TURKISH AVIATION ACADEMY

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Slots and Demand Management

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Objective and Topics

- **Objective:**
  - To summarize the current approach to allocating slots at congested airports, describe some proposed alternatives and discuss central issues i
- **Topics:**
  - Why “slots” and demand management
  - Current status around the world
  - Current approach to demand management
  - Proposed market-based approaches to demand management
  - Experience with secondary trading and the value of slots
  - A form of market regulation?

Outline

- Why “slots” and demand management
- Demand Management based on the IATA Guidelines
  - Current status around the world
  - Slot facilitation and slot coordination
  - Description of current practices
  - Strengths and weaknesses
- “Market-based” schemes for demand management
  - Congestion pricing
  - Auctions
  - Experience with secondary trading and the value of slots
- A form of economic regulation?

Demand Management Fundamentals

- Demand management measures may be taken when expected demand at an airport will habitually exceed available capacity
- Airport capacity expansion should be the principal means of accommodating growth of demand
- Demand management should be used to address:
  - short- and medium-term problems
  - long-term problems when capacity expansion:
    - becomes unreasonably expensive; or
    - is constrained by challenging political, social or environmental barriers
- Demand management is generally practiced today through "schedule coordination", essentially a reservation system for access to congested airports

The Concept of Schedule Coordination

- Slots are "permissions to use a runway and airport infrastructure on a specific date and time for an arrival or departure"
- Schedule Coordination allocates scarce capacity among airlines to achieve adequate utilization of the airport, while keeping delays at reasonable levels
  - "smoothens peaks and valleys" in daily demand
  - keeps demand below an upper limit specified by the airport's "declared capacity"
- Important to estimate declared capacity accurately and to understand the relationship and tradeoffs between number of flights served and delay

Declared Capacities – Brussels, 2009

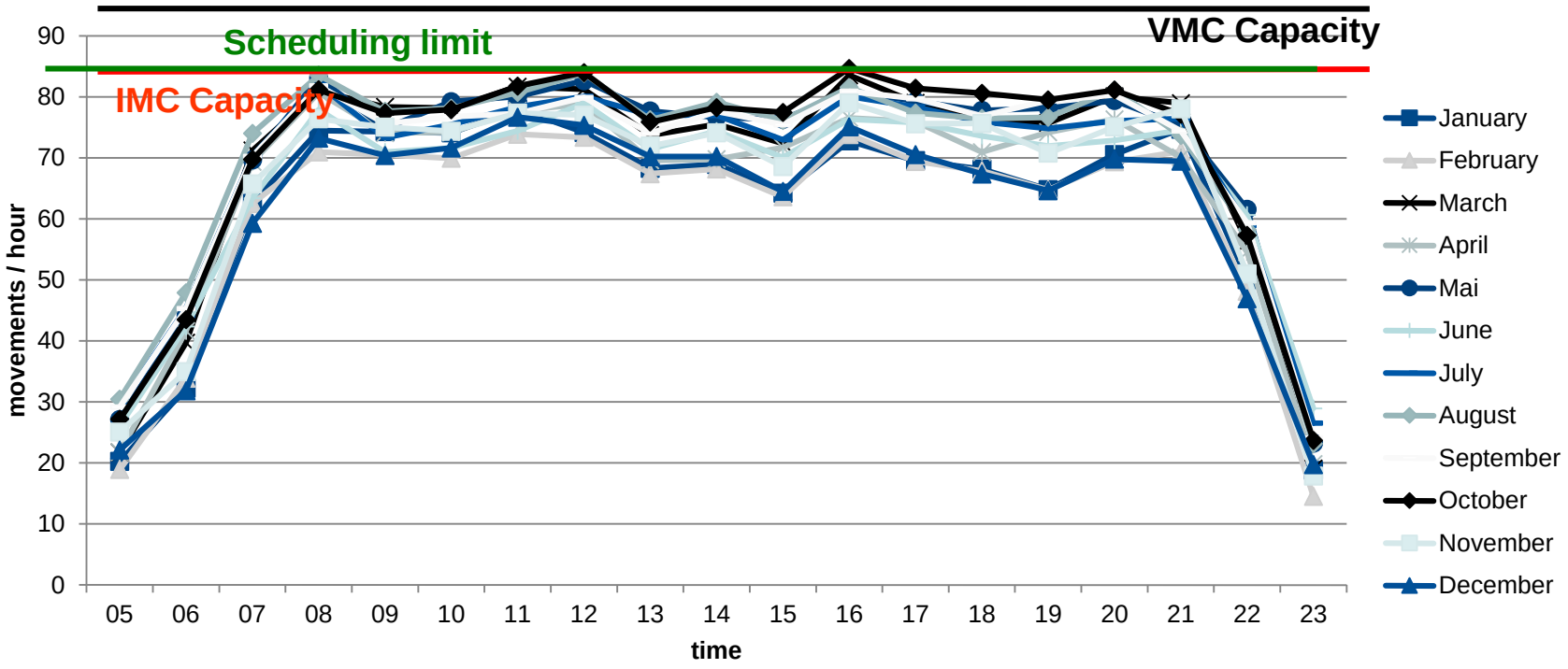
times / period		05 min			10 min			30 min			60 min		
from	until	arr	dep	total	arr	dep	total	arr	dep	total	arr	dep	total
00.00	05.55	5	5	8	9	9	9	16	16	16	30	30	30
06.00	06.55	5	5	9	10	9	13	24	27	35	35	40	45
07.00	22.55	6	5	10	10	9	15	30	27	40	48	44	74
23.00	23.55	5	5	8	9	9	9	16	16	16	30	30	30

Source: Morisset, 2010

Determining Declared Capacity

- No standard methodology exists for determining declared capacity (= the number of "slots" available at an airport)
  - At some airports sophisticated approaches are used that include simulations and extensive consultation with stakeholders (airlines, airport operator, ATC)
  - Many use *ad hoc*, "back-of-the-envelope" approaches with limited inputs and "politicized" considerations
- Declared capacities are typically set with reference to the capacity of the airport under Instrument Meteorological Conditions (IMC):
  - Lower (or much lower) than IMC capacity in most cases
  - Very close to (and sometimes slightly above) estimated IMC capacities at some of the busiest airports (e.g., Heathrow, Frankfurt, Gatwick, Munich)
  - Terminal building capacity may also be a constraint

FRA – Average daily schedule by month (2007)



- Evenly distributed demand profile from 07:00 to 21:00
- Hourly demand peaks at 84-movement hourly slot limit

IATA Schedule Coordination Process

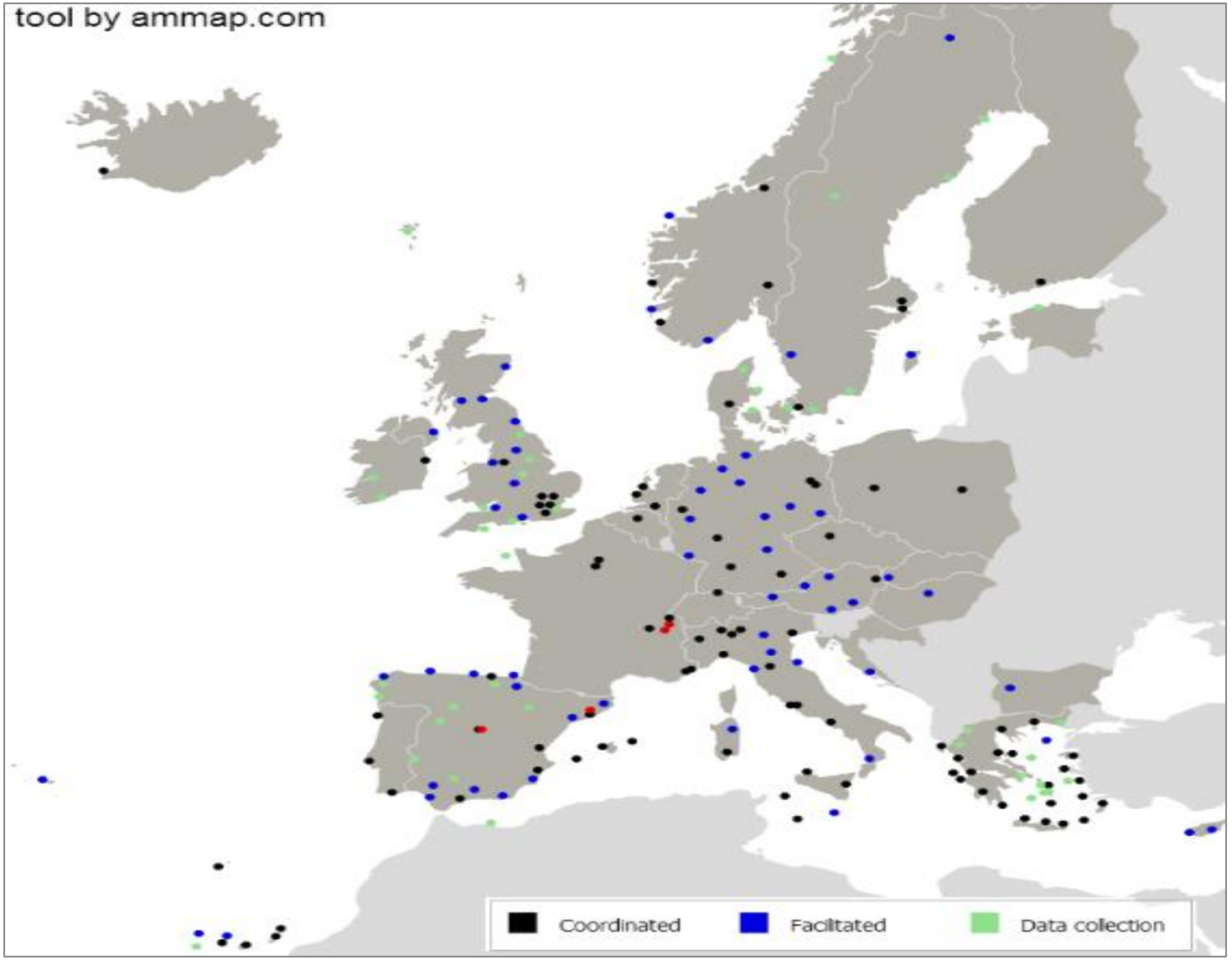
- Level 1 (“non-coordinated”)
- Level 2 (“schedules facilitated”) (~ 120 airports)
- Level 3 (“fully coordinated”)
  - ~ 170 airports (~100 in Europe, practically all busiest ones outside US)
  - Coordinator appointed by appropriate authority, usually assisted by a coordination committee
  - IATA Schedule Coordination Conferences (SCC); in June and November for subsequent season
  - Attended by ~300 air carriers, coordinated airport reps, schedule coordinators, etc.

Level 3 and Level 2 Airports (Feb 2015)

Region	Level 3	Level 2
Asia Pacific	36	16
Europe	100	74
Middle East and Africa	11	12
North Asia	13	2
Americas	7	12
Total	167	116

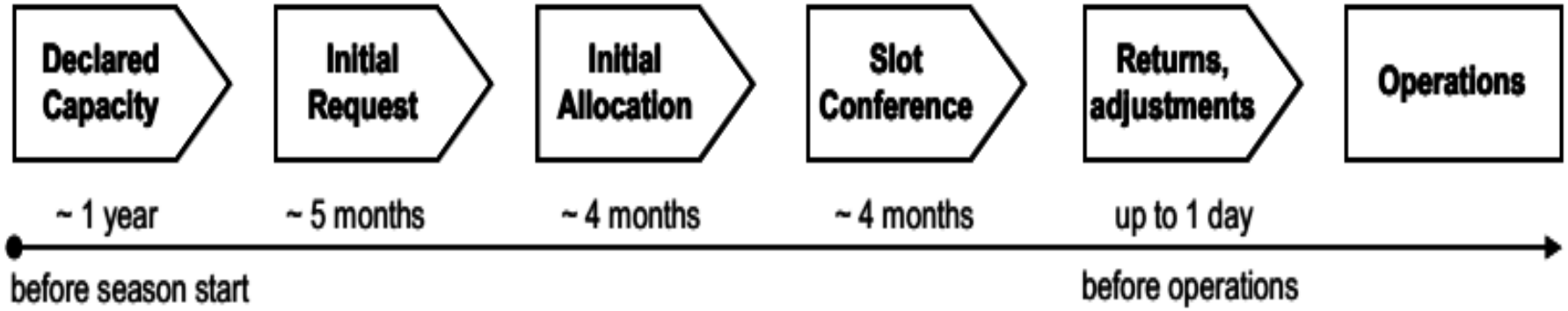
Source: IATA

Level 3 and Level 2 Airports in the EU (2015)



Source: N. Ribeiro from EUACA

Milestones in the Slot Allocation Process

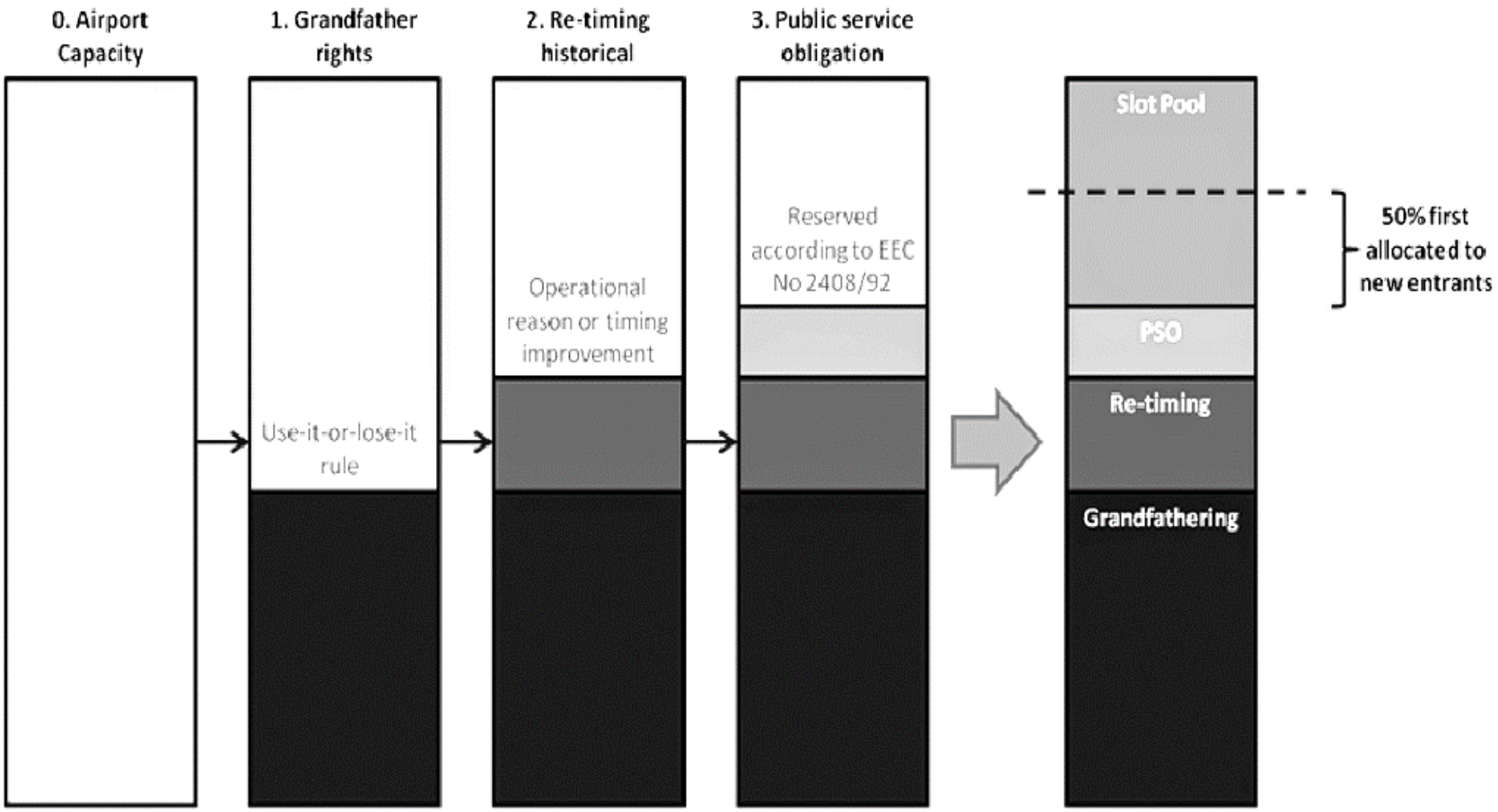


Source: N. Ribeiro (2015) from RTWH Aachen (2014)

IATA Schedule Coordination Process [2]

- Carriers must submit slot requests 27 days before SCC
- During SCC and post -SCC, coordinators resolve conflicts, finalize schedules
- ***Historical precedent is over-riding criterion***
- Carriers may change use of slots or exchange slots
- **Use-it-or-lose-it clause (80% use required)**
- **New entrants are allocated up to 50% of "free" slots**
- ***Restrictive definition of "new entrant"***
  - ***Maximum of 4 slots in a day after being awarded new slots***
- Other allocation criteria: size and type of market, length of period of operation, curfews, etc.
  - "Transparent" slot buying/selling permitted in some EU countries (authorized as an option by EU Commission in 2008)

Steps in Filling Up the Slots at Level 3 Airports



Source: N. Ribeiro (2015) from ACCESS Report (2014)

LHR Slots: Summer 2015

Runway Scheduling Limits Summer 2015

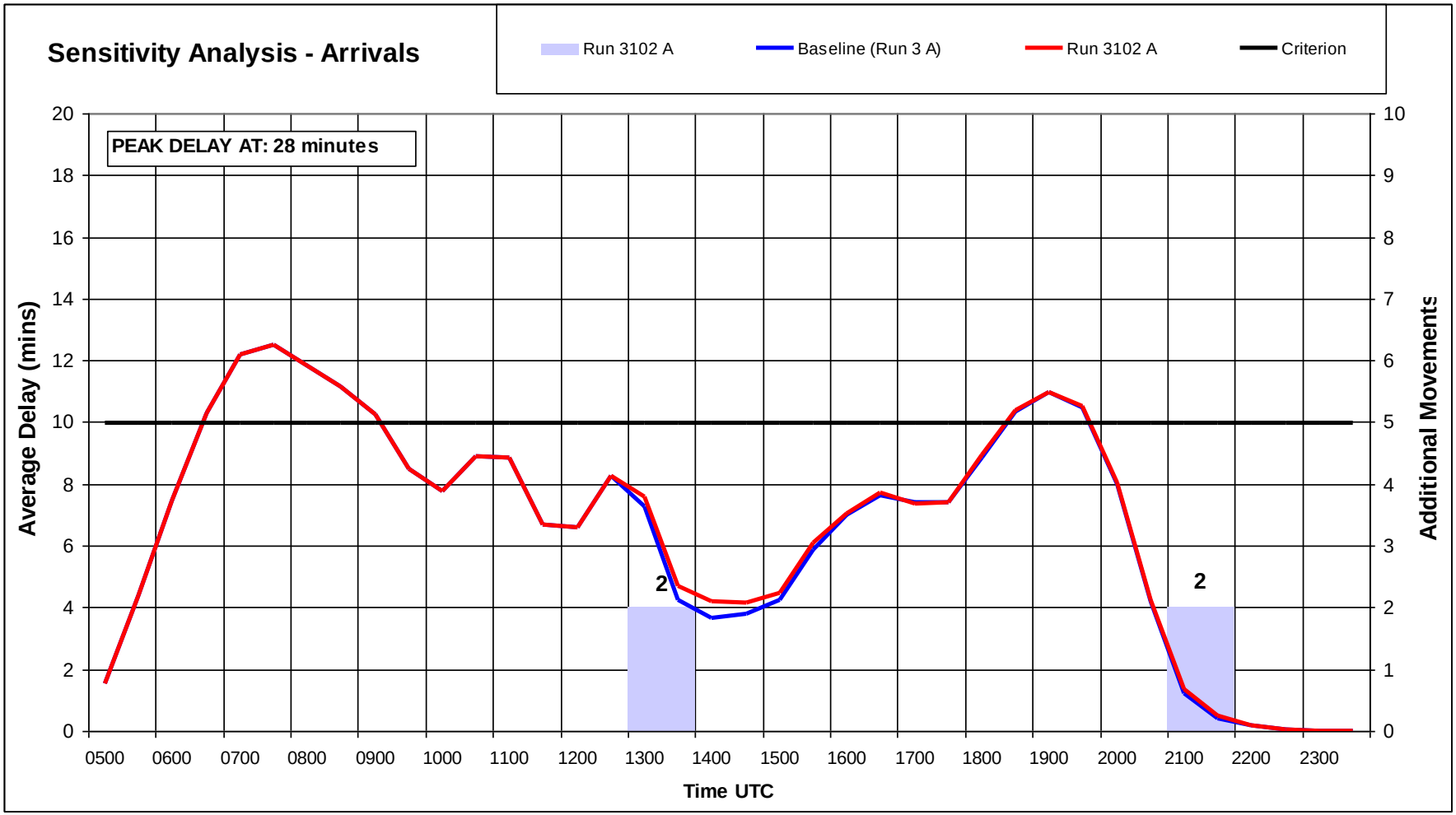
Arrivals																		
Hour (UTC)	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**Average**	**Total**
Summer 2014	38	39	37	40	40	41	40	43	43	41	41	44	44	43	38	44	20	39.8	676
Capacity change	+1							+1	-1	+1		+1				-1	+3		
Summer 2015	39	39	37	40	40	41	40	44	42	42	41	45	44	43	38	43	23	40.1	681

Departures																		
Hour (UTC)	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**Average**	**Total**
Summer 2014	25	46	43	43	41	42	41	44	44	44	42	43	44	44	38	38	30	40.7	692
Capacity change				+1	+1				+1		+1			-1	+2				
Summer 2015	25	46	43	44	42	42	41	44	45	44	43	43	44	43	40	38	30	41	697

Air Transport Movement Cap
Weekly Planning Limit: 9,620

Summer 2009: Arrs. 676, Deps. 691; Weekly, 9524
Annual Limit: 480,000 movements (Terminal 5 agreement)
2014: 73.4 mio pax, 473,000 movements

Example: Sensitivity of Delay at LHR



Source: Manager, Slot Coordination, Airport Coordination UK

Passenger Limits: LHR, Summer 2015

Terminal	A/D	Constraint	Time Period (GMT)	Lower Limit	Initial Coordination Limit	Upper Limit
T1	D	International 1 Hour	0000 - 2359	200	**500**	1000
		International 3 Hour	0000 - 2359	1000	**1200**	2000
	A	International 1 Hour	0000 - 2359	250	**500**	1100
		International 2 Hour	0000 - 2359	500	**1000**	2200
T2	D	Combined 1 Hour	0000 - 2359	2500	**2800**	3500
		Combined 3 Hour	0000 - 2359	6000	**6800**	9000
	A	International & CTA 1 Hour	0000 - 2359		**2600**	3900
		International & CTA 2 Hour	0000 - 2359		**5100**	6500
		Domestic 1 Hour	0000 - 2359		**400**	600
T3 – S15 live	D	International 1 Hour	0000 - 2359	1700	**2000**	4000
		International 3 Hour	0000 - 1559	4200	**5000**	9000
			1600 - 2359	4000	**4200**	9000
	A	International 1 Hour	0000 - 2359	3000	**3500**	4000
T3 – "end game"**	D	International 1 Hour	0000 - 2359	2700	**3000**	4000
		International 3 Hour	0000 - 2359	5800	**7000**	9000
	A	International 1 Hour	0000 - 2359	3000	**3500**	4000
T4	D	International 1 Hour	0000 - 2359		**1650**	2500
		International 3 Hour	0000 - 2359		**3750**	5500
	A	International 1 Hour	0000 - 2359	1400	**1800**	2500
		International 2 Hour	0000 - 2359	2800	**3200**	4300
T5	D	Combined 1 Hour	0000 - 2359		**4500**	5000
	A	International 1 Hour	0000 - 2359		**3750**	4500
		Domestic 1 Hour	0000 - 2359		**950**	1150

Assumed Load Factors: LHR, Summer 2015

Summer 15	T1 International	T1 International	T2 Domestic	T2 CTA & International	T2 Combined	T3 International		T4 International		T5 Domestic	T5 International	T5 Combined
Day of Week	A	D	A	A	D	A	D	A	D	A	A	D
1	88%	81%	82%	87%	86%	88%	91%	86%	86%	90%	87%	86%
2	86%	82%	72%	85%	84%	88%	87%	86%	84%	88%	86%	85%
3	85%	81%	70%	84%	85%	86%	89%	83%	85%	87%	85%	84%
4	87%	85%	72%	85%	86%	87%	89%	85%	85%	87%	88%	86%
5	88%	86%	75%	86%	89%	90%	91%	87%	87%	87%	90%	88%
6	89%	86%	77%	89%	91%	90%	92%	86%	88%	91%	89%	89%
7	91%	85%	80%	87%	88%	90%	90%	89%	88%	88%	89%	89%

Stand Limits: LHR, Summer 2015

Total Physical Stand Supply - For Information Only, this is not the S15 Declared Stands

Summer 15										
Apron	F	E	E (747-400)	E (777-200)	D (767-300)	D (757)	C (A321)	C (A319)	B	TOTAL
T1	0	0	0	1	1	3	5	0	0	10
T2	10	10	0	3	0	0	13	0	0	36
T3	9	19	5	3	2	3	3	0	0	44
T4	6	12	7	1	3	0	4	1	0	34
T5	15	15	10	0	4	0	15	1	0	60
Total exc. Cargo	**40**	**56**	**22**	**8**	**10**	**6**	**40**	**2**	**0**	**184**
CARGO	0	3	3	0	0	0	0	0	0	6
Total inc. Cargo	**40**	**59**	**25**	**8**	**10**	**6**	**40**	**2**	**0**	**190**

Slot Availability at LHR: The Limits!

ARRIVALS							
HOUR	Mon	Tue	Wed	Thu	Fri	Sat	Sun
0600	0	0	0	0	0	1	0
0700	0	0	0	0	0	0	1
0800	0	0	0	0	0	0	3
0900	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
1100	0	0	0	0	0	1	1
1200	0	0	0	0	0	0	1
1300	0	0	0	0	0	1	1
1400	2	1	2	0	3	0	4
1500	0	1	1	0	0	0	0
1600	0	0	0	0	0	0	0
1700	0	0	0	1	0	0	0
1800	0	0	0	0	0	0	0
1900	0	0	0	0	0	2	0
2000	0	0	0	0	0	3	0
2100	0	0	0	0	0	15	1
2200	4	3	1	2	2	12	3

DEPARTURES							
HOUR	Mon	Tue	Wed	Thu	Fri	Sat	Sun
0600	0	0	0	0	0	3	12
0700	0	0	0	0	0	0	9
0800	0	0	0	0	0	0	0
0900	0	0	0	0	0	0	0
1000	0	0	0	0	0	0	0
1100	0	0	0	0	0	0	0
1200	0	0	0	0	0	0	0
1300	0	0	0	0	0	0	0
1400	0	0	0	0	0	0	0
1500	0	0	0	0	0	0	0
1600	0	0	0	0	0	0	0
1700	0	0	0	0	0	0	0
1800	0	0	0	0	0	0	0
1900	0	0	0	0	0	0	0
2000	0	0	0	0	0	4	0
2100	8	1	1	0	0	12	0
2200	0	2	2	1	0	5	0

Source: Manager, Slot Coordination, Airport Coordination UK for Summer, 2001

IATA: Partial List of Badly Congested Airports (2014)

Region	IATA Code	Name	RUNWAYS			TERMINAL		
			Aircraft Movements	Growth Rate	Capacity limit reached	Passengers in Millions	Growth Rate	Capacity limit reached
Asia Pacific	CGK	Jakarta	398,985	4.9%	2021	60.1	4.1%	FULL
	HND	Tokyo Haneda	403,242	3.1%	2018	68.9	3.2%	2035
	BKK	Bangkok	301,747	-4.8%	2023	51.4	-3.1%	FULL
North Asia	PEK	Beijing	567,759	1.9%	2019	83.7	2.2%	FULL
	SHA	Shanghai	243,916	3.8%	2021	35.6	5.2%	2016
	HKG	Honk Kong	382,782	5.7%	2016	59.6	6.3%	FULL
Europe	AMS	Amsterdam	440,057	0.5%	2021	52.6	3.0%	2018
	IST	Istanbul	406,317	11.5%	2017	51.3	13.7%	2017
	LHR	London Heathrow	471,938	-0.7%	FULL	72.4	3.3%	2026
Latin America	BOG	Bogota	322,546	1.0%	2020	25.0	14.2%	FULL
	GRU	Sao Paulo	284,191	3.8%	2020	36.2	11.4%	2018
	MEX	Mexico	396,567	5.0%	2022	31.5	6.9%	2015
Middle East	DOH	Doha	205,744	7.7%	2026	23.4	9.8%	2018
	AUH	Abu Dhabi	135,213	11.2%	2023	16.5	12.4%	FULL
	DXB	Dubai	369,953	7.5%	2019	66.4	15.2%	2016
North America	YYZ	Toronto	431,323	-0.6%	2031	36.1	3.4%	2019
	EWR	Newark	419,850	1.4%	2018	35.0	2.9%	2031
	LGA	La Guardia	371,565	0.4%	2017	26.7	3.9%	2020

- Airports with full terminals: 90 in 2014; 223 in 2020
- Airports operating at 90% capacity of the runways: 6 in 2014; 63 in 2020
- Source: IATA (2014) *The Infrastructure Challenge*, courtesy of Dr. Joe Sulmona

Outline

- Why “slots” and demand management
- Demand Management based on the IATA Guidelines
  - Current status around the world
  - Slot facilitation and slot coordination
  - Description of current practices
  - Strengths and weaknesses
- “Market-based” schemes for demand management
  - Congestion pricing
  - Auctions
  - Experience with secondary trading and the value of slots
- A form of economic regulation?

Criticisms of Slot Coordination As Done Today

- Grandfathering allows no consideration of the economic value of a slot; an airline has no way of obtaining a slot to which it assigns high value
- By prioritizing punctuality, slot-coordinated airports may often be setting their declared capacity to smaller than optimum values, i.e., may be serving fewer than the optimum number of flights
- Heavy reliance on historical precedent in the allocation of slots and limitations on access by new entrants may inhibit competition
- May mask need for and economic value of additional capacity

Economically-Based Demand Management Schemes

- For at least 50 years, many economists and other aviation experts have suggested that the existing approach to allocating airport capacity among the airlines should be modified
  - To include some economic considerations, i.e., to consider the economic value of the slots to the airlines
- The three fundamental types of approaches that have been proposed are:
  - Congestion pricing of access to airports
  - Auctioning of slots
  - Secondary trading of slots
- Secondary trading can also be used (and is already used) to supplement the existing approaches

Congestion Pricing

- Congestion Pricing develops pricing schemes designed to prevent or reduce congestion at popular facilities
- Essentially, the price of access to the facility is set in a way that discourages use of the facility during periods when demand is at its peak
- Congestion Pricing is based on an important body of economic theory (see References at the end for an introduction)
- The fundamental idea: Make the users of the facility pay for the cost that they impose on other users, when they use the facility during a period of high demand

Possible Forms of Congestion Pricing

Due to the many practical difficulties, the realistic possibilities for application of congestion pricing seem limited to charging *during peak periods*:

- A surcharge in addition to the weight-based landing fee
- A flat fee independent of aircraft weight (or variation thereof)
- A multiplier applied to the weight-based landing fee
- A landing fee equal to the larger of a specified minimum charge and of the weight-based landing fee

Landing Fees, BAA (2005)

	Heathrow		Gatwick		Stansted	
Aircraft weight (tons)	Peak	Off-peak	Peak	Off-peak	Peak	Off-peak
MTOW ≤ 16	£ 590	£ 250	£ 385	£ 110	£ 95	£ 85
16<MTOW≤ 50	£ 590	£ 250	£ 385	£ 110	£ 142	£ 105
50 < MTOW	£ 590	£ 425	£385	£ 125	£ 231	£ 131
For MTOW > 250	£ 590	£ 425	£385	£ 125	£ 400	£ 400

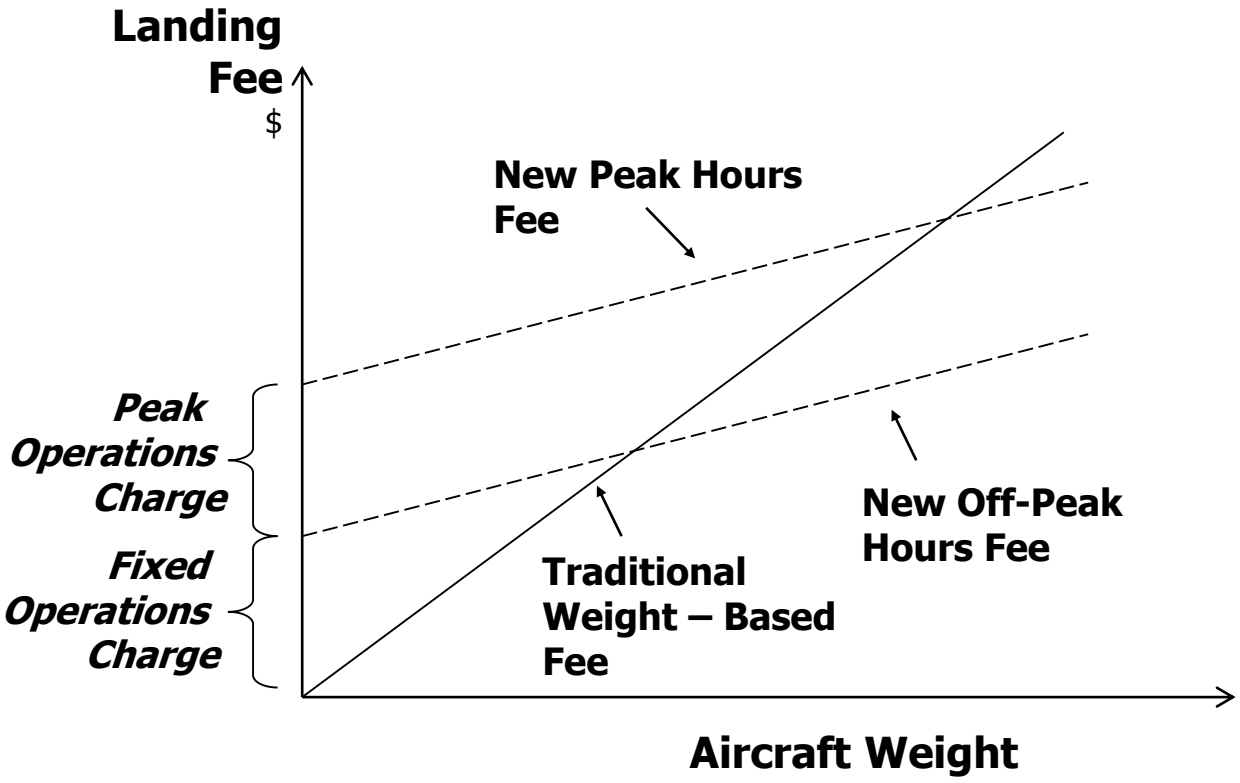
Apply to domestic and international flights

Note: "Peak" varies by airport (e.g., Heathrow peak: 07:00-9:59 and 17:00-18:59 GMT, April 1-Oct. 31)

Some Major Airport Fees, LHR (2015)

- Landing fee for Chapter 3 and 4 aircraft: £ 2,934 and £ 1,430, respectively, irrespective of weight. [*Note:* The fee is closely tied to "noise"; further adjustments are made for noise characteristics and for late night (00:30-03:30) operations.]
- Air navigation service fee: £ 80.53 + 1.08 per metric tonne of MTOW.
- Charge per departing passenger: £ 29.59 for European destinations; £ 41.54 for others.

Boston (1993): Proposed Landing Fee vs. Traditional Weight-Based Fee



Auctions

- A much-discussed approach for which there is no practical experience to date*
- Possible Scenario:
  - Carriers submit sealed bids for any number of slots
  - All slots are auctioned simultaneously

- BUT: How to do this and address all the complexities remains an open question!

* China has announced plans to begin auctioning in 2016 some domestic slots at some of its airports

Complexity of Slot Auctions

- The value that an airline derives from a slot depends on what other slots it obtains
  - Landings and takeoffs
  - Alternative times for a given flight
  - Slots for connecting flights
- Network effects are also important
  - A slot at a given time at airport A may be useless without a corresponding slot at airport B
- Hence, there is a *huge* number of combinations that each carrier may be interested in at *each* airport.
  - How does one prepare such bids and how does the auction administrator select the best bids?
- A follow-up market is also clearly needed to adjust auctioned slot allocations

Secondary Trading of Slots

- Several countries now allow the trading of slots (purchasing, leasing) at Level 3 airports
- European Commission (2008): Leaves it up to Member States to permit or ban secondary trading of slots; such trading must "take place in a transparent manner".
- LHR rules:
  - The Coordinator must confirm feasibility of trade
  - Buyer purchases runway slot pair along with historical terminal and stand capacity (e.g., Code D aircraft with 150 seats in T3)
  - May "re-time" slot or change terminal subject to availability
  - Transactions are public, but price need not be disclosed
  - Once the slot has grandfather rights, it can be traded (must wait 2 years for new entrant slots)

Some Slot Prices from Secondary Trading

- Highest published price (until recently): $207 million for four daily pairs at LHR
- LHR: A non-daily slot pair may be worth up to £0.5 million for a single day
- LGA (New York) and DCA (Washington) slot pairs valued at about $5 million each
- Compensation may not be purely monetary (e.g., swap slots at other airports)
- Eligibility to acquire slots may be restricted
- February 2015: SAS sold two pairs of slots at LHR; a morning pair for $60 million and an afternoon pair for $22 million; now has 19 more available pairs at LHR

[Sources: Morrell, 2012; LHR Holdings, Ltd, 2012]

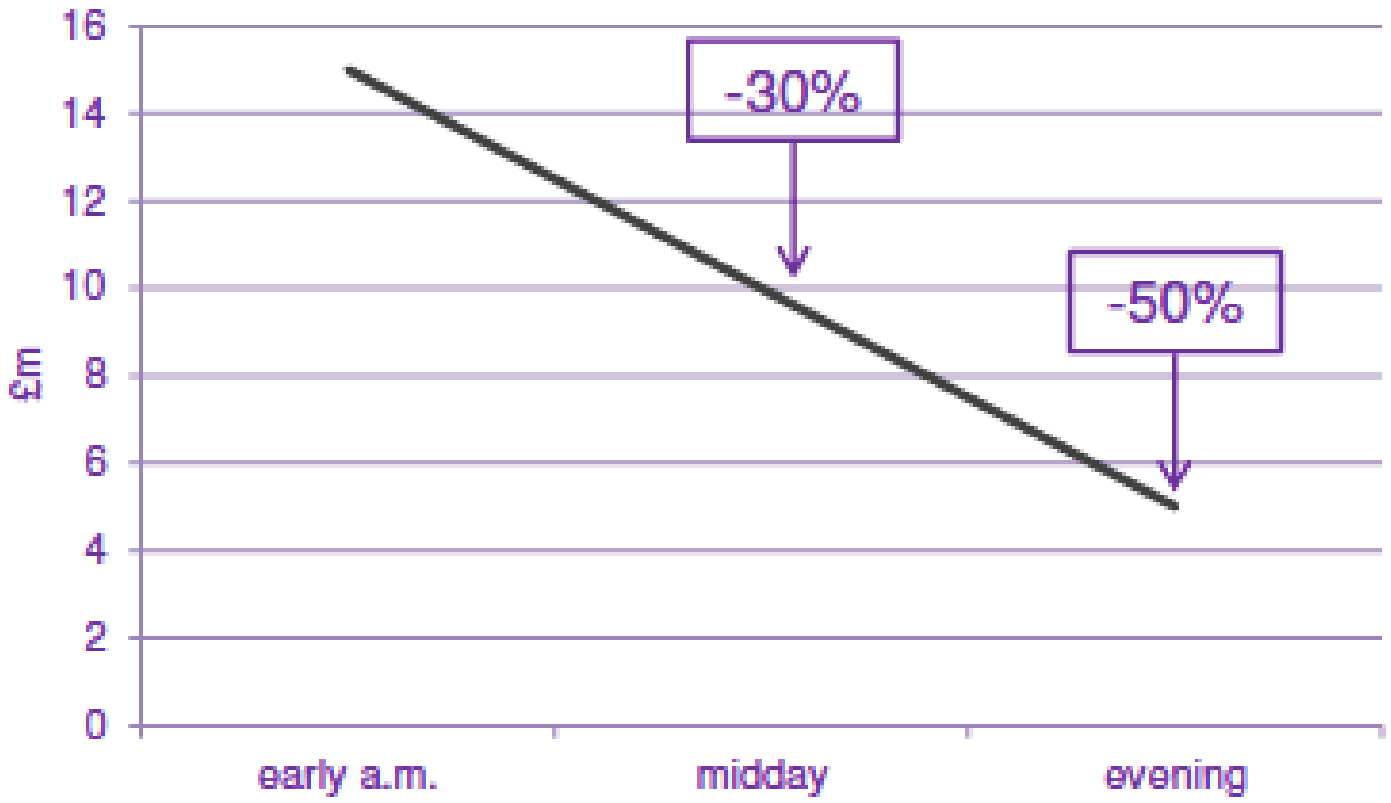
A Pattern Is Developing

- October 2015: Delta and its partner, Virgin Atlantic bought 6 pairs of slots at LHR from Air France – KLM which are reducing their operations at LHR
- Price: about $30 million per pair
- Delta/Virgin Atlantic will be operating 26 non-stop flights daily between the US and LHR
- Becoming major competitors of British Airways/American Airlines on LHR – North Atlantic market
- Strategy of AF-KLM seems similar to that of SAS (slots previously used for short- and medium-haul flights are sold to carriers that can use them for long-haul flights or for “feeding their hubs”)

Some Simple Arithmetic

- The proposed new third runway at LHR, if it is built, will create about 40 arrival and departure slots per hour, or 20 pairs of slots per hour
- Roughly 16 hours of operations per day
- Just the value of the slots that will be created will therefore be about $10 billion (= 20 pairs per hour x 16 hours x $30 million per pair)!
- (Note: The above estimate is based on an important assumption, which may not be true!)
- In addition to the value of the slots, we have the value of some 40 million additional passengers per year (made possible by the new runway) plus time savings due to increased capacity, etc.

More on Slot Valuation



- Time of day is important; morning slots at LHR are the most valuable

[Sources: LHR Holdings, Ltd, 2012]

Future Trends: Demand Management

- Innovative slot allocation schemes with emphasis on more efficient use of slots (e.g., incentives for use of large aircraft, "specialized" airports with respect to traffic)

and/or

- Slot allocation schemes that include economic criteria and approaches:
  - Congestion pricing
  - Slot auctions
  - ("Secondary) slot trading

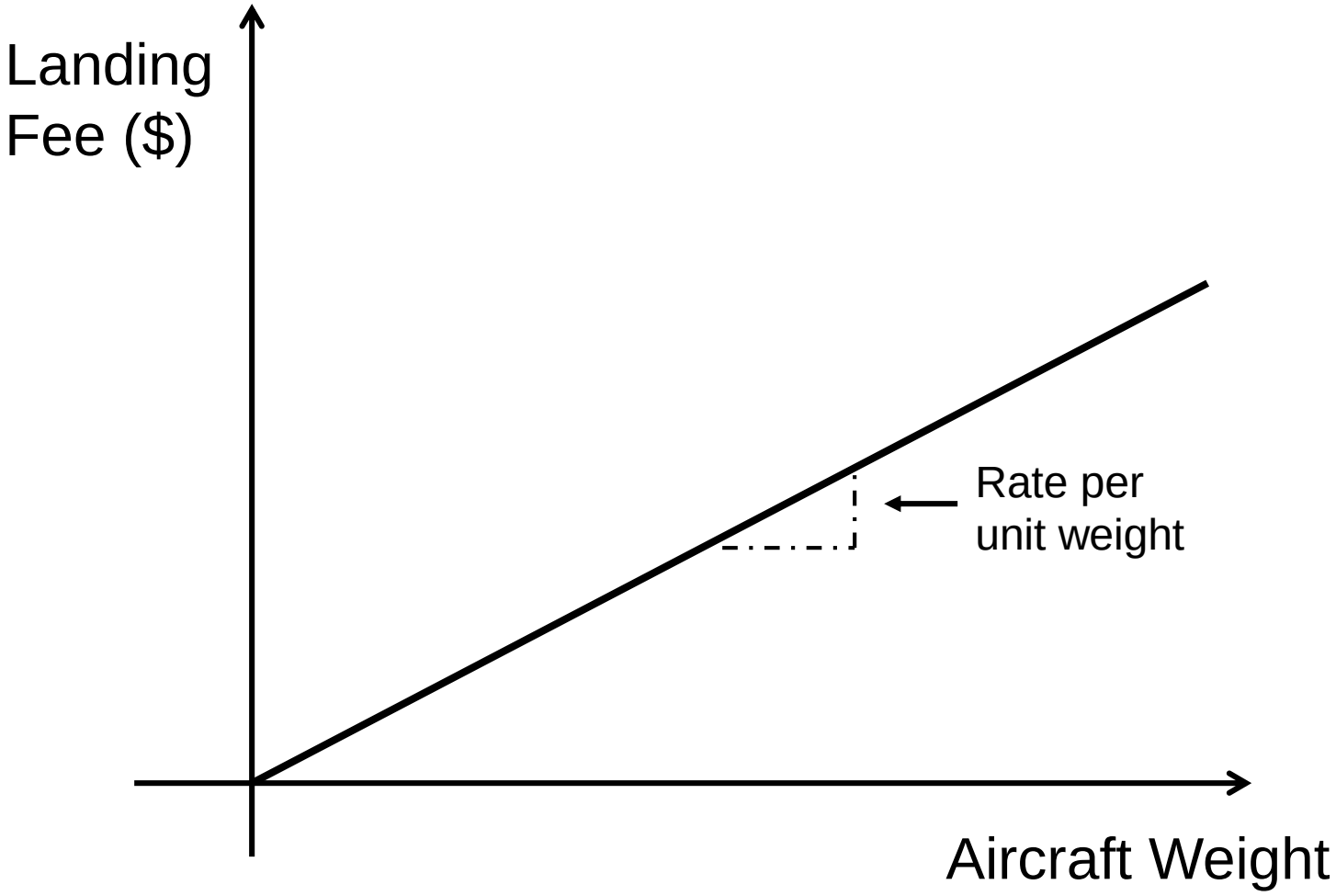
References

1. de Neufville, R. and A. Odoni (2013) *Airport Systems: Planning, Design and Management,* 2nd Edition, McGraw-Hill Education. [Chapter 12]

2. Czerny, A. I., Forsyth, P., Gillen, D., and Niemier, H-M. (eds.) (2008) Airport Slots: International Experiences and Options for Reform, Ashgate Publishing, Hampshire, U.K.

Questions? Comments?

Traditional Weight-Based Landing Fee



Congestion Pricing: A Key Observation

- The marginal congestion cost associated with an aircraft movement has 2 components:
  - Cost of delay to that movement (***internal*** cost)
  - Cost of additional delay to all other aircraft operators (***external*** cost)
    - At congested airports, this second component can be very large -- often much more than $1000 *per aircraft movement*

- *Congestion pricing aims at increasing the efficiency of resource utilization by forcing users to "internalize external costs" through the payment of a congestion toll*