
- Each configuration is described by:
  - The set of runways which are active
  - The type of operations (arrivals only, departures only, or mixed) assigned to each of the active runways
- Example: A common configuration at IST consists of "05 for arrivals, 35L for departures" (denoted as "05|35L")
- Only a single runway configuration may be available under certain combinations of weather and wind direction/strength
- But, in calm winds and good weather, ATC often has the option of selecting among several alternative configurations
- Capacity and environmental impacts are the main criteria used for configuration selection in such cases

Complexity of Multi-Runway Configurations

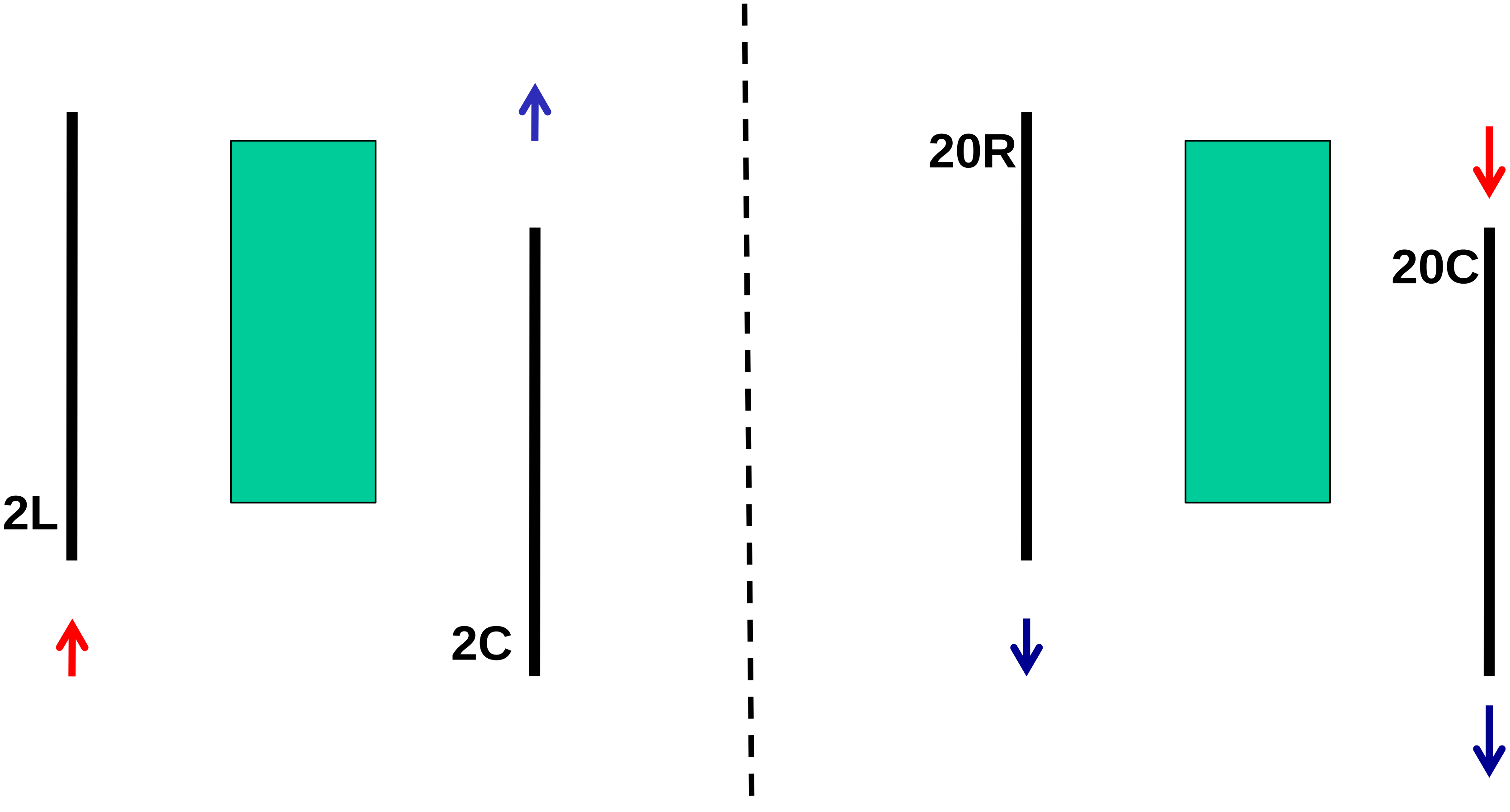
- When a configuration with more than one runways is in use, it may be necessary for ATC to maintain separation requirements between aircraft operating on different runways
- These requirements may have a very important impact on the total capacity of the runway configuration
  - Close-spaced parallels
  - Medium-spaced parallels
  - Intersecting runways
  - Converging runways

Parallel Runways (IFR)

Separation between runway centerlines	Arrival/ arrival	Departure/ departure	Arrival/ departure	Departure/ arrival
Closely-spaced 700/1200 – 2500 ft (213/366 – 762 m)	As in single runway	As in single runway	Arrival touches down	Departure is clear of runway
Medium-spaced 2500 – 5000* ft (762 – 1525* m)	1.5 nmi (diagonal)	Indep′nt	Indep′nt	Indep′nt
Independent > 5000* ft (> 1525* m)	Indep′nt	Indep′nt	Indep′nt	Indep′nt

* 3400 ft (1035 m) or 4300 ft (1310 m) are alternative limits; 3000 ft (915 m) stated as feasible by ICAO and FAA, subject to conditions

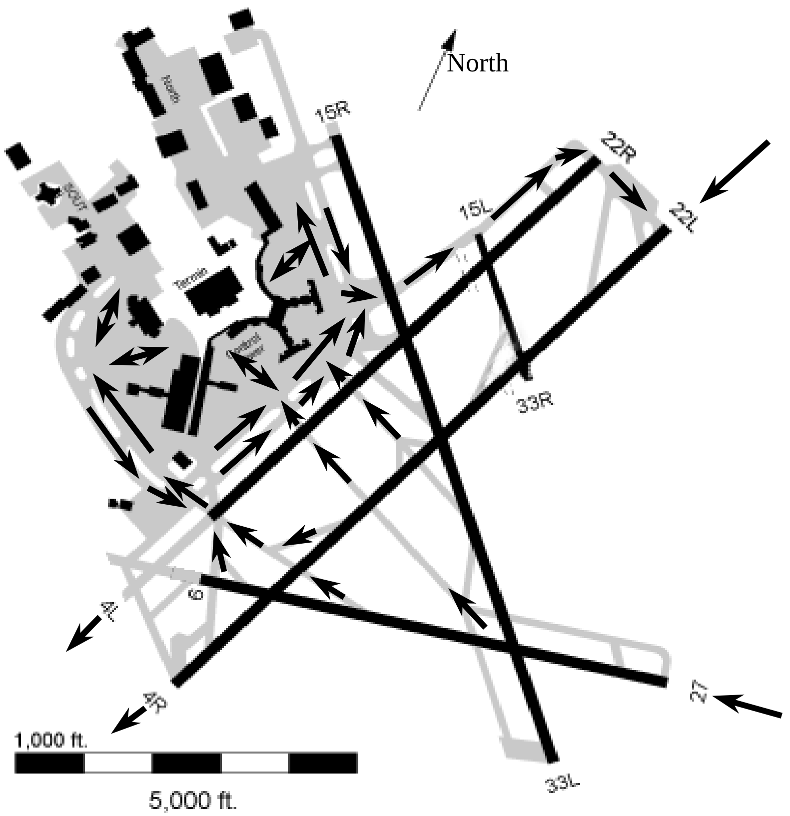
Singapore: Example of Two Configurations



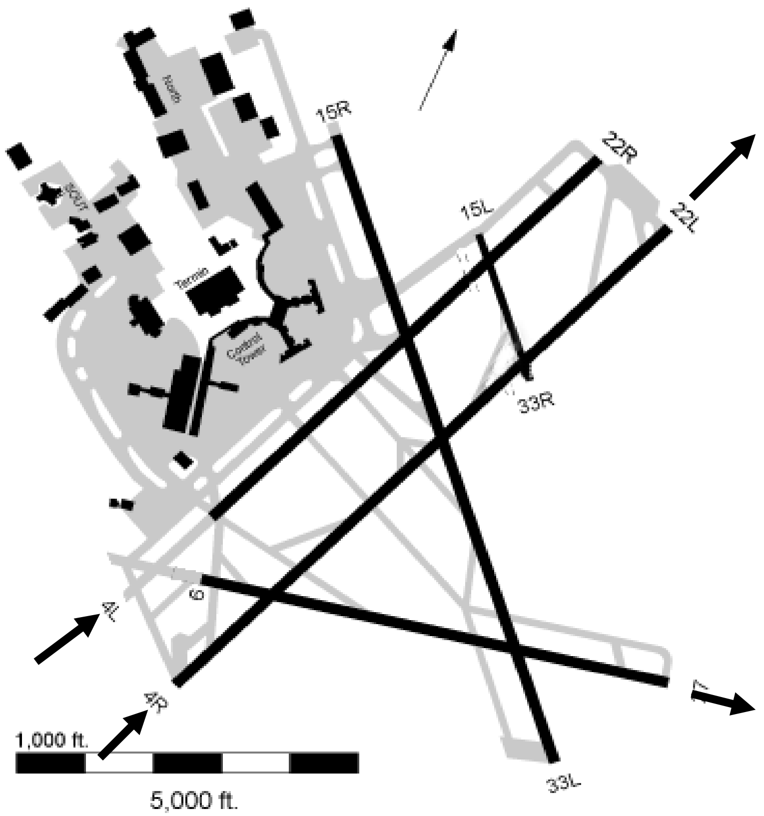
Istanbul Atatürk (IST) Airport

High-capacity configurations in opposite directions, Boston/Logan (VMC)

27-22L | 22R-22L



4R-4L | 4R-4L-9



LBPIA: Single-Runway and Dedicated Two-Runway Capacities

Type of Operation	Example Runway Configuration	IMC	VMC
Single Runway, Mixed Operations	Arr 05, Dep 05	48	56
Dedicated Dependent East/West Operations	Arr 06R, Dep 06L	60	70
Dedicated Independent North/South Parallel Operations	Arr 15R, Dep 15L	63	65
	Arr 33L, Dep 33R	68	75
Dedicated Independent East/West Parallel Operations	Arr 05, Dep 06L	80	82
	Arr 23, Dep 24L	80	82

Range of Airfield Maximum Throughput Capacities

- The saturation capacity of a single runway varies greatly among airports, depending on ATM rules and performance, weather conditions, traffic mix, operations mix and other factors identified earlier
- At major commercial airports, in developed countries, the typical range per runway in good weather conditions is
  - 25 – 44 arrivals per hour for arrivals-only operations
  - 30 – 55 departures per hour for departures-only ops
  - 30 – 56 movements per hour for mixed ops
- Depending on the number of runways and the airport's geometric configuration, total airfield capacity of major commercial airports ranges from 30 per hour to 260+ per hour

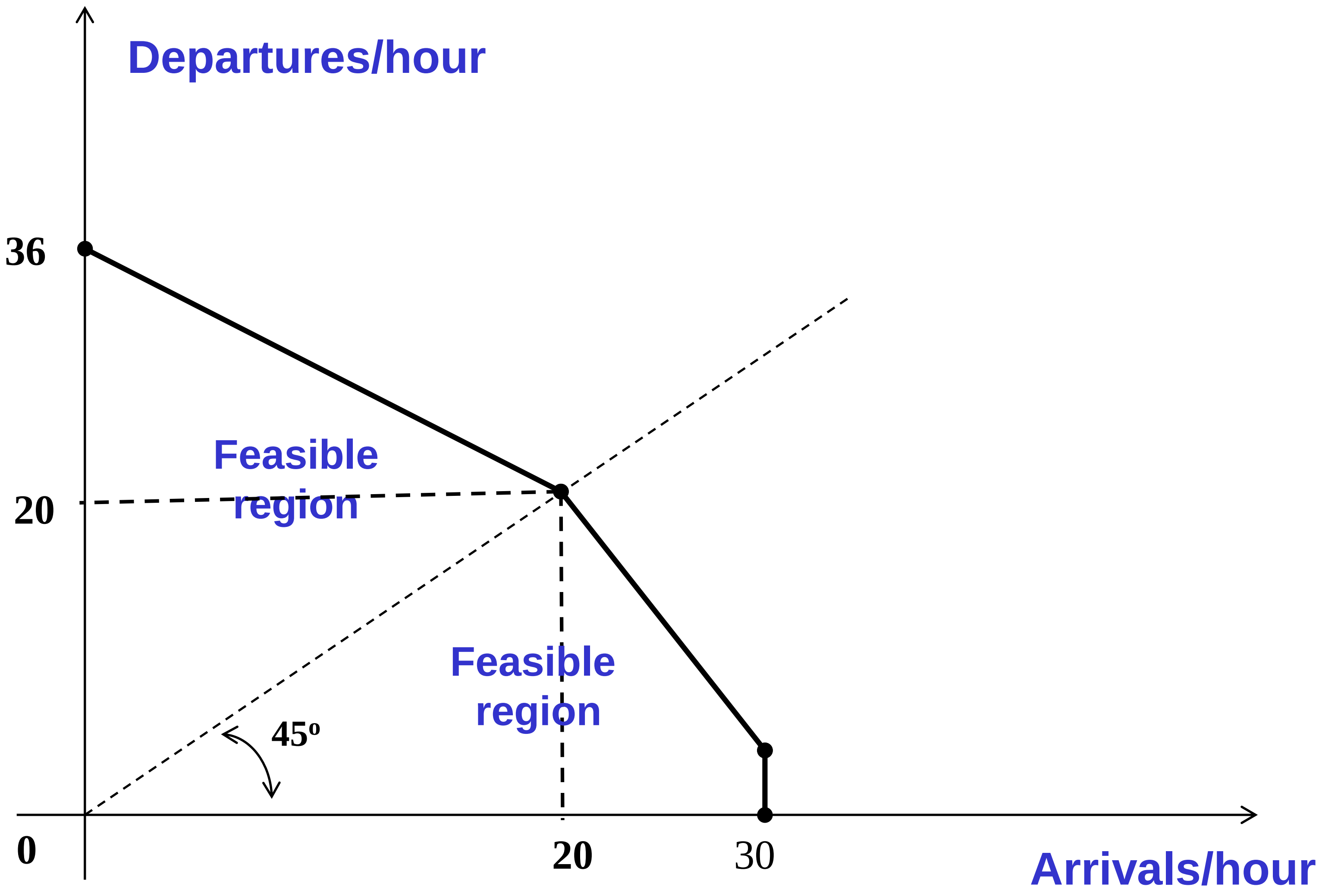
Outline

- On Measuring/Estimating Capacity
- Landside vs. Airside Capacities
- Runway Systems: The Principal Bottleneck
- Capacity of a Single Ruway
- Runway Configurations and their Capacity
- **Capacity Envelopes and Capacity Coverage Charts**
- Annual Capacity of a Runway System
- Increasing Runway Capacity
- Taxiways and Aprons: A Summary

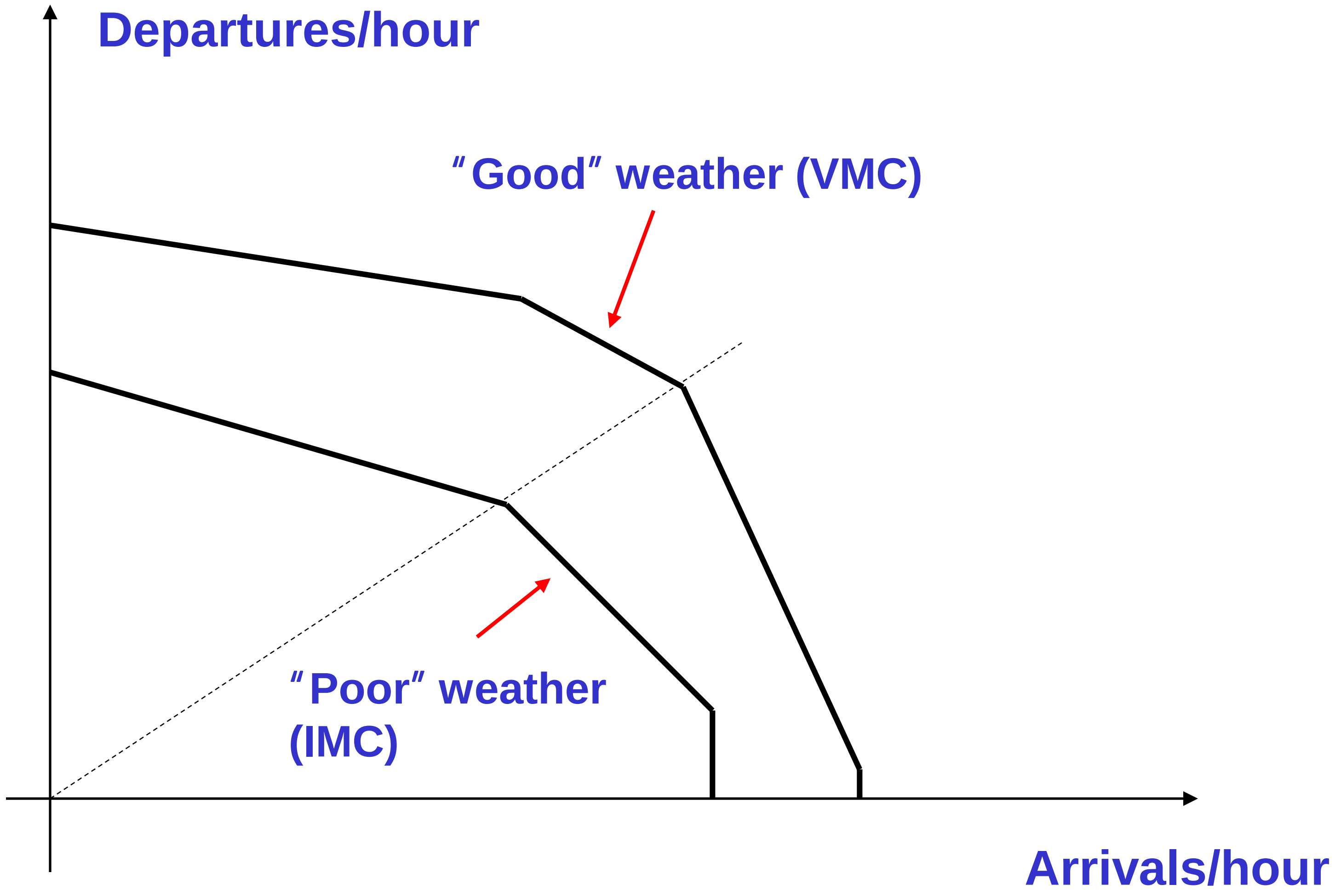
Summarizing Runway System Capacity

- Capacity envelopes: For any given runway configuration, the capacity envelope shows the number of arrivals and departures that can be performed per "unit of time" (one hour or 15 minutes or other) for all possible "mixes" of arrivals and departures
- Capacity coverage charts: For a specified long period of time (one year, one month) capacity coverage charts show how much total capacity is available at the airport for what percentage of time

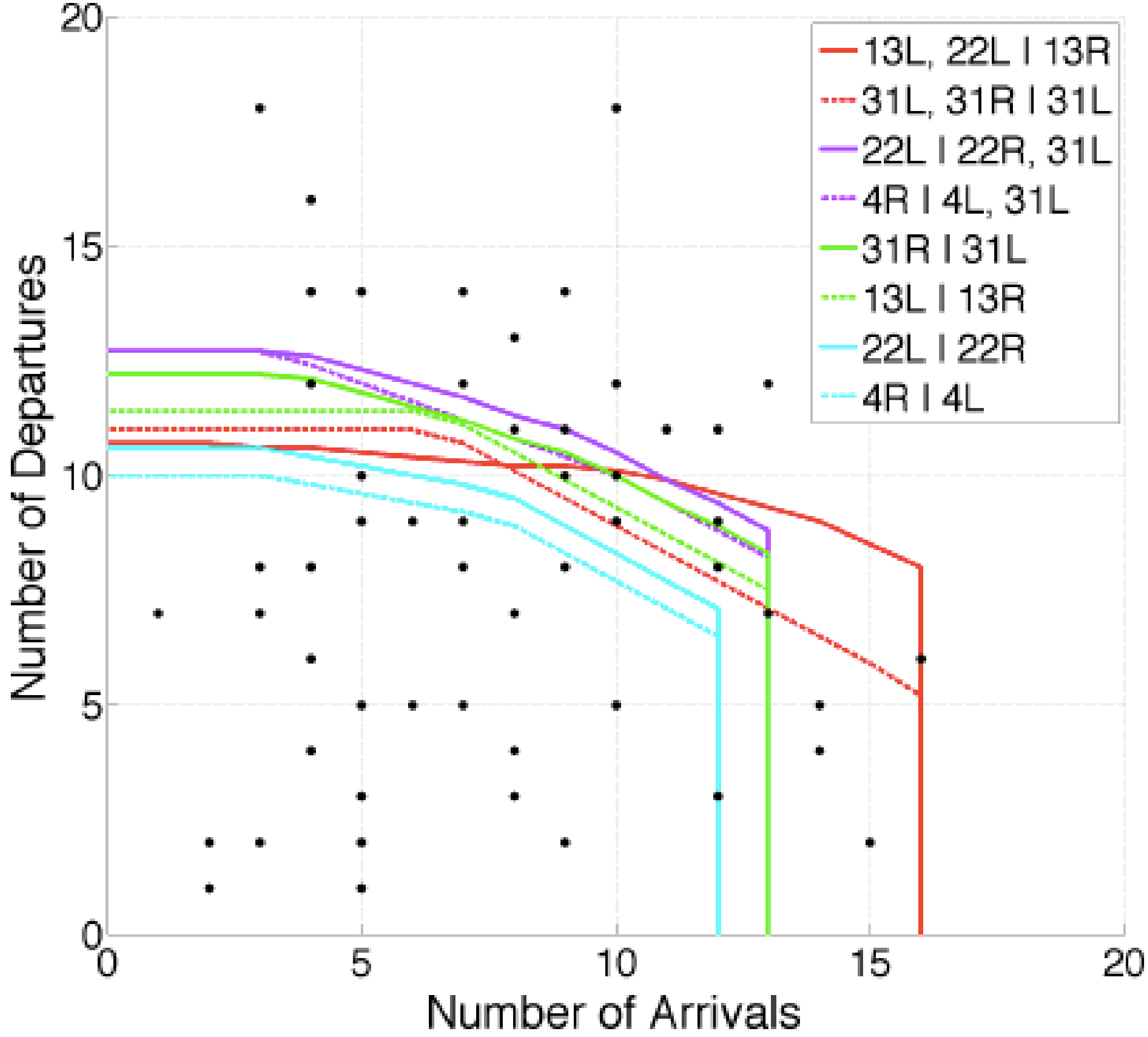
Typical capacity envelope ("Pareto envelope") for a single runway



VMC vs. IMC Envelopes

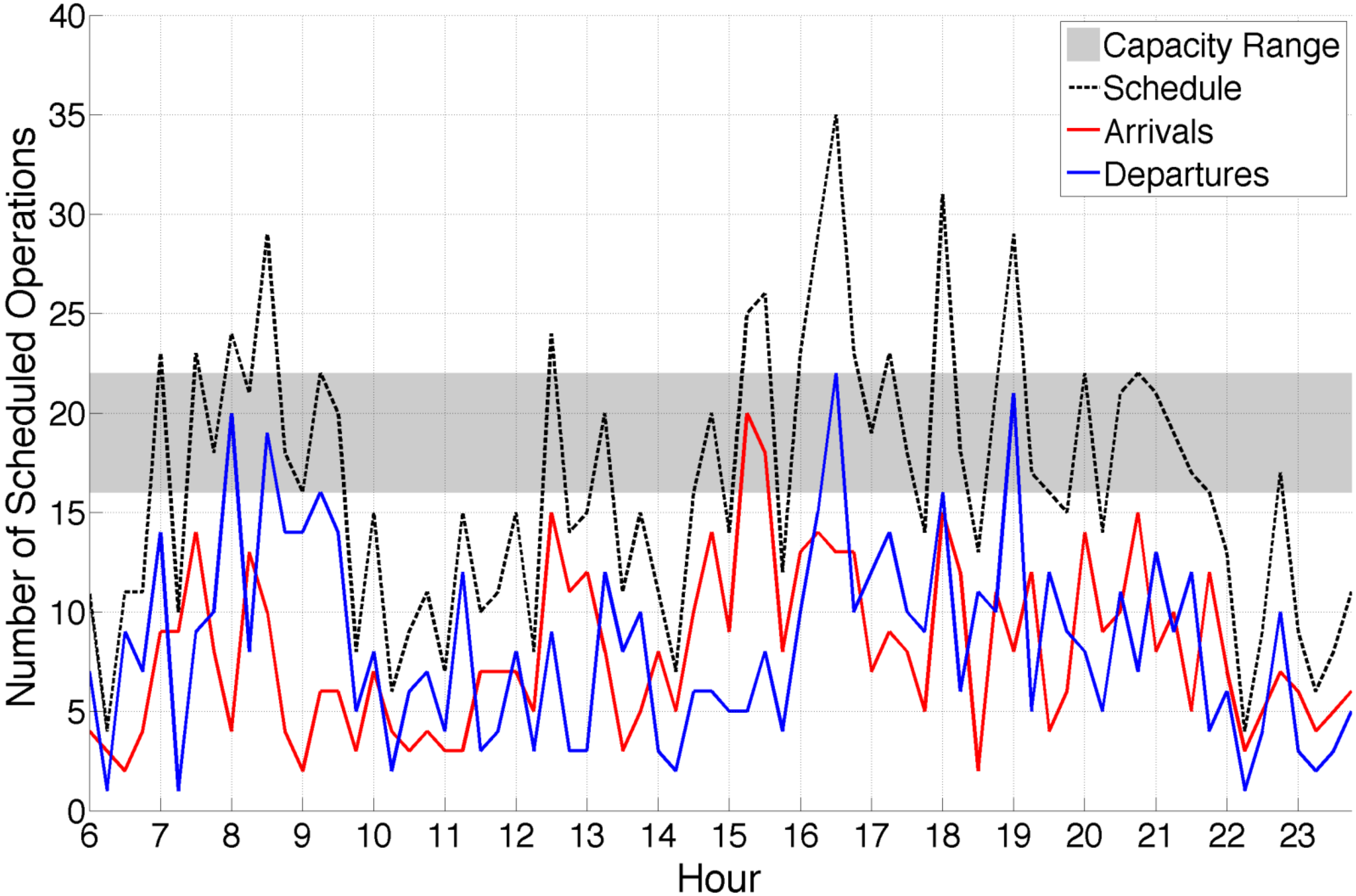


Capacity Envelopes and Demand: JFK



Shown on scale of "arrivals and departures per 15 minutes"

NY JFK: Scheduled Movements per 15 Minutes

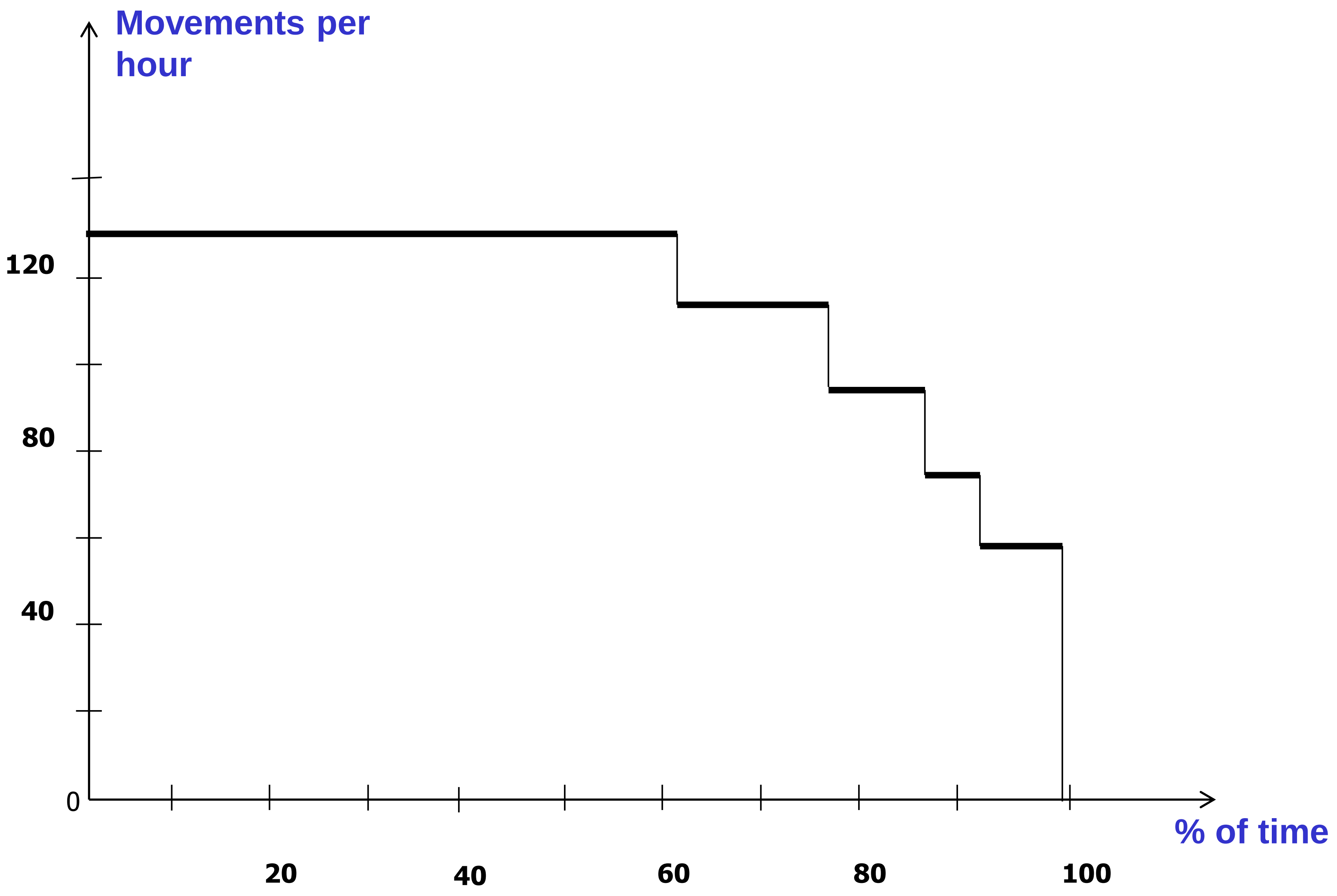


Capacity Coverage Chart (CCC)

- CCC shows how much capacity is available for what percentage of time
- Assumptions:
  - airport will operate at all times with the highest capacity configuration available for prevailing weather/wind conditions
  - the capacity shown is for a 50%-50% mix of arrivals and departures

Note: Neither of these assumptions is necessarily true in practice (e.g., noise may be the principal consideration in selecting configuration during periods of low demand)

Annual Capacity Coverage Chart: Boston/Logan



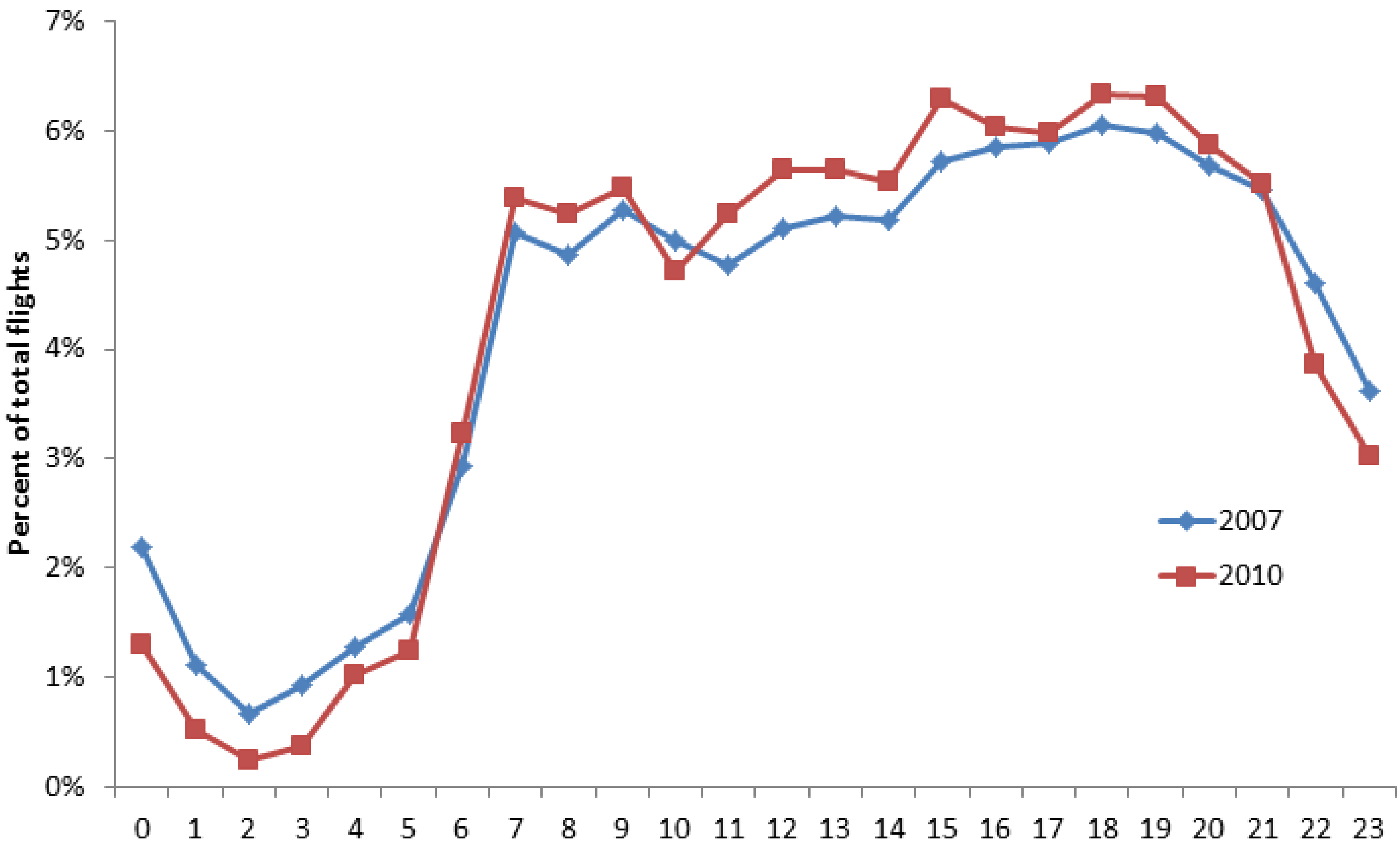
Outline

- On Measuring/Estimating Capacity
- Landside vs. Airside Capacities
- Runway Systems: The Principal Bottleneck
- Capacity of a Single Ruway
- Runway Configurations and their Capacity
- Capacity Envelopes and Capacity Coverage Charts
- **Annual Capacity of a Runway System**
- Increasing Runway Capacity
- Taxiways and Aprons: A Summary

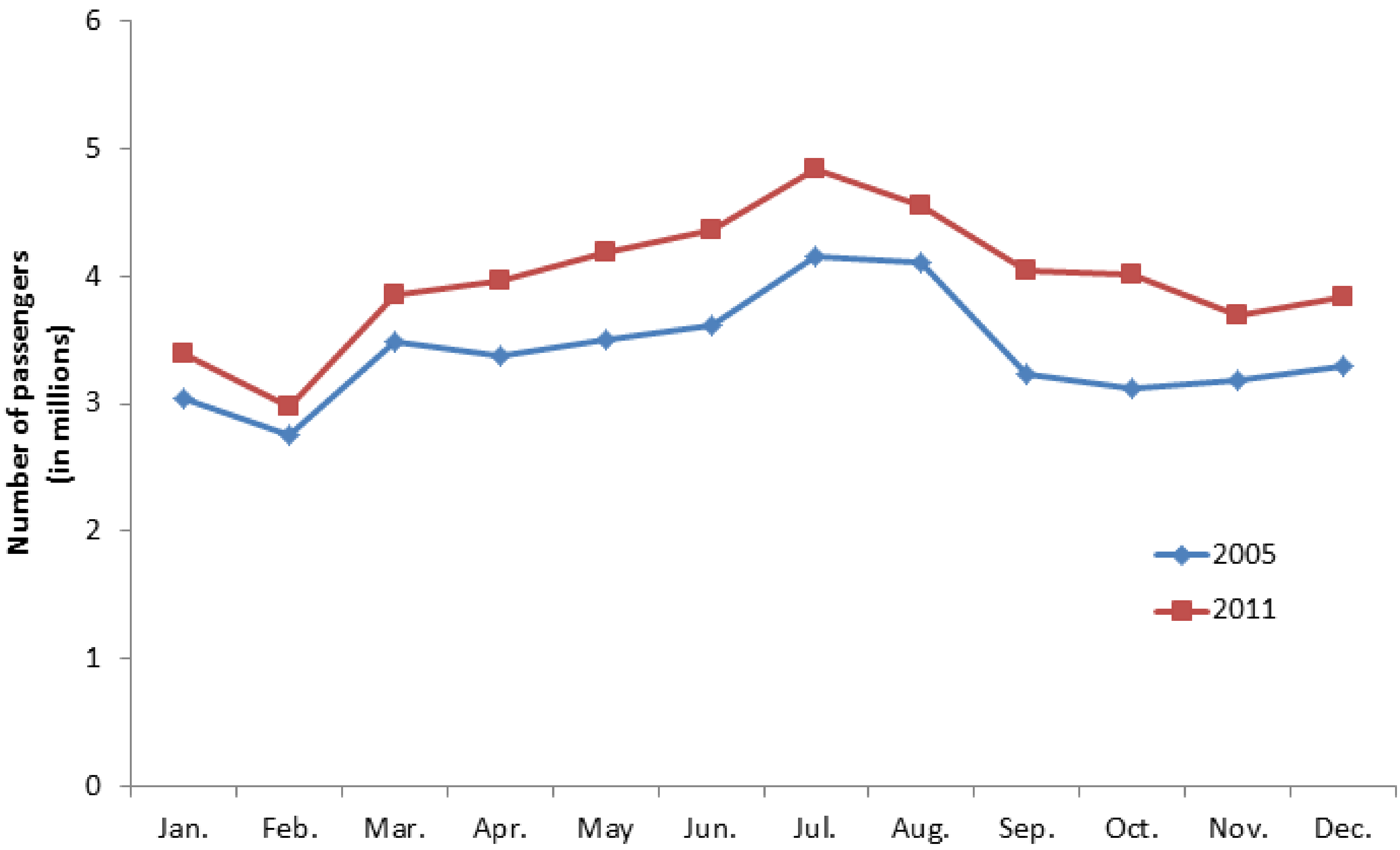
Annual Airside Capacity

- = The number of aircraft movements that can be handled at a reasonable level of service in one year
- Very important for planning purposes
- Runway system is typically the limiting element
- Estimation of annual capacity must consider:
  - Typical hourly (saturation) capacity
  - Pattern of airport use during a day (largely determined by type of airport demand and by geographical location)
  - Acceptable level of delay during busy hours
  - Seasonal and day-of-the-week peaking patterns of demand

Daily Demand Profile: Newark Aircraft Movements (% of Daily Movements)



Stability of Monthly Patterns: No. of Passengers at NY JFK



Annual Airside Capacity: Boston Example

1. Typical hourly runway capacity = 115 per hour

   Compute: A = 115 x 24 x 365 = 1,007,400

2. Equivalent of ~16–17 hours of strong activity per day.

   Compute: 1,007,400 x (16/24) = 671,600

3. ~85% utilization in busy hours to ensure delays are tolerable

   Compute: 671,600 x 0.85 = 570,860

4. Summer season days have about 15% more movements than winter season days

   (570,860 / 2) + (570,860 / 2)x(1/ 1.15) ≅ 534,000

This is a *rough estimate* of the ultimate capacity of Logan airport, absent any further capacity increase

- **Note: the annual capacity amounts to only about 50% of A**

An Important Benchmark

- The study on the need for a new runway in London concluded that, if a third independent runway is built at London Heathrow (LHR), it will add, as an upper limit,
  - Approximately 250,000 aircraft movements per year
  - Approximately 40 million passengers per year
- Remember: LHR operates for 17 hours per day and currently carries about 155 passengers per movement
- For most of the busiest airports with advanced ATC systems, a reasonable range may be:
  - 220,000 – 250,000 aircraft movements per year
  - 33 – 40 million passengers per year

Outline

- On Measuring/Estimating Capacity
- Landside vs. Airside Capacities
- Runway Systems: The Principal Bottleneck
- Capacity of a Single Ruway
- Runway Configurations and their Capacity
- Capacity Envelopes and Capacity Coverage Charts
- Annual Capacity of a Runway System
- **Increasing Runway Capacity**
- Taxiways and Aprons: A Summary

Increasing Runway Capacity

- At high levels of utilization, even small increases in the capacity of the runway system can have a large impact on air traffic delays
- This is the motivation behind many of the current efforts of airport operators and of ANSPs (e.g., NextGen and SESAR)
  - Reducing, even marginally, separation requirements (e.g., at many US and several European airports)
  - Improved precision in separations, especially on arrival
  - Sequencing of landing aircraft to minimize the use of wake vortex separations (e.g., LHR, Denver, Dallas/Ft. Worth)
  - Intersection departures to reduce separations between departures (e.g., Munich, LHR)
  - Time-based inter-arrival separations in headwinds (LHR)
  - Re-definition of aircraft classes (RECAT)

IFR Separation Requirements: Single Runway (USA)

Arrival-Arrival:

(1) Airborne separations on final approach (nmi):

Trailing aircraft

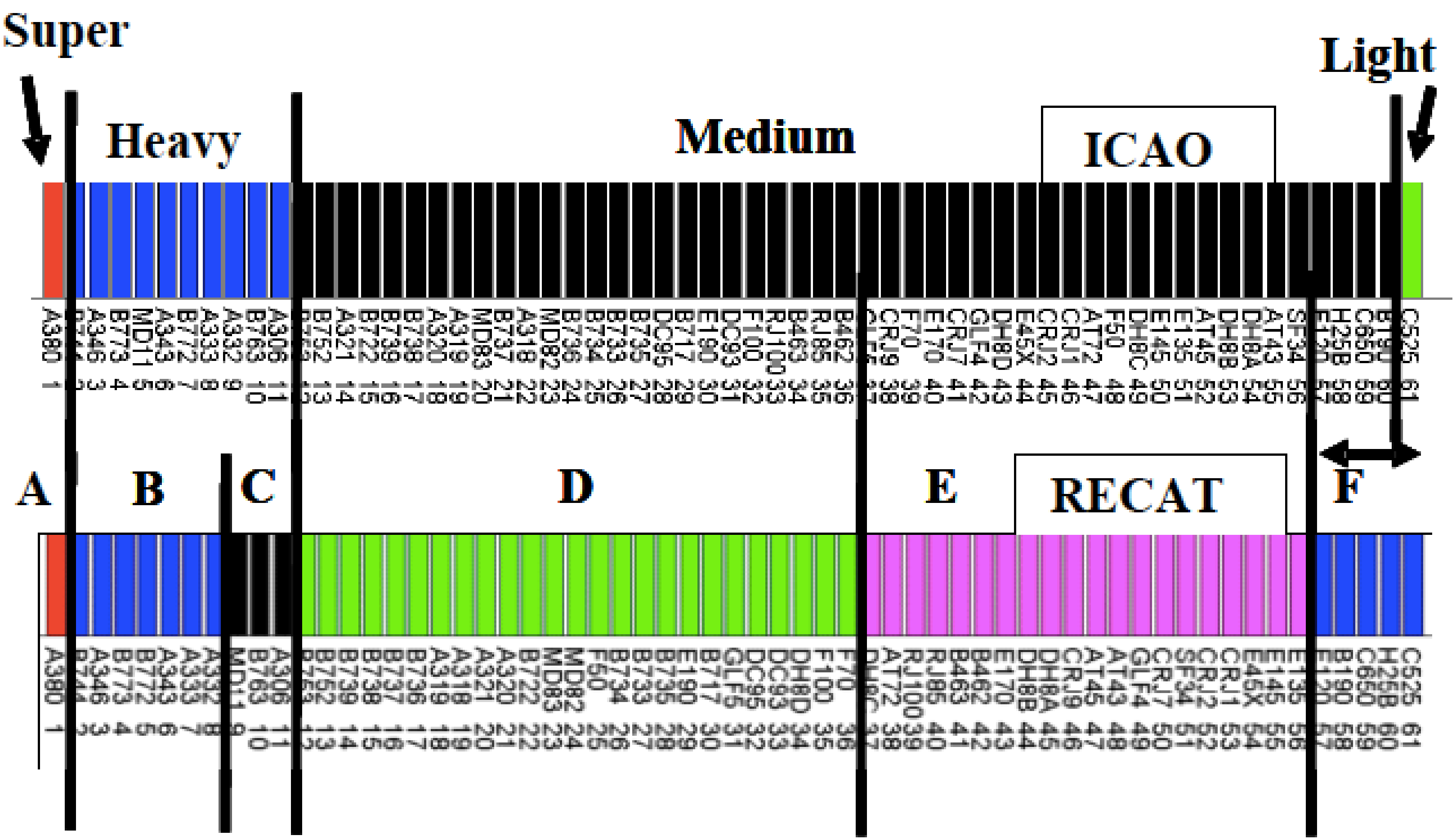
Leading aircraft

	H	L or B757	S
H	4	5	6*
B757	4	4	5*
L	2.5	2.5	4*
S	2.5	2.5	2.5

** Applies when leading aircraft is at threshold of runway*

(2) Leading aircraft must be clear of the runway before trailing aircraft touches down

Current ICAO vs. Proposed RECAT Classes



Need for More Capacity

- ATM innovations will result in only limited increases in *runway system* capacity at the busiest airports [e.g., +10% – 20%(??) over 20 years]
- Quantum increases in capacity can only come from new airports or new runways at existing airports
- Practically no new primary airports planned in North America and Western Europe (New Istanbul is the major exception); but several in Asia (India, China, Middle East)
- New runways are planned at a very few busy airports in Europe and US and at many major airports in Asia and South America

Outline

- On Measuring/Estimating Capacity
- Landside vs. Airside Capacities
- Runway Systems: The Principal Bottleneck
- Capacity of a Single Ruway
- Runway Configurations and their Capacity
- Capacity Envelopes and Capacity Coverage Charts
- Annual Capacity of a Runway System
- Increasing Runway Capacity
- **Taxiways and Aprons: A Summary**

Capacity of Taxiways and of Apron/Stands

- The capacity of the taxiway system is almost never the capacity bottleneck of major airports
- However, some specific parts of the taxiway system may consistently act as "hot spots" (points of congestion), especially at older, limited-area airports
- Much more common problem: long taxiing times (20+ minutes) as airfields of busiest airports become larger and more complex
- Estimating the dynamic capacity of the apron/stands (=the number of parked aircraft that can be processed per hour) can be difficult (need simulation)
- The number of aircraft served by a single contact gate is typically 6 – 7 per day and can be significantly smaller for gates serving long-range flights

Questions? Comments?