Air Transportation System (ATS) Analysis:
Dynamic System Model of the ATS

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Summary

• U.S. Domestic Air Transportation System (ATS):
  – amazing success story over last century
  – significant contributor to the U.S. economy

• ATS is faced with (9) major challenges

• Use Dynamic System Model of ATS to understand:
  – cause-effect of challenges ?
  – can system “self-heal” ?
Summary

• Results of analysis:
  1. ATS exhibits *Time Constants* and *Equilibrium Points* that should be taken into account in strategic plans
     • Key metrics: (1) effective capacity, (2) demand
     • 75% of capacity rule
  2. Sustainability in a future ATS (e.g. NGATS) can be attained by “designing” mechanisms to:
     a) balance capacity and demand
     b) signal need for capacity enhancement
     c) incentivize innovation
Organization

1. Success & Challenges
2. Air Transportation System Model
3. Results of Analysis
4. Opportunities
1. Successes, Challenges
Air Transportation Faces Challenges

EU: Airlines Must Compensate Passengers

By ACIFE WHITE
The Associated Press
Tuesday, January 10, 2006; 8:34 AM

BRUSSELS, Belgium -- European airlines lost a legal bid Tuesday that aimed to strike down new EU rules guaranteeing passengers compensation for flight delays or cancellations.

The European Court of First Instance said the airlines didn't disprove the grounds for striking the rules invalid. The airlines claim the breach was a breach of the airlines' freedom to conduct their business.

Los Angeles World Airports to Undertake Historic Noise Studies That May Lead to Future Noise Restrictions at Los Angeles and Van Nuys Airports

Los Angeles, March 21, 2006 (PRIMEZONE) -- The Los Angeles Board of Airport Commissioners today awarded a $6,482,085 contract to Harris Miller Miller and Hanson, Inc., of Burlington, Mass., for noise studies at Los Angeles International (LAX) and Van Nuys (VNY) airports. The studies will support efforts to seek restrictions from the federal government on future noise generation and aircraft operations. Los Angeles World Airports (LAWA) is the first airport authority in the United States to embark on two simultaneous Part 161 studies at separate airports. In addition, the VNY study is the first in the U.S. to attempt to implement multiple proposed noise and access restrictions.

FAA: Atlanta Airport Is Busiest in U.S.

By Kimberly Johnson
01/10/2006 08:55:21 AM

Hartsfield-Jackson Atlanta International Airport has topped the ranks, the Federal Aviation Administration said Tuesday.

MWIAA Bonds Get Strong Ratings Despite Independence Air Exodus

In Announcing Increases, FAA Chief Says Tops

By Stephen Barr
Friday, January 6, 2006, Page B02

The Federal Aviation Administration, one of the few agencies to link pay to performance, announced yesterday that most FAA employees will receive a 3.1 percent salary increase and an additional 1 percent, on average, in a locality pay raise.

The performance raise, known as an "organizational success increase," hinges on whether the FAA met a series of business and air traffic goals. Among those eligible for the raise are 19,000 employees covered by the FAA's Core Compensation Plan and about 18,000 employees involved in air traffic control.
Success Story – Capacity

ATS Capacity

Domestic Enplanements
Domestic RPMs (Millions)
Domestic ASMs (Millions)
Success Story - Airfares

Domestic Real Yield (1978 Cents)

- Jets
- Widebodies, Radar
- Hub-&-Spoke
- Yield Mgmt
- TFM, Internet, LCCs

Yield = Before Tax Revenue per Seat-Mile

Source: ATA (2005)
Challenges?

1. **Airline Profit/Loss Cycles**
   – Finding economic equilibrium?

2. **Equal Access**
   – Airlines consolidating service to high socio-economic metro areas
   – Eroding access from small communities (Essential Air Service subsidies)

3. **Passenger Experience**
   – Delays and cancellations

4. **Congestion**
   – Wasted resources and low predictability

5. **Environmental issues** (emissions, noise)

6. **Airport & Airspace Trust Fund eroding**

7. **Airport & Airspace innovation cycle is dormant**

8. **ATC innovation cycle is dormant**
   – Modernization efforts effectively stalled

9. **ATC labor issues** (salary, staffing)
Challenges – Airline Finances

Source: ATA (2005)

Symptom, not a cause
Challenges – Passenger Experience?

Velocity = 54.874 × Distance^{0.2859}  
R^2 = 0.9068
Challenges – Passenger Experience

[Diagram showing passenger delay per enplanement (mins) vs route distance across various routes such as JFK-ORD, ORD-JFK, STL-PIT, LAS-MCO, MCO-LAS, LAS-DCA, DCA-LAS, JFK-ORD, EWR-PIT, JFK-PHL, EWR-BWI, JFK-PHL, PHL-STL, ORD-JFK, LAS-MCO, MCO-LAS, LAS-DCA, DCA-LAS, JFK-PHL]
Challenges ? - Congestion

- Properties of system adds average 30 mins to a 110 minute flight (28%)
- Properties of system results in significant variability that makes planning difficult
  - Actual $\mu/\sigma = 3.25$
  - Schedule $\mu/\sigma = 20$
- Congestion fuel costs to airlines = 2-3% of revenue from flight
- Adjusting schedule to mean actual block time costs airline 12% in aircraft utilization

Schaar, Drexler, Sherry (2005)
Challenges – A&ATF

Airport & Airway Trust Fund

Source: ATA (2005)

Shift to RJs, results in more ATC operations, A&TF less revenue
Challenges – ATC Labor

ATSC Hiring

- Shortfall in Certified ATCS
- # Candidate + Developmental + Certified ATCS on Payroll
- ATSC in Excess of Target Level of Staffing on Payroll

FAA-NATCA Target Staffing Level

# ATSC Attrition = #ATCS Hired

# Certified ATCS

# Developmental ATCS

Year

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

Cumulative Rate of Attrition of ATCS

# of ATCS

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000

# ATSC
Addressing the Challenges?

- Are Challenges symptoms or causes?
  - What are cause-effect relationships?
- What is the systemic structure of the industry?
  - Can this knowledge explain behavior?
  - Can this knowledge focus R&D?
  - How do policies, regulations, and procedures affect the system?
  - How does NGATS affect these success and challenges?
2. Air Transportation System
Air Transportation System

• **Air Transportation System is …**
  – Layers of networks
  – Networks composed of agents
  – Agents:
    • Distributed
    • Autonomous

• **Networks and agents operating with own objective functions**
  – Reinforce/Undermine each other

• **Networks exhibit:**
  – stochastic behavior
  – operate in non-equilibrium state
    • Economically
    • System Performance
## ATS Stakeholders

<table>
<thead>
<tr>
<th>STAKEHOLDERS</th>
<th>OBJECTIVE FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passengers and Cargo</strong></td>
<td>Optimize costs, time and reliability</td>
</tr>
<tr>
<td>• Purchase air transportation services</td>
<td></td>
</tr>
<tr>
<td><strong>Airlines</strong></td>
<td>Profit</td>
</tr>
<tr>
<td>• Provide capacity for air transportation of passengers and cargo</td>
<td>Marketshare in competitive marketplace</td>
</tr>
<tr>
<td>• Scheduled Flights (routes, frequency and aircraft)</td>
<td>Maximize economies of scope and scale</td>
</tr>
<tr>
<td><strong>Airports &amp; Airways</strong></td>
<td>Regional Economy</td>
</tr>
<tr>
<td>• Provide capacity for Airline’s Scheduled Flights</td>
<td>Effective Capacity</td>
</tr>
<tr>
<td>• Airways and their navigational aids, Flightlevels, Runways, Gates, …etc.</td>
<td>Congestion</td>
</tr>
<tr>
<td><strong>Air Traffic Control</strong></td>
<td>Throughput (Delays)</td>
</tr>
<tr>
<td>• Provide sequencing and separation of air traffic (flow)</td>
<td>Airports &amp; Airspace Utilization</td>
</tr>
<tr>
<td><strong>Public Natural Resources</strong></td>
<td>Capacity</td>
</tr>
<tr>
<td>• Provides “natural resources” consumed by air transportation</td>
<td>Rate of Utilization</td>
</tr>
<tr>
<td></td>
<td>Rate of Replenishment</td>
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Relationship between Stakeholders

**PUBLIC NATURAL RESOURCES**

**AIR TRAFFIC CONTROL**
- Seq. & Sep. of Flow of Traffic
- Capacity for Absorbing Noise Emissions from Traffic
- Flow of Traffic

**AIRSPACE & AIRPORTS**
- Gates, Runways, Airways, ...
- Scheduled Operations

**AIRLINES & OTHER USERS OF THE NAS**
- Available Seats
- Unconstrained Trip Demand

**PASSENGERS & CARGO**

**AIR TRANSPORTATION SYSTEM**
Variability in Demand

- Congestion
- Accident prevention
- Weather
- Budgets, Labor, Contract
- Technology

- Competition, Prices of competing modes
  - Supply Chain price (e.g. Fuel)
  - Technology & Labor costs
  - Supply of resources (e.g. gates, aircraft)

- Seasonal, Day-of-Week, Hour-of-Day,
- Income Elasticity
- Price Elasticity

Air Transportation System

- Environmental
- Demographics

Traffic Flow Service Providers:
Air Traffic Control (TFM, AOCs, ARTCCs, TRACONs, Towers)

- Environment
- Demographics

Infrastructure Service Providers:
Airports and Airspace

- Environment
- Demographics

Air Transportation Service Providers:
Airlines

- Environment
- Demographics

Air Transportation Consumers:
Passengers & Cargo

- Environment
- Demographics
3. ATS Dynamics

3-1) Time Constants
3-2) Demand and Capacity Balancing Feedback Loops
3-3) System Equilibrium
Dynamical System Model

Control Law: Price Setting through “Price Curve”

Plant: Consumer Demand through “Demand Curve”

Supply of Service/Product

Value of Substitute Service/Product

Demand for Service Product

Plant exhibits non-linear dynamics (e.g. price elasticity)

Equilibrium

No-equilibrium
Time Constants?

- Changes in Pax & Cargo demand
  - $\tau =$ Weeks to Months
- Changes in Airlines supply
  - Routes, Frequency, Gauge
    - $\tau =$ Weeks to 3-6 Months
  - Increased Fleet
    - $\tau =$ 3 years
- Changes in A&A supply
  - Sector changes
    - $\tau =$ 3-6 months, 2 years
  - Runways, gates, routes, Crz FLs
    - $\tau =$ 10 – 30 years
- Changes in ATC
  - Staffing, Sectors
    - $\tau =$ 7 – 10 years
Pax v. Seats Feedback Loop (1)

- **Strong feedback-loop**
  - Airfares set by airlines based on demand for available seats
  - Scarce resources (seats) result in higher prices
    - Revenue Management
  - Loop has no external costs

- **Feedback distorted by:**
  - Hyper-competition for marketshare
  - Monopolies on given routes
  - Bankruptcy protection
  - Network integrity
  - Use-it-or-Lose it rules

- **Innovation Rate**
  - Very high
Flights v. Slots - Feedback Loop (2)

- Weak feedback-loop
  - Fees and Taxes based on:
    - Revenue-neutrality
    - Congestion (delay) costs
      - Weak
  - FAA F&E Budget
  - Costs borne by (third party) passengers
  - Administrative measures (slots, uni-laterals)
    - not responsive to market

- Feedback distorted by:
  - Absence of *value* of scarce resource

- Innovation Rate
  - Slow
  - Negligible productivity improvements at chokepoints
Slots v. Sep. - Feedback Loop (3)

- Weak feedback-loop
  - Contract, budget & staffing plans determine staffing levels based on forecasts
  - Costs borne by (third party) passengers (& taxpayers)

- Feedback distorted by:
  - Absence of value of scarce resource

- Innovation Rate
  - Slow
  - Negligible productivity improvements
    - # aircraft per sector in 15 mins
Slots v. NPR - Feedback Loop (4)

• Weak feedback-loop
  – Capacity and Rate-of-Replenishment is under debate
  – Costs borne by (third party) public
  – Regulations (noise abatement, engine upgrades)

• Feedback distorted by:
  – Absence of value of scarce resource
  – Global and local issue

• Innovation Rate
  – High in some areas
  – Driven by forces other than scarcity of resources
Feedback Loops

AIR TRANSPORTATION SYSTEM

Consumers:
Passengers & Cargo (Trips)

Service Providers:
Airlines (Flights)

Infrastructure:
Airports and Airspace

Balancing Mechanism
(staffing, salaries, budgets)

Excess Demand
Excess Supply

Service Providers:
Airlines (Seats)

Balancing Mechanism
(airfares, subsidies)

Demand
Supply

Infrastructure:
Airports and Airspace

Balancing Mechanism
(landing fees, ticket tax, admin measures)

Demand
Supply

Service Providers:
Traffic Flow

Natural Resource Providers:
Public/Government

Demand
Supply

Service Providers:
Airliners (Seats)

Balancing Mechanism
(airfares, subsidies)

Demand
Supply

AIR TRANSPORTATION SYSTEM

Service Providers:
Airliners (Flights)

Balancing Mechanism
(landing fees, ticket tax, admin measures)

Demand
Supply

Infrastructure:
Airports and Airspace

Balancing Mechanism
(staffing, salaries, budgets)

Excess Demand
Excess Supply

AIR TRANSPORTATION SYSTEM
Feedback Loops

• Absence of feedback loops prevents:

1. **Maximizing use of scarce resources**
   • Exacts costs on third parties not part of loop (Golaszewski, 2005)
     – delays, workload, overtime, sick-leave, pollution
     – not a problem until resource becomes scarce

2. **Signaling for improvement**
   • Crisis results in action
   • 75% of capacity rule (Miller and Clarke, 2005)

3. **Innovation**
   • absence of value of resource (given demand) prevents return-on-investment (ROI)
   • absence of ROI prevents venture capital (VC)
   • absence of VC prevents best-minds from investing time & energy
Equilibrium?

• Equilibrium:
  – supply = demand
    • No shortage/excess
  – ability to anticipate changes

• ATS is unable to reach and maintain equilibrium due to:
  – Time constants
  – Weak feedback loops

• Contributes to challenges to ATS
4. Opportunities
Opportunities

1. Create awareness and educate decision-makers, media, and public
   • Gross mis-understandings exist, must be addressed
   • NAS Strategy Simulator

2. Plans & budgets should incorporate dynamics of model
   • time-constants, equilibrium points
     • Key metrics: (1) effective capacity, (2) demand
     • 75% of capacity rule
Opportunities

3) Sustainability in future ATS (e.g. NGATS) can be achieved by including in the specification of mechanisms to

- **balance** existing supply with demand
  - Establish property rights and liability (Coase, 1988)
- **signal** need for capacity enhancement
- **incentivize** innovation, renewal, & expansion
  - Airports & Airspace, Air Traffic Control, Public Natural Resources
Thank you

Questions?

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