1.232/15.05/16.71/ESD.217 The Global Airline Industry

Airports: A Brief Overview

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Outline

- Some standard runway system configurations
- Regional characteristics
- Airport capacities
- Typology of passenger terminals
- Evaluation of passenger terminal concepts and level of service
- Future issues and trends
- Airport revenues (if time)

Reference: Ch. 12 in *The Global Airline Industry*

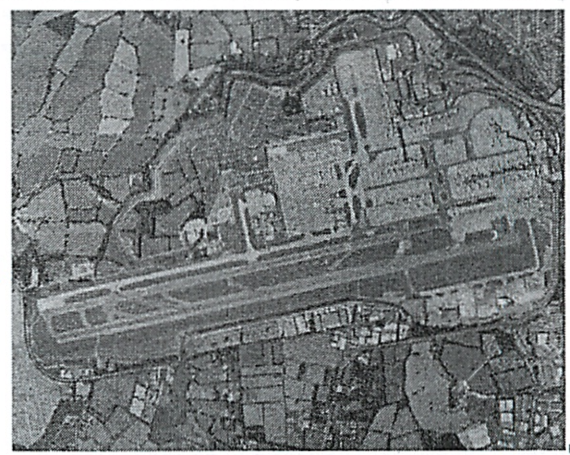
† class on airport systems

Airport Physical Layouts

- Airport layouts exhibit enormous variability (general arrangement of facilities, no. of runways, geometric configuration of runways, length of runways, location and configuration of terminal facilities)
- Range from very simple to complex geometries
- Area occupied is only mildly correlated with traffic volumes
- Layouts are greatly influenced by historical and local factors
- Some common configurations:
  - 1 runway
  - 2 intermediate parallels
  - 2 close + 1 independent
  - Intersecting runways
  - 2 close parallels
  - 2 independent parallels
  - 2 independent close pairs
  - Many others (local factors)

some airports small – but lots of pax

London Gatwick (LGW): 1 runway



$3 billion
32-35 million pax/year on its 1 runway

large aircraft

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Designation of Runways

- Runways are identified by a two-digit number, which indicates the magnetic azimuth of the runway in the direction of operations to the nearest 10°
- When parallel runways are involved the indication R ("right"), L ("left") and, with three runways, C ("center") is also used (e.g., Runway 22R)
- Note that 22R is 04L in the opposite direction
- With 4-6 runways, one pair is marked to the nearest 10° and the other to the next nearest 10°

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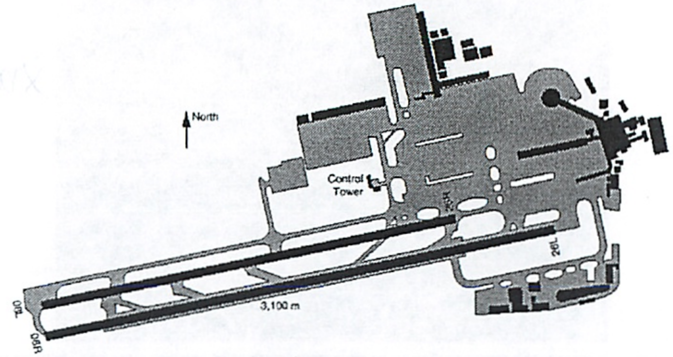
- seems confusing + dump

London Gatwick (LGW)



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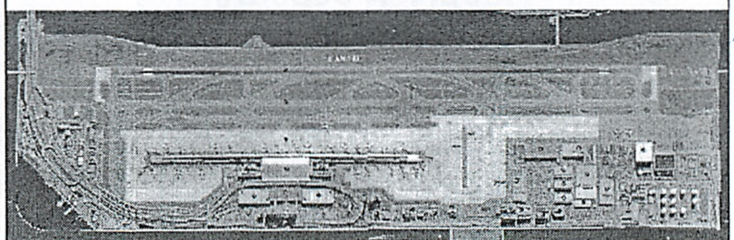
Osaka Kansai International (KIX)



Cost $11 billion in 1987

- one of most expensive single airport runway

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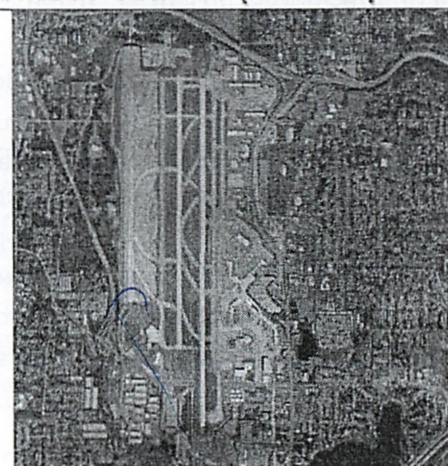
- built a new runway recently
- artifical island
- 2nd runway just stimulus package
- often to stimulate economy
- very political

Seattle / Sea-Tac (2 close parallel)

800 ft between runways



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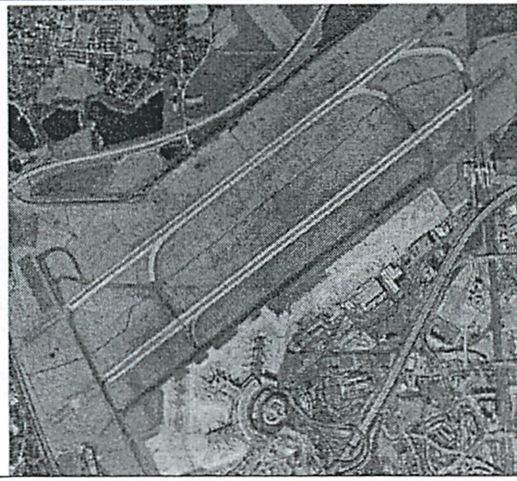
3rd runway recently added
arrival is the shorter one so instruments don't interfear

Dusseldorf International Airport (2 close parallel)

still



1620 ft between runways

← can build centerline taxiway
– much easier to operate

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Seoul Incheon: 2 close parallel

w/ taxiway in between

new runway now here

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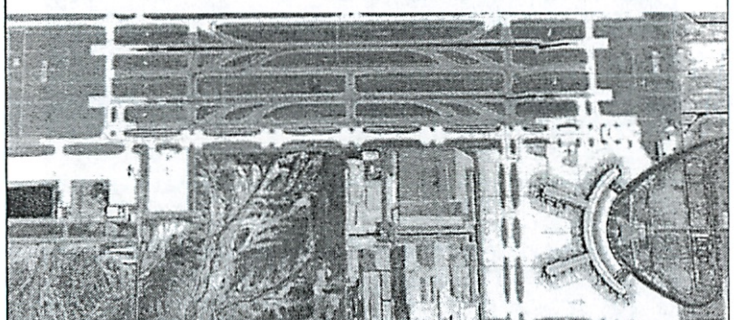
new – artificial airway
best airport in world
growing quickly

Seoul Incheon International Airport [2007]



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Milan Malpensa: 2 medium-spaced parallel

2640 ft between runways

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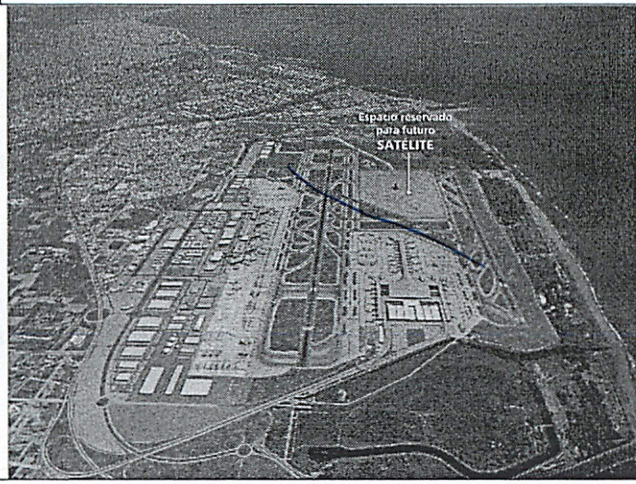
arrivals + departures can be used independently
or both departures (and diverge)
can't have both arrivals – dependent

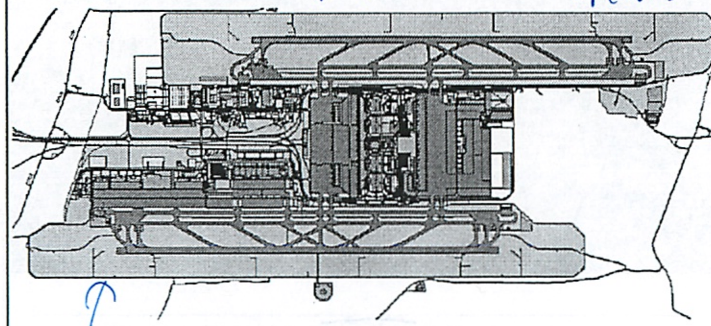
Barcelona: 2 medium-spaced parallel (+ 1 intersecting)



intersecting when lots of wind

Munich: 2 independent parallel

↓departures when operating



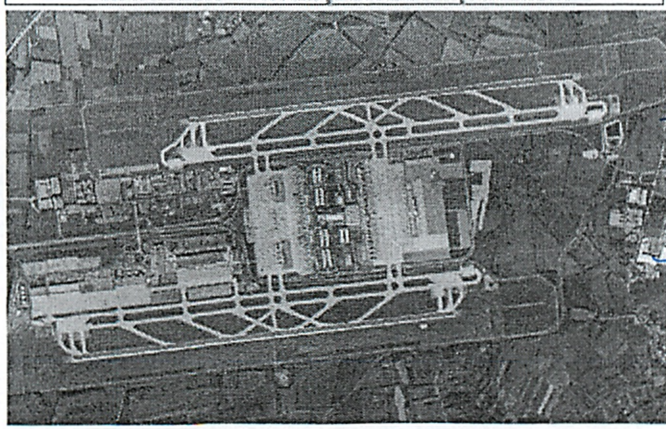
7530 ft between runways

↑ arrivals
↳reduce taxiway time

Very sucesful

- Some security benefits
- only 1 way to approach

Munich: 2 independent parallel



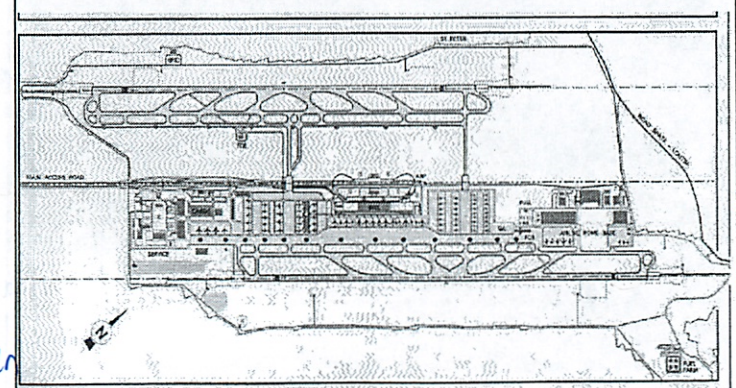
7530 ft (2296 m) between runways

lots of space in middle so put facilities in between

- but can become two crowded

↑almost the standard

Athens International (ATH)



5140 ft (1567 m) between runways

← built on side so can help it expand
but splits terminal

8000 ft b/w

Guangzhou International Airport (CAN)

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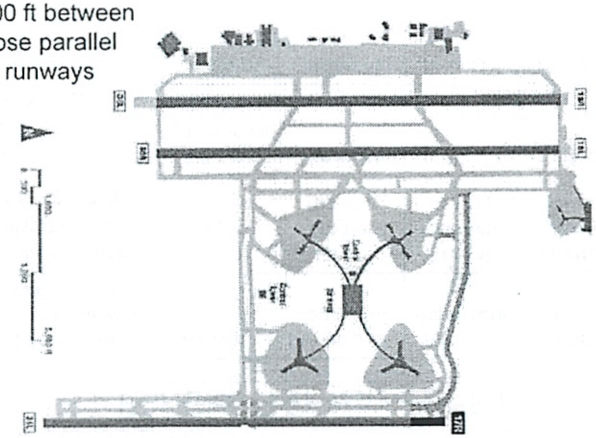
One of fastest growing

Orlando, Florida (in 2003): 2 close + 1 independent

1500 ft between close parallel runways



begining to build on previous concept

Source: Airliners.net

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Soon to be bussiest airport

two pairs of ind runways

2 km distance

Paris CDG: 2 independent pairs

1260 ft between close parallel runways

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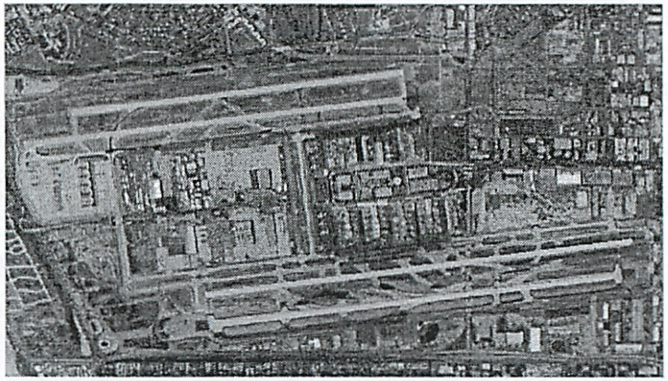
built over many years

very often experimental grounds

Los Angeles International: 2 independent pairs



700 and 800 ft between runways

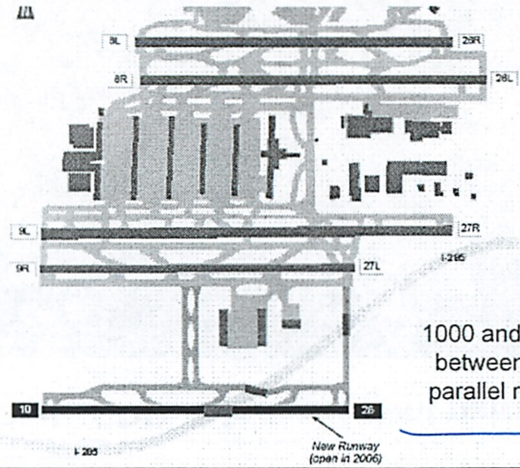
LAX

terminal in the middle

two pairs of close parallel runways

historical reasons important – no wide body aircraft
can't really ever expand

Atlanta Hartsfield International (ATL)

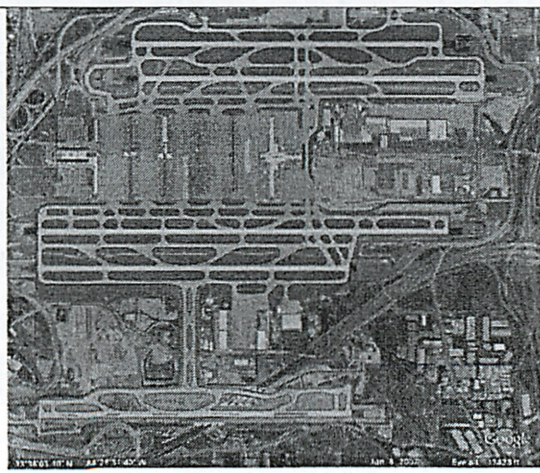


1000 and 1050 ft between close parallel runways

regional + small aircraft

busiest airport in the world

Atlanta Hartsfield International (ATL)



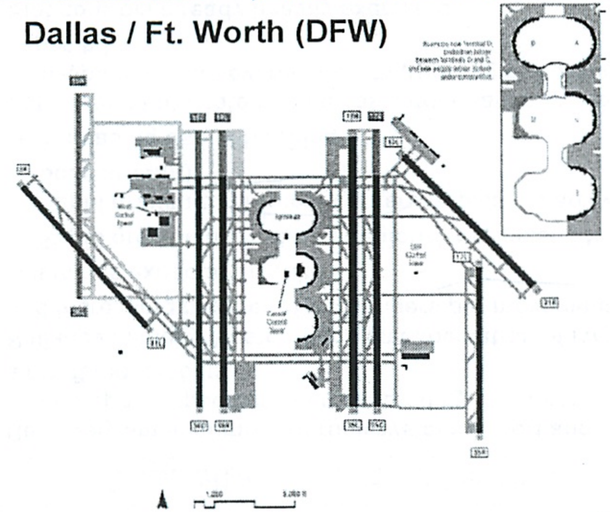
Parallel Runways (IFR)

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

Some more not standard designs

Dallas / Ft. Worth (DFW)



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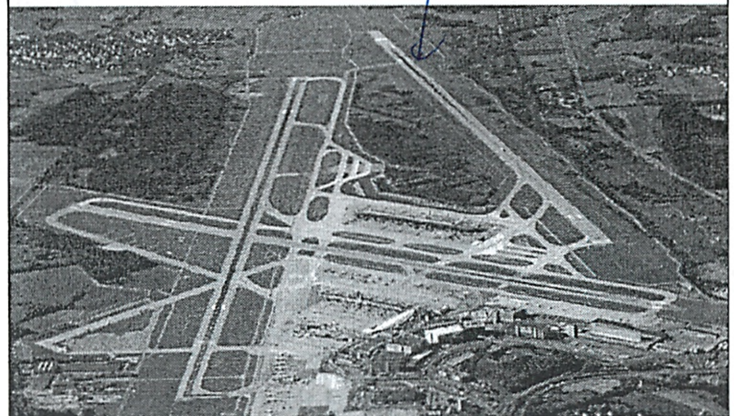
3 runways — landings only

Zurich International (ZRH)



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Toronto Lester B. Pearson International

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One of highest capacities

due to typography # of pax much lower!

30 Busiest Airports in the World (2008)

(1) = pax (million); (2) = movements (thousand)

	(1)	(2)	(1)/(2)		(1)	(2)	(1)/(2)
Atlanta	90.0	979	92	Houston	41.7	576	72
Chicago/O'Hare	69.4	882	79	Phoenix	39.9	502	79
London/Heathrow	67.1	479	140	Bangkok	38.6	249	155
Tokyo/Haneda	66.8	340	196	Singapore	37.7	235	160
Paris/CDG	60.9	560	109	Dubai	37.4	270	82
Los Angeles	59.5	623	96	San Francisco	37.2	388	96
Dallas/Ft. Worth	57.1	656	87	Orlando/MCO	35.7	334	107
Beijing	55.9	432	129	New York/Newark	35.4	434	82
Frankfurt	53.5	486	110	Detroit	35.1	463	76
Denver	51.2	620	83	Rome/Fiumicino	35.1	347	101
Madrid	50.8	470	108	Charlotte NC	34.7	536	65
Hong Kong	47.9	310	155	Munich	34.5	432	80
New York/JFK	47.8	441	108	London/Gatwick	34.2	264	130
Amsterdam	47.4	447	106	Miami	34.1	373	91
Las Vegas	43.2	579	75	Minneapolis-St. Paul	34.1	450	76

Source: ACI (2008)

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domestic (Atlanta, Chicago/O'Hare) — international (London/Heathrow, Tokyo/Haneda)

14 in USA
down from 20 10 years ago

regional difference

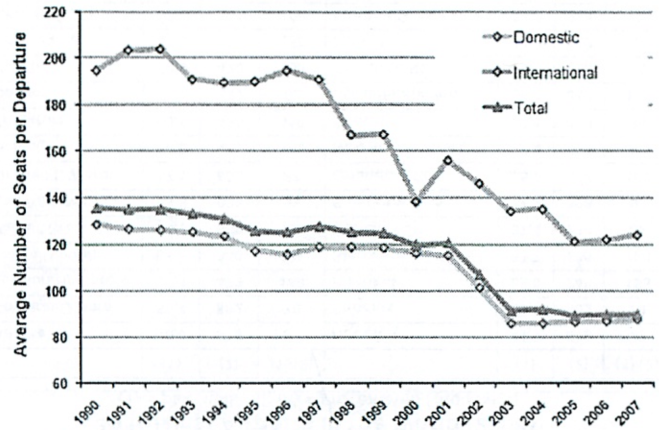
Capacity of North American Airports

- Heavy reliance on large capacities (as measured by aircraft movements); airports with multiple runways (3 – 6)
- Practically no slot controls (only 5 slot-controlled airports)
- Airlines are free to add flights anywhere at any time of day
- US FAA capacity benchmarks (2004): 35 busiest airports
  - 26 of 35: VMC capacity > 100/hour; range: 56 – 279
  - 16 of 35: IMC capacity > 100/hour; range: 48 – 193
  - 12 of 35: Plan new runway by 2013
- Only four non-US airports have a declared capacity of more than 100/hour(!) – a few more within next 5-10 years
- Unexpected(?) consequences:
  - Airlines compete on frequencies ("RJ phenomenon")
  - Small number of passengers per movement
  - Large delays, unreliability of schedules

older airports
CDG
Toronto
...

- but does not translate into conjestion free environment

Average No. of Seats Per Departure: USA



Source: Bonnefoy and Hansman (2008)

Capacity of Asian Airports

- Relatively small number of runways per airport and thus small airport capacities, as measured by the number of aircraft movements
- Reliance in many Master Plans on expectation of large and increasing number of passengers per movement
- But is this expectation valid?
  - Rapid growth in short-haul regional + domestic traffic
  - Rapid growth of low-cost carriers (typically narrow-body aircraft)
  - Increasing use of hubbing
- Estimates of ultimate annual passenger capacity proving over-optimistic at several airports (running out of runway capacity!)
- Slot controls already heavily exercised

– historically – bad assumption
many asian airports having a problem on this

Averages for 15 Busiest Airports (2007)

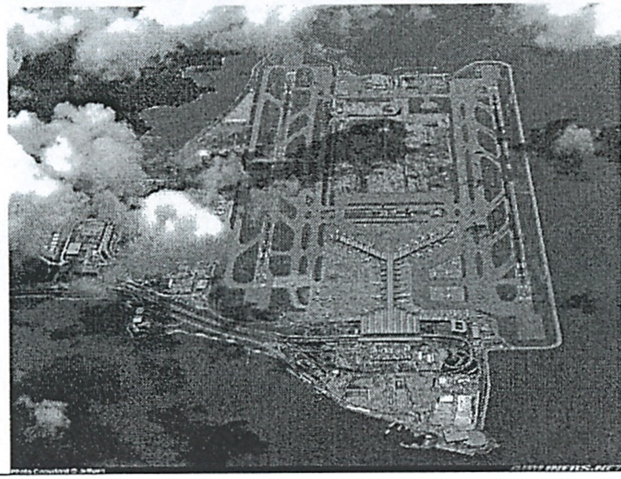
Busiest 15 Airports in…	Millions of Annual Passengers (average)	Thousands of annual aircraft movements (average)	Passengers per movement
North America	53.1	642	83
Europe	37.2 (-30%)	348 (-46%)	107 (+29%)
Asia	35.8 (-33%)	234 (-64%)	153 (+84%)

*Data: Airports Council International (2008)

airfield over capacity
not pax buildings

many new much smaller aircraft

Hong Kong: 2 independent parallel



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Example: Hong Kong International

- Opened in 1998; two independent parallel runways
- Airport capacity:
  - was forecast as 87 million to be reached in 2030-40
  - based on forecast of 348 passengers per movement by 2040
- BUT: average aircraft size has declined rapidly since 1998 from 295 seats per movement to 240 seats per movement in 2007
  - Reason: rapid growth of domestic traffic in China and hubbing in Hong Kong
- Result: Capacity is now estimated as 55 – 60 million!
- In 2007 the airport already served 47 million passengers!
- No place to build a third runway!

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close to capacity after 10 years

Capacity of European Airports

- Persistently fast-growing demand since 1993, exceeding predictions
- Limited increase in runway capacities of airports, despite airline behavior increasingly imitating the "American model"
- Heavy reliance on administrative slot allocation
  - 17 major airports already receiving more slot requests per week than total weekly capacity
- Grandfather rights in slot allocation give strong advantage to former and current "flag carriers" at the most desirable airports
- Possibly world's most problematic region in terms of long-term ability to match capacity to demand, due to ambivalent government attitudes toward infrastructure expansion

total week – not just peak capacity

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Some Approximate Benchmark Capacities

Configuration	Mov'ts/hour	Mov'ts/year	Annual Pax
Single runway	40 (typical) 25 – 55 (range)	~ 200,000 150 – 280 K	35 mio (max) 10 – 22 mio (typical)
2 close parallel runways	60 (typical) 48 – 70 (range)	~ 300,000 250 – 370 K	45 mio (max) 15 – 33 mio (typical)
2 medium-spaced parallels	70 (typical) 55 – 80 (range)	~ 350,000 280 – 420 K	50 mio (max) 18 – 38 mio (typical)
2 independent parallels	80 (typical) 65 – 100 (range)	~ 400,000 340 – 530 K	65 mio (max) 25 – 50 mio (typical)
3 (2 close + 1)	100 (typical) 75 – 120 (range)	~500,000 400 – 600 K	80 mio (max) 30 – 60 mio (typical)
4 (Indep'nt pairs of close parallels)	120 (typical) 90 – 140 (range)	~ 600,000 450 – 750 K	90 mio (max) 50 – 70 mio (typical)

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different attitudes on how much clout an airport can have

can't ban small aircraft – feed larger aircraft

per aircraft fee – ruled illegal

too much processing
too inefficent - abondoned

Typology of Passenger Terminals

- With respect to processing departing passengers:
  - Centralized vs. decentralized
- With respect to the configuration ("concept")of the building:
  - Linear
  - Transporter
  - Finger (or pier)
  - Conventional satellite
  - Midfield satellite
- However, these distinctions become blurred as an airport becomes busier and older: "hybrid" configurations become more common
- All of the above have advantages and disadvantages

Security

lost favor - need more frontage plus bad for no shops

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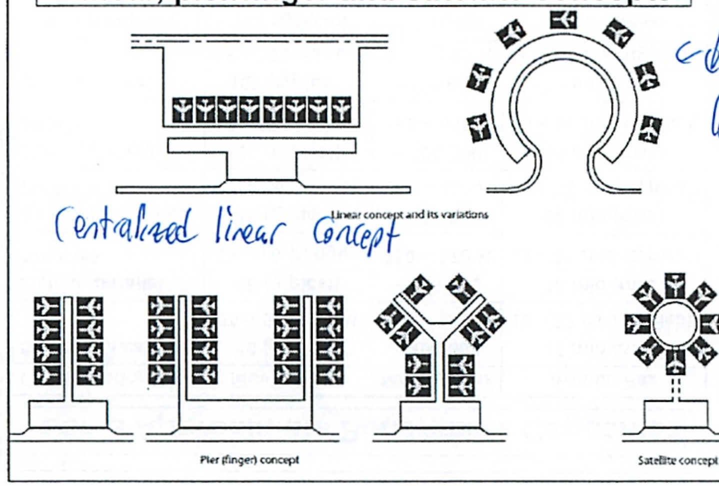
Linear, pier/finger and satellite concepts



Centralized linear concept

← decentralized lots of entrances

Barcelona: South Terminal (2009)

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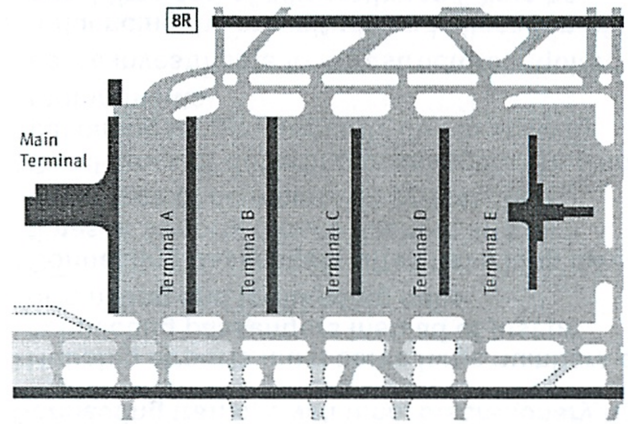
√ finger concept gone crazy

88% transfer

Midfield linear satellites: Atlanta (ATL)



not easy – many stakeholders

Stakeholders in Passenger Building Design/Planning

- Airport operator
- Airlines
- Passengers
- Government (security, immigration, customs, etc.)
- Commercial vendors and interests

best – from whose POV?

Evaluation Measures for Passenger Terminals

- **Direct:**
  - Capacity — Time-in-system
  - Waiting time — Space requirements
  - Facility requirements — Walking distances
- **Indirect:**
  - Non-aeronautical revenues
  - Operating costs — Staffing requirements
  - Flexibility — Security
  - Ambience / image — Signalization/orientation

Level of Service (LOS)

- A verbal description of Quality of Service in terms of Ease of Flow and Delays
- Six standard categories:

LOS	Flows	Delays
A - Excellent	Free	None
B - High	Stable	Very Few
C - Good	Stable	Acceptable
D - Adequate	Unstable	Passable
E - Inadequate	Unstable	Unacceptable
F - Unacceptable	--- System Breakdown ---	

- System Managers, Designers should Specify LOS
  - Level C is recommended minimum
  - Level D is tolerable for peak periods

Level of Service Standards: Space (sq. m. per occupant)

	A	B	C	D	E	F
Wait and circulate with bags	2.7	2.3	1.9	1.5	1.0	?
Wait and circulate w/o bags	2.0	1.8	1.6	1.4	1.2	?
Wait with bags	1.8	1.6	1.4	1.2	1.0	?
Wait without bags	1.4	1.2	1.0	0.8	0.6	?

Source: IATA Airport Development Reference Manual, 8th ed., 1995

Space Required

- Space Required, sq. meters =
  (Load, persons/hour) (Standard, sq.m./ person) (Dwell time, hours)
- Example:

  What space is required for passport inspection of 2000 passengers per hour when maximum dwell is 20 minutes?

Space Required = 2000(1)(1/3) = 667 sq. m.

Connecting traffic, dwell time, discretionary time

- Hubbing airports must serve large numbers of connecting passengers instead of just on originating and terminating ones
- Connecting passengers often have long dwell times at airports (space needed) and take advantage of commercial services there
- Dwell times of departing passengers are also becoming longer, primarily due to security requirements
- Large investments in infrastructure required
- Influencing the magnitude and allocation of dwell time and of “discretionary” time has become critical for airports

Other Important Issues / Trends re Passenger Terminals

- Automation of processing
  - Becoming the standard for check-in
  - Interchangeable use of check-in desks (CUTE, CUSS)
  - Security processing (multi-layer BHS, biometrics)
- Centralized vs. decentralized processing
  - Centralized has won the day (efficiency, security)
- Efficient terminal vs. "shopping mall"
  - Construction / operating costs vs. commercial revenues
- LCC Terminals (e.g., Singapore, Marseille, Lyon)
- Use of people movers, etc.
  - Rapidly expanding; fully automated
  - Changes parameters of design

Future Trends: Capacity Expansion

- Very few new primary airports in North America and Western Europe; several in Asia (India, China, Middle East)
- New runways at major existing airports when opportunities arise (few in Europe, more in US)
- Global emphasis on increasing capacity through improvements in Air Traffic Management systems (NextGen, SESAR, etc.); but will result in only limited changes in *runway* capacity at the busiest airports North America and Western Europe [+10% – 20%(??) over 20 years]
- Growing role for Air Traffic Flow Management Centers to co-ordinate traffic flows in major world regions

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

Future Trends: Multi-Airport Systems

- Growing reliance on multi-airport systems around the globe, through the utilization of existing (and some new) secondary airports near major hubs of air transport activity
- Decreasing traffic share of primary airports within multi-airport systems

Already in full swing!

Multi-Airport Systems (2007)

Source: Bonnefoy (2008)

Future Trends: Bypassing Large Hubs

- ❑ Increasing number of point-to-point connections between "second-tier" cities/airports on both long-haul and short-haul routes
- ❑ Supporting developments:
  - Rapid growth of low-cost carriers
  - Expansion and construction of new airports near second-tier cities
  - Increased utilization of secondary airports within multi-airport systems
  - Open skies agreements: EU-US, EU-Canada, Singapore-UK, et al
  - Boeing 787, Airbus A350,... vs. Airbus 380

Forms of Ownership and Management of Airports

A. Government-owned; operated by Department or Agency of national government
B. Government-owned; operated by municipal/regional Department or Agency
C. Government-owned; operated and managed by private contractor
D. Operated by an independent Airport Authority which is fully owned by municipal and/or regional and/or national government
E. As in 'D' but with minority private shareholders (some shares may be publicly traded)
F. Privately-owned (fully or in majority, possibly with some or all shares publicly traded); operated as independent airport authority

Types of User Charges: Aeronautical

- ❑ Landing (and/or takeoff)
- ❑ Terminal-area air navigation
- ❑ Passenger service (terminals)
- ❑ Cargo service
- ❑ Aircraft parking and hangars
- ❑ Security
- ❑ Airport noise
- ❑ Aircraft noxious emissions
- ❑ Ground (ramp and traffic) handling
- ❑ En route air navigation

Non-Aeronautical Charges

- ❑ Statements by the Council: "Should be developed to the maximum possible"
- ❑ Concession fees for aviation fuel and oil
  - – Concessionaire or airport itself
  - – Council: treat like non-discriminatory aeronautical charge
- ❑ Concession fees from commercial activities
  - – Fixed amount or percentage of gross sales (10-60% with guaranteed minimum)
- ❑ Revenues from car parking and car rentals
  - – Operator itself; third-party operator; BOT agreements
  - – On-premises vs. off-premises car rental facilities
  - – Fast growing!

Non-Aeronautical Charges [2]

- ❑ Rentals for airport land, space in buildings (including advertising space) and equipment
- ❑ Fees charged for tours, admissions, etc.
- ❑ Fees derived from provision of engineering services, utilities, etc., by airport operator
- ❑ Off-airport revenues
  - Consulting services
  - Education and training services
  - Management contracts at other airports
  - Management contracts for other activities
  - Equity investments in travel-related or other ventures
  - Equity investments in other airports

30 Busiest U.S. Commercial Airports (2009)

Revenue Sources	Revenues ($ 000)	% of Total
Terminal rental charges	2,977,097	21
Landing fees	2,259,527	16
Cargo and hangar rentals	349,312	2
Fuel sales	119,939	1
Other	758,484	5
Aeronautical Revenues	6,464,359	45
Land, non-terminal fac'y leases	243,562	2
Terminal concessions	1,113,440	8
Rental cars	807,569	5
Parking	1,685,203	12
Other	422,591	3
Non-Aeronautical Revenues	4,272,365	30

30 Busiest U.S. Commercial Airports (2008)

Revenue Sources	Revenues ($ 000)	% of Total
Interest income	436,333	3
Grant receipts	914,467	6
Passenger facility charges	1,838,979	13
Other	385,930	3
Non-Operating Revenues	3,575,709	25
Total	14,312,433	100

Source: Operating and Financial Summary Report, FAA Form 127

More 2009 Financial Statistics for 30 Busiest A/Ps

- Revenues of 30 busiest airports ($14.3 billion – see previous slide) equal 61% of total revenues ($23.4 billion) of 519 airports with commercial service
- Expenditures:
  - Operating: $6.6 billion ($2.7 billion for personnel, $2.0 billion for contractual services)
  - Non-operating: $2.5 billion for interest
  - Depreciation: $3.1 billion
- Expenditures for projects: $6.8 billion ($3.1 billion for terminals, $1.3 billion for airfields)
- Bond proceeds: $3.8 billion
- Bond indebtedness: $49 billion

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Q-Value

11/28

- need to know for p-set 4
- WP calls it the False discovery rate
- look in wolfram Math world
  - lots of records
  - Q-factorial?
  - Q-gamma?
- Then there is one for bikes
- WP "Factor analysis"
  - describe variability among variables (~variance??)
  - factors = unobserved variables
  - (this is confusing - just want to see example)
- lots of examples on web
  - "suffered from confusion concerning purpose"
- was it in lecture?

②

Oh ~~[illegible]~~ duh - just look in lecture

Q = death risk per randomly chosen flight

N = # of flights of interest

X(i) = fraction of people killed on that flight

$$Q = \sum \frac{x(i)}{N}$$

- So its like variance

~~$\frac{1}{N} \, x$~~

No its not really like expected value or var

5. Should our new airline implement bag match.

- I would not unless rest of industry was doing it
  - If others doing it, must do it, or will be weakness in the system
  - But if others are not doing it, I would not do it
    - Terrorists don't target specific airlines
    - They pick airlines randomly
    - Passengers would not fault the specific airline on which the accident happened
      - No evidence from previous terrorist events
      - But if this memo becomes public, they may
      - Which is why I would never actually write this memo
    - Losses of airplane, likly covered by inscrance
      - Confirm
    - Even if not, everyday cost far exceeds risk
      - Our share of cost only ~$300 million, not the $15 billion cost to society.
    - So need to pull bags on 1 in 70 flights
    - 13 minute delay
    - But ripples through the system

(1)

Don't want to go too low cost like Mega Bus!

Iseral does it

Seems to be fairly low cost

What about if have bag scanners?
- still show what learned
  ? Thats the point!

$500 million

Michael Plasmeier 11/29

16.71J/1.232J/15.054J/ESD217 The Airline Industry

Assignment #4 – Individual **Due: Monday 29 November 5pm**

1. Western European airlines had the following fatal accidents on scheduled flights over 1/1/00-12/31/08:

Date	Location	Passengers: Aboard	Killed
1/10/00	Switzerland	7	7
8/29/01	Spain	44	3
10/8/01	Italy	104	104
11/24/01	Switzerland	28	21
11/6/02	Luxembourg	19	18
8/20/08	Spain	162	144

Over this period, Western European airlines performed approximately 60.9 million flights.

(i) Given these data, work out the Q-value for passengers on Western European airlines over 2000-08.

(ii) In 2009, there was one fatal accident on these airlines: an Air France plane crashed into the Atlantic, killing everyone aboard. Estimate the Q-value for Western European airlines from 1/1/00-12/31/09, making clear what approximations you used.

2. Suppose that Mendel, a global consultant, makes 50 nonstop air trips per year on First World Airlines, 15 such trips on airlines from Advancing nations, and 12 on airlines from the Least Developed nations. He expects to be doing this each year over a career that has 30 years to go. Using Q-values from the Barnett paper "Cross-National Differences in Aviation Safety Records", estimate the overall chance that he will perish in an air accident over his career. (Do not read the whole Barnett paper: just look at the tables, until you find one that is directly relevant to this question.)

3. Under the *quadratic rule* for runway collision risk discussed in Chapter 11:

(i) Suppose that operations drop by 10% at all US airports. What would be the corresponding drop in collision risk?

(ii) Give a numerical example involving two airports in which the *total* number of operations they perform is the same in two consecutive years, but the total risk of a runway collision goes up by 10%. (Assume that the risk at each airport is proportional to the square of its number of operations.)

4. Read the discussion in Chapter 11 about the inspection of checked luggage with three consecutive explosives detectors.

(i) Assuming that the bag is loaded if any of the detectors declare it harmless, find the probability of an erroneous loading of a dangerous bag if $P_1 = .05$, $P_2 = .02$, and $P_3 = .02$.

(ii) Assuming that $Q_1 = Q_2 = Q_3 = .10$, find the probability that a harmless bag is erroneously rejected.

(iii) If each erroneously rejected bag entails a dollar cost of $100, what fraction of bags have to be dangerous before the dollar benefits of this three-detector policy exceed the costs. (Assume that erroneously loading a dangerous bag results in the destruction of the airplane, and that each successful terrorist act costs $15 billion.)

5. Suppose that a meeting of your new entrant airline team has been called to discuss whether to implement bag-match at point of origin for all travelers.

Taking into account any data and arguments you have heard or read, the expected business model(s) and economic circumstances of your proposed airline, and anything else you consider relevant, prepare a short memo (no more than two pages, double spaced) with a policy recommendation for this measure. Do your recommendations depend on whether your competitors join you in adopting a given measure? (Do not feel at all obliged to agree with Professor Barnett, wise though he is.)

(This is an individual assignment, not a team effort.)

Michael Plasmeier P-Set 4 11/29

9.3/10

1. Western European airlines flew 60.9 million flights and and had 6 accidents.

a) What is the Q-value ? (2000-2008)

Q = Death risk in a randomly chosen flight

N = # of flights of interest

x(i) = fraction of people killed on flight

$$Q = \frac{\sum x(i)}{N}$$

- Chance of selecting flight i = $\frac{1}{N}$
- Conditional prob of death given flight i selected is x(i)
- add up probabilities for N choices b/c they are mutually exclusive

N = 60.9 million

$$x(i) = \frac{9}{} + \frac{3}{44} + \frac{1}{} + \frac{21}{28} + \frac{18}{19} + \frac{144}{162} = \frac{8755}{1881}$$

(2).

$$Q = \frac{\frac{8755}{1881}}{\approx 60.9 \text{ million}}$$

don't care about

$$= \frac{1751}{2241058000}$$

$\approx 7.64 \cdot 10^{-8}$

$\approx .0000000764$

ii) In 09 was 1 fatal accident killing everyone.

Calculate Q value for 2000 - 2009

$$\frac{\left(\frac{8755}{1881} + 1\right)}{(60.9 \text{ million} + 7{,}612{,}500)}$$

$\approx 8.253 \cdot 10^{-8}$

$\approx .0000000 8253$

$$\frac{60.9 \text{ million}}{8} = 7{,}612{,}500$$

Since flights fairly even over the decade

So project 00-08 period average

(3)

2. Globe trotter Mendel flies in a year

50 First World flights
15 2nd "
12 3rd "

30 year period

Estimate the overall chance he will die in an aircraft accident this year

Death risk from Barnett paper 2000-2007 p 8

1st world	1 in 14 million	$7.14 \cdot 10^{-8}$
2nd "	1 in 2 million	$5 \cdot 10^{-7}$
3rd "	1 in 800,000	$1.25 \cdot 10^{-6}$

$P(\text{Death in 1 year}) = 50 \cdot 7.14 \cdot 10^{-8} + 15 \cdot 5 \cdot 10^{-7} + 12 \cdot 1.25 \cdot 10^{-6}$

$= .00002457$

$P(\text{Death in 30 years}) = .00002457 \cdot 30$

$= .0007371$

(4)

3. Under the quadratic rule (from Chap 11) for runway collision

i) Suppose that operations drop by 10% at all US airports. What would the corresponding drop in collision risk be?

Chap 11

M = # of aircraft operations in an airport

M^2 = Probability of being on the site of a runway collision

$$\frac{M(M-1)}{2} = \frac{(M^2-M)}{2} \approx \frac{M^2}{2}$$

Matches data

Baseline $= M^2$

New $= (M - .1M)^2 = .81M^2$

Change $(M-.1M)^2 - M^2 = -.19M^2$

A 19% drop ✓

Test w/ M=100

10,000

8,100

-1900

Hope My stats right

(5)

ii) Give a numerical example involving 2 airports in which the total # of operations they perform is same in 2 consecutive years, but total risk of runway collision goes up by 10%

- If the flights become more concentrated throughout the day

Example

	Hour 1	Hour 2	Total M^2
Old	$M=10$ $M^2=100$	$M=10$ $M^2=100$	200
New	$M=13$ $M^2=169$	$M=7$ $M^2=49$	218

roughly 10% increase

Exact answer (average movements per hour)

$$x^2 + y^2 = 220 \qquad x + y = 20$$

Solve

$$x = 10 - \sqrt{10} = 6.8377$$
$$y = 10 + \sqrt{10} = 13.16$$

Same happens at both airports due to new hub banking strategy

(6)

4. Read chap 11 about impact of inspection of checked luggage w/ 3 consecutive explosive detectors.

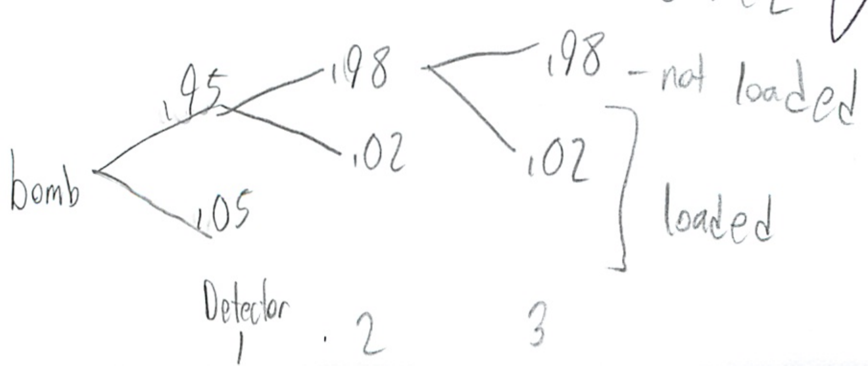
i) Assuming that if bag is loaded if any of the 3 detectors declare it harmless, find P of erroneously loading a dangerous bag if

$P_1 = .05$
$P_2 = .02$
$P_3 = .02$] both of these given previous one declared safe

<u>Chap 11 Reading</u>

False negitive - bomb declared safe
False positive - safe bag declared bomb

$$P(\text{load given dangerous}) = P_1 + (1-P_1)P_2 + (1-P_1)(1-P_2)P_3$$
$$= .05 + (1-.05).02 + .95 \cdot .98 \cdot .02$$
$$= 108762$$



(7)

ii) Assuming that $Q_1 = Q_2 = Q_3 = .10$

Find prob that harmless bag is erroneosly rejected

P(not loaded given harmless) $= Q_1 Q_2 Q_3$

$= .1 \cdot .1 \cdot .1$

$= .001$

✓

iii) If each erronasly rejected bag cost \$100

What fraction of bags must be dangerous for cost to be worth it

Cost of terrorist attack = \$15 billion

= Cost of loading dangerous bag

X # dangerous · \$15 billion = # harmless · \$100

↑ if 1

↑ Then this would have to be 150 million

See soln on website

but must consider probabilities of detection, right?

(8)

dangereous · ~~A~~ 15 billion = .001 · # harmless ·100

↑ if 1 ↑ must only consider here

Now would have to be 150,000,100,000

1 in 150 billion bags.

(15/20)

On Positive Passenger Bag Match

Dear Colleagues,

This memo contains our position on Positive Passenger Bag match (PPBM). With positive passenger bag match, if a passenger does not show up for his/her flight, his bag is pulled. Based on industry experience, this occurs in approximately 1 in 70 departures. When it occurs it delays flights by approximately 13 minutes. No additional employees are needed to manage the bag match, so there are no direct costs to us. There will be a slight lengthening of flight times for these 1 in 70 flights. This is troubling for me, as our airline strives to operate on time. However, the day to day costs to our operation are slight compared to the losses if a terrorist were to succeeded. If we look at our block hour cost (even though the doors are not closed by the time PPBM has to be invoked) and an estimate of ground/gate costs the cost is roughly ~$4,000/hour. Therefor the cost of this policy on a delayed flight is approximately:

$$\frac{13}{60} * \$4,000 = \$866\, per\ delayed\ flight$$

However, remember that this only happens on 1/70 flights. Thus the cost per flight is:

$$\frac{1}{70} * \frac{13}{60} * \$4,000 = \$12.38\, per\ flight$$

I am not considering the "network effects" of cascading delays. However, 13 minutes is well within our usual take off delays, and we have sufficient padding within our schedule to absorb this cost within the air. If PPBM starts causing delays, we will add a few minutes to the schedule to compensate the next time we review our schedule.

The cost of a successful terrorist attack is simply too great. Even when only considering direct costs, a successful terrorist attack is expensive. The loss of our crew and aircraft hull and engines is significant. I estimate that these cost roughly ~$300 million to replace the aircraft and compensate the crew's family members. We are not considering the effects that a successful terrorist attack will have on demand in the industry or the economy (total ~$15 billion) because much of that cost will not be borne by us. Our revenue would decrease, however. Past experience with 9/11 has shown that revenue at LCCs was basically flat in 2001 vs 2000. Looking at the LCC industry revenue gains in later years, I roughly estimate that 9/11 prevented ~$200 million of revenue gains for LCCs. In addition, prior experience with 9/11 has shown that passengers do not attribute a terrorist attack to a particular airline and penalize it in the marketplace.

With our 100 flights a day, this policy would cost us approximately $500,000 a year. Therefore, this policy makes sense for us if there is a possibility that a terrorist will attempt to load a bomb in his bag and an explosive machine will not catch it in 1 in 1,000 years.

You might be wondering how Positive Passenger Bag Match helps if terrorists have shown the willingness to die to carry out their missions. We have consulted with Arnold Barnett, the *George Eastman Professor of Management Science* at the *Massachusetts Institute of Technology Sloan School of Management*. Professor Barnett believes that although terrorists are willing to die for their cause, they are not willing to spend their lives in jail. Without PPBM, a terrorist can drop a bag off at our check in counter, and immediately leave the airport. If we or the TSA discover the bag, we are unlikely to discover the terrorist, who is free to try again. However, if the terrorist knows that he must be present for his bag to get on the plane, he knows that he/she must show up at the check in counter. If a bomb is discovered, the TSA and local police can arrest the individual at the check in counter. It is Prof. Barnett's belief that this measure significantly reduces the likelihood that bombs will be packed in suitcases.

Once bomb scanning machines are fully implemented, we will reevaluate this policy taking into account the false negative rate of the scanning machines. Early indications show that the false negative rate on these machines is still too great.

Good, but too little at the start or end making your position clear.

-Michael Plasmeier

Director of Operations

18/20

The Airline Industry-Homework 4

Solution to part (iii) of Problem 4

In the first two parts of Problem 4, we establish that the conditional probability of loading a dangerous bag is .0876, while the conditional probability of rejecting a harmless one is .001. Suppose that M bags arrive for loading over a long period (M extremely large), and that fraction p of them are dangerous. Then we note that:

- When a dangerous bag arrives, the probability is 1-.0876 = .9124 that it is *not* loaded. The benefit of not loading is $15 billion.
- When a harmless bag arrives, the probability is .001 that it will not be loaded, and a cost of $100 is incurred when a harmless bag does not travel.

Therefore, costs and benefits are equal when:

$$Mp(.9124)(\$15 \text{ billion}) = M(1-p)*(.001)*\$100.$$

Cancelling out the M's and solving for p, we find the value of p at which benefits equal costs is *1 in 137 billion*. For any values of p greater than this threshold value, the benefits exceed the costs. For values of p below this threshold, costs exceed benefits.

(Note: It is not correct to equate the costs of the two kinds of failures: loading a dangerous bag and not loading a harmless one. Neither of these quantities involves the benefits of the policy.)

Disrupted -> can't follow exact itenary - must be reassigned on diff. itenary

Airline Delays- Flights, Passengers, and the Impacts of Schedule Competition

Cynthia Barnhart (barnhart@mit.edu)
Douglas Fearing
Vikrant Vaze

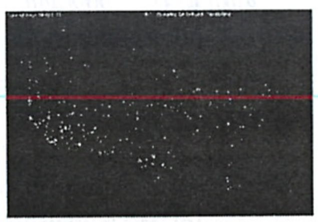
16.71J The Airline Industry
November 29, 2010

Outline

- **Quantify delays to flights and passengers**
- Understand impact of schedule competition on delays

Airline Operations

1. Aircraft delays result from
   - Weather, unscheduled maintenance requirements, unavailable crews, gates, ground resources, etc.
2. Flights are delayed or cancelled
3. Delays propagate through the network
4. Aircraft, crew and passengers are delayed/ disrupted …



Complexity

Passenger Delays

- Depend on flight delays, flight cancelations, missed connections, and re-accommodation
  - Flight delays alone are not enough to look at pax delay (Bratu & Barnhart, 2005) <many existing studies
- Cost U.S. passengers billions of dollars per year
- Multiple methodologies, cost estimates for 2007:
  - Air Transport Association (**$5 billion**), U.S. Senate Joint Economic Committee (**$7.4 billion**) (ignoring flight cancelations & passenger connections)
  - Sherry and Donahue (**$8.5 billion**) (ignoring passenger connections)
- Exact amount unknown because data is proprietary

wanted to get more accurate estimate

flight cancelation good to get things back on schedule

11/29

Sources of Data

- Airline Service Quality Performance (ASQP)
  - US airlines earning revenues of $1 billion or more annually in scheduled service
  - U.S. domestic flights only
  - Jet aircraft operations only
  - January through September only
- Actual or Estimated Itinerary Demands and Passenger Flows ← not pubically avalible

why estimating data has been difficult

Quantifying Passenger Delay

1. Multinomial Logit model for itinerary flow estimation
2. Passenger delay estimation
3. Annualized cost of passenger delays
4. Regression model to simplify delay estimation
5. Selected findings

Combined demand modeling + optimization to get estimates of pax flow

Passenger Travel Estimation

- Developed statistical model of itinerary shares
  - Regression function includes time-of-day, day-of-week, connection time, cancelations, and seats — share of flow into 4 hr slots
  - Trained on one quarter of booking data from a large carrier
- Generate potential non-stop and one-stop itineraries from flight schedule data
- Randomly allocate passengers to itineraries based on estimated proportions — Then allocate them to particular itinaries
  - Using aggregated passenger demand data to determine total number of passengers and one-stop route proportions

–not random not any better

to fill in

trying to estimate utility of each model

Multinomial Logit Model

- Model specification:

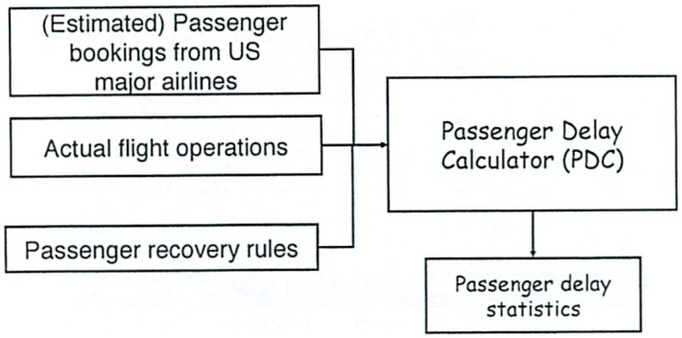
$$u(x_i) = \sum_{d=1}^{7}\sum_{n=1}^{6}\beta_{dn}^{\text{day-time}} I(x_i^{\text{day}} = d) I(x_i^{\text{time}} \in T_n) + \sum_{m=1}^{3}\beta_m^{\text{connect}}\left(\min\{x_i^{\text{connect}}, c_m\} - c_{m-1}\right) + \beta^{\text{cancel}} x_i^{\text{cancel}} + \beta^{\text{seats}} x_i^{\text{seats}}$$

- Utility:
  - Week divided into 42 4-hour time periods: 0-1 dummy for each time period
  - Piecewise linear function of connection times
  - Flight cancellation 0-1 dummy[4] – historic cancelation rate
  - Aircraft size[5]
- Model estimated using one quarter of proprietary booking data from a large legacy carrier

–price missing – no data on that

Must know something about delays

Major Airline Model



Passenger Delay Calculation

- Extension of Passenger Delay Calculator developed by Bratu & Barnhart (2005)
  - To account for multiple carriers
- Disrupted passengers are determined by analyzing historical (realized) flight schedule data
- Passengers are re-accommodated on alternative itineraries in the order they are disrupted
  - Attempt re-accommodation on ticketed carrier and partner carriers first, and then consider all carriers
- Maximum delay of 8 hours for daytime disruptions (5:00am - 5:00pm) / 16 hours for evening disruptions

after this → then tried other airline
if not, just used these #

Summary of Estimation Results

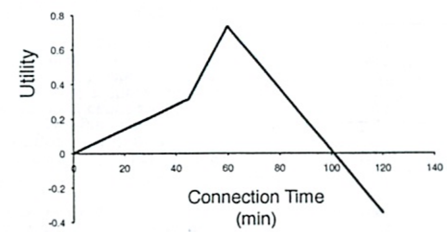
- 45 out of 46 parameter estimates significant with at least 99% confidence level
- Likelihood ratio test: overall model is statistically significant with extremely low p-value ($<10^{-30}$)
- Highest utility for travel on Sundays, Thursday and Friday evenings, and Monday mornings
- Lowest utility for late night and pre-dawn travel

Parameter Description	Estimate	Std Error	p-value
Connection time (minutes) ≤ 45	0.007	0.00013	0.00
Connection time (minutes) > 45 and ≤ 60	0.028	0.00055	0.00
Connection time (minutes) > 60	-0.018	0.00004	0.00
Flight cancellation	-0.143	0.00956	0.00
Seating capacity	0.005	0.00010	0.00

(actually has less utility)

Estimation Results contd.

- Maximum utility at 60 min connection time, lower to longer and shorter connections



- Positive coefficient of aircraft size: more passengers travel on larger aircraft
- Negative coefficient of cancellation dummy: airlines preferentially cancel flights with fewer passengers

Alternate model

Passenger Delay Results

- Total passenger delay in the US in 2007 = 244,482,655 hrs
- Assuming $37.6/hr value of passenger time (same as the one used in JEC report), the total cost of passenger delays

  = $9.19 billion
- Out of all passenger delay, – what the other papers looked at
  - (only) 52% due to flight delays
  - 30% due to cancelled flights
  - 18% due to missed connections
- Avg. passenger delay = 30.15 min
  - Nearly twice of avg. flight delay (15.32 min)

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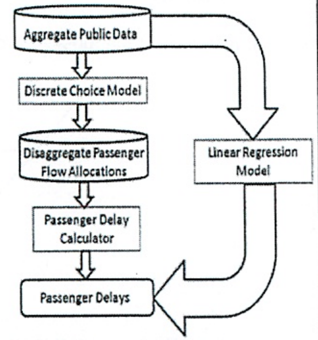
Regression Model to Bypass Passenger Allocation Procedure

- Simplified one-step approach to passenger delay estimation using public data directly
- Dependent variable = Average passenger delay
- Independent variables = Aggregate attributes of airline schedules, passenger itineraries etc
  - Average flight delay
  - Fraction of canceled flights
  - Fraction of connecting passengers
  - Fraction of flights with at least 60 minutes of delay
  - High load factor dummy
- Regression model estimated using the allocation based delay estimates



change aircraft delay to pax delay

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turned out to work pretty well

Parameter Estimates

- 20 airlines x 365 days in the year = 7300 observations

Parameter Description	Estimate	Std Error	p-value
Intercept	-1.34	0.24	0.00
Average flight delay	1.00	0.01	0.00
Fraction of cancelled flights	458.77	2.92	0.00
Fraction of cancelled flights x High load factor dummy	96.79	4.62	0.00
Fraction of connecting passengers	10.14	0.50	0.00
Fraction of connecting passengers x Fraction of flights with at least 60 minutes of delay	139.14	4.53	0.00

- All parameter estimates are statistically significant with at least 99.99% confidence level
- Model R^2 value of **95.06%**

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Error Comparison at Different Aggregation Levels

- Regression-based estimation has slightly larger error than the complicated process

Aggregation Level	Passenger Allocation and Delay Calculation	Regression-based Delay Estimation
By Carrier-Day	11.1%	15.1%
Daily	10.3%	12.4%
Monthly	3.3%	8.0%
Quarterly	2.7%	8.0%

error increases by day

estimates off

L if error ±10% simplified model would be the

- Passenger delay estimation for 2008 (a sample application of the direct approach)
  - Model inputs: Flight schedules and aggregate passenger flows
    - 6% fewer passengers and 6.7% lower avg. passenger delays compared to 2007 resulting in 12.2% lower total passenger delays

underestimate

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relationship b/w delays + load factor
– system is reaching capacity

Key Findings #1

- *The ratio of average passenger delay to average flight delay is maximum for regional carriers, and minimum for low-cost carriers, owing primarily to their cancellation rates and connecting passenger percentages*
  - Overall ratio = 1.97
  - Overall Cancellation rate = 2.4%
  - Overall Connecting passengers= 27.2%

	Regional	Legacy	Low-cost
Avg Pax Delay to Avg Flight Delay Ratio	2.61 (Range: 2.27 to 2.99)	2.03 (Range: 1.65 to 2.23)	1.61 (Range: 1.49 to 1.89)
Cancellation Rate	3.4%	2.2%	1.2%
% Connecting Passengers	39.6%	31.0%	17.0%

Key Findings #2

- *EWR, ORD, LGA, IAD, JFK and PHL are the worst transfer airports for connecting passengers in terms of average passenger delays. These are also the only 6 airports in the US where at least 10% of the connecting passengers get disrupted.*

	6 worst airports	Other airports	Difference
Avg. Passenger Delay (min)	78.5	45.6	32.9
Avg. Due to Flight Delay (min)	23.1	15.9	7.2
Disrupted Passengers	12.2%	6.9%	5.3%

Key Findings #3

- *Average delay to disrupted nonstop passengers on routes with at least 10 daily flights per carrier is 30% lower than overall average and on routes with at least 3 daily flights per carrier is 13% higher than the overall average*
  - Overall avg. delay to disrupted nonstop passengers is 443.6 min
  - With daily nonstop frequency of at least 10 flights, it decreases to 304.1 min
  - With daily nonstop frequency of at most 3 flights, it increases to 511.5 min

few routes a day → delays worse

Key Findings #4

- *Average evening passenger delay (37.8 min) is 86.8% greater than average morning passenger delay (20.3 min)*
  - Main reason is that the average evening flight delay (18.5 min) is 89.4% greater than average morning flight delay (9.8 min)
  - But fraction of disrupted passengers is only 18.9% greater in evening (3.52%) than in the morning (2.96%)
  - But greater ease of rebooking for morning passengers is evident as average delay to disrupted passengers in the evening (532.6 min) is 66.3% greater than that for morning passengers (320.3 min)

and delays propegate though the day

Key Findings #5

- *Southwest Airlines has the lowest average passenger delay, nearly 55% lower than its competitors, even though its average flight delay is only 36.3% lower. Primary reason is fewer disruptions.*
  - *1.0% cancellations as compared to 2.8% for other carriers*
  - *0.4% missed connections as compared to 1.4% for other carriers*

  ...because of,

  1) Fewer connecting passengers : 15.5% compared to 30.0% for other carriers

  2) Longer connections: 41.9% connections longer than 1.5 hours, compared to 36.1% for other carriers

·fly out of less busy airports

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lots of slack in block time
– so usually arrive on time

References

1. Schumer, C.E. and Maloney, C.B. (2008) *Your flight has been delayed again: flight delays cost passengers, airlines, and the US economy billions. The US Congress Joint Economic Committee. May 2008.*
2. *Sherry, L. and Donohue, G. (2007) US airline passenger trip delay report. Center for Air Transportation Systems Research, George Mason University. April 2008.*
3. Bratu, S., & Barnhart, C. (2005). An analysis of passenger delays using flight operations and passenger booking data. *Air Traffic Control Quarterly , 13 (1), 1-27.*
4. Tien, S., Churchill, A., & Ball, M. (2009). Quantifying the relationship between airline load factors and flight cancellation trends. *Transportation Research Record , 2106*, 39-46.
5. Coldren, G., & Koppelman, F. (2005). Modeling the competition among air-travel itinerary shares: GEV model development. *Transportation Research Part A , 39*, 345-365.
6. Ball, M., Barnhart, C., Dresner, M., Hansen, H., Neels, K., Odoni, A., Peterson, E., Sherry, L., Trani, A., & Zou, B. (2010). *Total Delay Impact Study. NEXTOR.*

12. Barnhart, C., D. Fearing, and V. Vaze (2010a). Analyzing Passenger Disruptions in the National Air Transportation System. Under Review. *The AGIFORS 50th Anniversary Journal.*
13. Barnhart, C., D. Fearing, and V. Vaze (2010b). Modeling Passenger Travel and Delays in the National Air Transportation System. Under Review. *Operations Research.*

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Outline

- Quantify delays to flights and passengers
- **Understand impact of schedule competition on delays**

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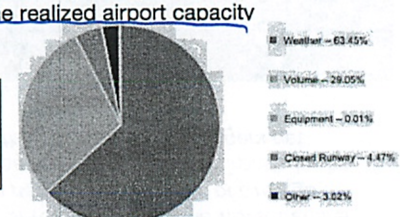
↓flight delays

Delays and Demand-Capacity Imbalance

- Cost of domestic flight delays to US economy in 2007≈ $32.9 billion *
  - $8.3 billion in additional aircraft operating costs
  - $16.7 billion in passenger delay costs
  - $7.9 billion in indirect costs: e.g. lost demand and impact on GDP
- 92.5% of National Aviation System (NAS) delays attributed to demand exceeding the realized airport capacity

Causes of National Aviation System Delays**:



*NEXTOR, Total Delay Impact Study (Ball, et al., 2010)

**Bureau of Transportation Statistics (www.bts.gov, 2008)

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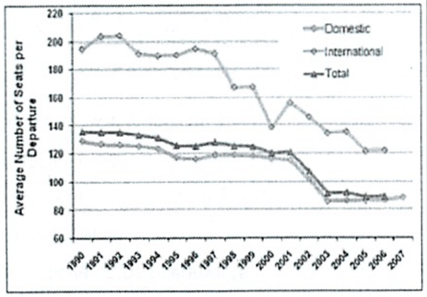
b/c freq wars

Aircraft Sizes and Load Factors

1. Airlines prefer to fly many small planes rather than few big planes
   => Fewer seats per aircraft
2. Low load factors on routes between congested airports
   => Fewer passengers per seat



As a result:
- Very few passengers per aircraft out of congested airports
- Out of LGA: 67 pax/flight on average

Some extreme examples: (Source: T100 Segment Data) 2007

Origin	Destination	Load Factor
BOS	LGA	53.3%
LGA	BOS	52.5%
DCA	LGA	50.4%
LGA	DCA	50.8%

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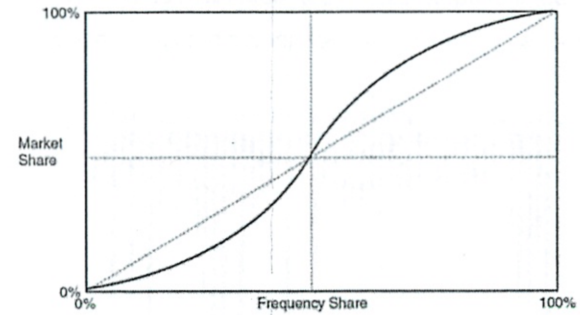
└ bad usage of airports

Frequency Competition



- S-curve relationship between market share and frequency share
- Higher frequency shares associated with disproportionately higher market shares

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Prior Research Work

1. In the absence of competition, existing capacity found to be more than enough to satisfy all passenger demand, with a similar level of service
   - resulted in approximately 82% reduction in congestion related delays

   (Vaze and Barnhart, 2010a) w/ same level of service (# of flights) - if no competition

2. The extent of inefficiency (congestion) introduced by competition is directly proportional to
   - market profitability
   - number of competitors
   - curvature of the S-curve

   (Vaze and Barnhart, 2010b)

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Impacts of Delays of Schedule Competition

- Model of frequency competition
- Solution methodology
- Validation of Nash equilibrium outcome
- Slot reduction schemes
- Results
- Sensitivity to assumptions

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The more profitable the market, the more competitors, the less efficent it is

Model of Frequency Competition

- Set of airlines: a system of profit-maximizing autonomous agents
- Nash Equilibrium solution concept

  A frequency profile f is a Nash Equilibrium if for every airline a, f_a is the best response to f_{-a}

- Myopic best response solution methodology

  While there exists a carrier a whose current decision (f_a) is not optimal in relation to others' decisions (f_{-a}), re-optimize for that carrier

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tand =librium solution

Optimization Sub-Model

$$Maximize: \sum_{s \in S} (P_{a,s} * Q_{a,s} - C_{a,s} * f_{a,s})$$

Maximize total profit = fare revenue – operating cost

Subject to:

$$Q_{a,s} \leq \frac{f_{a,s}^{\alpha}}{\sum_{a' \in A} f_{a',s}^{\alpha}} * M_s \ \forall s \in S$$

S-curve relationship between market share and frequency share

$$Q_{a,s} \leq Seats_{a,s} * f_{a,s} \ \forall s \in S$$

Seating capacity constraint

$$\sum_{s \in S} f_{a,s} \leq MAX\_SLOTS_a$$

Maximum number of available slots

$$\sum_{s \in S} f_{a,s} \geq MIN\_SLOTS_a$$

Minimum number of slots that must be utilized (Use-It-Or-Lose-It)

$$f_{a,s} \in \mathbb{Z}^+ \ \forall s \in S$$

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blue left = actual   red = right = model

Solution using Dynamic Programming

- Nonlinear constraints together with integrality constraints
- But the structure is suitable for dynamic programming since:
  - slot restrictions are the only coupling constraints across different segments
  - objective function is additive across segments
- No. of stages = No. of segments
- No. of states per stage = Maximum no. of slots

Profit(s, n) = Segment s profit due to exactly n flights per day

$$R(0,0) = 0, \quad R(0,n) = -\infty \ for \ n \geq 1$$

$$R(s,n) = \max_{0 \leq n' \leq n} (R(s-1,n') + Profit(s,n-n'))$$

$$Optimal\ total\ profit = \max_{MIN\_SLOTS_a \leq n \leq MAX\_SLOTS_a} R(|S|,n)$$

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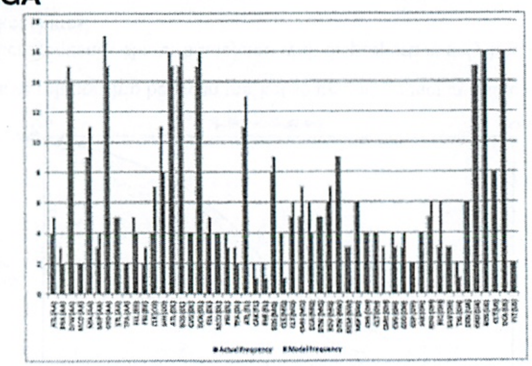
Empirical Validation: Nonstop Segments Out of LGA



- Model predicted actual frequencies within 7% error
- Very fast convergence, regardless of the starting point

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will converge in finite # of steps

?Look at what model says vs what airlines actually did

need the S-curve

An Example of Over-scheduling 2007

LGA-BOS:

40 direct flights per day

Carrier	Flight No.	Dep. Time	Arr. Time
DL	1906	6:00	7:00
US	2114	6:00	7:00
DL	1908	6:30	7:34
MQ	4803	7:00	8:15
US	2116	7:00	8:12
DL	1910	7:30	8:37
US	2118	8:00	9:12
MQ	4802	8:20	9:30
DL	1912	8:30	9:40
US	2120	9:00	10:16
DL	1914	9:30	10:46
US	2122	10:00	11:15
DL	1916	10:30	11:47
MQ	4805	10:50	12:05
US	2124	11:00	12:15
DL	1918	11:30	12:46
US	2126	12:00	13:10
DL	1920	12:30	13:39
US	2128	13:00	14:11
DL	1922	13:30	14:39

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Slot Reduction Schemes Tested

1) Proportionate slot reduction
   - Number of slots available to each carrier reduced by same proportion
2) Reward based slot reduction
   - Slot reduction for each carrier proportional to inverse of passengers/slot
   - Idea is to reward those who are using their slots efficiently

Assumptions:

1. The aircraft sizes remain unchanged
2. The average load factor on any segment can never exceed 85%
3. Leg based deterministic demand and constant average fares
4. Revenue calculated assuming full itinerary fare (no fare proration)

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or
- Congestion pricing
- administrative control

big limiting restrictions

need a mechanism to adjust airline behavior ↗

Overall Impacts

lots of stuff behind this

Stakeholder	Metrics	No Reduction	12.3% Reduction: Proportionate	12.3% Reduction: Reward-based
Airline	Total Operating Profits (Excluding Flight Delay Costs)	$1,237,623	$1,475,217 (19.20%)	$1,446,520 (16.88%)
	NAS Delay per Flight	12.74 min	7.52 min (-40.97%)	7.52 min (-40.97%)
Passengers	Total Passengers Carried	22,184	21,680 (-2.27%)	21,728 (-2.05%)
	Average Passenger Delay (due to NAS Delays)	25.10 min	14.81 min (-40.97%)	14.81 min (-40.97%)
	Average Schedule Displacement	25.35 min	27.58 min (8.8%)	27.55 min (8.7%)

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Impact on Individual Airlines

to IFR (Instrument flight rules) capacity

Carrier	No Reduction	12.3% Reduction: Proportionate	12.3% Reduction: Reward-based
Network Legacy Carrier 1	$366,952	$416,322 (13.45%)	$406,107 (10.67%)
Low Cost Carrier 1	$48,061	$59,507 (23.82%)	$59,507 (23.82%)
Network Legacy Carrier 2	$65,996	$74,466 (12.83%)	$70,581 (6.95%)
Network Legacy Carrier 3	$196,215	$252,231 (28.55%)	$252,900 (28.89%)
Low Cost Carrier 2	$39,694	$46,632 (17.48%)	$48,331 (21.76%)
Regional Carrier 1	$19,831	$31,318 (57.92%)	$29,831 (50.43%)
Network Legacy Carrier 4	$112,578	$143,084 (27.10%)	$130,316 (15.76%)
Regional Carrier 2	- $1,579	$39,126 (n.a.)	$40,582 (n.a.)
Network Legacy Carrier 5	$208,020	$224,697 (8.02%)	$218,922 (5.24%)
Network Legacy Carrier 6	$181,855	$187,834 (3.29%)	$189,443 (4.17%)

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differences different for each carrier

need the entire industry to do it

Result Summary

- Slot reduction schemes can lead to:
  - approximately 15% to 20% increase in total airline profits
  - approximately 1% to 2% decrease in passengers carried
- Results not very sensitive to the assumptions
  - in most cases, assumptions were found to be conservative, further reinforcing the main conclusion of the study

if can change size of plane

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References

- Vaze, V., and C. Barnhart (2010c). Modeling Airline Frequency Competition for Airport Congestion Mitigation. Under Review. *Transportation Science.*
- Vaze, V., and C. Barnhart (2010b). Price of Airline Frequency Competition. Working Paper. MIT.
- Vaze, V., and C. Barnhart (2010a). An Assessment of the Impact of Demand Management Strategies for Efficient Allocation of Airport Capacity. Under Review. *International Journal of Revenue Management.*

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Thank you. Questions?

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Airlines don't like
- don't want to pay for something they get for free
- might have to be quite expensive
- don't want to lose something they have

Used fixed ticket prices
- would pax be less WTP

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Looking Back and Ahead: Critical Challenges for US Airlines

16.71J The Airline Industry
William S. Swelbar, Research Engineer, MIT

December 1, 2010

Massachusetts Institute of Technology

Simply, the Last Three Decades

- Barriers to entry for new and existing carriers were removed
  - If one had a dollar, an airplane and a certificate: an airline was born
    - This is changing
- Barriers to exit for inefficient carriers were about to be erected
  - Bankruptcy, government, labor as an internal source of capital
  - Inefficient providers remained in the market
- Competition ensued: healthy or unhealthy?
- Boom and bust cycles describe the industry
  - And they really are no good for any stakeholder group
- An industry too big to be sustainable was created?

in begining

today hard to get capital

everyone stayed in market

– is competing on price good?

even in bad times capacity added

2

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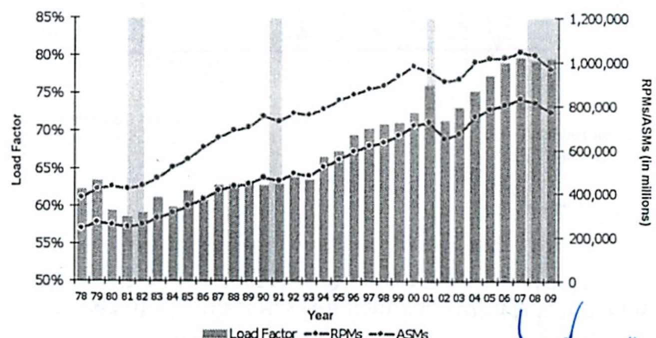
U.S. Airlines: An Industry That Grew Too Big



now finally capacity being cut

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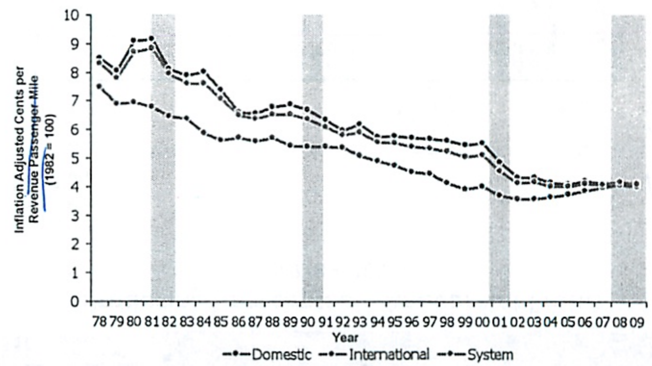
Decreasing Real Fares Became the "Great Enabler" Unsustainable Economics



decreasing real airfair

yields 55% lower

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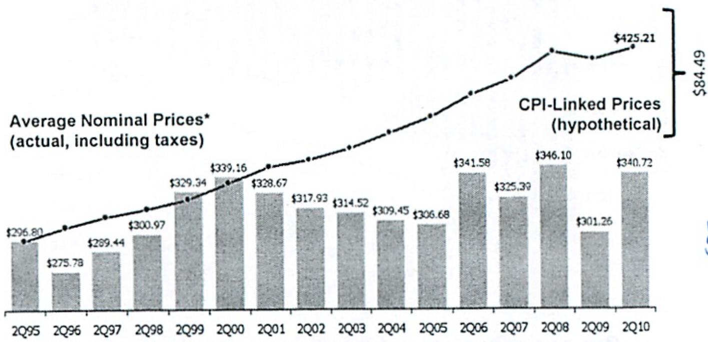
The Price* of Air Travel Has Not Kept Pace With U.S. Inflation

U.S. CPI Rose 43.3% from 2Q95 to 2Q10, Leaving Ticket Prices $84.49 "Short"



* BTS reports average fares based on domestic itinerary fares (round-trip or one-way for which no return is purchased). [Averages do not include frequent-flyer or "zero fares."] Fares are based on the total ticket value, which consists of the price charged by the airlines plus any additional taxes and fees levied by an outside entity at the time of purchase.

Sources: BTS National-Level Average Fare Series (http://www.bts.gov/xml/atpi/src/avgfareseries.xml) and BLS (http://www.bls.gov/cpi/tables.htm)

if fares went up at rate of inflation would be $84 more

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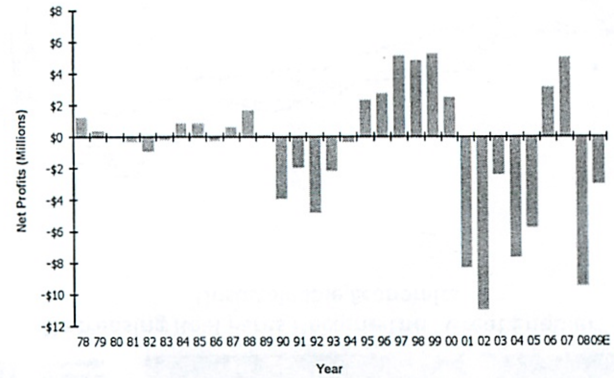
Producing Unacceptable Annual Net Profits

1978 – 2009E



not a good biz for companies

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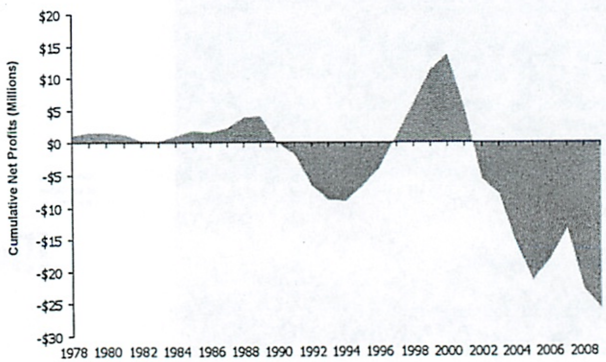
Or.... An Industry That Has Lost $22 Billion Since 1978

1978 – 2009E



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Bankruptcies

	BANKRUPTCIES	CUMULATIVE BANKRUPTCIES	SOME HIGHLIGHTED CARRIERS
1978			
1979	2	2	New York Air
1980	4	6	
1981	5	11	
1982	10	21	Braniff
1983	5	26	Continental
1984	17	43	Air Florida, Wien
1985	10	53	PBA, Cascade
1986	6	59	Frontier
1987	9	68	Air Atlanta, Air South
1988	11	79	Mid Pacific
1989	7	86	Eastern, Presidential
1990	6	92	Continental
1991	16	108	Pan Am, Eastern, Bar Harbor, Midway, America West
1992	5	113	TWA
1993	3	116	Hawaiian
1994	2	118	
1995	5	123	TWA
1996	4	127	
1997	4	131	Air South, Western Pacific
1998	2	133	
1999	4	137	
2000	7	144	Tower, Legend
2001	2	146	TWA, Midway
2002	4	150	Vanguard, United, US Airways
2003	2	152	Hawaiian
2004	6	158	US Airways, ATA, Polar
2005	7	165	Delta, Northwest, Independence Air
2006	1	166	
2007	2	168	Maxjet
2008	5	173	Aloha, ATA, Skybus, Frontier, Air Midwest

8

will be likly profitable this year | only sucessful carriers America West, JetBlue, Virgin America

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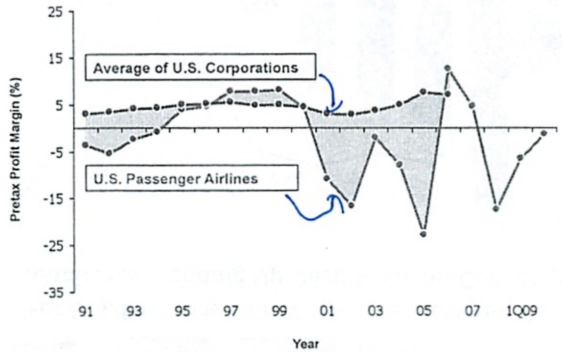
The "Boom and Bust" Simply Destroys Capital

Pretax Profit Margin Highly Cyclical and Well Below U.S. Corporate Average



Source: Air Transport Association

shareholders don't want to invest

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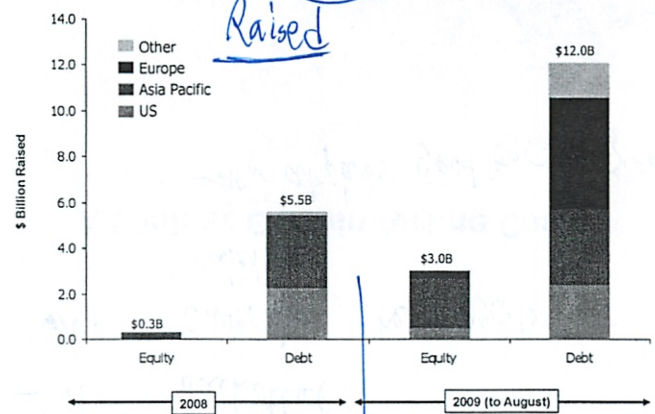
So Airlines Remain In Survival Mode

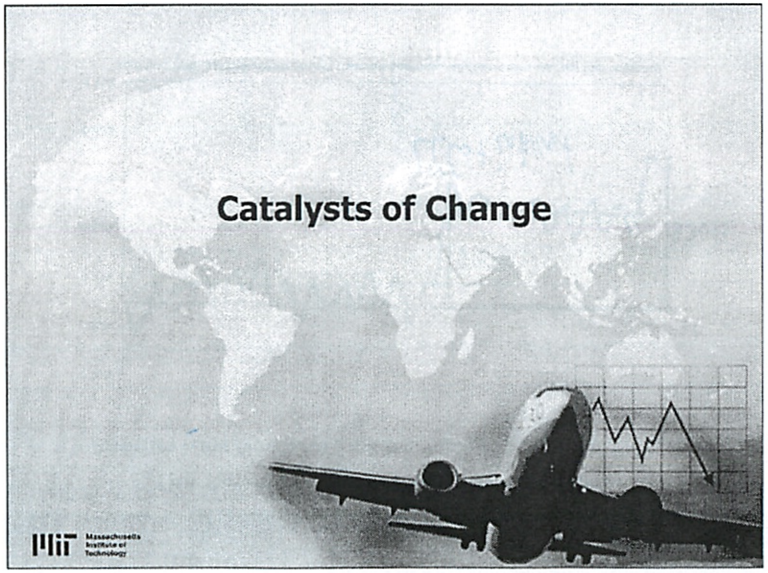
Capital Market Cash Raising By Airlines, $ Billion

Raised



Source: Bloomberg, IATA

JetBlue started w/ a lot of equity



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The Restructuring Refuses to Stop Honestly, It Cannot

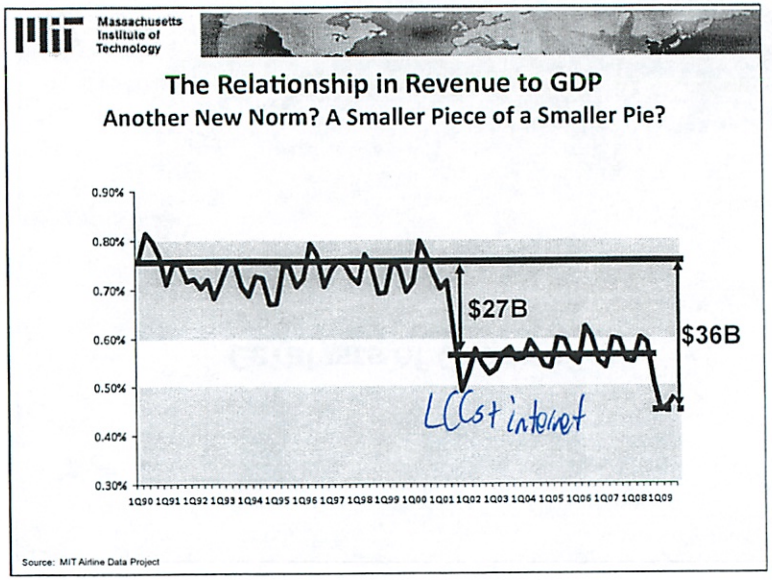
- **The historic relationship of GDP as a predictor of US airline industry health breaks down**
  - The revenue breakdown caused the industry to resort to cost-cutting as we had never experienced – as there was little to no choice
  - New revenue sources
- **The Growth of the Low Cost Carriers and the Internet**
- **The legacy network carriers shift/outsource capacity to their regional partners**
- **The restructuring that occurred between 2002 and early 2007, removed approximately $20 billion in expense**
  - But the restructuring began when fuel was an equivalent of $30 per barrel "in the wing"; and today we are paying $23 billion more
  - The new economic order is all about $80 - 90+ per barrel fuel
- **Tomorrow, global forces will shape our domestic services**

12

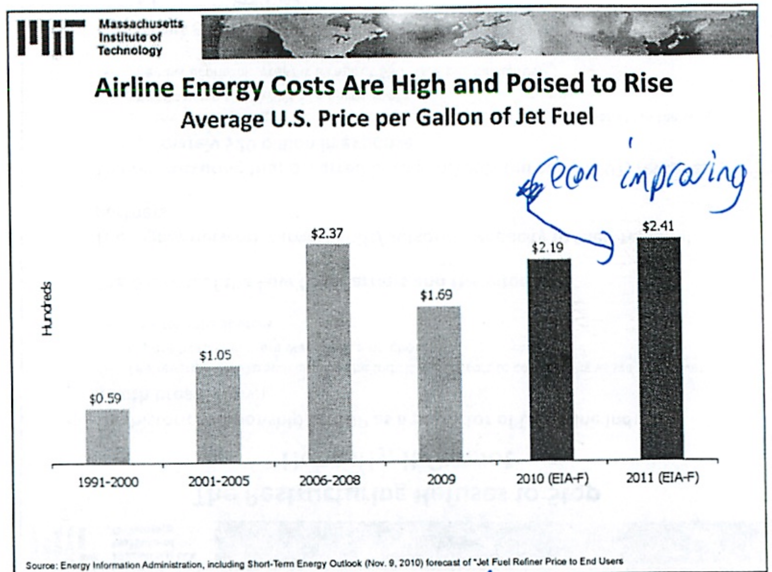
Stress test for oil

-Alaska, JetBlue major code share
-Puts people on your domestic service

-well capitalized?
-backup plan?

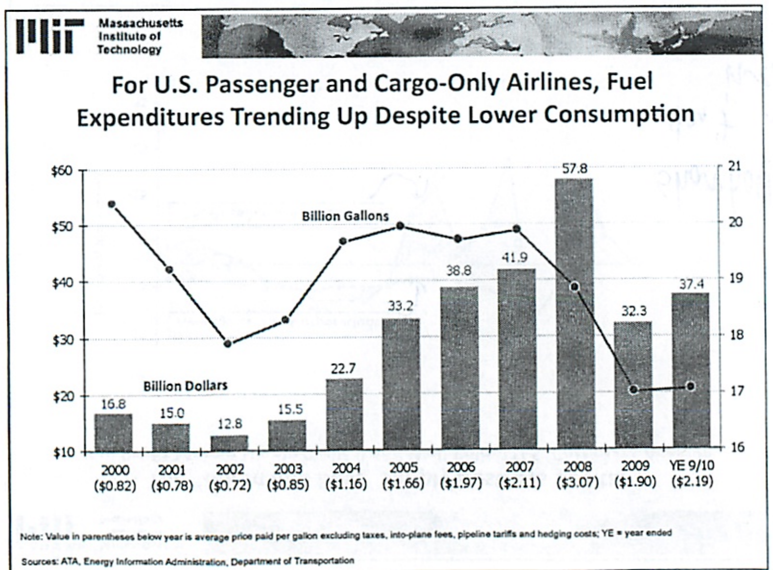


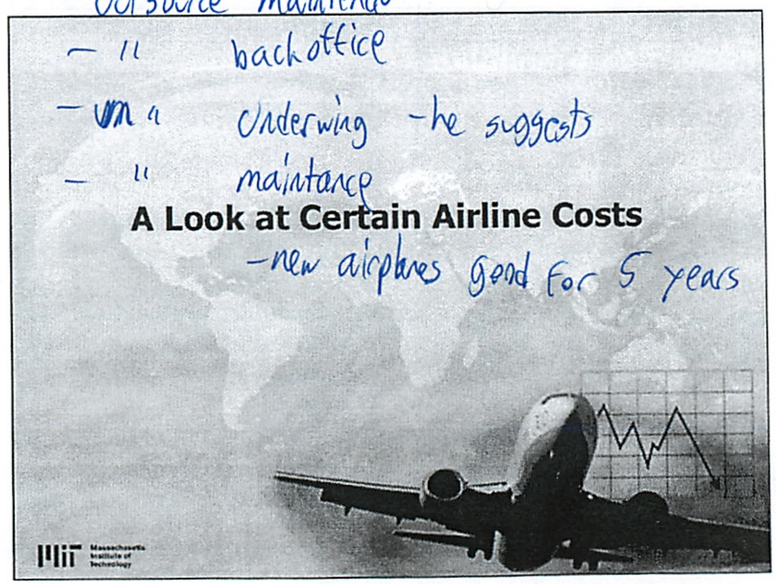
LCCs + internet



econ improving

How will you do the costs?
- outsource maintence
- " backoffice
- " Underwing - he suggests
- " maintance





- new airplanes good for 5 years

volitility has not gone away

Why capital structure is important

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The Expense Portion of the Income Statement 2001 - 2008

- **Labor:** Significant cuts in headcount, pay and benefits
- **Maintenance:** An area of concern as materials costs increasing – and airplanes getting older. No secret as to why older aircraft are being removed as quickly as possible. Outsourcing questions remain. Activist agencies of government
- **Commissions:** Most fruit has been picked – but……
- **Aircraft and non-aircraft rentals; food service; and infrastructure:** many reduced, but not enough. Airport and other costs could go up given their inverse relationship to activity
  - Payments to Regional Partners: an unfolding battleground.

17

spare parts expensive
tie up a lot of capital
lots of volatility in maint. costs
distribution
direct is best
all types of airport costs
every piece of industry based on growth

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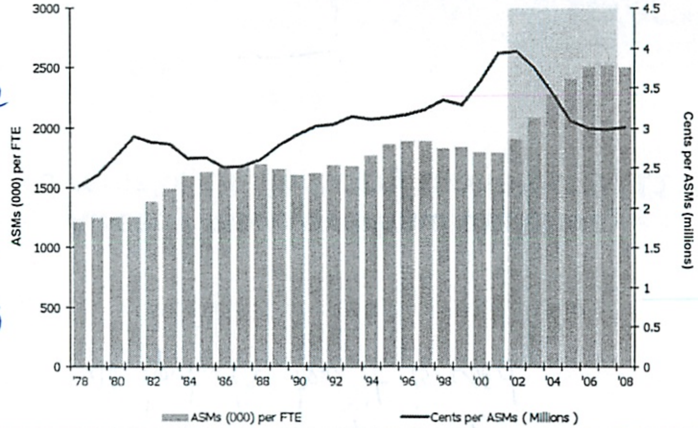
Labor Efficiencies and Unit Costs Were Significantly Altered During the Restructuring Period



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dramatic improvement in productivity
SW has high productivity

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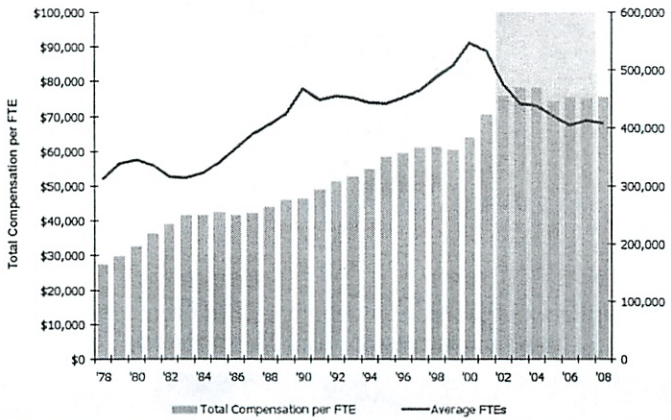
But as We Reduced Headcount, the Average Cost of Labor Does Not Change Commensurately



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Seniority – laid off lesser paid workers

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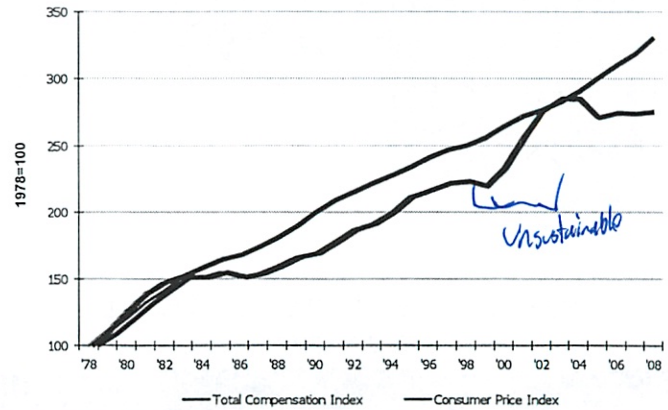
Despite the Boom and Bust Cycles of Labor Negotiations, Labor Costs Have Been Reduced in Real Terms



managed labor costs relative to inflation loyalty program important

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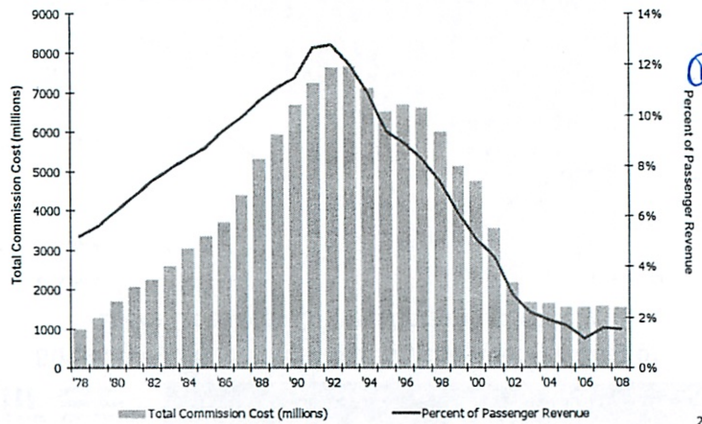
Passenger Commissions and the Internet
A Classic Example of "Competing Away" the Efficiencies



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did really well
↓ cost of distribution

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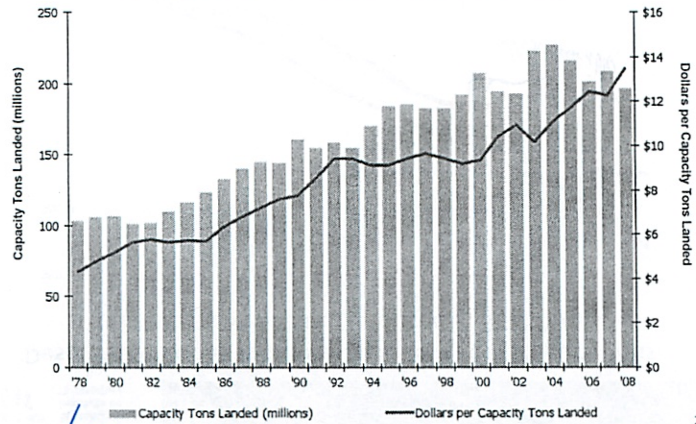
Landing Fees
The "Age Old" Airline v. Airport Conflict



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Fight w/ each other
PFC = pax facility charge
no input in how it is used

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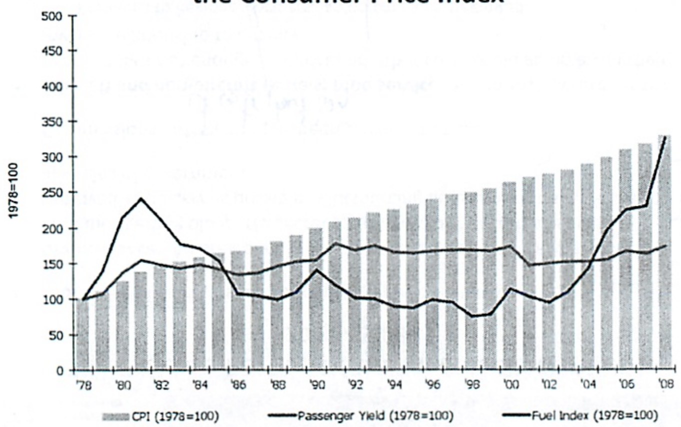
Passenger Yield and Fuel Relative to the Consumer Price Index



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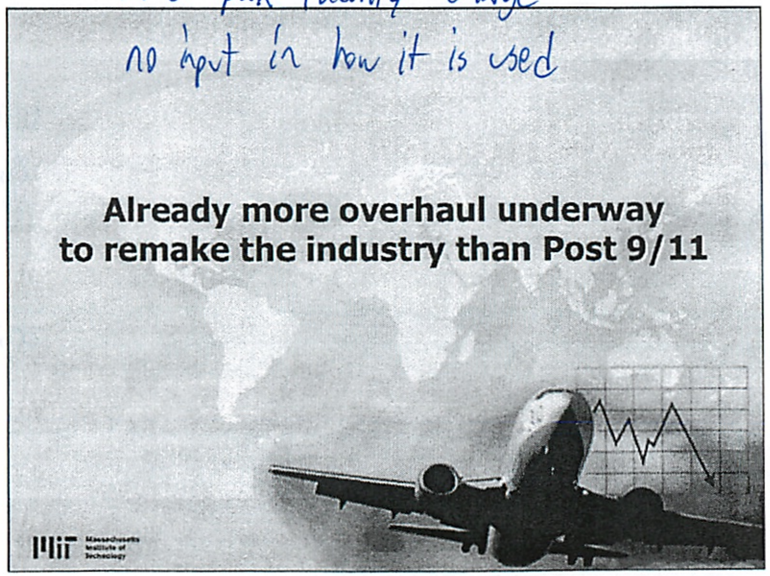
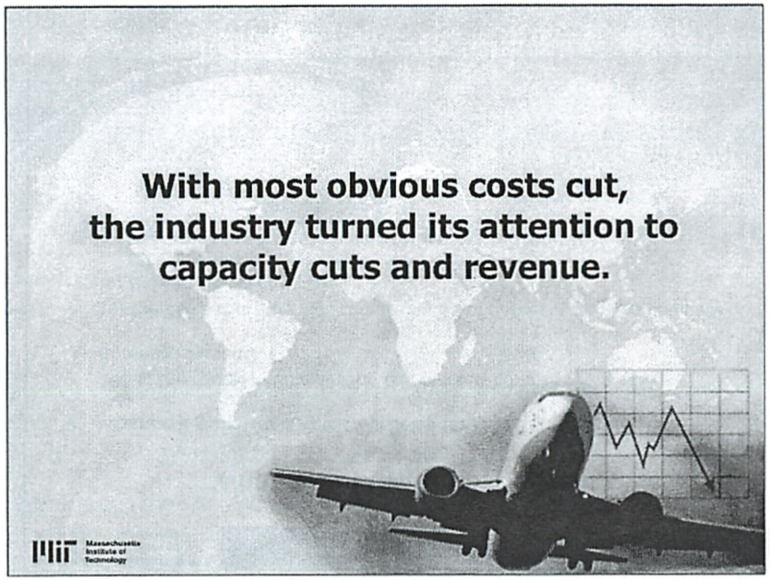
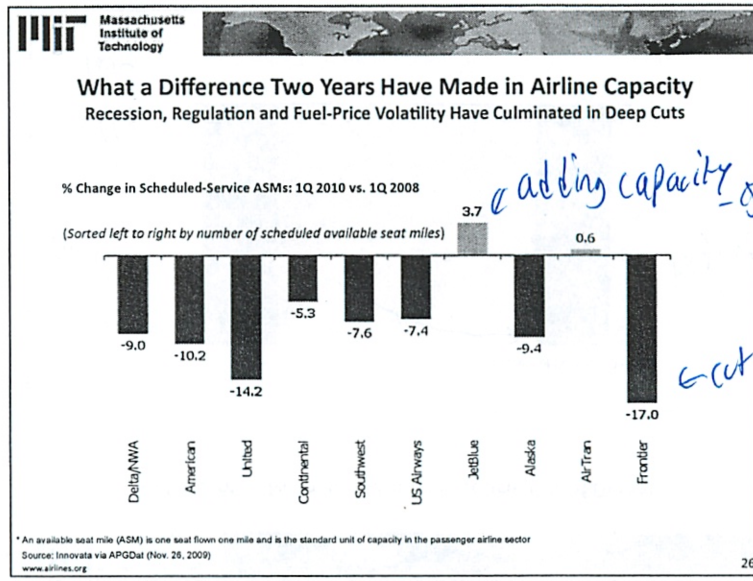


want flexibility
Long term lease – locks you in / at airports

Capacity displine - is very good thing for industry

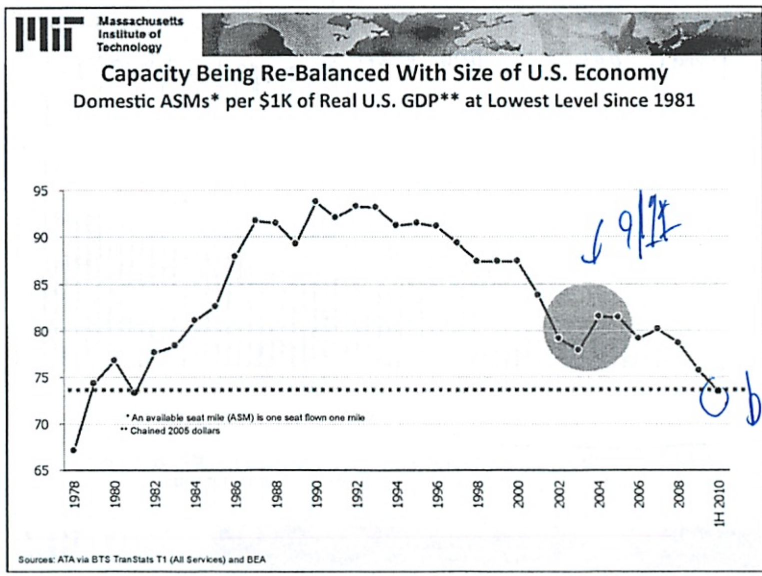




adding capacity - growing international

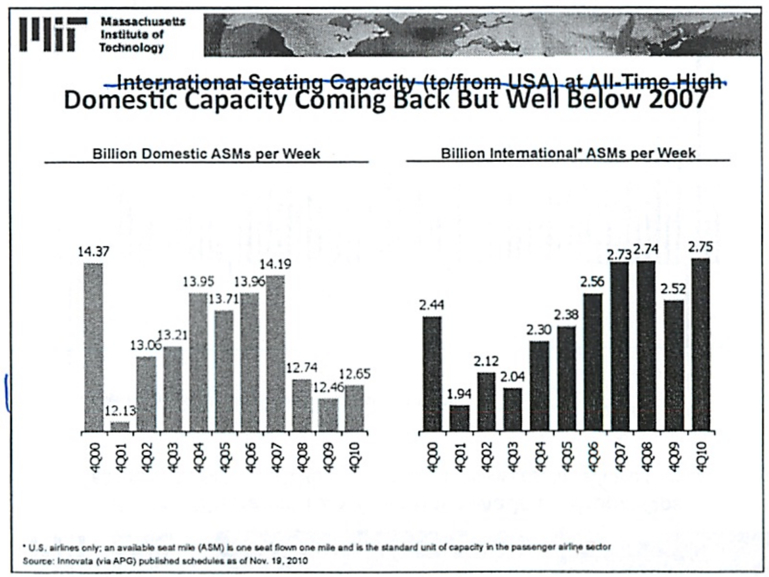
← cut

? more now than in bankrupcy



↓ 9/11

back to 1981



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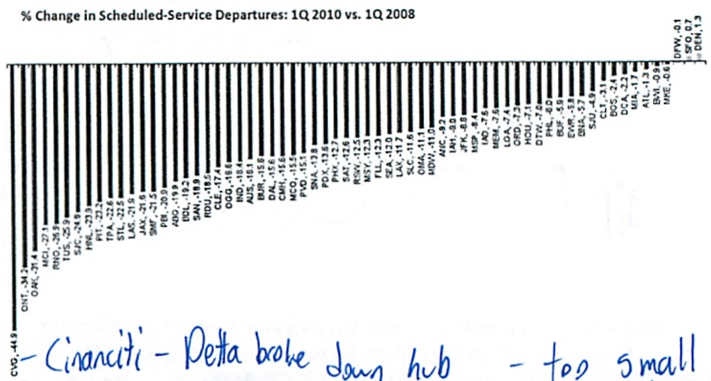
What a Difference Two Years Have Made in Airport Ops

63 of the 65 FAA "Large" and "Medium" U.S. Airports Have Lost Scheduled Flights



– Cinancti – Delta broke down hub – too small of a town

Sources: Innovata (Nov. 26, 2009) and Federal Aviation Administration
www.airlines.org

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Even biggest markets – Others may be good opportunity

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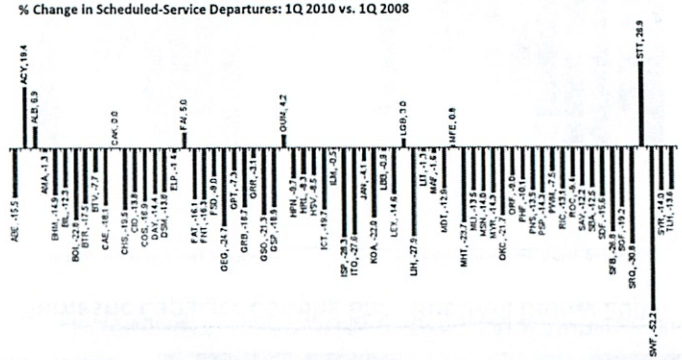
What a Difference Two Years Have Made in Airport Ops

63 of the 71 FAA "Small Hub" U.S. Airports Have Lost Scheduled Flights



Sources: Innovata (Nov. 26, 2009) and Federal Aviation Administration
www.airlines.org

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Reductions not nearly as great

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What About the Airport System

- Whereas a global issue, focus will be on the U.S.
- 200 of the roughly 450 mainland U.S. markets comprise 97% of domestic demand
- Yet the 250 airport markets comprising 3% of domestic demand compete for the same pool of dollars
- Is the current airport system right for tomorrow's industry?

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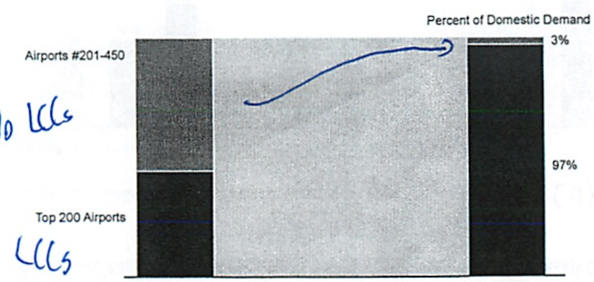
40 Percent of Mainland Airport Produce 97% of Demand

No LCCs

LCCs here



highly concentrated

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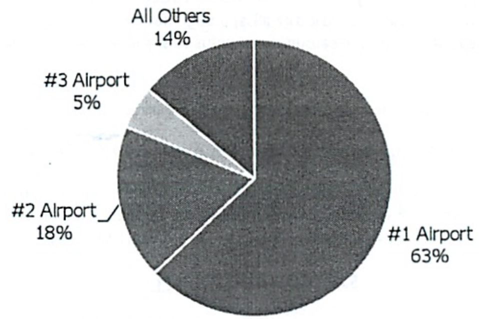
The Largest Airport in Each State Accounts for Nearly 2/3 of All Domestic Seats



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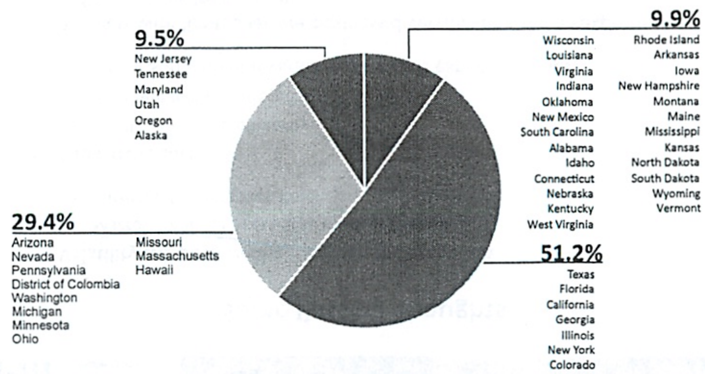
And 80+ Percent of All Domestic Seats Are Located in 17 States – 90 Percent in 25 States



So as we begin the process of deemphasizing the domestic market, it is about the international market

growth in international biz

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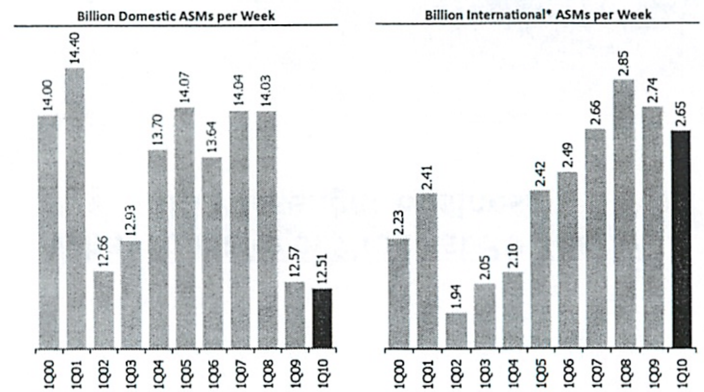
1Q 2010 Domestic Capacity Below 1Q 2002 Level

U.S. Airlines' International Capacity Comparable to 1Q 2007 Level



* U.S. airlines only; an available seat mile (ASM) is one seat flown one mile and is the standard unit of capacity in the passenger airline sector

Source: Innovata (via APG) published schedules as of Nov. 26, 2009

www.airlines.org

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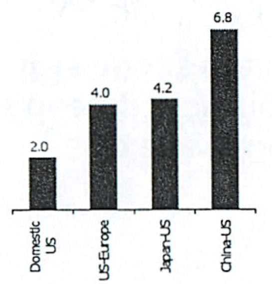
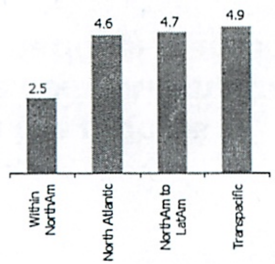
Thinking Outside the [Domestic] Box

The Future Lies Across the Pond(s)

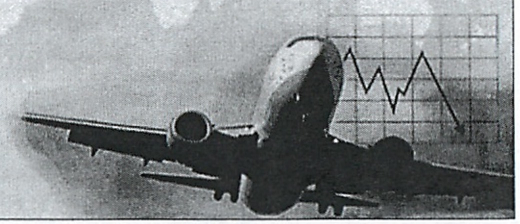
Airbus Global Market Forecast
Annual Traffic Growth: 2009-2028



Boeing Current Market Outlook
Annual Traffic Growth: 2009-2028



What to Make of the Last 30 Years? US Passenger Business



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The Stakeholders

- **Consumers:** the only clear winner as prices accomplished what the deregulators wished for. As for reliability, the existing system is neither good for the industry nor the consumer
- **Labor:** Winner/Neutral as jobs that remain are relatively high-paying jobs
- **Manufacturers:** Both good and bad. Subject to the boom and bust cycles that describe the industry
- **Airports:** Generally winners as small communities did not suffer near as much as what was initially envisioned. Some large airports have benefited from being both a mega-hub and an international gateway
- **Vendors:** Could be classified as a winner due to the industry's explosive growth and demand for goods and services
- **Lenders:** Both good and bad. Lots of fees earned. Lots of write-downs due to the many in-court and out-of-court restructurings
- **Shareholders:** Losers.

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Only TV sets price fell that much
Still high paying + good benefits
lots of communities have lots of service
big winners - high margins

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Some Passing Thoughts

- **Volatility will be more the rule than the exception**
  - Macroeconomic forces unlike those in the past?
  - Currency, Commodities, Credit,
- **Capacity reductions**
  - Finally a path to profitability?
  - But there really is little left to cut
    - At some point revenue loss exceeds expense savings
- **Markets with limited leisure:business diversification can be expected to suffer over the longer term**
  - More than likely a whole new breed of service provider?
- **Alliance shifting underway**
  - Relationship with single alliance or multiple alliances or remain unaligned?

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Fraport prints $
US airports will privatize to fill tax hole?

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Economic Forces

- Commodity Prices
  - Oil
  - Jet Fuel
    - Crack Spread
  - Currencies
- Macroeconomy
  - Restoring historical relationship to GDP?
  - Credit
    - Impact on carriers
    - Impact on consumers
- Rethinking the Travel Dollar
  - Finding a balance between air fares, hotels, ground transportation

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Carrier Challenges/Opportunities

- American
  - **Positives:** liquidity concerns addressed; fleet replacement program underway (operational savings); management; active in technology area – lots of things in mind
  - **Negatives:** fleet replacement program underway (CAPX requirements); relative performance v. the industry; cost disadvantage; labor negotiations (pension and retiree health expense) operational performance
- Continental
  - **Positives:** regarded still as "best in class"; membership switch to STAR Alliance; relatively good labor environment; Houston and New York; relatively young fleet; decent liquidity position; merger with UAL creates world's largest airline company
  - **Negatives:** managing the merger of two companies – distraction; culture maintenance – culture important – not many guys have good culture
- United
  - **Positives:** operational performance improving; liquidity concerns mitigated; lack of pension expense; excellent management of non-fuel unit costs; aggressive capacity cutting could provide great leverage in a recovery scenario
  - **Negatives:** low labor costs; high non-labor costs; no growth on the horizon will make managing unit costs increasingly difficult

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liquidity in all – cash is king | expect big wage ↑

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Carrier Challenges/Opportunities

- Delta
  - **Positives:** world's second largest carrier; unrealized synergy benefits from merger; good relative cost position; pilot issues complete; size has its advantages (further capacity cuts, value chain); 8 groups vote to be union free
  - **Negatives:** sheer number of regional jet units (50 seats); reliance on relatively small hub markets good to supplement – not main network
- Southwest
  - **Positives:** not charging fees a differentiator; new markets through redirecting of uneconomic capacity; strong balance sheet
  - **Negatives:** maturing carrier experiencing declines in returns on invested capital; perception that Southwest is becoming a legacy carrier; ancillary fees?; not necessarily THE low cost provider – bought THE low cost provider ↑ wall St. thinks
- jetBlue
  - **Positives:** good liquidity; leveraging New York; ↓ partnerships capacity cuts – now growing
  - **Negatives:** some suffering from rapid initial growth; business model still defining itself (long haul economics difficult); still a leisure carrier; is recent growth warranted? ← long haul w/ high fuel cost not so good

43

Are we going to charge for bags?
He is unsure SW bag thing has helped – prob true

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Carrier Challenges/Opportunities

- US Airways ↓ really turned it around
  - **Positives:** incredible operational turnaround; good relative cost position; balance sheet concerns have been addressed ↓ scary in 2008
  - **Negatives:** sheer number of regional jet units; reliance on relatively small hub markets; pilot integration (nearly 6 years and still not settled); network predominantly domestic; low relative costs; too big to be small, too small to be big ↑ too many eggs in 1 basket

Will we offer internet
– free to freq flyers I say

44

Compare things to other companies
– excluding fuel

Seniority

Jet Blue just contracts - no unions

? just seniority on bidding work

but do you also pay them more

- hard to avoid discussion

don't know can totally avoid costs

Can you run a union-free environment

always tried to make it a short term job

- take it to court

- make it a career

Jet Blue will face unionization

- will be easier to unionize

But Delta they voted against it 3x

- what are they doing?

Profit sharing is important

Management pay - not too high!

Get employees to buy in

Get something more agile to econ cycle

Airline Industry Presentations

12/6

~~Raceway airlines~~

- subject eval
- also group evaluation
  - what is the game theory behind this

Raceway airlines

LCC

Indiapolis

CRJ-700

low frills

Underserved overpriced markets

biz

looked at carriers w/ a monopoly

fitted yield vs distance

nice graphics

Nashville - Southwest

Also saw Hawaii

Indiapolis growing

(Their slides more about process than results)

doing multi stops

(2)

13 hr utilization

They used the airport diagrams

Look at delay metrics

(we should have done that - ours was just handwaving)

Short Term emphize on load factors

Then emphize on revenue

(But not as many profit metrics)

$21,000 profit / day

Did sensitive analysis

(i over estimated elasticity)

~~Q:~~ Overall thought good

not low frills - medium

Q: Q (FF) fare is not a fare

Q: ~~Q:~~ Perhaps profit too high → capture market w/ 10%

discount - how capture the market?

How convince people to switch?

- could signal more service, for same price

And how show fares lower - if avg fare

lowest is still same

Bills issue as well
- 10% fare cut not enough to get market share
- 40-50% SW did
  - but mature market
  - thinks smart
  - but need to take a bigger hit

More creditable if go lower on price
- more stimulation ?

Q: What is margin
- 12.6%
- ~~[illegible]~~ Load factors ~85%
- but your margins ~~[illegible]~~ don't go down much
- Some markets

Q: Price elasticity
- .8 - conservative
- did larger for Orlando and Boston
  - That is why so large revenue + lack of sensitivity on price

Q: But taking traffic from encumbents → Need bigger than 10%
~~Need~~ ~~bi~~

(4)

Suggestions

- see full report on metrics
- details
- Route analysis fine
- alt: schedule banks or something
- nice airports
- more detail on HR/LR
- example fares
- operating cost in bounds
- more details on calculation

(we have almost all of these)

Don't include spreadsheet

- nice job
- need more detail on HR
- how would deal w/ organizing activity

(5)

US

Q: Bag fees
- include in presentation

Q: Hub challenge air
- how withstand challenge of big airlines
- ; Code share - ; W MDW
- Resp: each a different competitor
- ~~???~~ good ans build on

Q: Specialty drink w/ umbrella

Q: Again, can you enter w/ minimal fare drop
- SW took 35 years
- ~~?~~ - ; bigger fare reductions

Nice piece
- SW started w/ triangle
- Concerned w/ competive impact
- flush out

Q: Would advertise PPBM?
- No, '
- But future will be mandated - no change cost

(6)

Q: His concern ERJ 145

- How convince people to take it

Q: Why handle cost of PPBM?

- felt like ~~th~~ not that much added cost

Q: Wifi cost

- make explicit efferort
- ~~the~~ put it on pax service
- he has no clue on cost
- just put it in - does not have to be accurate

Pretty good

~~accurate~~

Conservative

low elasticity

~~Very~~ biz-focused

Stronger differentiate

- marketing
  - or low fares

good on freq

good MOW

fare structure ok

(7)

Put in comparison w/ AA.com

Round trip vs each way

- say which

a bit more detail on MR/LR

Very reasonable presentation

Choose bad airplane

- may be gold in getting lower op cost

125,000/month a bit ago

55,000/month now

- can reduce

adjust economy seat # up 1

⑧

Who would have thought they would be defending bag fees?
At start of semestor

16.71 J Presentations

12/8

Find Sky

- luxury airline
- LA, NYC, Miami
- "exacting reliability"
- 1st class or private jet = competition
- Corp clients
- celebrity spokesperson
- free flights to these people
- high advertising cost
  (interesting this is first)
- 3x labor costs
- 1 free flight every 15 flights
  - or just give you cash to book on other airline
- roughly same price as normal first class
- just 1 set fare that does not change

doing JFK, LAX, MIA
  private jet hard in NYC

2 types of aircraft
2 day rotation

(2)

(we should add turnover time)

~~~~ preimum class 10-20% of pax

adding frequency

(I think first class assumption too high)

Ran demand estimation (other did this as well)

- w/ confidencence

E190 + E145

↑ ↗ how in all world do 1st class?

usually 100 usually 50

now 50 now 30

One route unprofitable (like us)

advertising better fatigue

(We should do SWOT)

- unproven model

Concern: two diff aircraft types

are inconstant

- can't do lieflat beds

- pricing?

- operating margin too big 34%

Or demand is very high
~~~~

(3)

Way too overly optimistic

NLCs can undercut

Would double think the l price

- "being who I am"
- why all preimum aircraft fails

economic down turn - kills you

during good time works well

Wifly airways

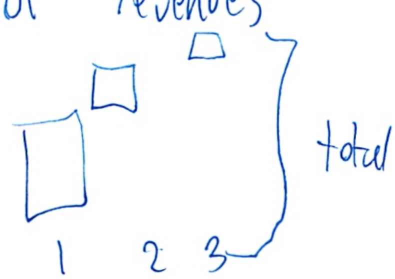
- nice slides
- Hub in Dullus
  - low competive index
  - high yield preium
  - large market

1 or 2 flights a day

(I don't think we calculated yield preium)

Also thought about interlining

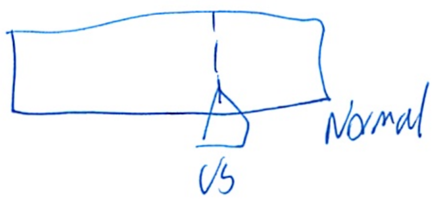
like chart of revenues



(3b)

Match LCC or undercut avg 20%

Nice chart on fares



~~Also 2 chart~~

each seat is an fare class

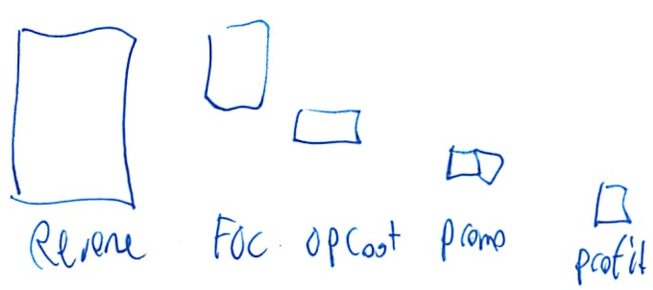
- cust picks price (weird) - sliders on website

(here chart kinda confusing)

will have a few ~4 promo fares

also looked at year to year

Cost breakdown



Also did fuel sensitivity analysis

(but no nice slides)

(4)

737-900

They did a nicer job on what to do HR wise

Yeah lot qu about the price slider
- pick your own price

Bill speechless - kinda

Will do a lot of competing w/ JetBlue
- how would you manage?
- service: wifi + outlets

Pricing mechanism + service
↑
this big deal

Why tampa? as feeder?
- low fare option as non-stop
- some intrinsic + connecting
- based on #

5

Avsone Airlines

Looked at city growth

Hub Austin

- growing city
- diversified econ

Want to expand to Sout america

Not many airlines at Austin

(first airline to go to small airport)

Opened 1999

36% Southwest

10 carriers

AVS Bos BWI LAS SFO

Picked Airbus A318

- efficent + greater range
- copied cost from Frontier

Small markets

- so 50-70% market share on some routes

3.10% margin

6

One morning + 1 evening connecting time
Maintance in SFO - not hub AUS
Wifi w/ Fees
$100,000 install fee on wifi
Flip image - free trade coffee
Viral marketing
- like JetBlue's dress up distribution
Code share opportunities in edge cities
~10% below JetBlue
Get sufficent capital up front
- ~~i~~
- fuel hedge to minimize uncertainty

One 1 non stop flights
- ignoring connection
- sensitivity analysis

Q: Why 318
- demand in market

Q: Why should a bank lend $45 billion beyond startup cost
(~~as~~ we did not have to consider this)

(7)

Important to American
—won't take it easily