Do More U.S. Airports Need Slot Controls?: A Welfare Based Approach to Determine Slot Levels

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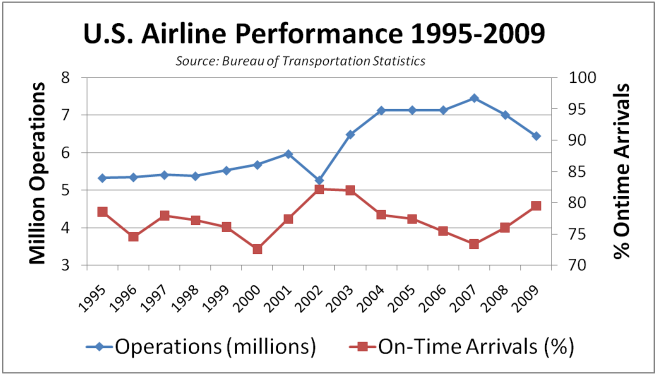
Outline

1. Introduction
   - Motivation
   - Research Agenda
2. Slot Controls: Design Issues and Tradeoffs
3. Estimation Models
   - Schedule Delay
   - Delay Against Schedule
   - Data
4. Results and Conclusions
   - Results
   - Wrap-up

Outline

U.S. Air Transportation Delays



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- As capacity utilization increases, suffers non-linear delays.
- Significant costs to airlines, passengers, and society.

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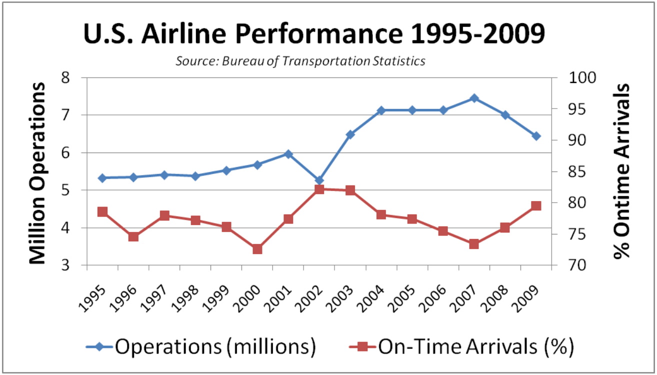

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Increase Supply

- Infrastructure enhancements:
- New runways, airports, capacity-enhancing technology and systems.
- Expensive, politically controversial, technically challenging.

Manage Demand

- Reduce peak capacity utilizations:
- Slot controls, congestion pricing.
- Influence behavior of passengers and/or airline companies.
- Likely to reduce service.
- Social and political hurdles.

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Contrasting Approaches to Congestion Management

Europe

- Virtually all major European airports are slot controlled (based on EEC and IATA rules).
- "Grandfather rights" and "use-it-or-lose-it" rules.
- Slot limits set near bad weather conditions (IMC), i.e. lower level of operations.

U.S.

- Largely first-come-first-served system.
- Access limited only by availability of terminal facilities.
- Historical exceptions:
  - High density rule (HDR), 1968.
  - Chicago OHare (ORD), Washington Reagan National (DCA) and NY airports: LaGuardia (LGA), Kennedy (JFK) and Newark Liberty (EWR).
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Airport Congestion Management in the U.S.

Inherent problem

- Multiple, competing airlines seek to use common airport capacity.
- Incremental addition of a flight may cause much more delay to other flights, than experienced by itself.
- . . . without controls, an airport will naturally evolve to a highly congested state.

Solution attempts

- A flurry of activity in last 8 years.
- Some bold proposals advanced, including a slot auction, but in the end strong entrenched forces have blocked change.
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Fundamental Research Questions

1. What are the key tradeoffs involved in setting a limit on the number of operations at an airport?
2. Should more US airports have slot controls?
3. How should the level of operations be set at slot controlled airports?
4. How to institute the slot controls?

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Two Related NEXTOR Research Projects

Congestion Management for US Airports

- Project funded by the FAA and US Department of Transportation; motivated by expiration of High Density Rule at LGA.
- Specifically considered various congestion management options for LGA (and other US airports).
- Project conducted two multi-day "strategic simulations" that brought together decision makers from airports, airlines and the Federal Government.

Total Delay Impact Study

- Quantified the total cost impact of all US air transportation delays at $28.9 b.
- Employed recent NEXTOR research that modeled passenger delays taking into account flight cancellations and missed connections.
- Quantified impact of demand lost to other modes.
- Expanded science base quantifying delays and their economic impact.

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Cost-Benefit Analysis of Slot Controls for Passengers

Primary Effects

- Movement of flights from peak to off-peak hours in schedule.
- Likely drop in service.
- Benefit: Saving in cost of delays-to-schedule.
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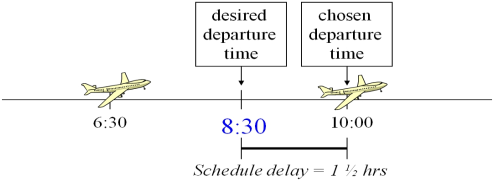

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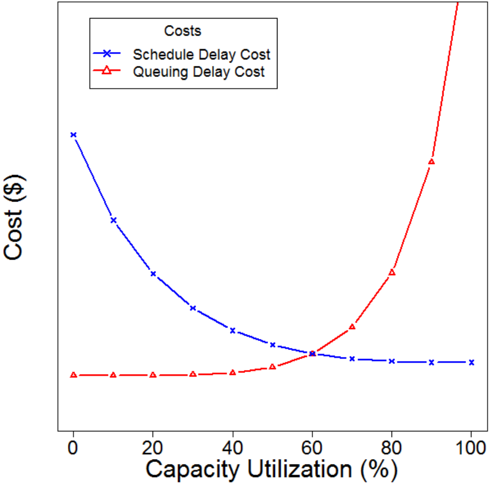

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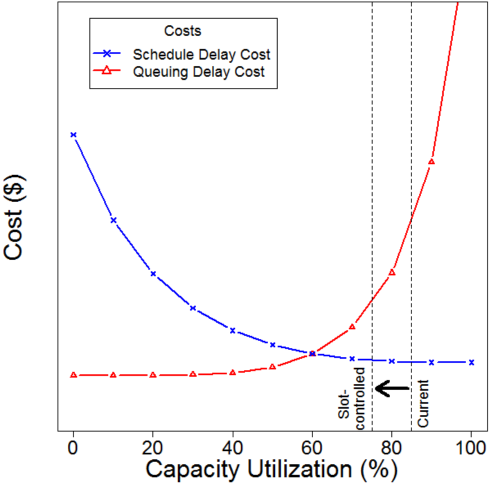

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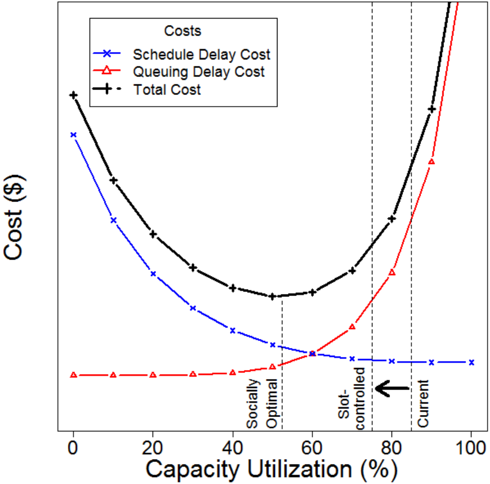

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Approaches to Estimate Schedule Delay

FlightMove Model

- Assumes airlines will not drop any flights upon imposing slot-controls.
- Suitable for relatively higher slot-levels.
- We use it for airports with sufficient capacity to handle current demand despite slot-controls.

FlightTrim Model

- Assumes airlines will drop flights in excess of slot-control limits.
- Suitable for stringent slot-levels.
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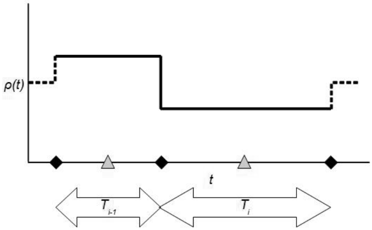


- Simple cost function derived for schedule delay cost from first principles.
- Marginal cost computed by iteratively dropping an "average" flight.
- Excess flights dropped until remaining flights are below the slot-level capacity.
- Marginal cost summed up over each iteration and destination.
- Cost of deleting one average flight (assuming 4-hour period):

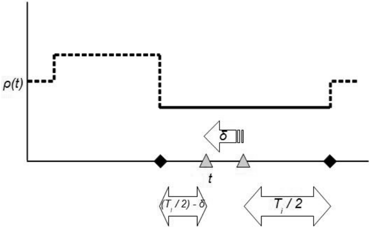
$$MSDC^{FT} = \sum_d 4\Lambda\rho_d \left(\frac{1}{N_d - 1} - \frac{1}{N_d} \right)$$

$$\Lambda = \text{passenger valuation of time}$$

$$\rho_d = \text{demand density function for destination } d$$

$$N_d = \text{number of remaining flights for destination } d$$

FlightMove Model



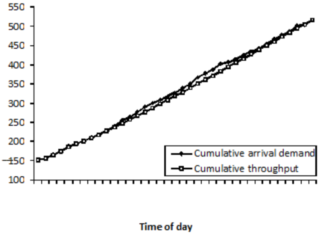
- Uses simulation to randomly perturb current schedule.
- At a time-point with excess flights, a portion of flights for selected destinations are moved to a nearby time-point.
- Iterates until all time-points have flights below the desired slot-level.
- Finds minimum cost of perturbation from actual schedule to simulated predicted schedule, using Transportation Model.
- Cost function derived for schedule delay on moving a flight across time-periods:

$$MSDC^{FM} = \sum_{d} \Lambda \rho_d \delta_d^2 f_d$$

δ_d = number of time-periods perturbed

f_d = number of flights of d perturbed

Deterministic Queuing Delay Model



- Models the operational demand and supply relationship.
- Predicts the observed flight delays at the national level well.
- Based on the time profile of scheduled flight demand and airport capacity over the course of a day
- Capable of capturing temporal characteristics of scheduled demand, such as peakedness.
- Employing Little's Law, total deterministic queuing delay is calculated as the area between the cumulative scheduled arrivals and cumulative throughput curves.
- Procedure repeated for each day in 2007 and each of the OEP35 airports.

Approach to Estimate Delay Against Schedule

Econometric specification:

$$D_{it} = \beta_0 + \beta_1 Q_{it} + \beta_2 Q_{it}^2 + \beta_3 Q_{it}^3 + \beta_4 IFR_{it} + \beta_5 IFR_{it}^2 + \beta_6 Wd_{it} + \beta_7 Temp_{it} + \beta_8 AAR_{it} + \beta_9 Connect_{it} + \sum_k \omega_k q_k(t) + \sum_j \lambda_j m_j(i) + \epsilon_{it}$$

D_{it}	=	Average positive arrival delay against schedule per flight, in minutes, at airport i during day t,
Q_{it}	=	Average deterministic arrival queuing delay per flight, in minutes, at airport i during day t,
Q_{it}^2	=	The square of average deterministic arrival queuing delay per flight,
Q_{it}^3	=	The cube of average deterministic arrival queuing delay per flight,
IFR_{it}	=	The portion of time during day t in which airport i operated under Instrument Flight Rules (IFR) conditions,
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Wd_{it}	=	Average wind speed, in knots, at airport i during day t,
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AAR_{it}	=	Airport arrival acceptance rate (number of arrivals per day) at airport i during day t,
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$q_k(t)$	=	Dummy variable for month q, i.e. $q_k(t) = 1$ if day t belongs to month k and 0 otherwise,
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Estimation Summary

Estimation Procedure:

- Panel created for all OEP35 airports for (almost) each day in 2007.
- Deterministic queuing delay model ran for all airports for each day.
- Prais-Winsten regression allowing first-order auto-correlations conducted.

Estimation Results Summary:

- All coefficients' signs as expected.
- Q coeff almost one, higher-powers have smaller coeff's.
- Higher IFR causes more delay, effect non-linear due to negative IFR^2 coeff.
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- Daily predictions using estimated coeff's averaged into monthly delays.
- Monthly average predictions also fit monthly average delays well.
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Data

Data Sources:

- FAA's Aviation System Performance Metrics (ASPM) for aggregate schedule and capacity data.
- US DOT's Bureau of Transportation Statistics (BTS) for on-time performance and load factors.
- Official Airline Guide (OAG) for detailed schedules.

Period:

- August, 2007 is target period of study.
- 2007 had worst on-time performance in history.
- August represents an "average" month, has no weather and holiday extremities.
- Tuesday, Wednesday, Thursday data used to capture busy period.

Scope:

- Arrival operations at each airport.

Outline

Combined Results

	Net Benefit(SL) = MQDC_SL − MSDC_SL			Incremental Benefit(SL)		Benefit Ratio(SL) $= \frac{MQDC\_SL}{MSDC\_SL}$			Rec SL
SL	80%	90%	100%	80%	90%	80%	90%	100%	
Airport	(i)	(ii)	(iii)	(iv)=(i)-(ii)	(v)=(ii)-(iii)	(vi)	(vii)	(viii)	(ix)
ATL	-$127,268	$130,015	$99,556	-$257,283	$30,459	0.63	3.42	4.78	90%
CLE	$50,774	$49,059	$40,904	$1,715	$8,155	5.74	8.07	9.55	80%
CLT	$98,902	$99,351	$86,283	-$449	$13,068	5.57	8.98	12.00	90%
DCA	$28,851	$34,950	$29,623	-$6,099	$5,327	3.48	7.41	10.34	90%
DTW	$58,467	$54,708	$46,440	$3,758	$8,268	3.07	4.31	6.20	80%
EWR	$351,971	$389,256	$30,565	-$37,285	$358,691	3.90	9.91	1.82	90%
IAD	$30,065	$24,060	$17,657	$6,004	$6,403	5.47	6.83	8.50	80%
JFK	$418,418	$387,939	$34,517	$30,478	$353,423	3.94	8.40	2.07	80%
LAX	-$9,791	$9,189	$3,081	-$18,980	$6,108	0.64	3.73	4.89	90%
LGA	$152,468	$170,489	$31,547	-$18,021	$138,943	3.47	7.25	4.54	90%
MSP	$31,558	$23,743	$12,143	$7,815	$11,600	2.83	3.85	4.04	80%
ORD	$64,012	$122,215	$47,737	-$58,202	$74,477	1.63	7.44	6.66	90%
PHL	-$101,722	$77,302	$83,597	-$179,024	-$6,295	0.62	2.64	5.38	100%
PHX	$46,851	$51,243	$44,986	-$4,392	$6,257	5.19	9.09	11.54	90%
SAN	-$18,270	$29,065	$33,305	-$47,335	-$4,240	0.67	4.83	13.93	100%
SEA	$2,977	$10,704	$7,814	-$7,727	$2,890	1.21	6.83	11.90	90%

16 airports in the U.S. could benefit by slot-limits set even at 100% capacity.

12 of them while serving current demand.

Combined Results

	Net Benefit(SL) = MQDC_SL − MSDC_SL			Incremental Benefit(SL)		Benefit Ratio(SL) $= \frac{MQDC\_SL}{MSDC\_SL}$			Rec SL
SL	80%	90%	100%	80%	90%	80%	90%	100%	
Airport	(i)	(ii)	(iii)	(iv)=(i)-(ii)	(v)=(ii)-(iii)	(vi)	(vii)	(viii)	(ix)
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SEA	$2,977	$10,704	$7,814	-$7,727	$2,890	1.21	6.83	11.90	90%

4 airports will see drop in service when slot-limits are at 80% and 90% capacity.

SL	EWR	JFK	LGA	ORD
80%	11%	9%	15%	7%
90%	4%	4%	7%	2%

Combined Results

	Net Benefit(SL) $= MQDC\_SL - MSDC\_SL$			Incremental Benefit(SL)		Benefit Ratio(SL) $= \frac{MQDC\_SL}{MSDC\_SL}$			Rec SL
SL	80%	90%	100%	80%	90%	80%	90%	100%	
Airport	(i)	(ii)	(iii)	(iv)=(i)-(ii)	(v)=(ii)-(iii)	(vi)	(vii)	(viii)	(ix)
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SEA	$2,977	$10,704	$7,814	-$7,727	$2,890	1.21	6.83	11.90	90%

Slot-limits at 90% and 100% capacity are justified at all of these 16 airports.

4 airports do not justify slot-limits at 80%: ATL, LAX, PHL, SAN.

Combined Results

	Net Benefit(SL) = MQDC_SL − MSDC_SL			Incremental Benefit(SL)		Benefit Ratio(SL) $= \frac{MQDC\_SL}{MSDC\_SL}$			Rec SL
SL	80%	90%	100%	80%	90%	80%	90%	100%	
Airport	(i)	(ii)	(iii)	(iv)=(i)-(ii)	(v)=(ii)-(iii)	(vi)	(vii)	(viii)	(ix)
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(iv) and (v) give Incremental Benefit for each airport going stepwise from 100% to 90% (v), and from 90% to 80% (iv).

2 airports have better incremental returns with slot-levels set at 100%: PHL, SAN.

9 airports have negative incremental returns with slot-levels set at 80%.

Remaining 5 airports have best incremental returns with slot-levels set at 80%.

Combined Results

	Net Benefit(SL) = MQDC_SL − MSDC_SL			Incremental Benefit(SL)		Benefit Ratio(SL) $= \frac{MQDC\_SL}{MSDC\_SL}$			Rec SL
SL	80%	90%	100%	80%	90%	80%	90%	100%	
Airport	(i)	(ii)	(iii)	(iv)=(i)-(ii)	(v)=(ii)-(iii)	(vi)	(vii)	(viii)	(ix)
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SEA	$2,977	$10,704	$7,814	-$7,727	$2,890	1.21	6.83	11.90	90%

(vi), (vii), (viii) give "Returns on Investment" for each airport at the three slot levels.

Note diminishing returns.

Combined Results

	Net Benefit(SL) = MQDC_SL − MSDC_SL			Incremental Benefit(SL)		Benefit Ratio(SL) $= \frac{MQDC\_SL}{MSDC\_SL}$			Rec SL
SL	80%	90%	100%	80%	90%	80%	90%	100%	
Airport	(i)	(ii)	(iii)	(iv)=(i)-(ii)	(v)=(ii)-(iii)	(vi)	(vii)	(viii)	(ix)
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Currently slot-controlled airports: DCA, EWR, JFK, LGA are in the list.

Indicates current slot-control levels are set too high.

Combined Results

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SL	80%	90%	100%	80%	90%	80%	90%	100%	
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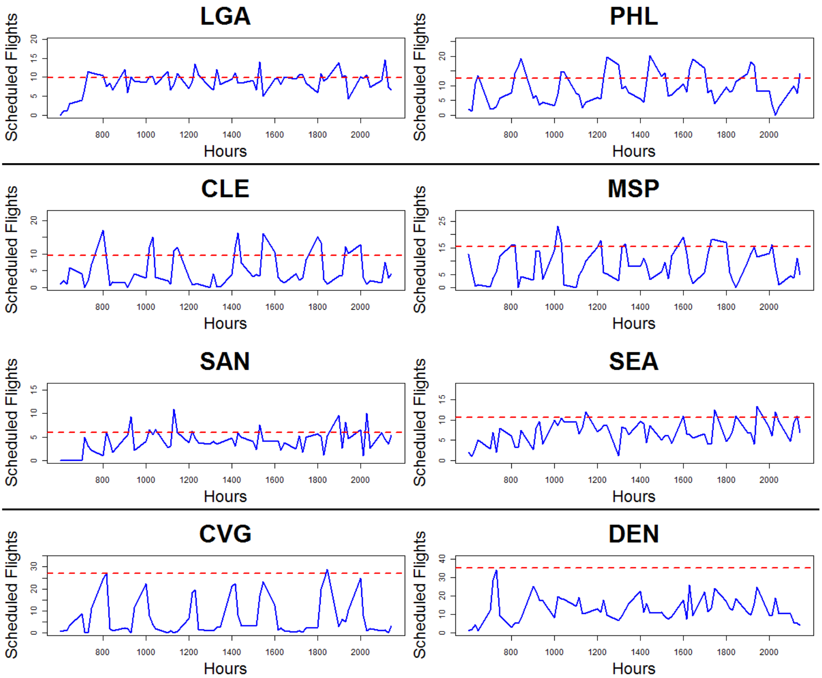
SEA	$2,977	$10,704	$7,814	-$7,727	$2,890	1.21	6.83	11.90	90%

List includes airports not considered to be highly congested: CLE, MSP, SAN, SEA.

These have few demand peaks beyond peak capacity, and leveling those peaks could be valuable at these airports.


LGA
PHL
CLE
MSP
SAN
SEA
CVG
DEN
Scheduled Flights
Hours
800
1000
1200
1400
1600
1800
2000

Wrap-Up

Summary of Contributions:

- Broad view of issues involved in imposing slot-controls at U.S. airports.
- Experience and feedback from Federal Government proposed rulemakings incorporated in outlining guidelines and concern areas.
- Non-linear relationship specified between queuing delay costs and schedule delay costs as functions of peak capacity utilization.
- Models developed to quantify costs and benefits of implementing slot-controls at major U.S. airports.
- Results indicate justification of more pervasive use of slot-controls.

Limitations:

- Impact on competition and fares not modeled.
- Administration and other costs involved in implementing slot-control not included.

Do More U.S. Airports Need Slot Controls?: A Welfare Based Approach to Determine Slot Levels

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