Looking for the Capacity in NGATS

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NextGen Research on Aviation Capacity

TRB January 2008
Outline

• What has Changed in 50 Years?
• Safety is the Underlying Capacity Constraint
  • Current Safety Trends
  • Airport Arrival – Departure 90% CEP
• What are the Underlying Causes of Delay?
  • Too Many Scheduled Flights into Too Few Runways
    – Average Aircraft Gauge Too Small
    – Stochastic Queuing Delays Too Inefficient
    – 80-90% Max Capacity Safety and Economic Optimum
• What Does NGATS do for Safety?
• What Does NGATS do for Capacity?
  • New Separation Standards in Terminal Airspace?
  • Wake Vortex Separation Reduction?
What has Changed since 1947?

- Transonic vs. Subsonic Aircraft
- 40,000 ft vs. 20,000 ft Altitude
- Avionics:
  - Flight Management Systems
  - Required Navigation Perf. 0.1nm
  - Required Time of Arrival
  - Traffic Collision Avoidance System – **On the Aircraft!**
  - AOC Data Links
  - Zero Visibility Landing Systems
- ATC radar Separation

**WHAT HAS NOT CHANGED**
- Air Traffic Controllers talking to Pilots using WW II AM Radio Technology
Some Little Discussed Facts

• Modern Jet Aircraft “Gate-to-Gate” Travel Time is the Same or Longer than Propeller aircraft (DC-6 circa 1947) for many routes in NE Triangle
  • Typical Jet Aircraft is 70% Faster and fly's 80% Higher
• Jet Aircraft can fly Over most bad weather
• Modern Commercial Jet Aircraft can Land in Very Low Visibility
• Airport Congestion Causes Most ATC Delays and Airline Schedule Padding Masks Real “Gate-to-Gate” Delay
Today’s Lack of Predictability is Predictable!

### Passenger Trip Delay Index (PTDI)

<table>
<thead>
<tr>
<th>Departure Hour</th>
<th>OK</th>
<th>Expect Delays</th>
<th>Expect Long Delays, Missed Connections, Cancellations, Overbooking, Diversions</th>
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Part 121 (Scheduled Commercial) Accident Rates are Increasing

Analysis from Zohreh Nazeri, PhD GMU 2007

y = 0.0533x + 1.0647
Safety at Principle Network Nodes (i.e. Airports) is the Capacity Constraint

- Aircraft Safety Separation Time over the Runway Threshold sets the ATS Capacity Limits
- Critical Technical Parameters that Define Network Capacity:
  - Runway Occupancy Time (ROT)
  - Landing Aircraft Inter-Arrival Time (IAT)
  - \( \text{Cap}_{\text{max}} = 90 \text{ sec IAT at } 10^{-3} P_{\text{SRO}} = 40 \text{ Arr/RW/Hr} \)
  - Queuing Delay Onset at \( \sim 80\% \) = 32 Arr/RW/Hr limit for Predictable Performance
Data Analysis Process to Estimate: IAT, IAD and ROT pdf’s

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Threshold</th>
<th>Leave Runway</th>
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</thead>
<tbody>
<tr>
<td>Heavy</td>
<td>10:23:14</td>
<td>10:24:04</td>
</tr>
<tr>
<td>Large</td>
<td>10:26:16</td>
<td>10:27:12</td>
</tr>
</tbody>
</table>

Col. Clint Haynie, USA PhD., 2002
Yue Xie, PhD. 2005
ROT vs. IAT to find Simultaneous Runway Occupancy (SRO) Probability: est to be $\sim 2/1000$.

- Detroit Metropolitan Airport (DTW)
- Freq ($IAT < ROT$) $\sim 0.0016$ in peak periods and $0.0007$ overall (including non-peak periods - 1870 total samples)
- IMC: $1/669 = 0.0015$ in peak periods
- Correlation coefficient $= 0.15$ [Babak, Shortle and Sherry, 2006]
How Will NGATS change these Distributions?

Changes in FAA Procedures, Airport Slot Controls and New Avionics Will Improve BOTH Safety and Capacity
DTW CEP* 90% (2000-2003)

**Calculated Capacity (Today) and Actual Throughput**

**Optimum Rate**

- Calculated Capacity - Today
- Facility Reported Rate - DTW (arrivals, departures per hr)

CEP 90% as a Measure of NAS Network Node Efficiency

- Each symbol represents actual traffic during a single hour

**Marginal Rate**

- Calculated Capacity - Today
- Facility Reported Rate - DTW (arrivals, departures per hr)

**IFR Rate**

- Calculated Capacity - Today
- Facility Reported Rate - DTW (arrivals, departures per hr)

* Contour of Equal Probability
EWR CEP 90% (2000-2003)

A New Metric for BOTH Safety and Capacity Efficiency!

NGATS needs to shrink the 90% CEP
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Queuing Delays set the Practical Capacity limitation set by Safety Separation Standards

- Lack of Schedule Synchronization and 90 second IAT generate Queuing Delays above about 80% of Maximum Runway Capacity
- Sched. Synch can reduce Delay by ~50%
NGATS Does Nothing about Too Many Flights on Small Aircraft: Passengers Pay the Price in Flight Delays and Cancellations
JFK Average Delay Profile (2006)


**Delay Incurred at Major Airports Propagate** *Network Wide* (Summer 2005)

*Total Delay* Ordered by Arrival Delay at Outbound Destination. (minute)

[20,000 Flight Hours]

[34 OEP Airport]

[Ning Xu GMU 2007]
Air Transportation System is Designed to Move Passengers and Cargo

Passenger Tier Performance = f (Vehicle Tier Performance, Passenger Factors i.e. Aircraft Gauge, Load Factor, Cancellations)

D. Wang GMU PhD 2007
Passenger Total Delay – Airports

- 10 of the OEP-35 airports → 50% Total EPTD
- some airports significantly impact Passenger Delay more than others (e.g. ORD, ATL, DFW and MCO)

Closed Network of OEP35 Airport in 2004

D. Wang GMU
PhD 2007
200 Routes generate 50% of Total Passenger Delay
What Does NGATS Do for These Routes?

- 17% of the 1044 routes between OEP-35 airports → 50% Total EPTD
- LGA, JFK, EWR, PHL connected Routes → 11 out of top 20 routes

Closed Network of OEP35 Airport in 2004

D. Wang GMU
PhD 2007
Minimum Economic Cost is at ~90% Max. Capacity

Donohue and Shaver 2008
Summary on Capacity

• ~40 Arrival per Runway per Hour is current Safety Maximum
• ~32 Arrivals per Runway per Hour is ONSET of Queuing Delays & Optimum Predictability and Economic Utilization Rate
  • How will NGATS Technology/Procedures Change This?
• Market Allocated Scheduled Landing/Departure times at 90% Max Capacity Will Be Required to Achieve Optimum Network Performance
  • EVEN WITH NGATS!
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IS NGATS Adequately addressing the Capacity related Safety Problems?

- What is the Wake Vortex Warning System?
- What is the ADS-B Back-up to GPS for aircraft without Inertial Guidance?
- ADS-B (out), 4-D trajectories, RNP-0.1
  - Good for Airline Fuel Efficiency but NOT ENOUGH for Increasing System Network Capacity!
- How will Aircraft Separation in Terminal Airspace and on the Runways be REDUCED by X3?
  - Closely Spaced, Fully-coupled Autopilot Formation Landings with 2 – Lane Runways?
- Can Closely Spaced Airports be Cross-linked with Runway Independent Air Transport (MegaPlex System Network Nodes)?
  - New Generation of Heavy Lift Helicopters?
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The Predicted Growth in Aviation Demand is based on \textit{Passenger Demand} NOT Aircraft Operations

- **Aircraft Gauge, Schedule Synchronization and Network Load Balancing will Be Required**
  - Annual Combinatorial Clock Slot Auctions ?
- **Larger Aircraft will be required** to meet X2 or X3 demand
- Business Jet and VLJ Air Taxi Service will emerge to compete with Commercial aviation due to current System Failure
  - May not be able to put the Geni back in the Bottle
  - Environmental Implications?
- **New Aircraft (e.g. B 787) should be Environmentally Friendly (Emissions/passenger/mi.?)**
  - US airlines are not currently ordering them due to poor financial position
- **New Public Policy will be needed to Deal with these Complex Adaptive System Problems**
  - NEXTGEN System not addressing these issues
Center for Air Transportation System Research
Publications and Information

- Other Useful Web Sites
  - http://catsr.ite.gmu.edu
  - http://mytravelrights.com
BACKUP Material
Trends for Incidents Associated with Accidents

Trends of the factors in incident databases

- Pilot factors decreasing
- Aircraft factors slowly decreasing
- ATC factors increasing

Analysis from Zohreh Nazeri, PhD GMU 2007
ATC factors – Communication Errors

Top complexity factors associated with ATC factors:

- **number of aircraft in airspace** -- airspace design
- **runway configuration** -- controller experience

These factors will get worse over time:

- air transportation is projected to grow for the next 10 years
- majority of controllers will retire within next few years

Analysis from Zohreh Nazeri, PhD GMU 2007
Aircraft factors

“Flight Control System” problems growing
Other aircraft factors decreasing

Analysis from Zohreh Nazeri, PhD GMU 2007
FAA: 2 Separate Functions with an Inherent Conflict of Interest

- A Safety Regulatory Agency
  - Airlines
  - Aircraft Manufactures
- An Air Traffic Management Operator
  - Safety Oversight of ITSELF
  - Many Industrialized Nations have Separated this Function from the Gov’t Oversight Agency
    - Australia, Canada, Germany, New Zealand, United Kingdom, etc.
My Opinion on WHY FAA has and Will Continue to Fail

• FAA Organization, Culture and Engineering Expertise is Totally Inadequate to the Task of Designing, Acquiring and Maintaining a Modern Telecommunications System
  • Exhibits Monopolist Behavior
  • Not Held Accountable!
• It is NOT in the Self Interest of a Wealthy, and Politically Powerful Union (NATCA) that has:
  • Total job Security (civil service protection)
  • Ability to Directly Lobby with the Public and Congress
  • VERY HIGH PAY and Wealthy PAC (some >$200,000/yr)
  • Short Work Hours (< 5 hours/day)
  • Low Educational Entrance Requirements (High School)
• No Accountability for Poor System Performance
EWR Free-Market Fleet Mix Appears to be Far from Optimum
• **Overbooked Flights**
  • Passengers can now get roughly double the existing compensation if they are bumped off a flight.
    – Compensation must be paid immediately.
    – These passengers must also be offered the choice of a refund, a flight back to their original point of departure, or an alternative flight to continue their journey.
  • May also have rights to meals, refreshments, hotel accommodation if necessary even free e-mails, faxes or telephone calls.

• **Cancelled Flights**
  • Offered a refund of your ticket, along with a free flight back to your initial point of departure, when relevant. Or, alternative transport to your final destination.
  • Rights to meals, refreshments, hotel accommodation if necessary, even free e-mails or telephone calls.
    – Airlines can only offer you a refund in the form of travel vouchers if you agree in writing
  • Refunds may also be paid in cash, by bank transfer or cheque
  • If the reason for your flight's cancellation is "within the airline's control", it must pay compensation.
  • Compensation for cancellations must be paid within seven days.

• **Delayed Flights**
  • Airline may be obliged to supply meals and refreshments, along with accommodation if an overnight stay is required.
  • If the delay is for five hours or more, passengers are also entitled to a refund of their ticket with a free flight back to your initial point of departure if this is relevant.
Air Transportation is Characterized as a Complex Adaptive System (CAS)

- Fleet Attributes
- Fleet Costs
- Fleet Revenue
- Effect on GDP
- Passenger Delays
- Effect on GDP
- Flight Delays & Cancellations
- Offered Flights by Fleet
- Inconvenience
- Baseline Demand
- Reference demand
- Market Clearing
- Trips flown by fleet
- Airport Capacity
- Enroute Capacity
- Schedule
- Effective Price
- Ticket price
- Effective price by length of trip
- Aircraft Fleets
- Active fleet

Bengi Mezhepoglu, PhD in progress