Capacity Constraints and the Dynamics of Transition in the US Air Transportation

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Simple Model of NAS Capability Transition Dynamics

Historically Transition Driven by Catalytic Accidents

What is Capacity Analogue?

Source: Alexandra Mozdzanaowska
Passenger Traffic by Region

Data source: ICAO, scheduled services of commercial air carriers (through 2005)
Trends in Aircraft Size

Data source: Form 41 Traffic data from Bureau of Transportation Statistics (US carriers)
U.S. Public Use Airports

Source: CAA statistical handbook of aviation, FAA statistical handbook of aviation, BTS
Public use airports decreasing at ~22 a year
Certificated airports decreasing at ~5 a year
US Flight Delays
from 1995 to 2007

Data source: FAA Operational Network (OPSNET)
Flight Cancellations from 2000 to 2007 (by month)

Growth Limits
Constraints vs Damping

Upside: Capacity, Market

Downside: Financial
Capacity Limit Factors

- **Airport Capacity**
  - Runways
  - Gates
  - Landside Limits (including Security)
  - Weather

- **Airspace Capacity**
  - Airspace Design
  - Controller Workload
  - Balkanization

- **Demand**
  - Peak Demand
  - Hub & Spoke Networks

- **Environmental Limits**
  - Noise (relates to Airport)
  - Emissions (local, Ozone, NOX, CO2)
Airport System Capacity Limit Factors

- Arrival/Departure Routes
- Runways
- Weather
  - Capacity Variability
- Gates
- Downstream Constraints
- Controller Workload
- Landside Limits
  - Terminals
  - Road Access
- Environmental
  - Community Noise
  - Emissions
- Safety

Adaptive System - Impedance Matching
Key Terminal System Flows
(adaptive system - impedance matching)
Airport System Capacity Limit Factors

- Arrival/Departure Routes
- **Runways**
- Weather
  - Capacity Variability
- Gates
- Downstream Constraints
- Controller Workload
- Landside Limits
  - Terminals
  - Road Access
- **Environmental**
  - Community Noise
  - Emissions
- Safety
Separation Requirements for Arrival (Same Runway)

- **Wake Turbulence Requirement**
  Radar Separation Requirements

<table>
<thead>
<tr>
<th>Leading Aircraft</th>
<th>Heavy</th>
<th>Large</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>B757</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Large</td>
<td>3(2.5)</td>
<td>3(2.5)</td>
<td>4</td>
</tr>
<tr>
<td>Small</td>
<td>3(2.5)</td>
<td>3(2.5)</td>
<td>3(2.5)</td>
</tr>
</tbody>
</table>

- **Visual Separation Requirements**
  - Pilots Discretion

- **Preceding arrival must be clear of runway at touchdown**
  Runway Occupancy Time Limit
A-380
Breakeven Separation for Airport Throughput?
Airport System Capacity Limit Factors

- Arrival/Departure Routes
- Runways
- **Weather**
  - Capacity Variability
- Gates
- Downstream Constraints
- Controller Workload
- Landside Limits
  - Terminals
  - Road Access
- **Environmental**
  - Community Noise
  - Emissions
- Safety
Airport Capacity Envelopes
Atlanta (ATL)

Each dot represents one hour of actual traffic during April 2000.

Source: FAA Benchmark Data
Airport Capacity Envelopes
Boston (BOS)

Source: FAA Benchmark Data
Variable Capacity Effects

1995 Delays vs Operations

From John Andrews, MIT Lincoln Lab
QuickTime™ and a Microsoft Video 1 decompressor are needed to see this picture.
Network Effects and Delay Propagation

Source: ASDI data
Delays at Chicago O’Hare

Source: FAA OPSNET data
Flight Delays Reemerging

OPSNET National Delays

Source: FAA OPSNET data
Solutions to Address Airport Demand/Capacity Inadequacy

**System view**

- **Demand**
  - Passenger Traffic
    - Aircraft movements

**Demand/Supply Inadequacy**

- **Changes in Infrastructure Utilization**
  - Demand Management
  - Regulation Based Mechanism
    - Other?
    - Range restrictions
    - Operation Type restrictions
    - Slot control
  - Market Based Mechanism
    - Secondary market trading
    - Congestion pricing
    - Auction
    - Other?
  - Debanking
  - Efficiency Improvement
  - Demand Diversion: Secondary Airport Emergence

**Capacity Enhancement**

- Airport Capacity Expansion

Source: Philippe Bonnefoy
Current Airport Expansion Projects

Top 30 Congested Airports in 2005

- SEA: 39 years + 46% improvement
- BOS: 37 years
- ATL: ~15 years 33% improvement
- LAX: ~10 years
- PHL: 3 years
- ORI: 2 years
- IAD: ~10 years
- STL: 8 years 48% improvement

Expansion Projects
Multi-Stakeholder Transition Model
with Implementation Barriers

Implementation Process
Safety and Environmental Approval Processes

Solution Refinement Loop
Decision Making
Negotiation Loop
Objective Formation
Stakeholder Preferences
Stakeholder Decisions
Collective Decisions

Demand
System Capability

NAS
Catalytic Event

Delays
Capability Options

Public Awareness
Stakeholder Awareness

Source: Alexandra Mozdzanaowska
Environmental Limitations

Noise

Emissions

Intergovernmental Panel on Climate Change
Airport Construction in Key Areas has Slowed

1970: NEPA passed requiring EIS

Airport Opening Date (top 30 airports in 2005)
# Capacity Improvement at OEP Airports

## (2000 vs 2006 Delay Rankings)

<table>
<thead>
<tr>
<th>Airport Code</th>
<th>Airport Name</th>
<th>Percentage of Operations Delayed</th>
<th>OEP New Runway Project (Date Completion/Capacity Benefit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGA</td>
<td>LaGuardia</td>
<td>15.6%</td>
<td></td>
</tr>
<tr>
<td>EWR</td>
<td>Newark</td>
<td>8.1%</td>
<td></td>
</tr>
<tr>
<td>ORD</td>
<td>Chicago</td>
<td>6.3%</td>
<td></td>
</tr>
<tr>
<td>SFO</td>
<td>San Francisco</td>
<td>5.7%</td>
<td></td>
</tr>
<tr>
<td>BOS</td>
<td>Boston</td>
<td>4.8%</td>
<td>2006 / +2%</td>
</tr>
<tr>
<td>PHL</td>
<td>Philadelphia</td>
<td>4.5%</td>
<td></td>
</tr>
<tr>
<td>JFK</td>
<td>Kennedy</td>
<td>3.9%</td>
<td></td>
</tr>
<tr>
<td>ATL</td>
<td>Atlanta</td>
<td>3.1%</td>
<td>2006 / +33%</td>
</tr>
<tr>
<td>IAH</td>
<td>Houston</td>
<td>2.8%</td>
<td></td>
</tr>
<tr>
<td>DFW</td>
<td>Dallas/Ft.Worth</td>
<td>2.4%</td>
<td></td>
</tr>
<tr>
<td>PHX</td>
<td>Phoenix</td>
<td>2.2%</td>
<td></td>
</tr>
<tr>
<td>LAX</td>
<td>Los Angeles</td>
<td>2.2%</td>
<td></td>
</tr>
<tr>
<td>IAD</td>
<td>Dulles</td>
<td>2.0%</td>
<td></td>
</tr>
<tr>
<td>STL</td>
<td>St. Louis</td>
<td>1.8%</td>
<td>2006 / +48%</td>
</tr>
<tr>
<td>DTW</td>
<td>Detroit</td>
<td>1.8%</td>
<td></td>
</tr>
<tr>
<td>CVG</td>
<td>Cincinnati</td>
<td>1.5%</td>
<td>2005 / +12%</td>
</tr>
<tr>
<td>MSP</td>
<td>Minn./St. Paul</td>
<td>1.3%</td>
<td>2005 / +19%</td>
</tr>
<tr>
<td>MIA</td>
<td>Miami</td>
<td>1.1%</td>
<td></td>
</tr>
<tr>
<td>SEA</td>
<td>Seattle</td>
<td>1.0%</td>
<td>2008 / +46%</td>
</tr>
<tr>
<td>LAS</td>
<td>Las Vegas</td>
<td>0.8%</td>
<td></td>
</tr>
<tr>
<td>DCA</td>
<td>Reagan National</td>
<td>0.8%</td>
<td></td>
</tr>
<tr>
<td>BWI</td>
<td>Balt.-Wash. Intl</td>
<td>0.7%</td>
<td></td>
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<tr>
<td>MCO</td>
<td>Orlando</td>
<td>0.6%</td>
<td></td>
</tr>
<tr>
<td>CLT</td>
<td>Charlotte</td>
<td>0.6%</td>
<td>2008 / +11%</td>
</tr>
<tr>
<td>PIT</td>
<td>Pittsburgh</td>
<td>0.4%</td>
<td></td>
</tr>
<tr>
<td>SAN</td>
<td>San Diego</td>
<td>0.3%</td>
<td></td>
</tr>
<tr>
<td>DEN</td>
<td>Denver</td>
<td>0.2%</td>
<td></td>
</tr>
<tr>
<td>SLC</td>
<td>Salt Lake City</td>
<td>0.2%</td>
<td></td>
</tr>
<tr>
<td>TPA</td>
<td>Tampa</td>
<td>0.2%</td>
<td></td>
</tr>
<tr>
<td>MEM</td>
<td>Memphis</td>
<td>0.0%</td>
<td></td>
</tr>
</tbody>
</table>

Data source: [Delay data: FAA Operational Network, OPSNET], [Capacity improvement: FAA Operational Evolution Plan OEP].
Runway, Runway Extensions, Reconfigurations or New Airports with Environmental Impact Statements or Planning Studies Underway

<table>
<thead>
<tr>
<th>Airport or Metropolitan Area</th>
<th>Project</th>
<th>Estimated CY EIS Will Be Completed</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago Metropolitan Area (Peotone)</td>
<td>New Airport</td>
<td>2007</td>
<td>Master plan and environmental underway</td>
</tr>
<tr>
<td>Ft. Lauderdale (FLL)</td>
<td>Extension</td>
<td>2007</td>
<td>Environmental began in Feb 2005</td>
</tr>
<tr>
<td>Portland International (PDX)</td>
<td>Extension</td>
<td>2007</td>
<td>Feasibility study underway</td>
</tr>
<tr>
<td>Philadelphia (PHL)</td>
<td>Reconfiguration</td>
<td>2008</td>
<td>Master plan and environmental underway</td>
</tr>
<tr>
<td>Salt Lake City (SLC)</td>
<td>Extension</td>
<td>2008</td>
<td>EIS to begin FY06</td>
</tr>
<tr>
<td>Las Vegas Metropolitan Area (Ivanpah Valley)</td>
<td>New Airport</td>
<td>2010</td>
<td>Environmental process began in 2005</td>
</tr>
<tr>
<td>San Diego Metropolitan Area</td>
<td>New Airport</td>
<td>TBD</td>
<td>Airport site selection program to identify a new airport site to supplement or replace existing airport underway</td>
</tr>
</tbody>
</table>

Data source: [Capacity improvement: FAA Operational Evolution Plan OEP].
Solutions to Address Airport Demand/Capacity Inadequacy

“Do Nothing”: Delay Homeostasis

Demand Management

Regulation Based Mechanism

Market Based Mechanism

Changes in Infrastructure Utilization

Efficiency Improvement

Demand Diversion: Secondary Airport Emergence

Debanking

Capacity Enhancement → Airport Capacity Expansion

Range restrictions
Operation Type restrictions
Other?
Slot control
Secondary market trading
Congestion pricing
Auction
Other?

Source: Philippe Bonnefoy
Emergence of Secondary Airports

“Southwest Effect”

Original Core airport
Emerged Core airport
Secondary airport
"Flow" of departure and arrivals:
- morning (dep. > arr., dep. to west coast)
- rebalances throughout the day with arrivals from west coast move back closer to ½ - ½ with departures to Europe in the evening
New York SDO Operations
Wake Implications of Tight RNP Routes?
Airport System Capacity Limit Factors

- **Arrival/Departure Routes**
- **Runways**
- **Weather**
  - Capacity Variability
- **Gates**
- **Downstream Constraints**
- **Controller Workload**
- **Landside Limits**
  - Terminals
  - Road Access
- **Environmental**
  - Community Noise
  - Emissions
- **Safety**
Solutions to Address Airport Demand/Capacity Inadequacy

“Do Nothing”: Delay Homeostasis

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Changes in Infrastructure Utilization

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Debanking

Efficiency Improvement

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Capacity Enhancement

Airport Capacity Expansion

Range restrictions
Operation Type restrictions
Other?
Slot control
Secondary market trading
Congestion pricing
Auction
Other?

Source: Philippe Bonnefoy
Crisis Driven Transition

*Capacity Crisis Stimulus?*

Historically Transition Driven by Catalytic Accidents

What is Capacity Analogue?

Source: Alexandra Mozdzanaowska
LGA Air 21 Impact

Historic Movements
Air-21 Induced Svc.

Time of Day

Source: William DeCota, Port Authority of New York
Classic Delay vs Demand Curve

DELAY

DEMAND

Linear Region

Non-Linear Region

Capacity Limit
LGA

Average Arrival and Departure Delay

**Departure Delay:** (Actual scheduled pushback time) + (taxi-out time minus 10 minutes)

**Arrival Delay:** Time spent waiting for proper separation from previous aircraft.

Source: William DeCota, Port Authority of New York

Internalized vs externalized costs
Flight Delays at LGA from 2000 to 2006

Source: FAA OPSNET data
Demand Management
Only Rapid Public Action

Demand Management

Implementation Process

Safety and Environmental Approval Processes

Solution

Collective

Decision Making

Negotiation Loop

Stakeholder Preferences

Objective Formation

Stakeholder Values, Context

Regional Economy

System Capability

NAS

Delays

Catalytic Event

Capability Options

Public Awareness

Stakeholder Awareness

Change Process

Regional Economy

Demand

Demand Management

Stakeholder Preferences
Solutions to Address Airport Demand/Capacity Inadequacy

“Do Nothing”: Delay Homeostasis

Demand/Capacity Inadequacy

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  - Market Based Mechanism

- Changes in Infrastructure Utilization
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  - Slot control
  - Secondary market trading
  - Congestion pricing
  - Auction
  - Other?

- Capacity Enhancement
  - Debarking
  - Efficiency Improvement
  - Demand Diversion: Secondary Airport Emergence

Source: Philippe Bonnefoy
Conclusions

- Capacity will not expand to meet demand at key airports
  - “Capacity Crisis”

- Delay Adaptation will occur when delay market works
  - Secondary Airports
  - Scheduling

- There will be a capacity crisis
  - Unclear what the public catalytic stimulus will be

- Number of demand managed airports will increase

- Need good understanding of alternatives

- Regional economic impact is not clear
Relationship Between Economy and Air Transportation

Economy

Travel/Freight Need

Financial Equity/Debt Markets

Demand

Supply

Air Transportation System

Revenue/Profitability

Pricing & Schedule

Airlines

NAS Capability

Vehicle Capability

Direct / Indirect / Induced employment effects

Economic Enabling Effect
(Access to people / markets / ideas / capital)
QuickTime™ and a Animation decompressor are needed to see this picture.