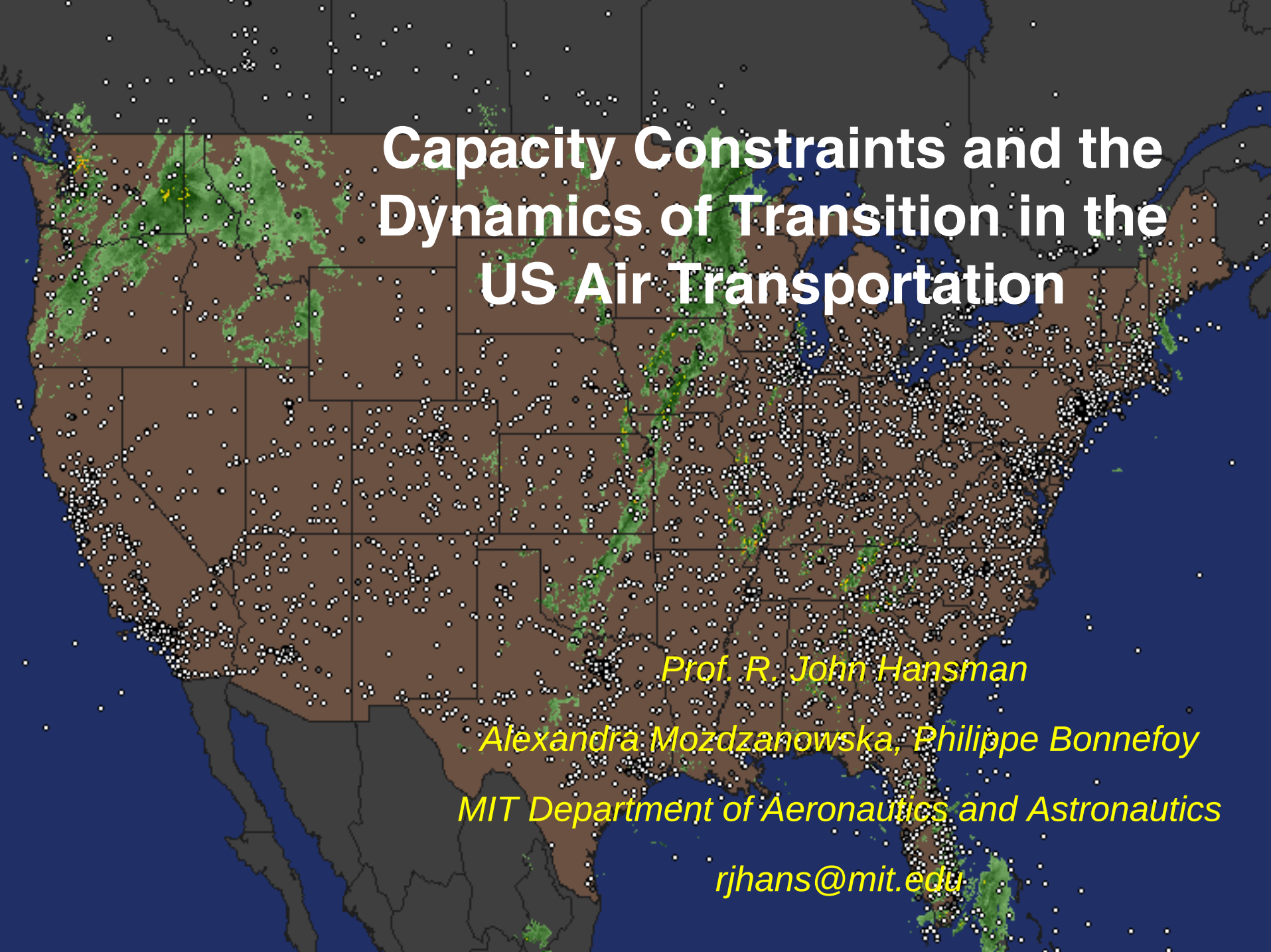


Capacity Constraints and the Dynamics of Transition in the US Air Transportation

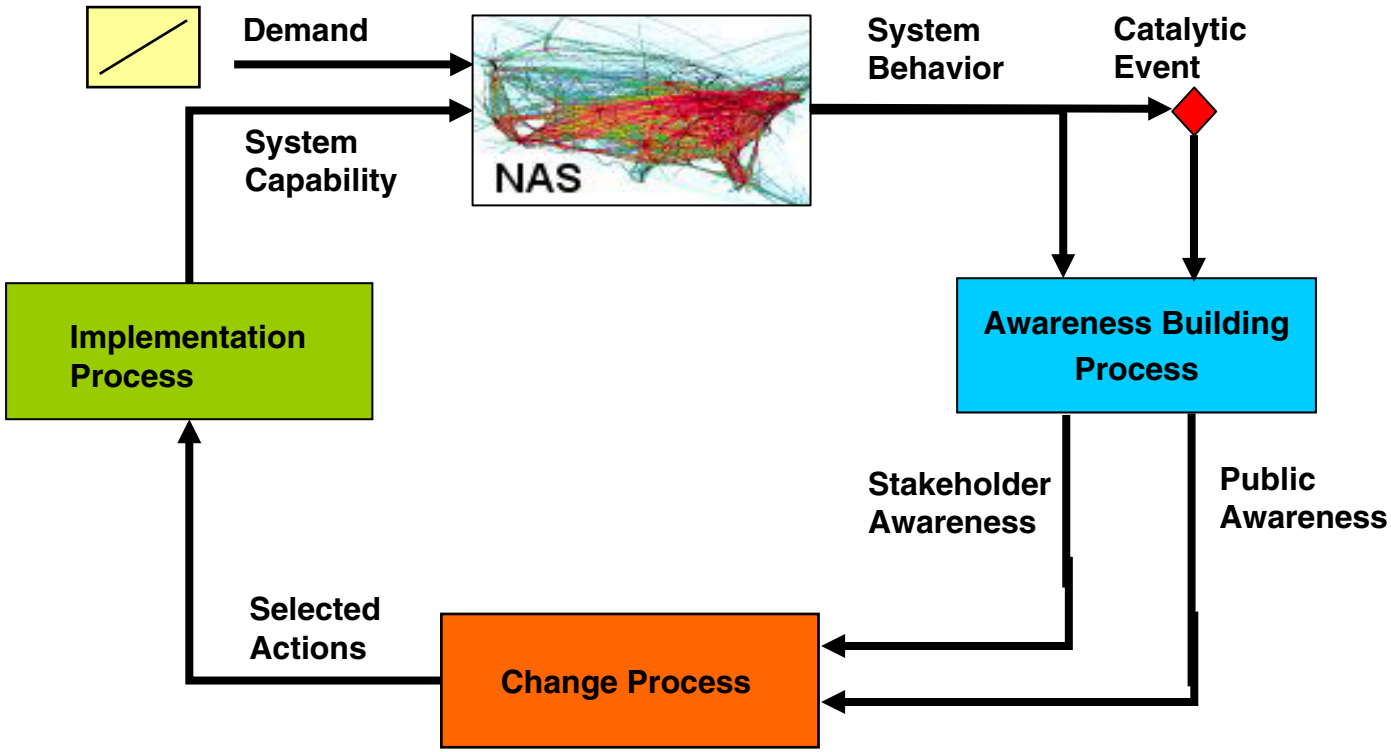
Prof. R. John Hansman

Alexandra Mozdzanowska, Philippe Bonnefoy

MIT Department of Aeronautics and Astronautics

rjhans@mit.edu

Simple Model of NAS Capability Transition Dynamics

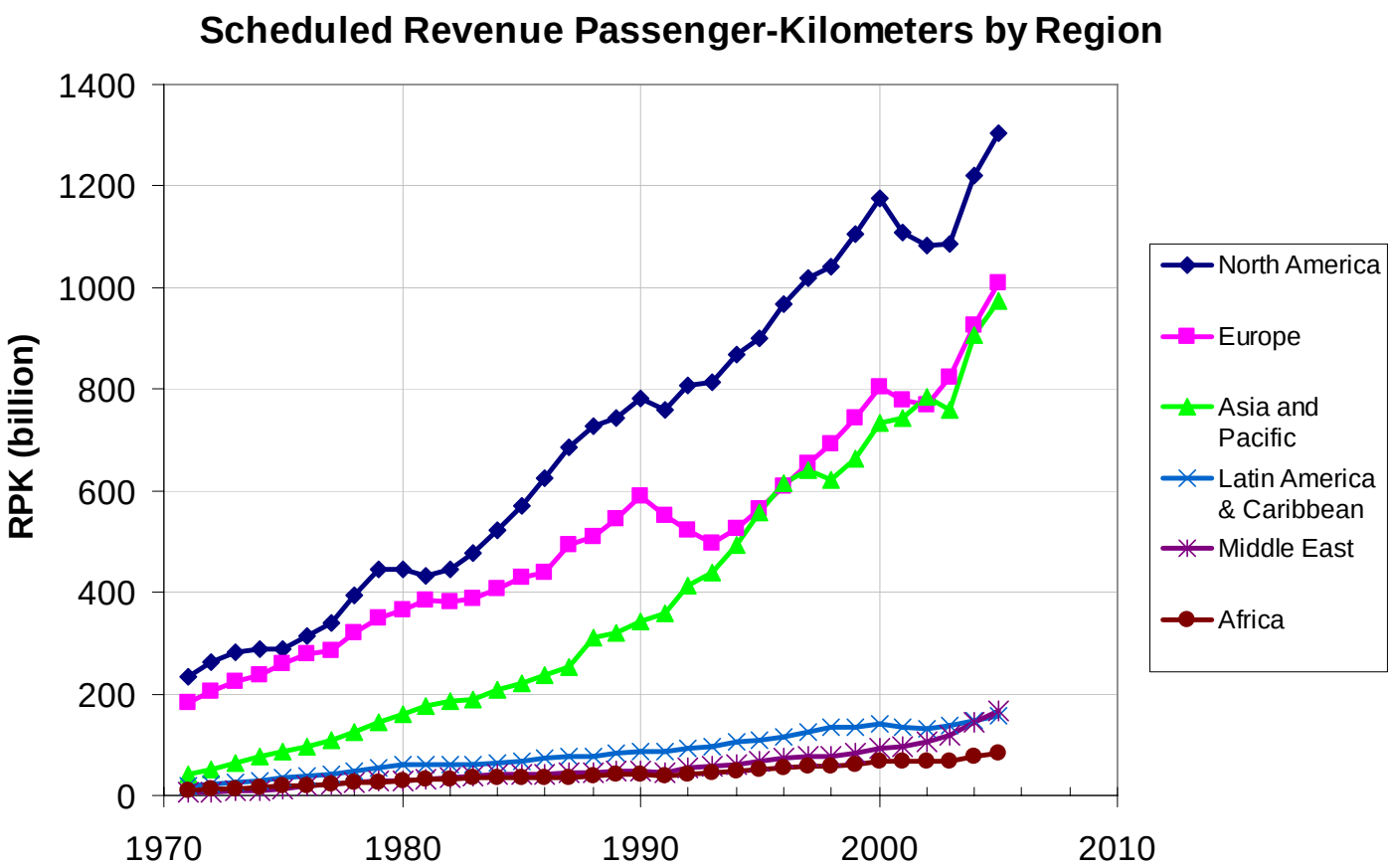


Historically Transition Driven by Catalytic Accidents

What is Capacity Analogue?

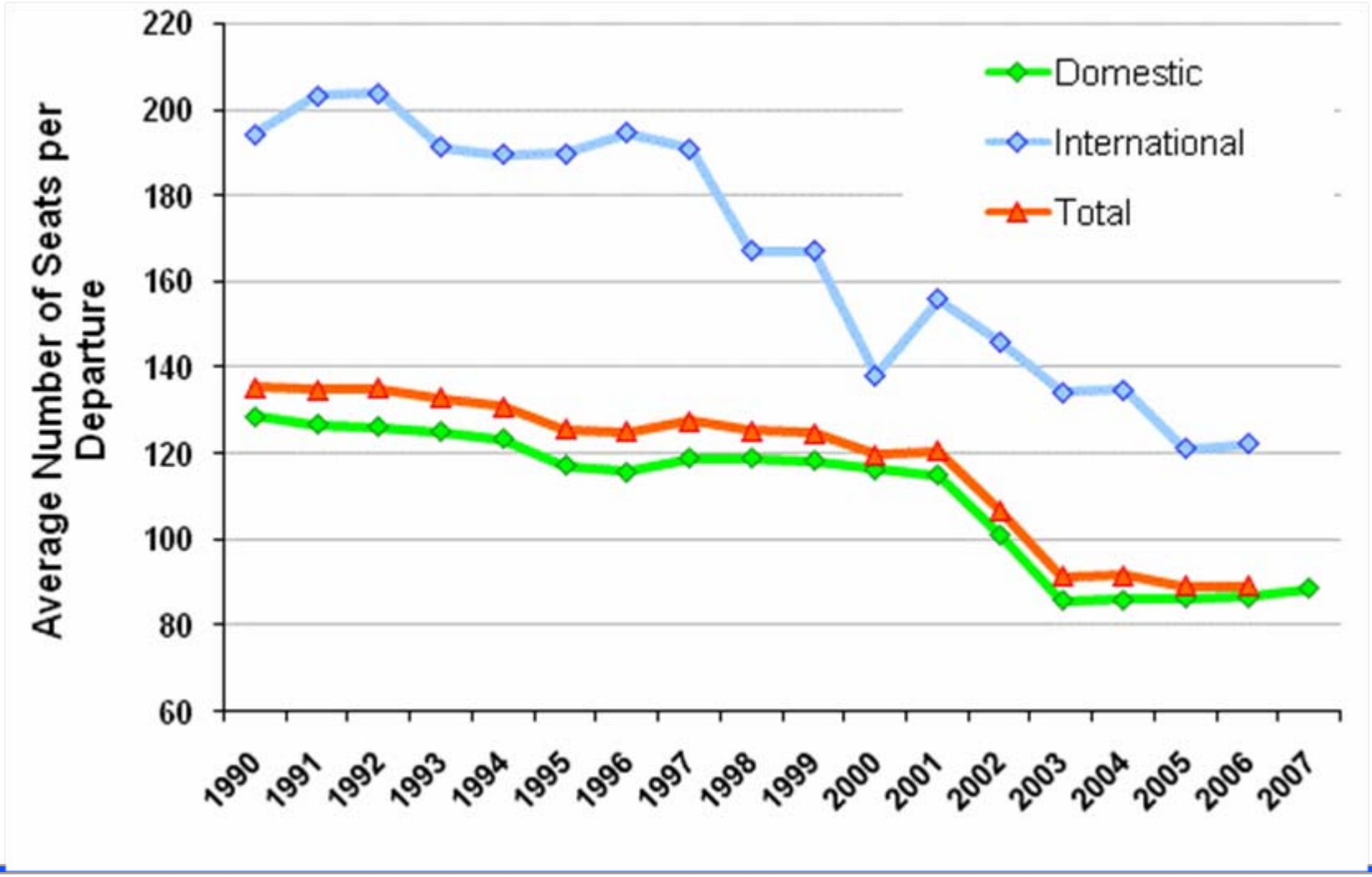
Source: Alexandra Mozdzanaowska

Passenger Traffic by Region



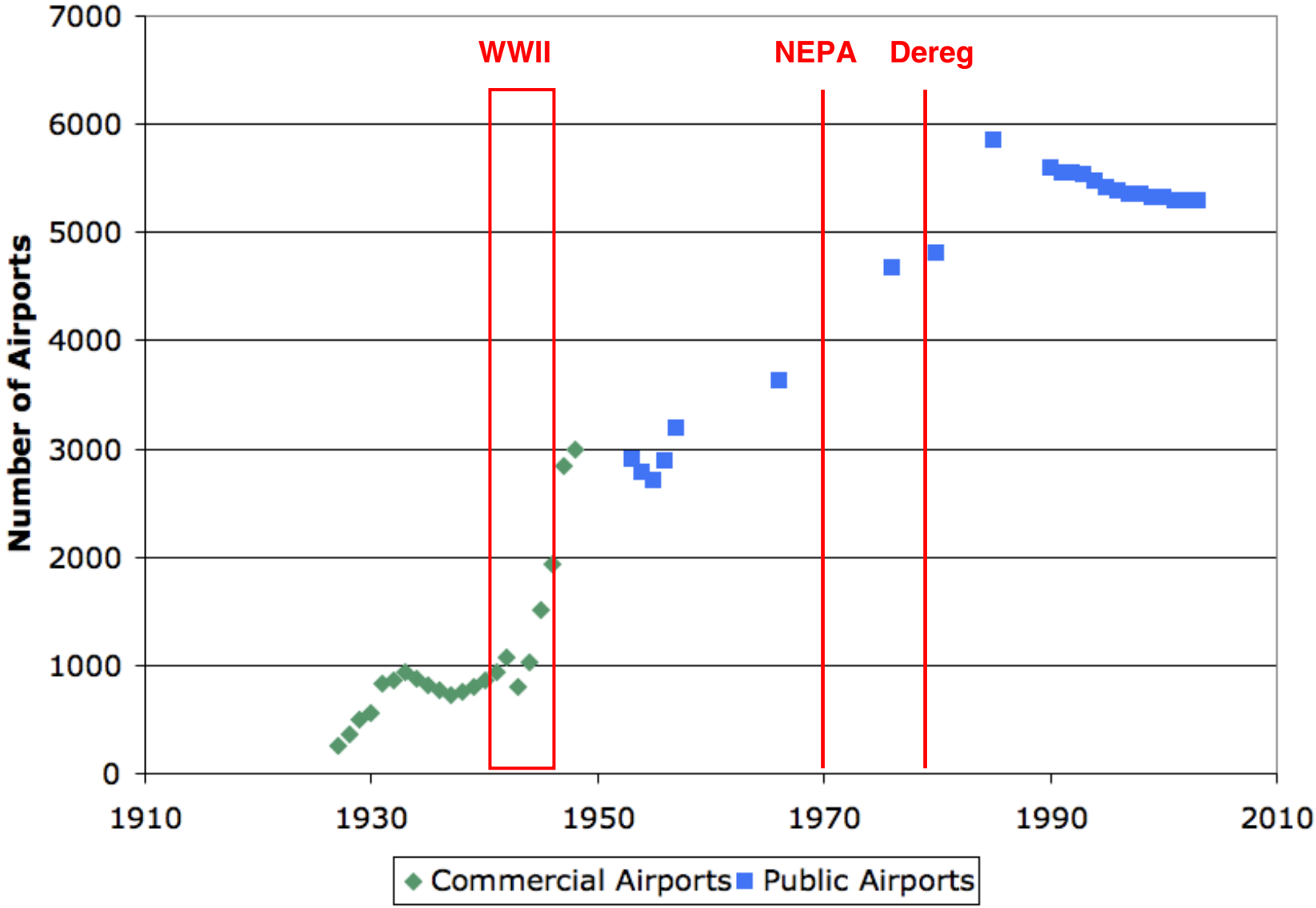
Data source: ICAO, scheduled services of commercial air carriers (through 2005)

Trends in Aircraft Size



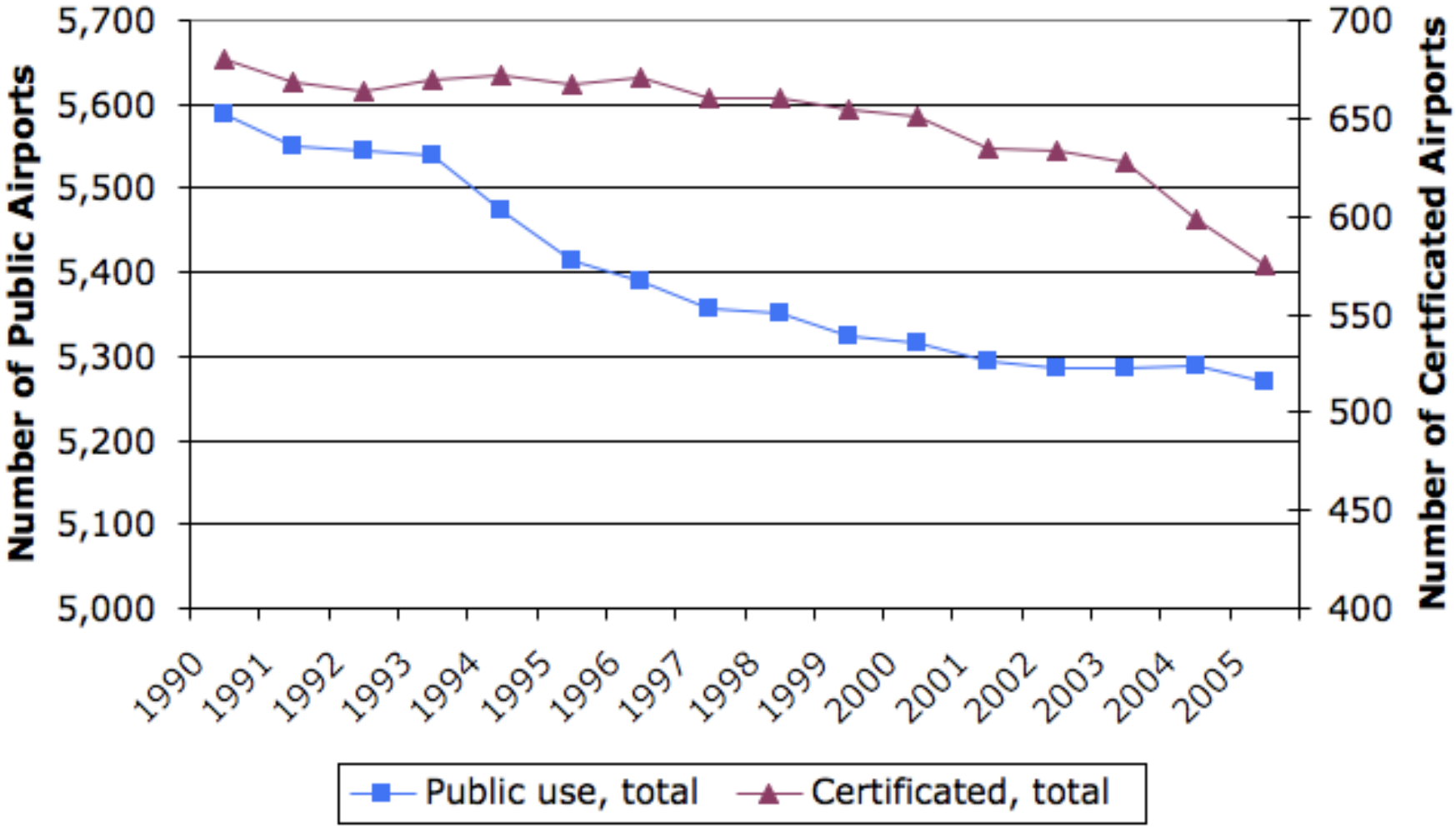
Data source: Form 41 Traffic data from Bureau of Transportation Statistics (US carriers)

U.S. Public Use Airports



Source: CAA statistical handbook of aviation, FAA statistical handbook of aviation, BTS

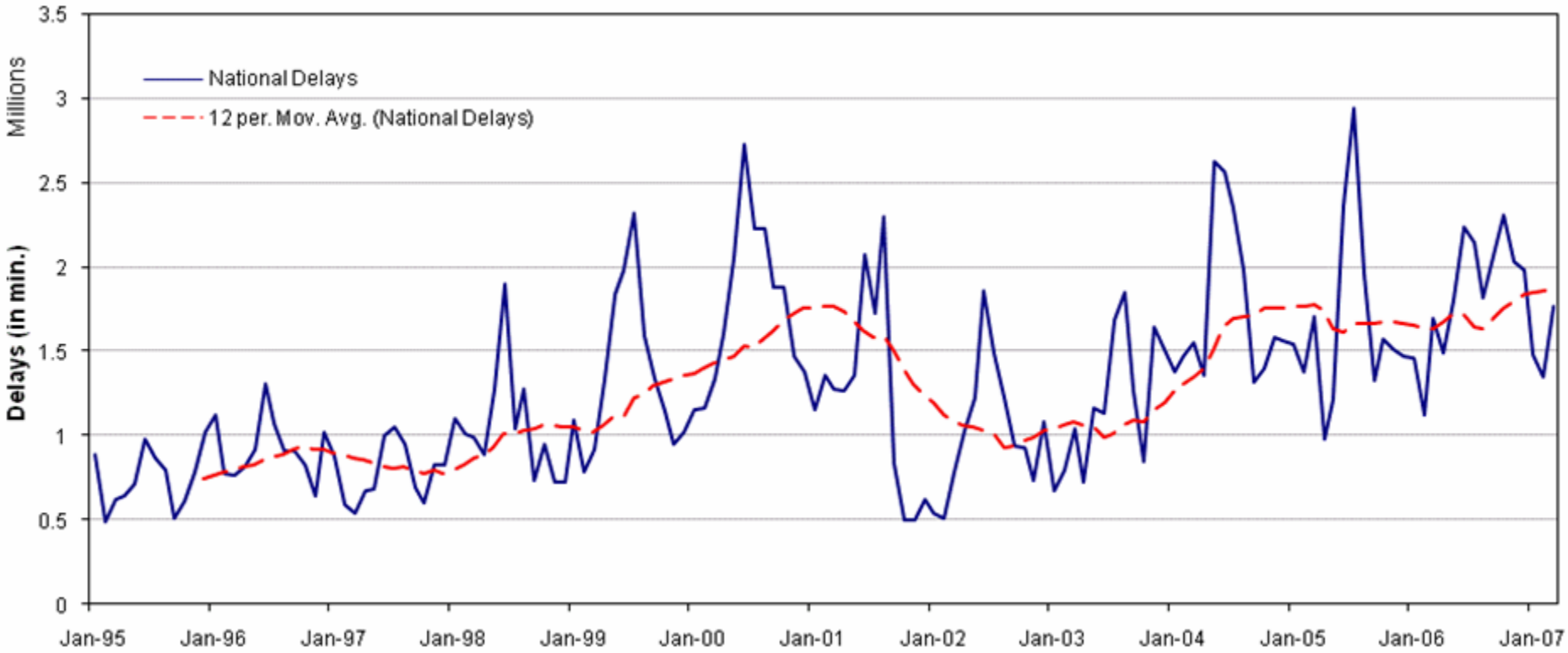
U.S. Public Use & Certificated Airports



- Public use airports decreasing at ~ 22 a year
- Certificated airports decreasing at ~5 a year

US Flight Delays

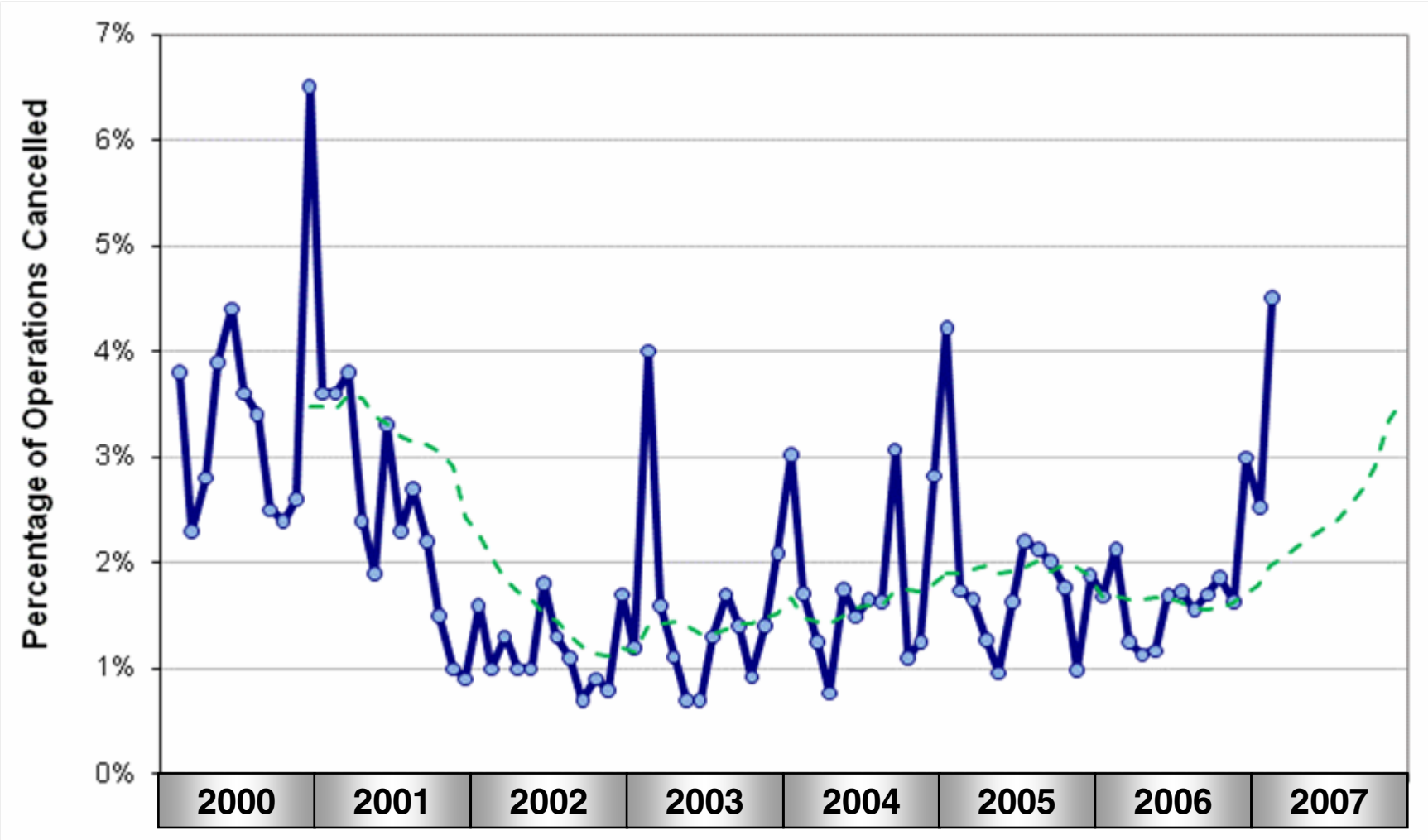
from 1995 to 2007



Data source: FAA Operational Network (OPSNET)

Flight Cancellations

from 2000 to 2007 (by month)

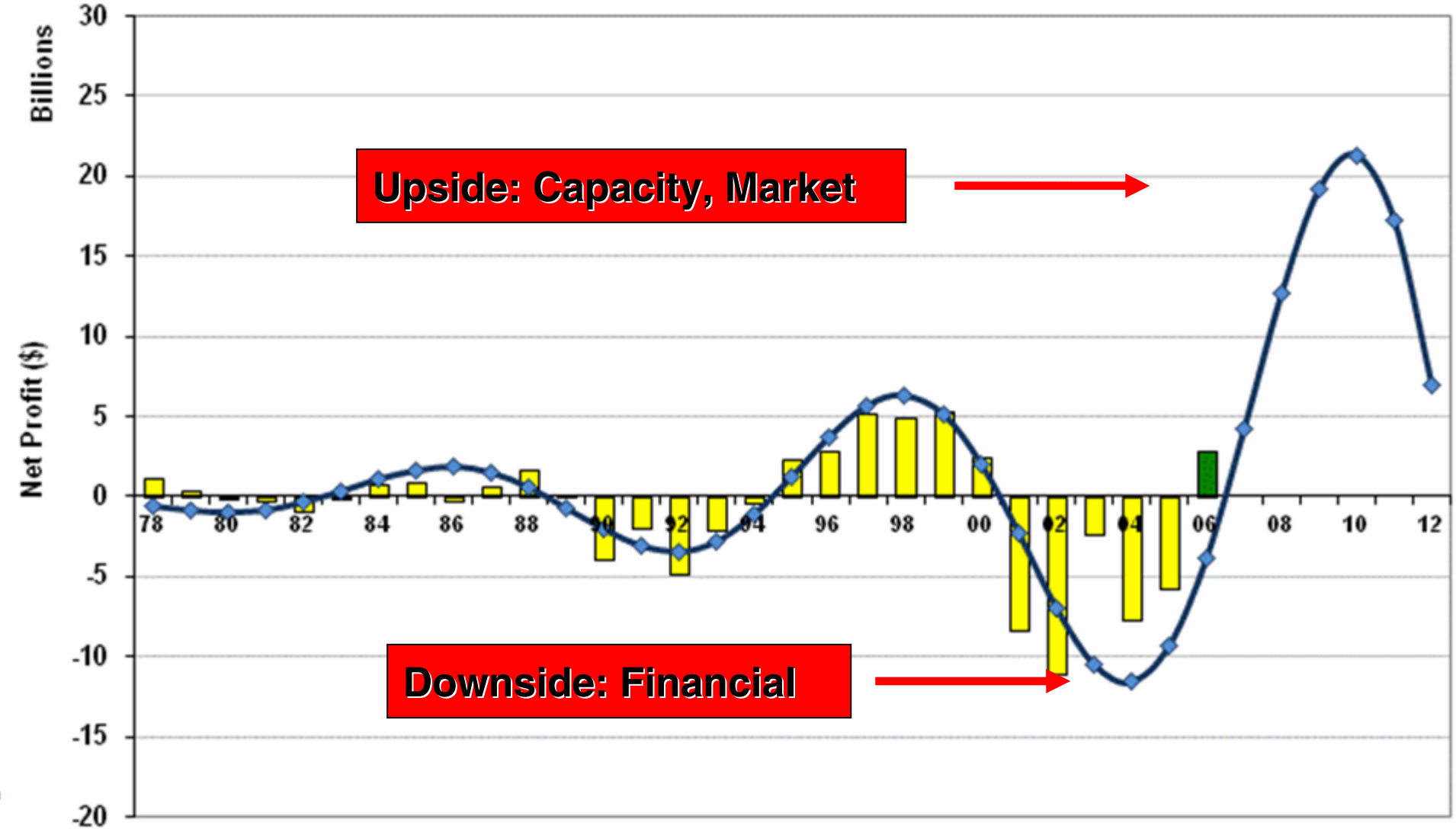


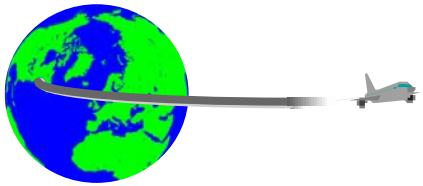
Source: DOT, Air Travel Consumer Report, http://airconsumer.ost.dot.gov/ **& BTS On Time Performance data**

(top 11 airlines from 2000 to 2002, top 20 airlines from 2003 to 2007)

Growth Limits

Constraints vs Damping



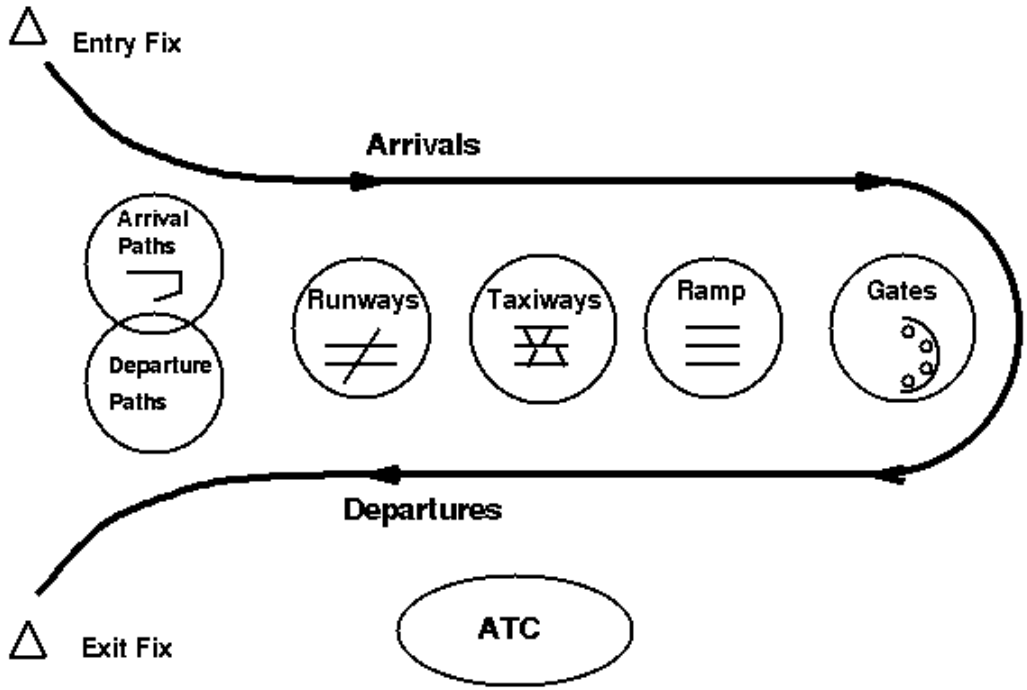


Capacity Limit Factors

- **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)

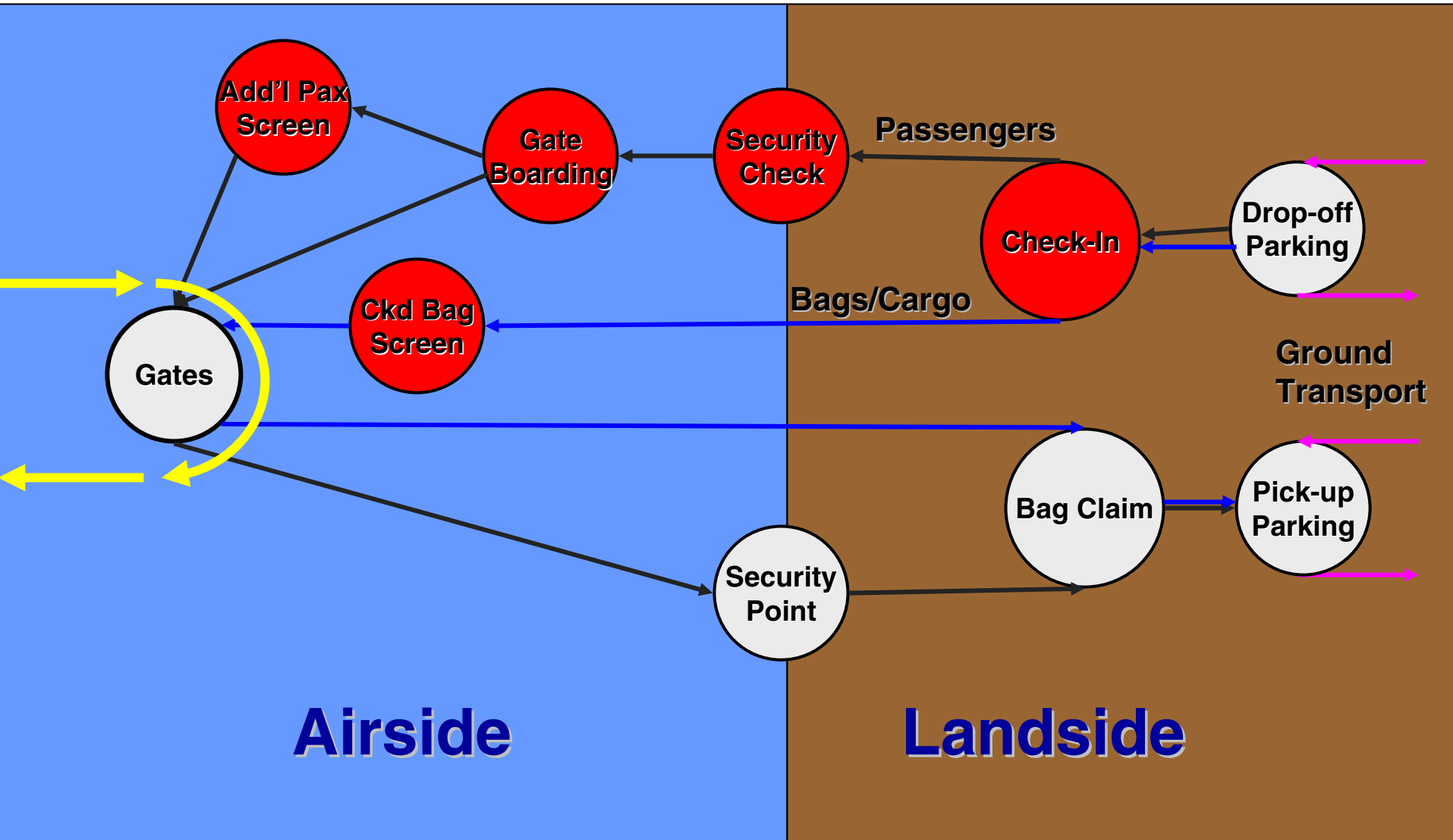
Airport System Capacity Limit Factors

- **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
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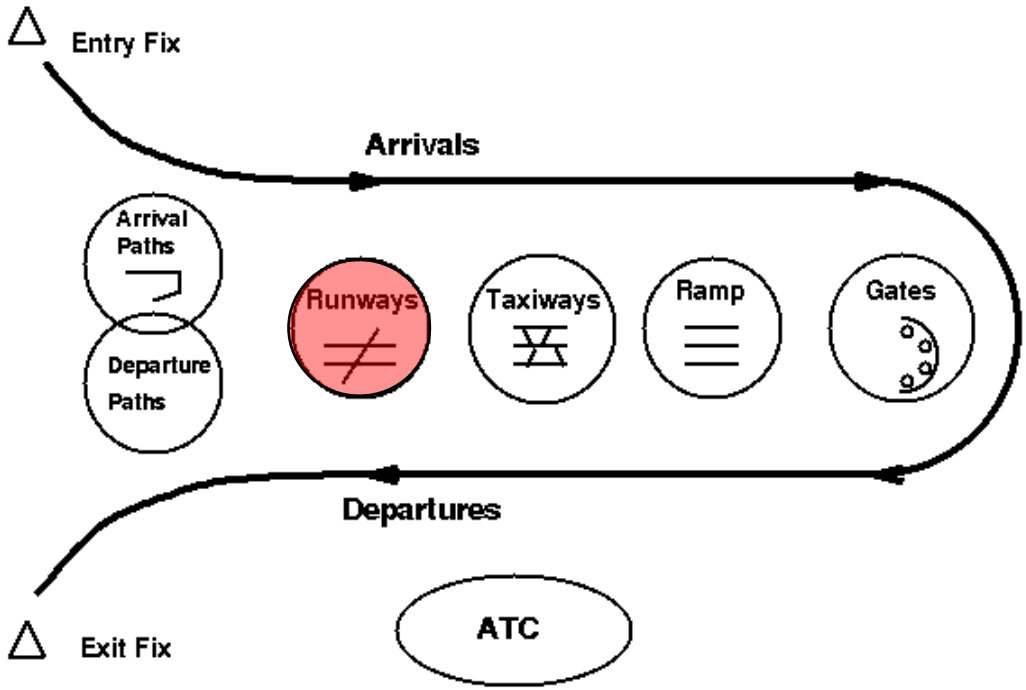
  - ❑ Road Access
- **Environmental**
  - ❑ Community Noise
  - ❑ Emissions
- **Safety**



Separation Requirements for Arrival (Same Runway)

- **Wake Turbulence Requirement**

  Radar Separation Requirements

Trailing Aircraft

Leading Aircraft	Heavy	Large	Small
Heavy	4	5	5
B757	4	4	5
Large	3(2.5)	3(2.5)	4
Small	3(2.5)	3(2.5)	3(2.5)

  Visual Separation Requirements
  - ◆ Pilots Discretion

- **Preceding arrival must be clear of runway at touchdown**

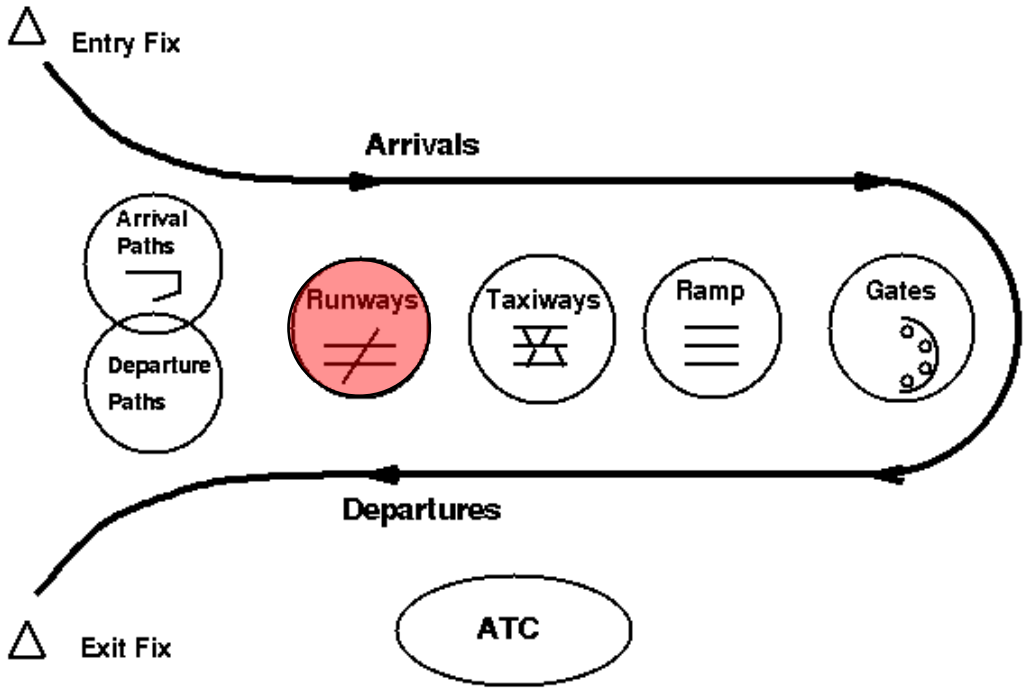
  Runway Occupancy Time Limit

A-380

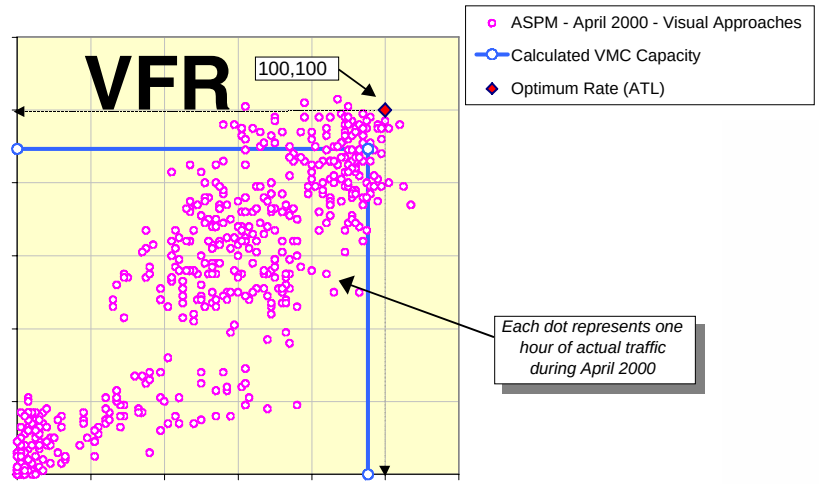
Breakeven Separation for Airport Throughput?

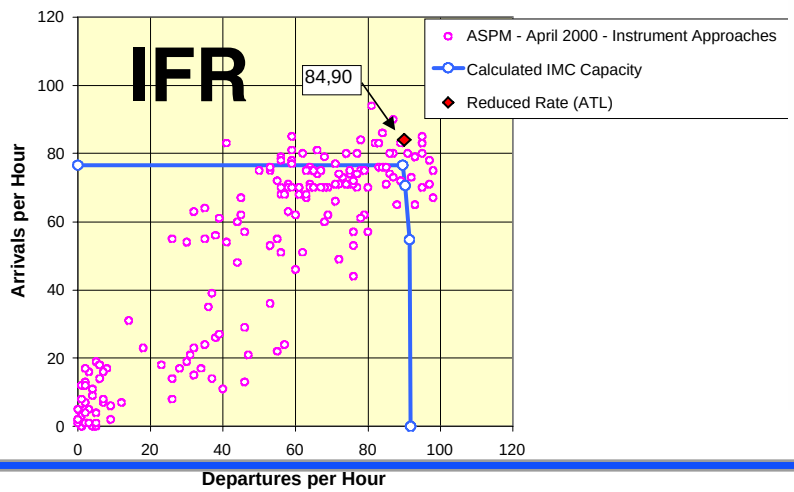
Airport System Capacity Limit Factors

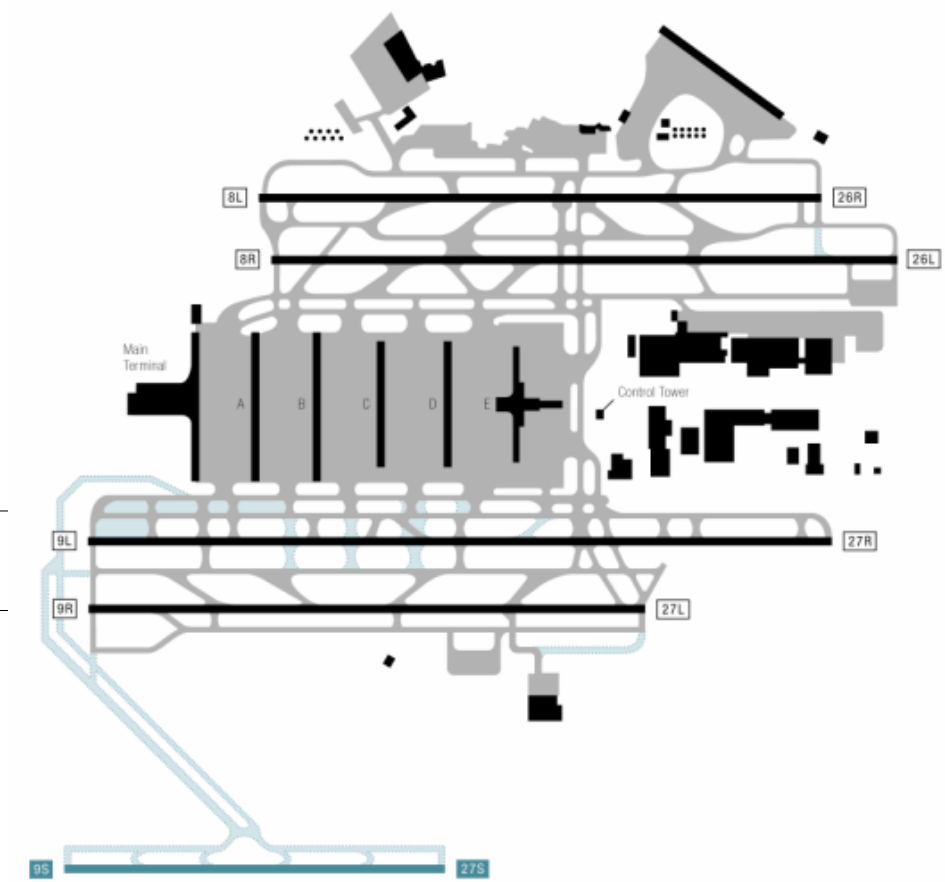
- **Arrival/Departure Routes**
- **Runways**
- **Weather**
  - ❑ Capacity Variability
- **Gates**
- **Downstream Constraints**
- **Controller Workload**
- **Landside Limits**
  - ❑ Terminals
  - ❑ Road Access
- **Environmental**
  - ❑ Community Noise
  - ❑ Emissions
- **Safety**



Airport Capacity Envelopes
Atlanta (ATL)

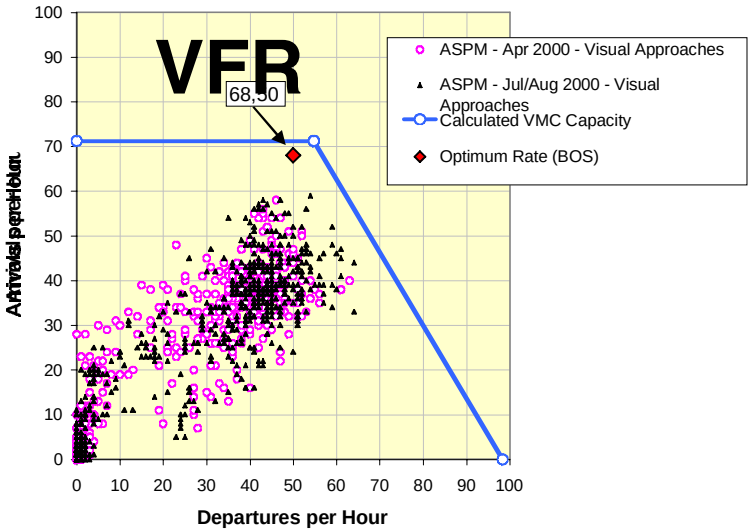


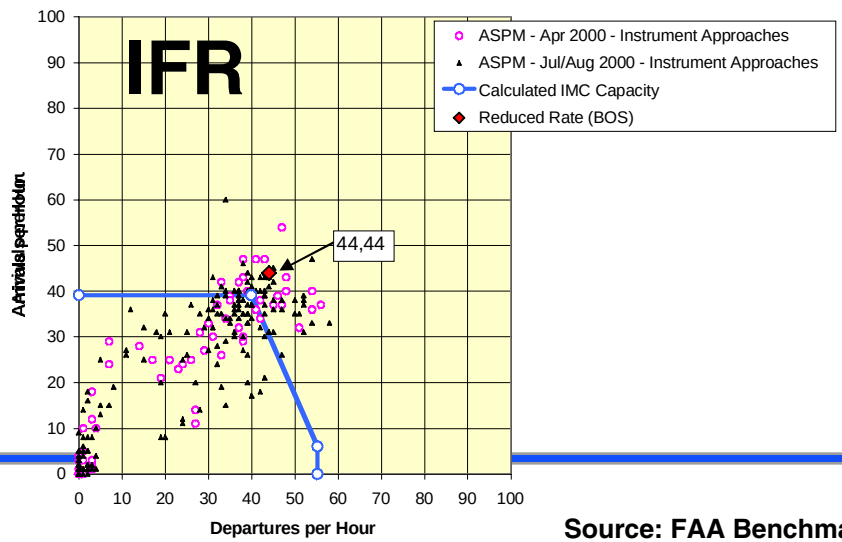


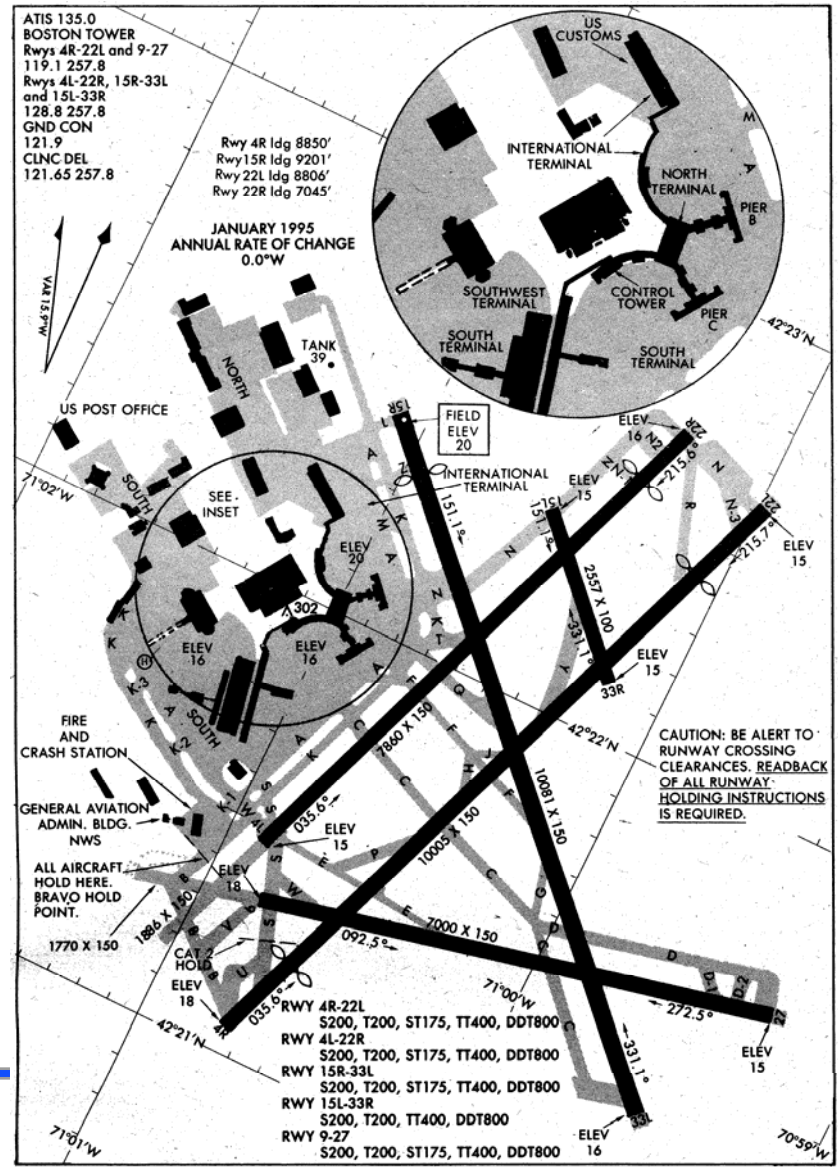


Source: FAA Benchmark Data

Airport Capacity Envelopes
Boston (BOS)

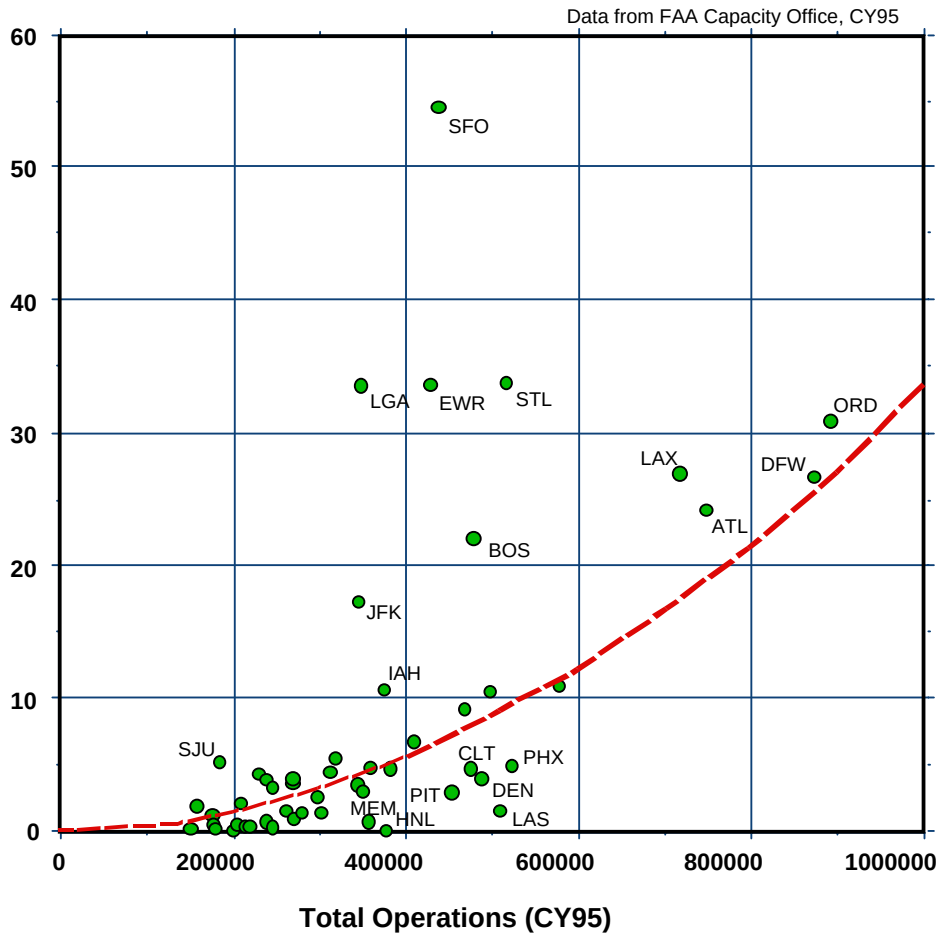






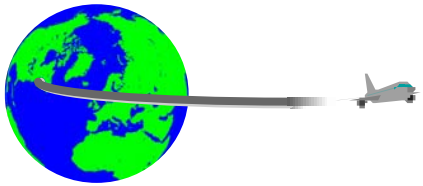
Source: FAA Benchmark Data

Variable Capacity Effects



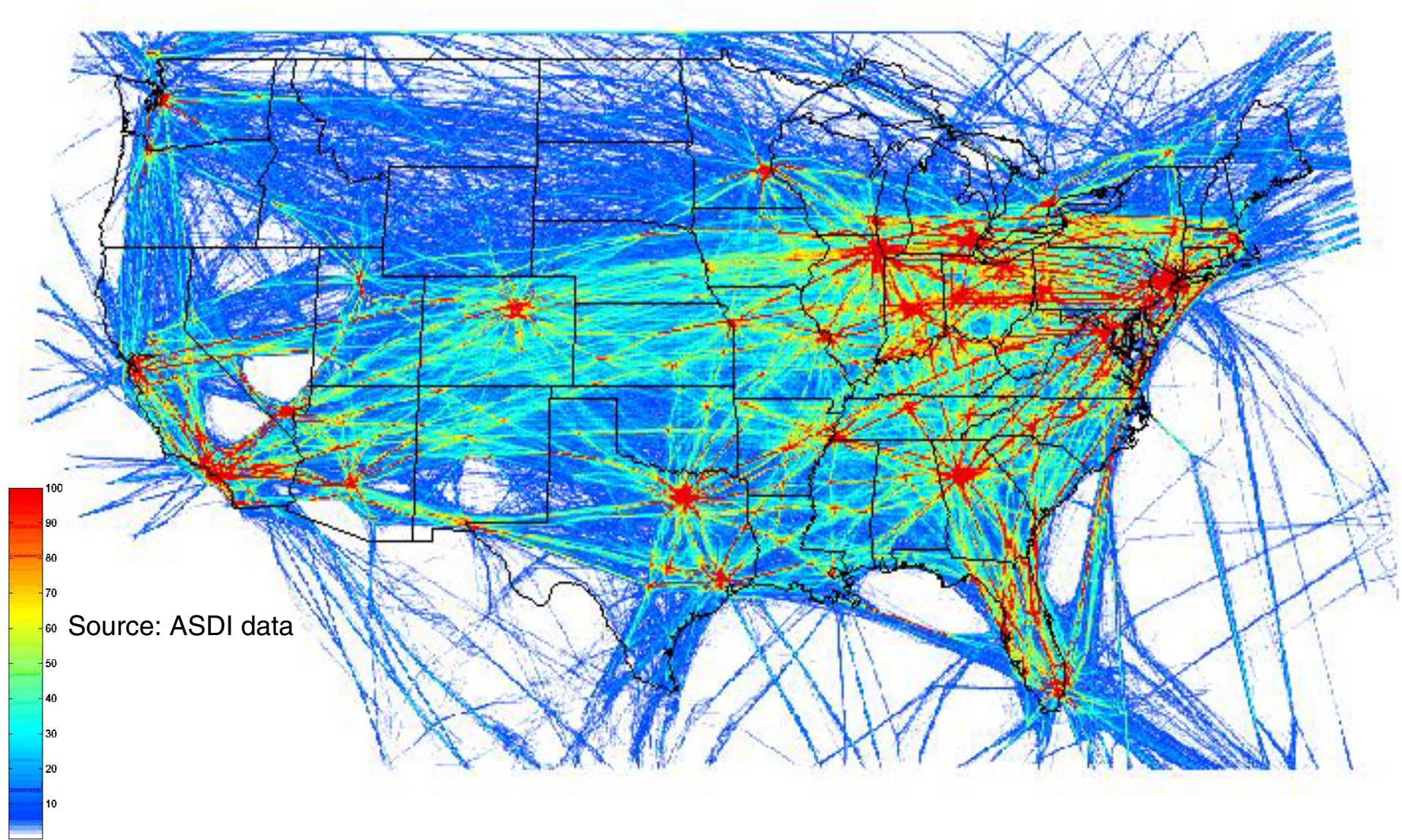
1995 Delays vs Operations

From John Andrews, MIT Lincoln Lab



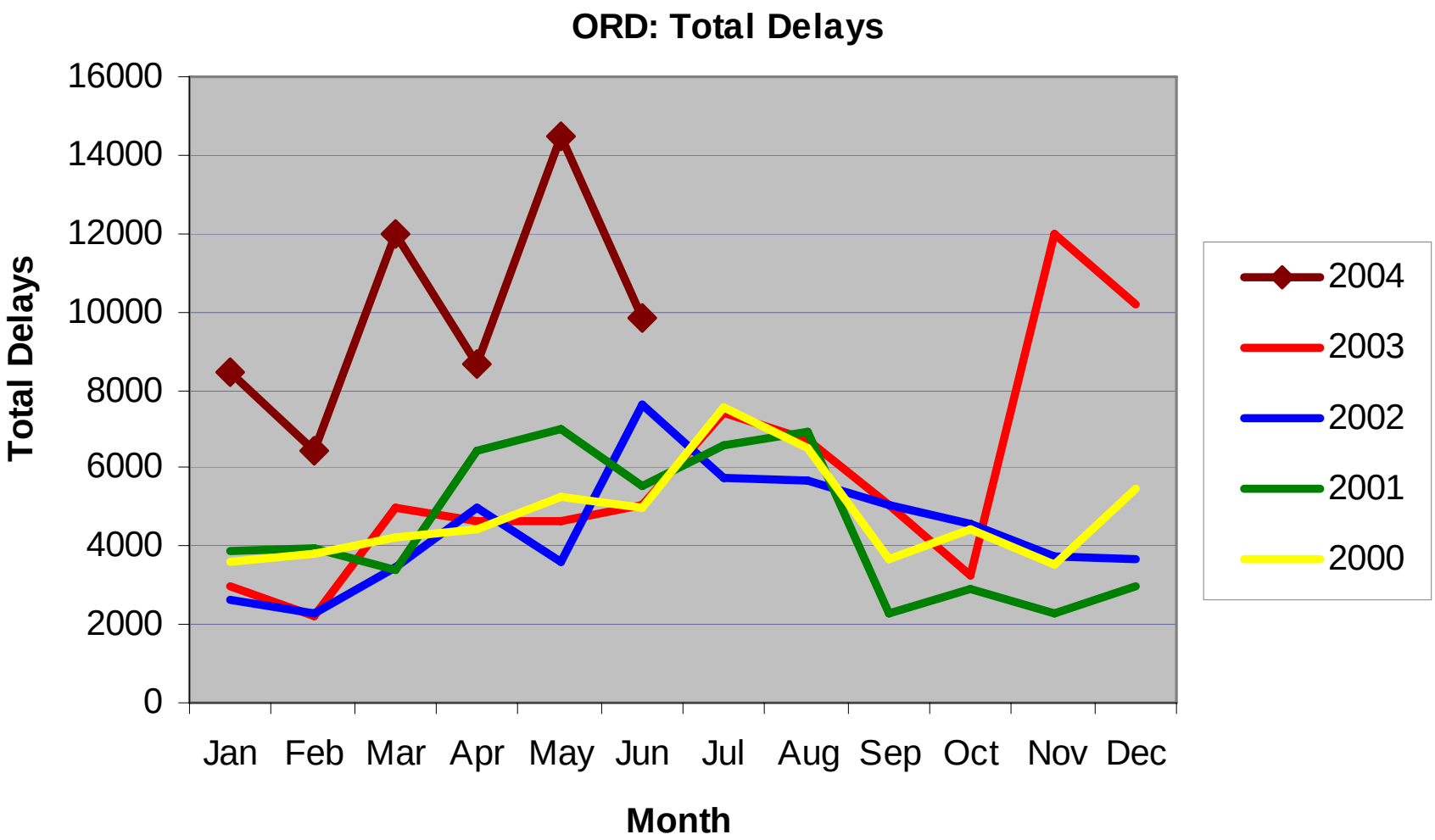
QuickTime™ and a
Microsoft Video 1 decompressor
are needed to see this picture.

Network Effects and Delay Propagation



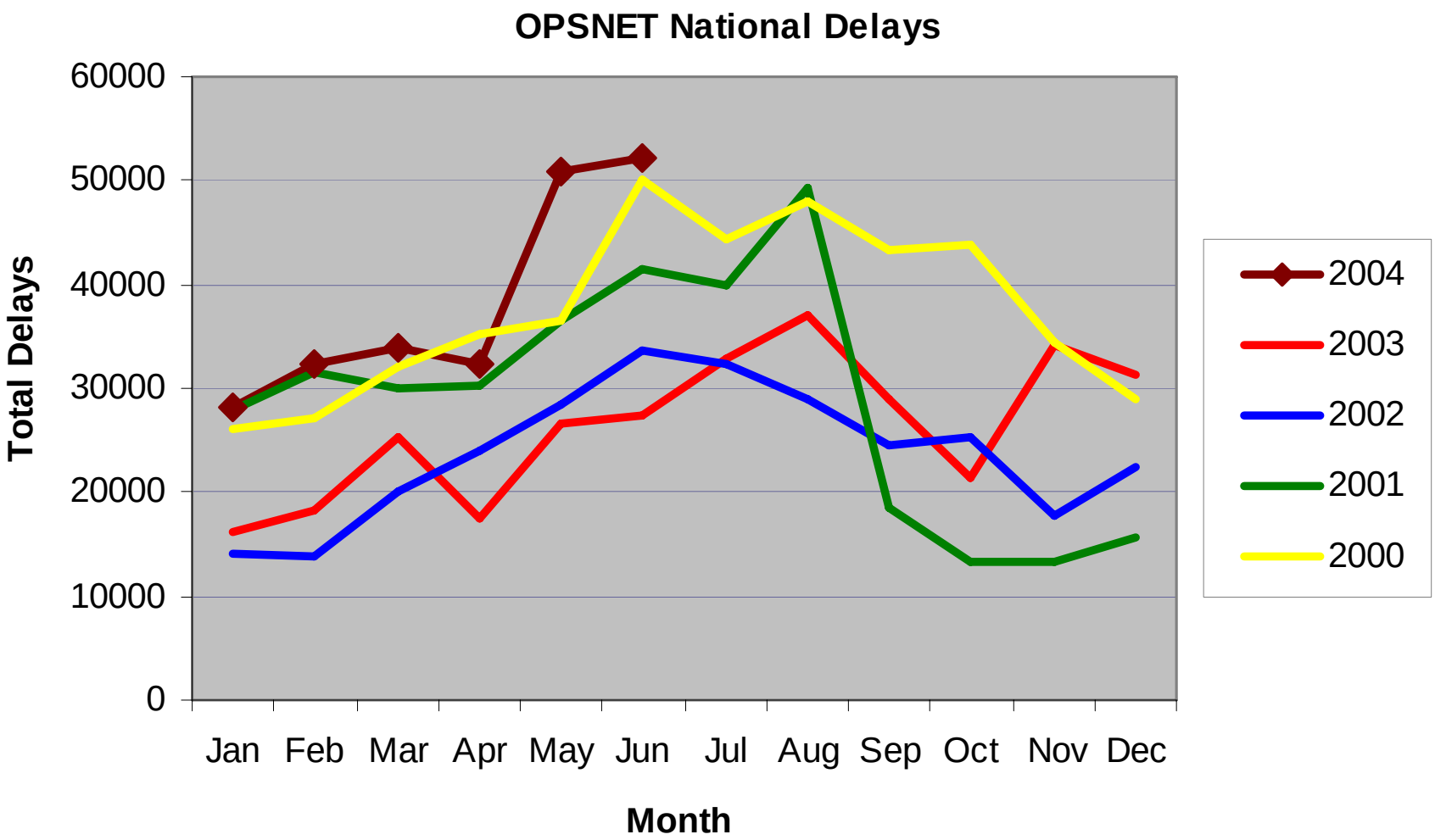
Source: ASDI data

Delays at Chicago O'Hare



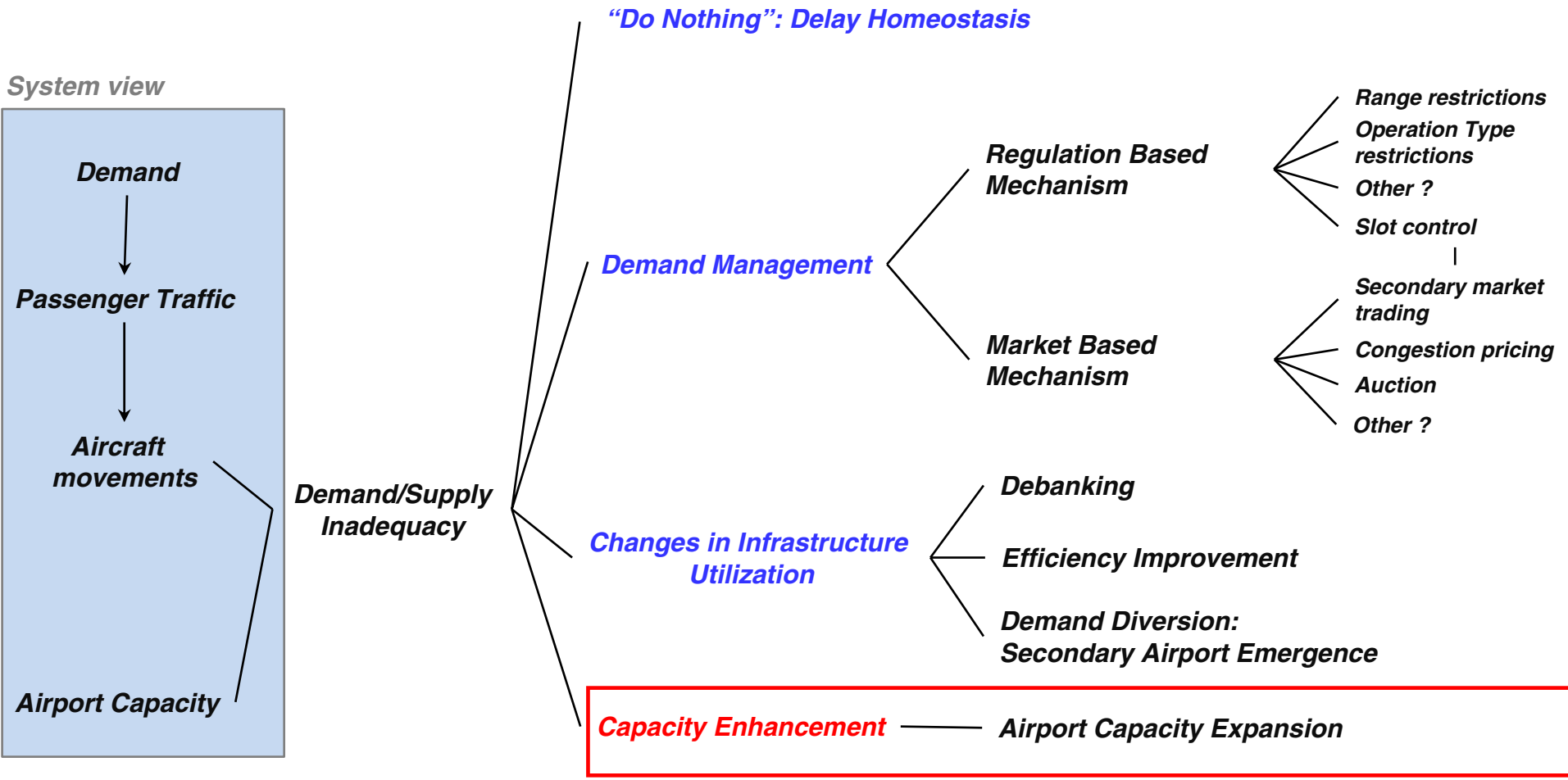
Source: FAA OPSNET data

Flight Delays Reemerging



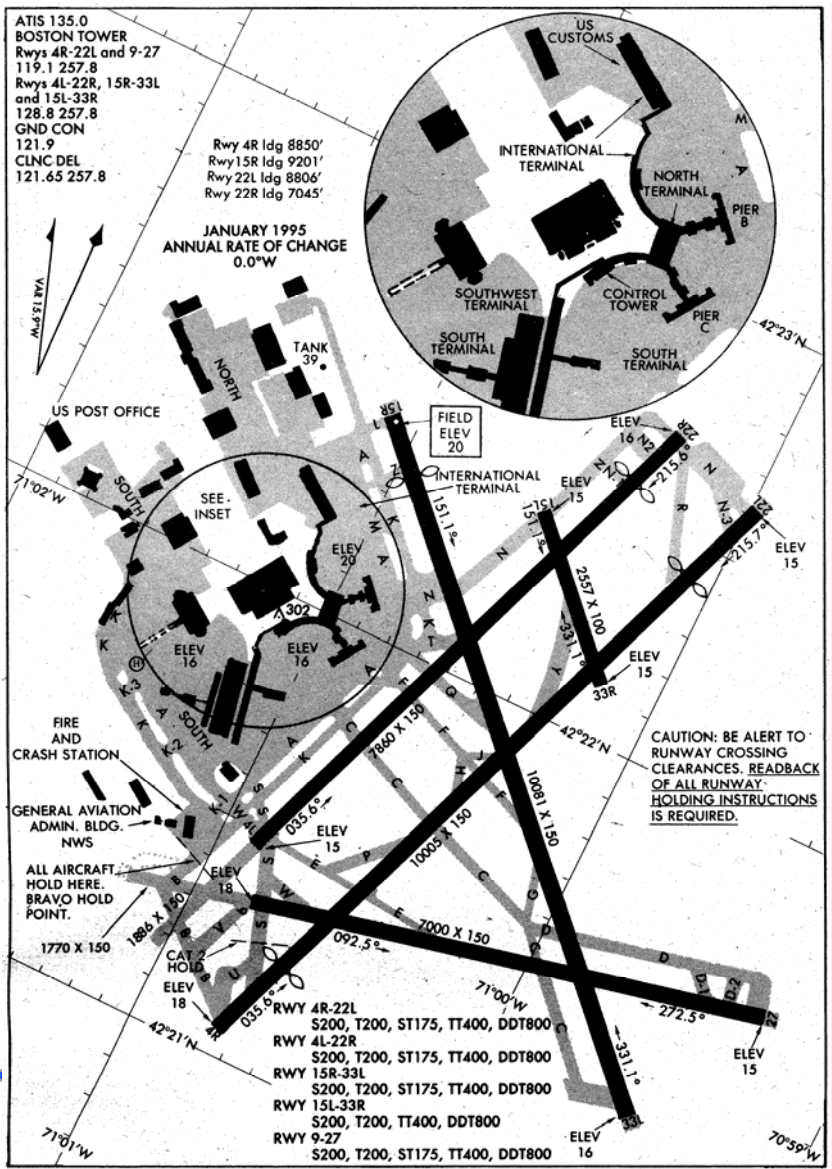
Source: FAA OPSNET data

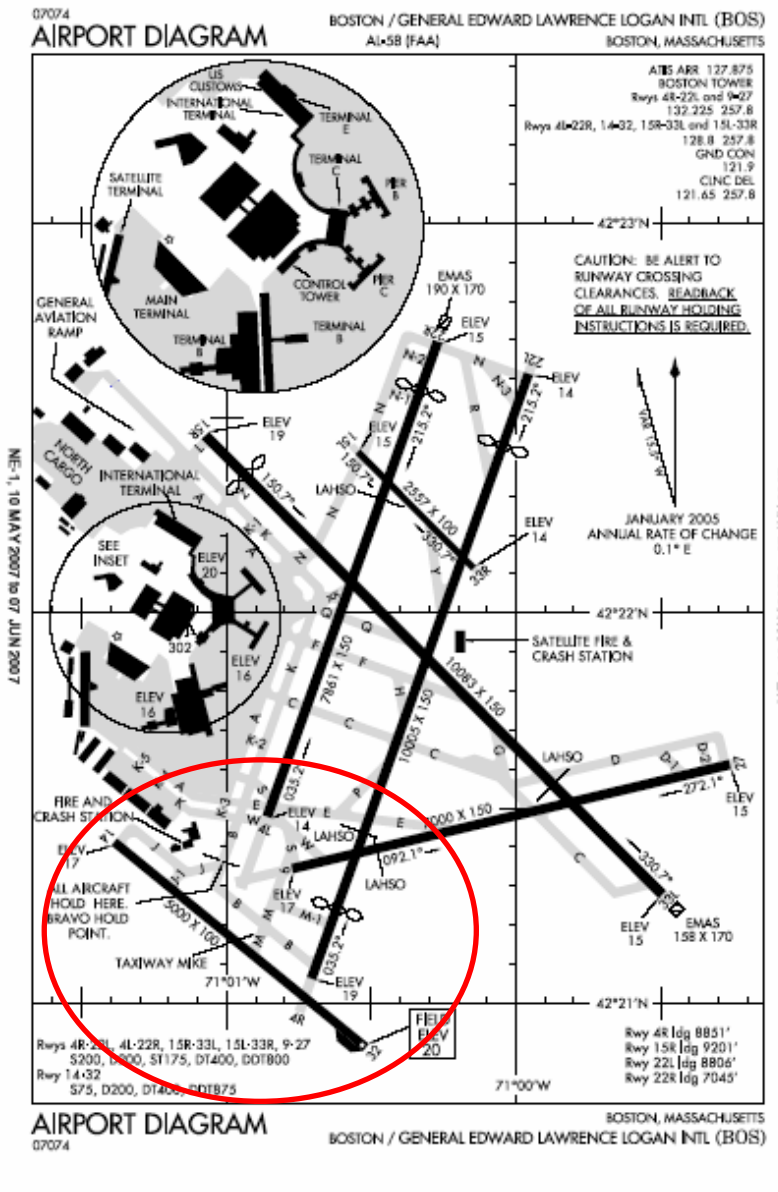
Solutions to Address Airport Demand/Capacity Inadequacy



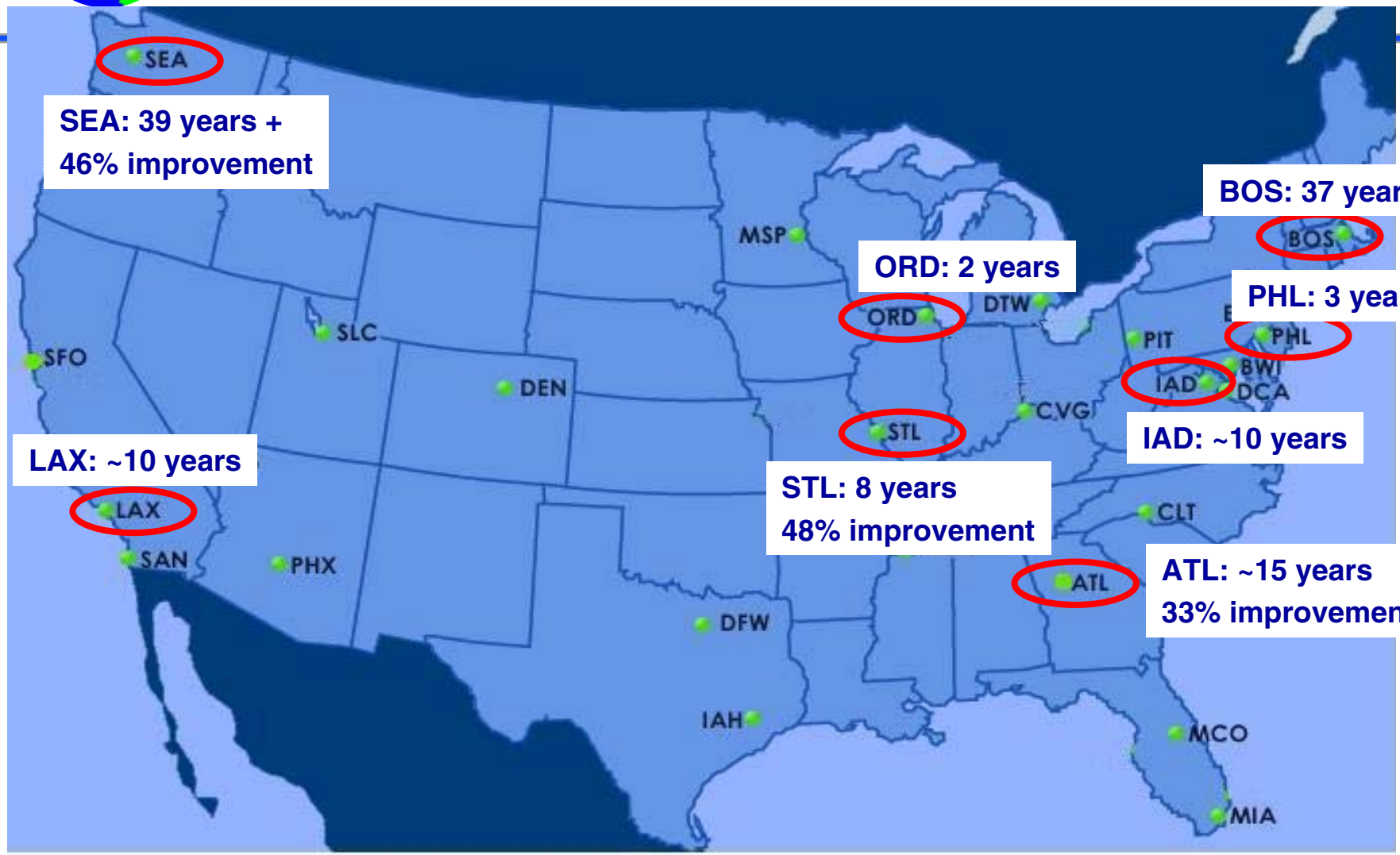
Source: Philippe Bonnefoy

Concrete Solution (BOS)





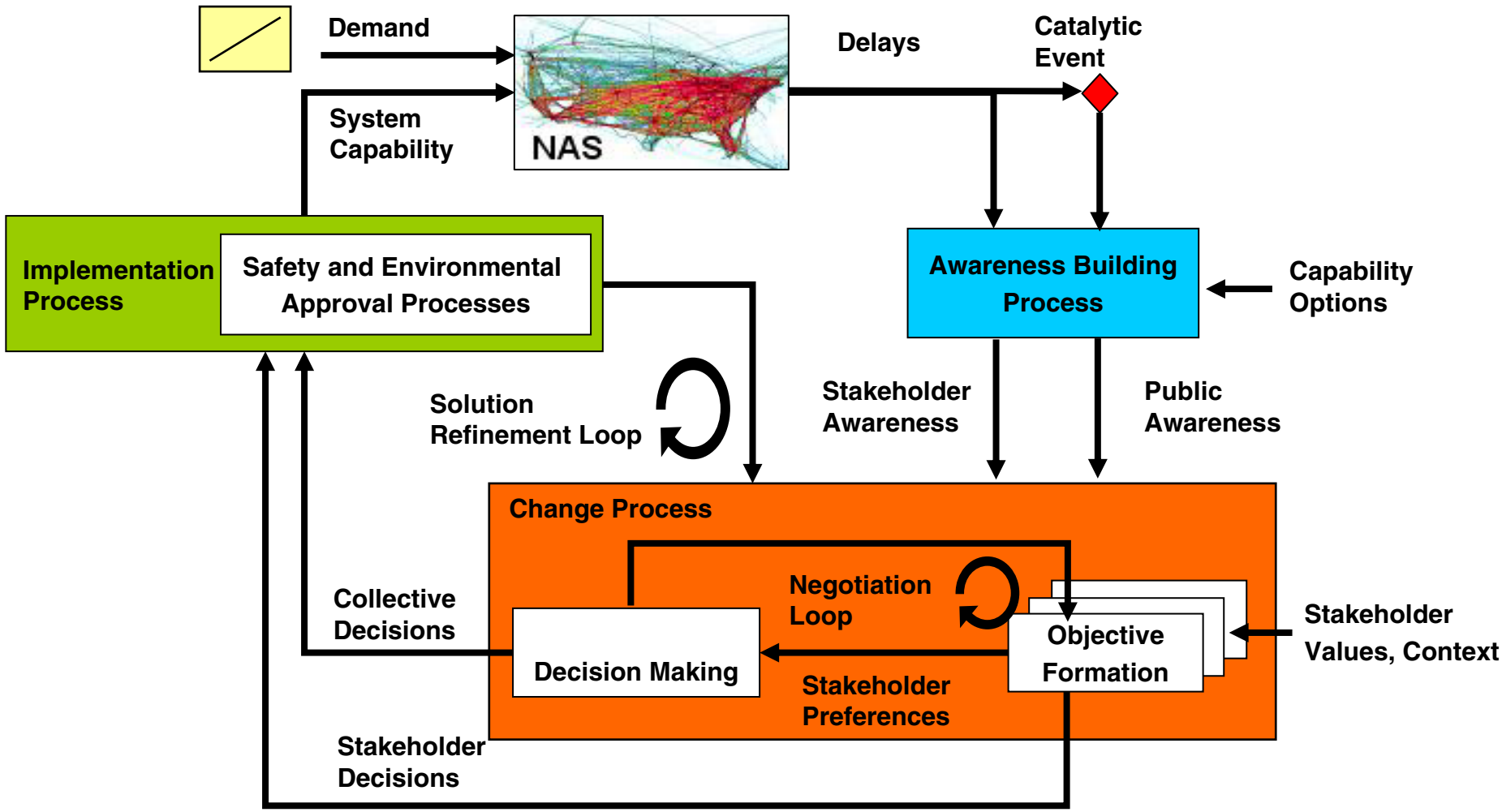
Current Airport Expansion Projects



Top 30 Congested Airports in 2005

Expansion Projects

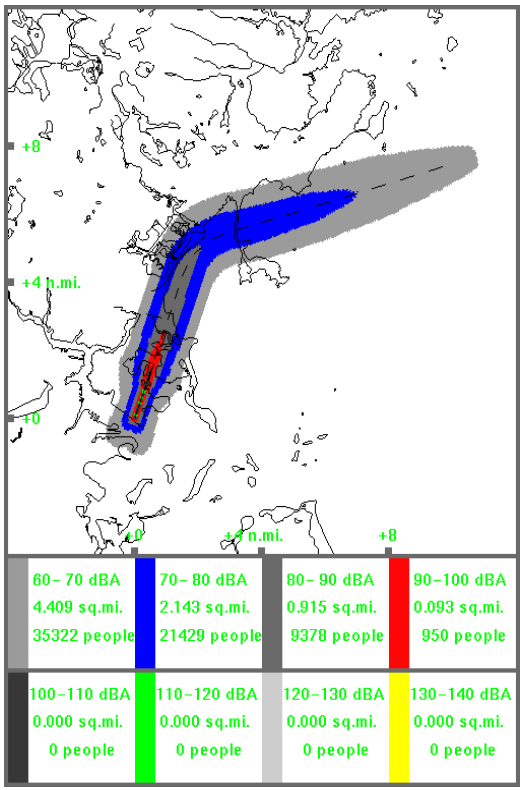
Multi-Stakeholder Transition Model
with Implementation Barriers



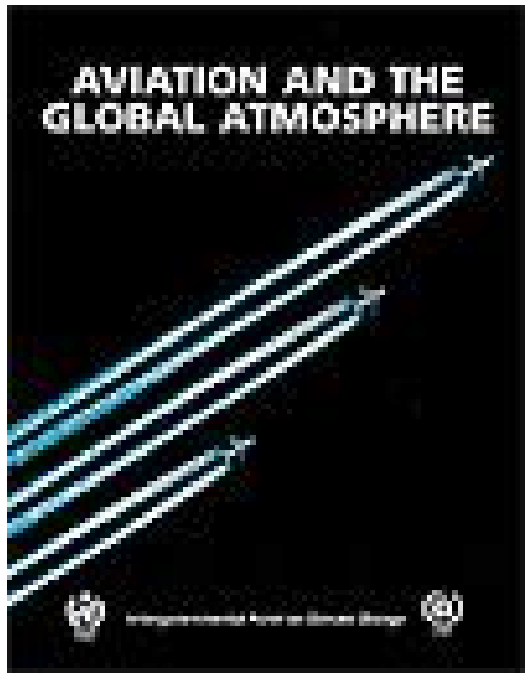
Source: Alexandra Mozdzanaowska

Environmental Limitations

Noise

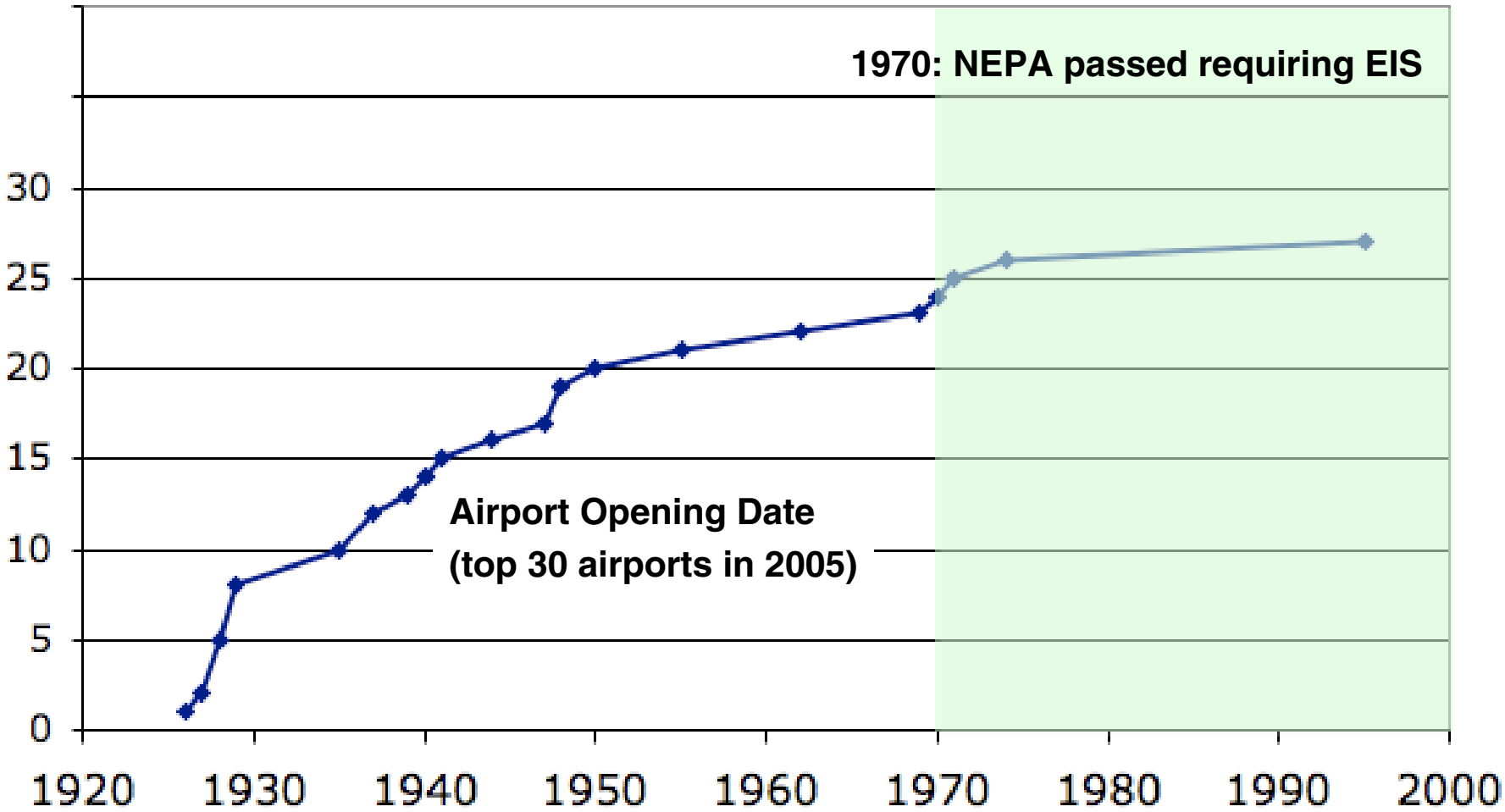


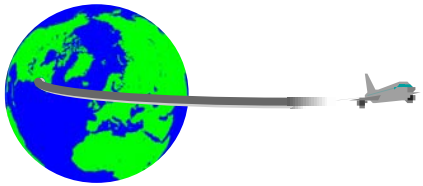
Emissions



Intergovernmental Panel on Climate Change

Airport Construction in Key Areas has Slowed





Capacity Improvement at OEP Airports (2000 vs 2006 Delay Rankings)

Year: 2000

Airport code	Airport name	Percentage of operations delayed	OEP new runway project (date completion/ capacity benefit)
LGA	LaGuardia	15.6%	
EWR	Newark	8.1%	
ORD	Chicago	6.3%	
SFO	San Francisco	5.7%	
BOS	Boston	4.8%	2006 / +2%
PHL	Philadelphia	4.5%	
JFK	Kennedy	3.9%	
ATL	Atlanta	3.1%	2006 / +33%
IAH	Houston	2.8%	
DFW	Dallas/Ft.Worth	2.4%	
PHX	Phoenix	2.2%	
LAX	Los Angeles	2.2%	
IAD	Dulles	2.0%	
STL	St. Louis	1.8%	2006 / +48 %
DTW	Detroit	1.8%	
CVG	Cincinnati	1.5%	2005 / +12 %
MSP	Minn./St. Paul	1.3%	2005 / +19 %
MIA	Miami	1.1%	
SEA	Seattle	1.0%	2008 / +46 %
LAS	Las Vegas	0.8%	
DCA	Reagan National	0.8%	
BWI	Balt.-Wash. Intl	0.7%	
MCO	Orlando	0.6%	
CLT	Charlotte	0.6%	2008 / +11%
PIT	Pittsburgh	0.4%	
SAN	San Diego	0.3%	
DEN	Denver	0.2%	
SLC	Salt Lake City	0.2%	
TPA	Tampa	0.2%	
MEM	Memphis	0.0%	

Year: 2006

Airport Code	Airport name	Percentage of operations delayed	OEP new runway project (date completion / capacity benefit)
EWR	Newark	12.0%	
LGA	LaGuardia	9.1%	
ORD	Chicago	6.9%	TBD
JFK	Kennedy	6.0%	
PHL	Philadelphia	5.6%	2007 / Delay Reduction
ATL	Atlanta	5.1%	2006 / 33%
BOS	Boston	2.9%	2006 / Delay Reduction
SFO	San Francisco	2.9%	
IAH	Houston	2.5%	
LAS	Las Vegas	2.4%	
CLT	Charlotte	1.3%	
PHX	Phoenix	1.1%	
DFW	Dallas/Ft.Wort	0.9%	
DTW	Detroit	0.9%	
MDW	Midway	0.9%	
IAD	Dulles	0.6%	2008 / 12%
DCA	Reagan Natior	0.6%	
SLC	Salt Lake City	0.4%	
LAX	Los Angeles	0.4%	2007 / NA
SEA	Seattle	0.4%	2008 / 46%
MIA	Miami	0.4%	
MEM	Memphis	0.4%	
MSP	Minn./St. Paul	0.3%	
CVG	Cincinnati	0.3%	
DEN	Denver	0.3%	
BWI	Balt.-Wash. Int	0.2%	
MCO	Orlando	0.2%	
PIT	Pittsburgh	0.1%	
STL	St. Louis	0.0%	2006 / 48%

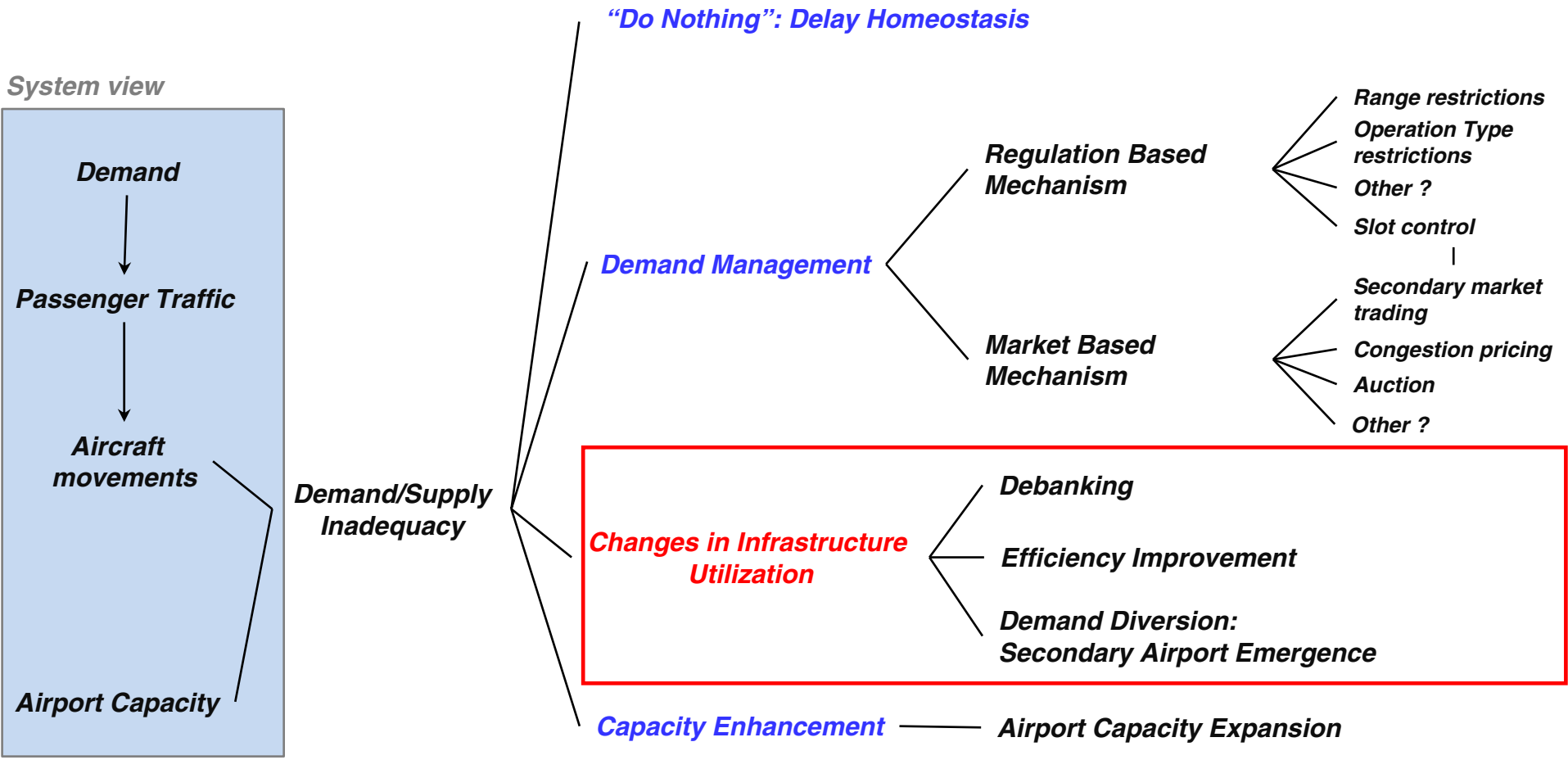
Data source: [Delay data: FAA Operational Network, OPSNET], [Capacity improvement: FAA Operational Evolution Plan OEP].

Runway, Runway Extensions, Reconfigurations or New Airports with Environmental Impact Statements or Planning Studies Underway

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

Data source: [Capacity improvement: FAA Operational Evolution Plan OEP].

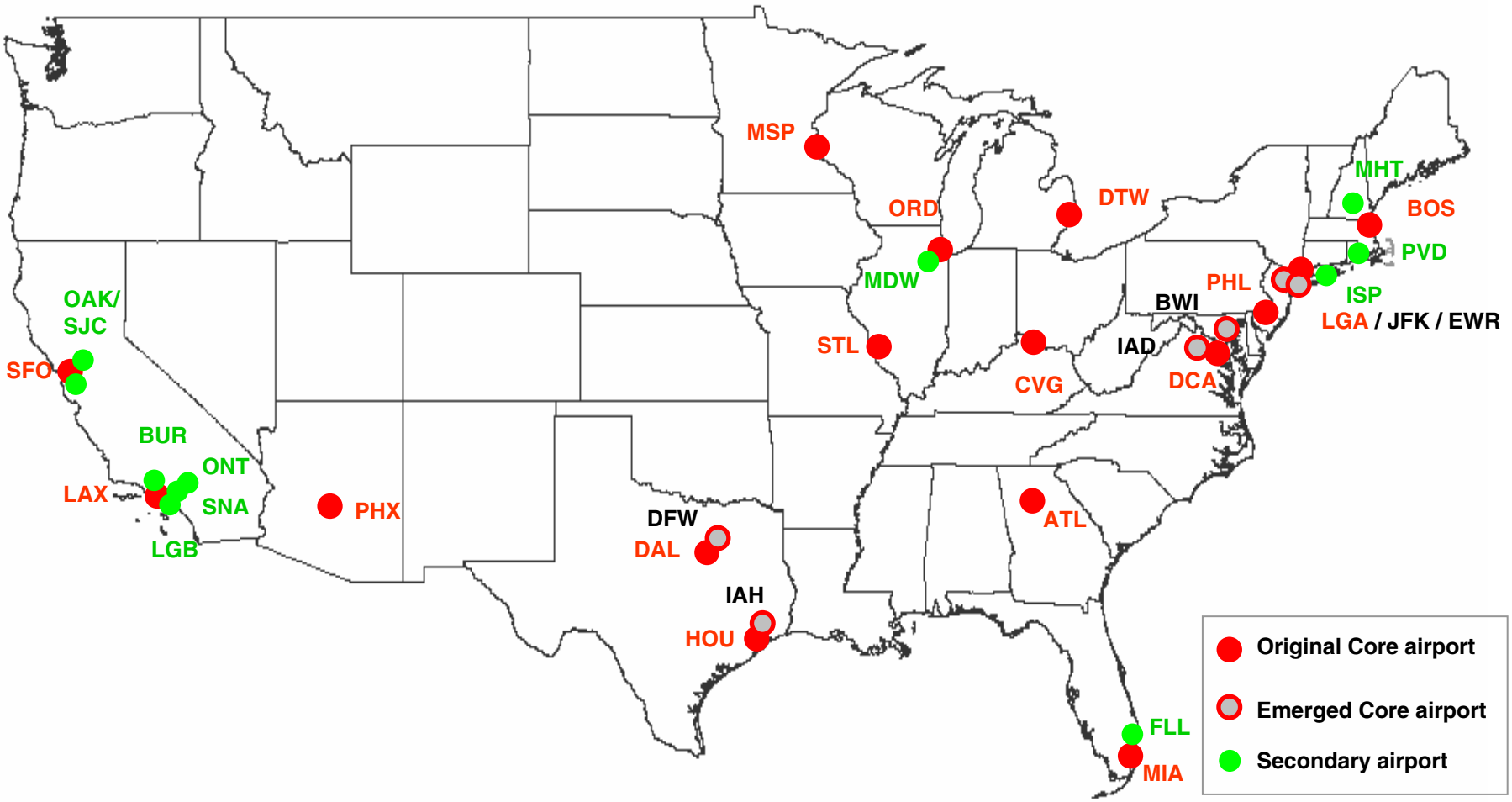
Solutions to Address Airport Demand/Capacity Inadequacy



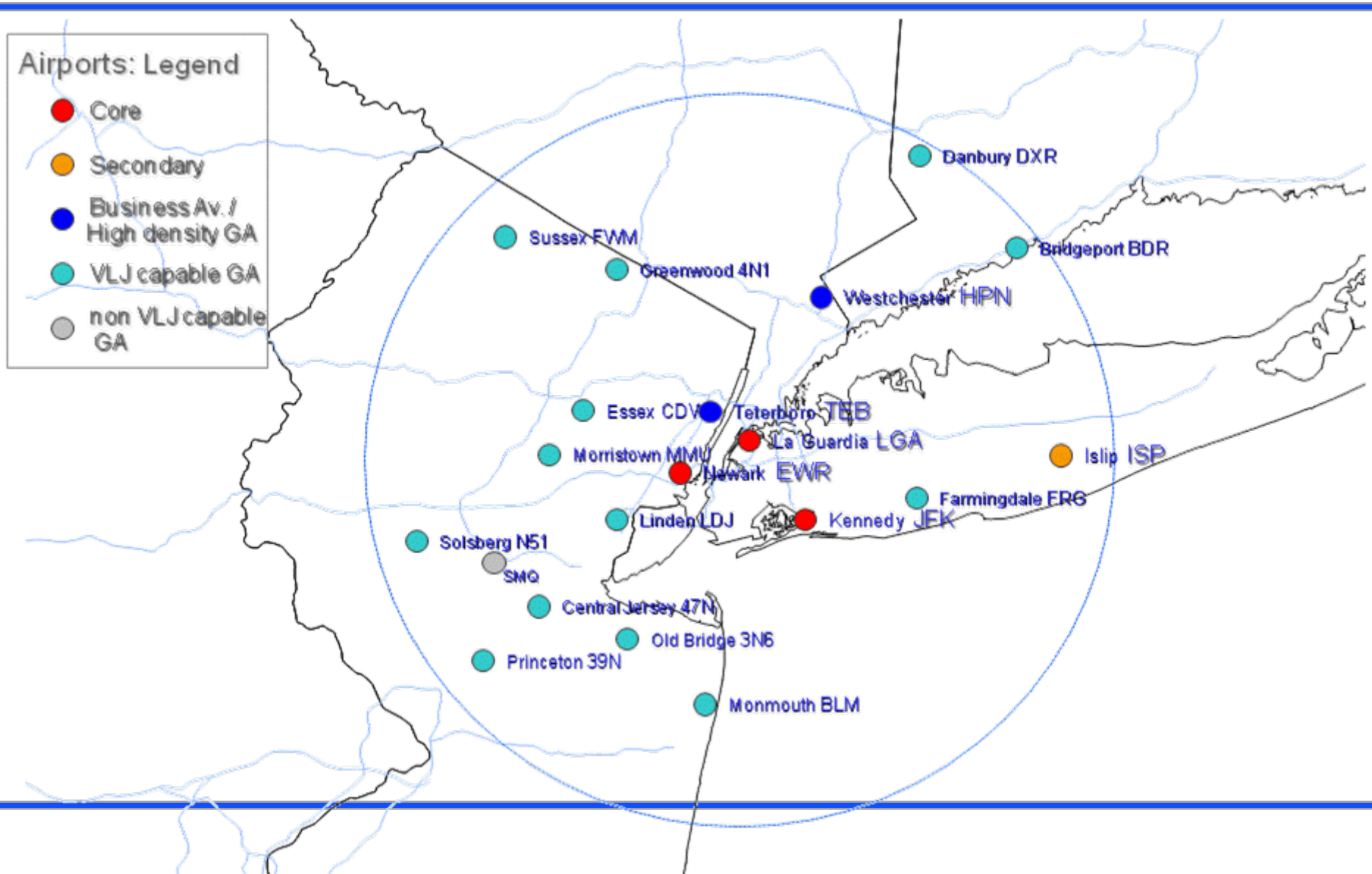
Source: Philippe Bonnefoy

Emergence of Secondary Airports

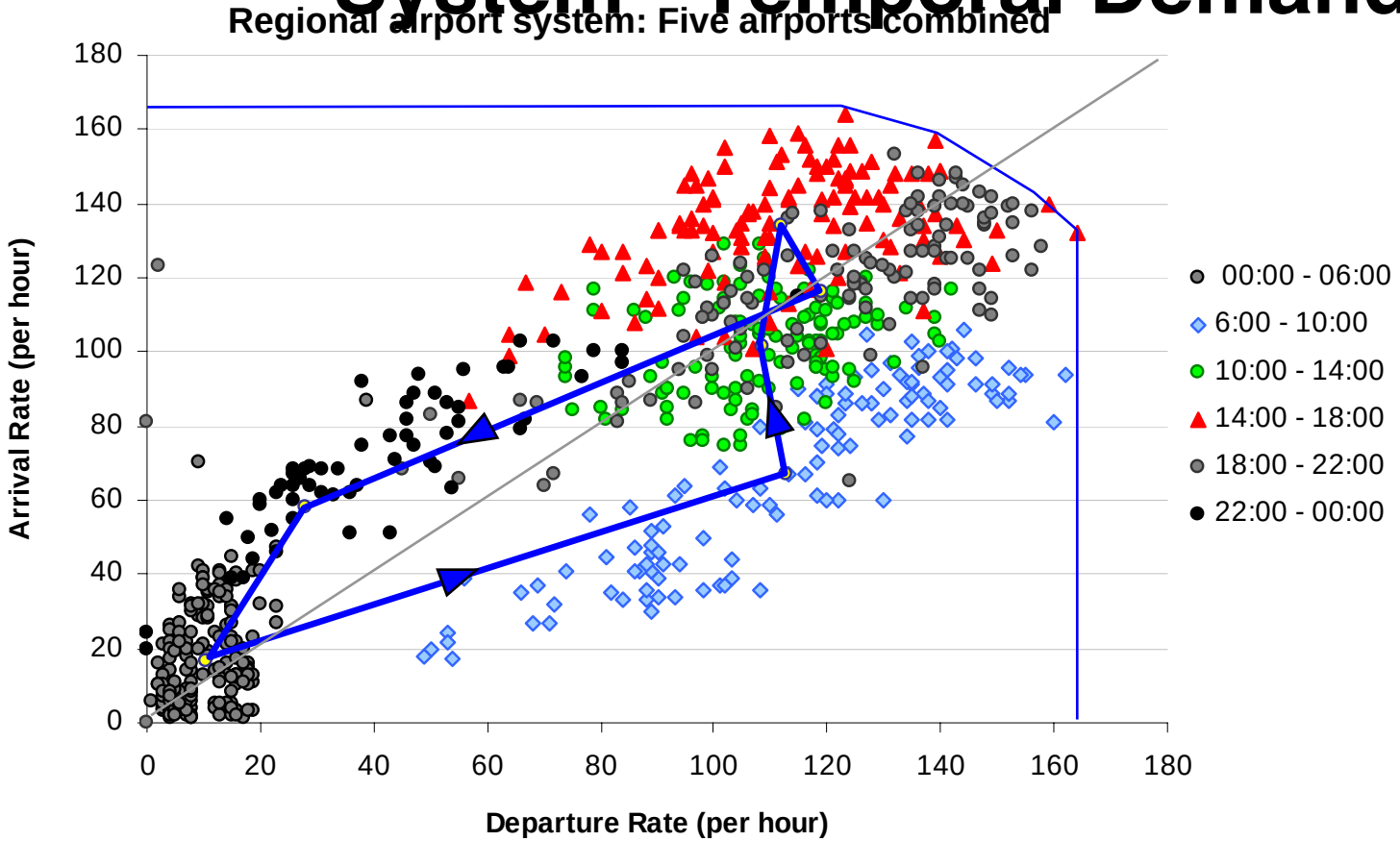
"Southwest Effect"



New York
Regional Airport System



New York Regional Airport System - Temporal Demand

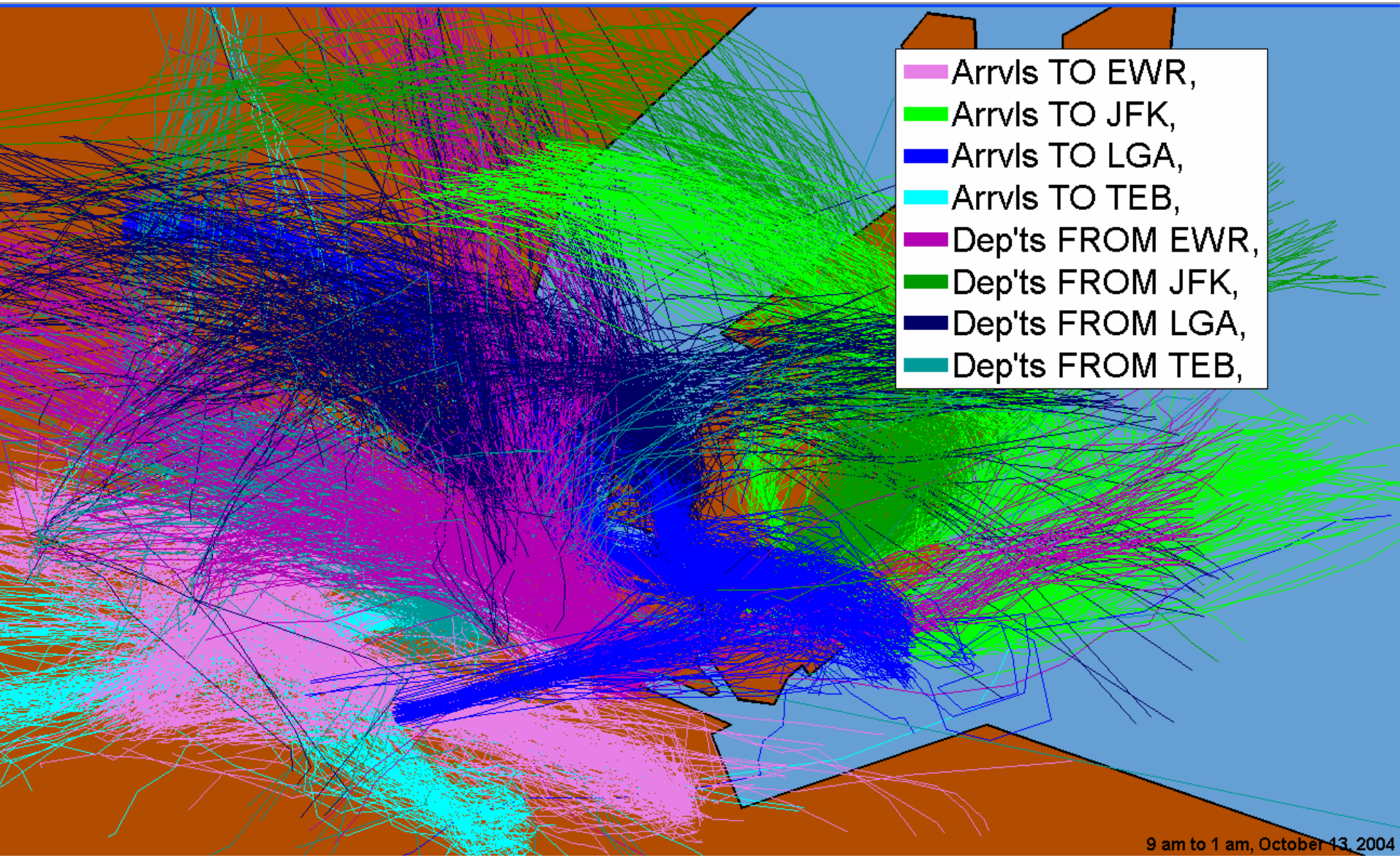


- "Flow" of departure and arrivals:
  - morning (dep.>arr., dep. to west coast)
  - rebalances throughout the day with arrivals from west coast move back closer to ½ - ½ with departures to Europe in the evening

- Terminal areas at capacity (closer to capacity) in the 16:00 – 20:00 time window

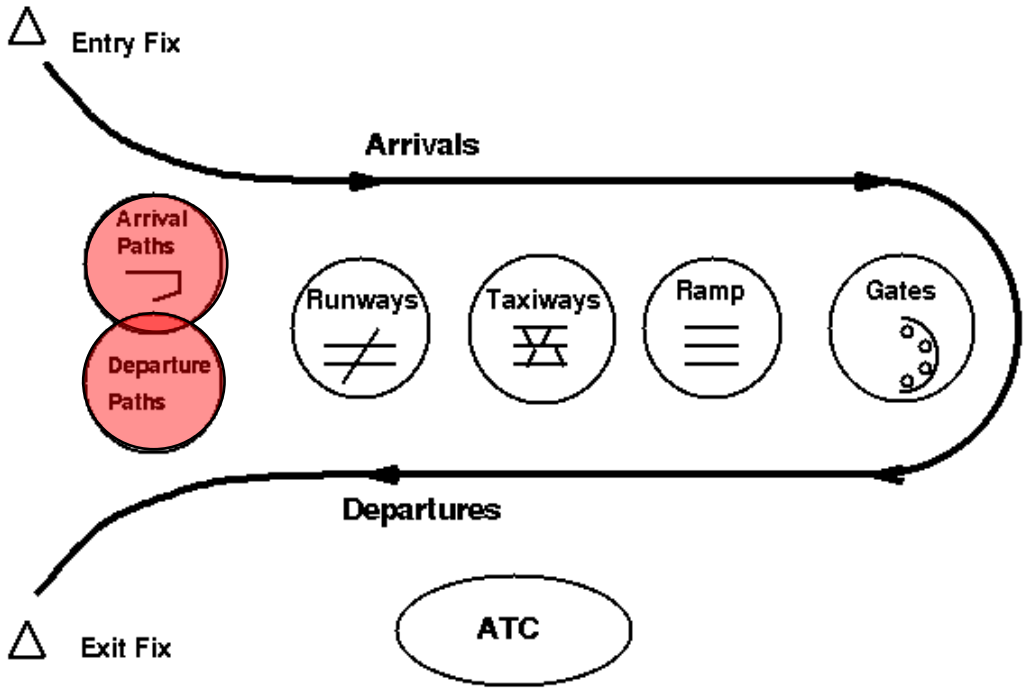
New York SDO Operations

Wake Implications of Tight RNP Routes ?

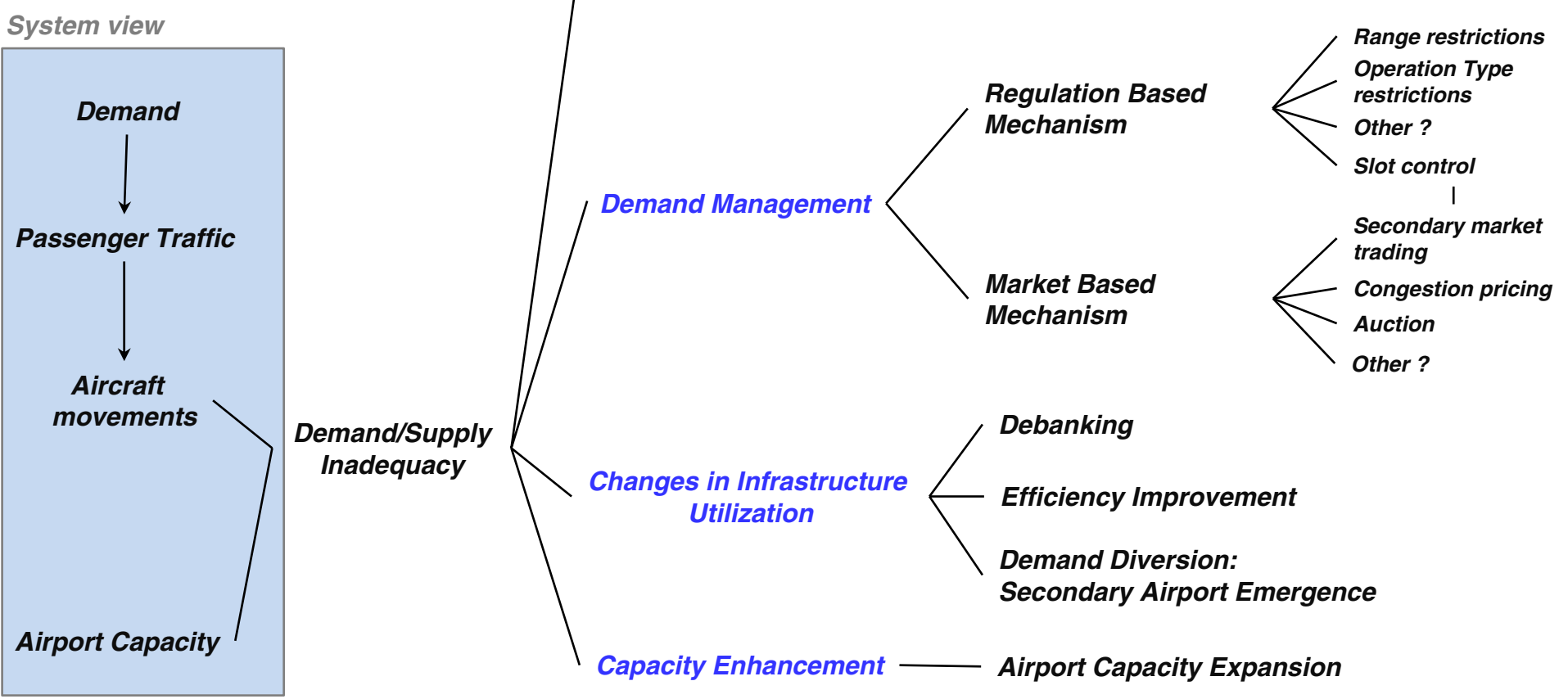


Airport System Capacity Limit Factors

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

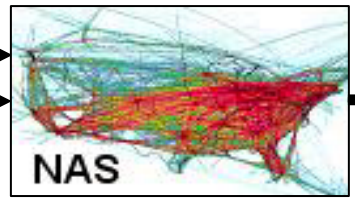


Solutions to Address Airport Demand/Capacity Inadequacy



Source: Philippe Bonnefoy

Delay Homeostasis



Regional Economy

Flight Schedules

Demand

System Capability

Delays

Catalytic Event

Implementation Process

Safety and Environmental Approval Processes

Awareness Building Process

Capability Options

Solution Refinement Loop

Stakeholder Awareness

Public Awareness

Change Process

Negotiation Loop

Collective Decisions

Decision Making

Objective Formation

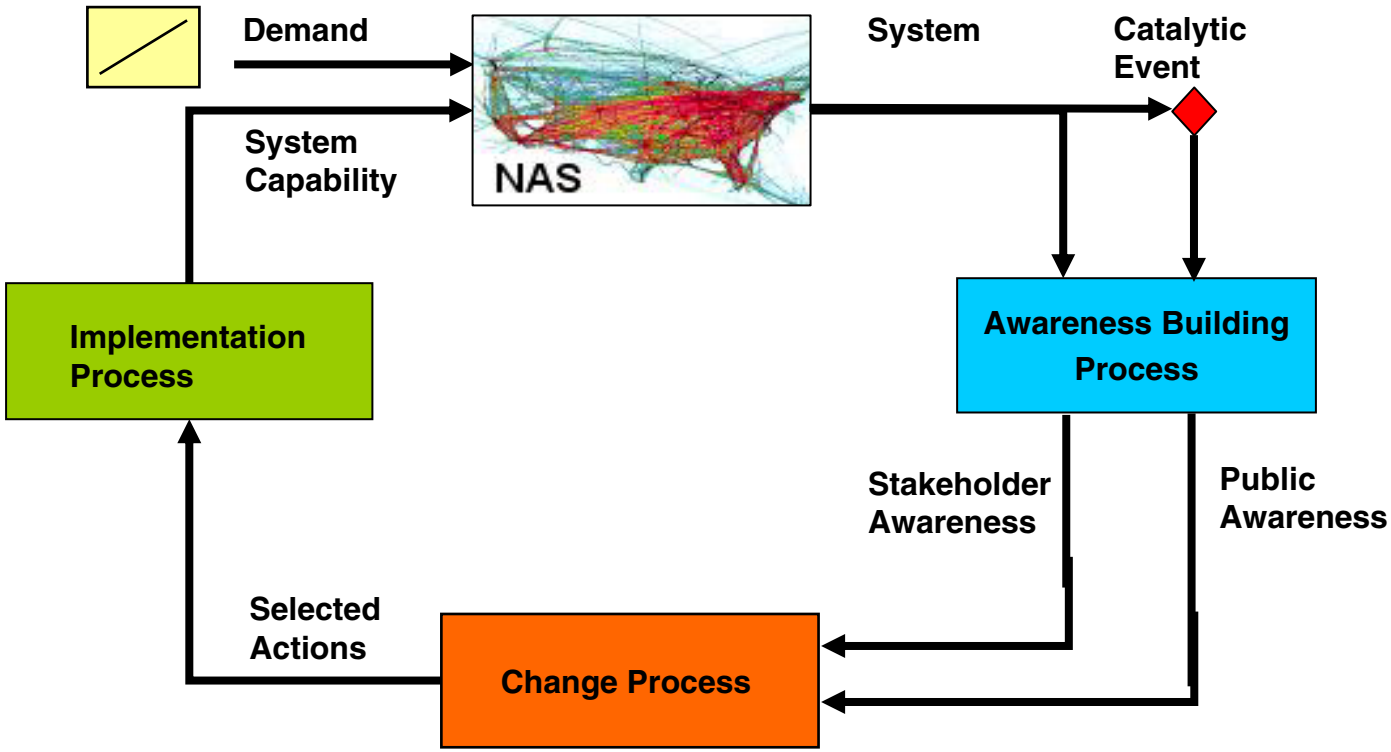
Stakeholder Values, Context

Stakeholder Scheduling Decisions

Stakeholder Preferences

Crisis Driven Transition

Capacity Crisis Stimulus?

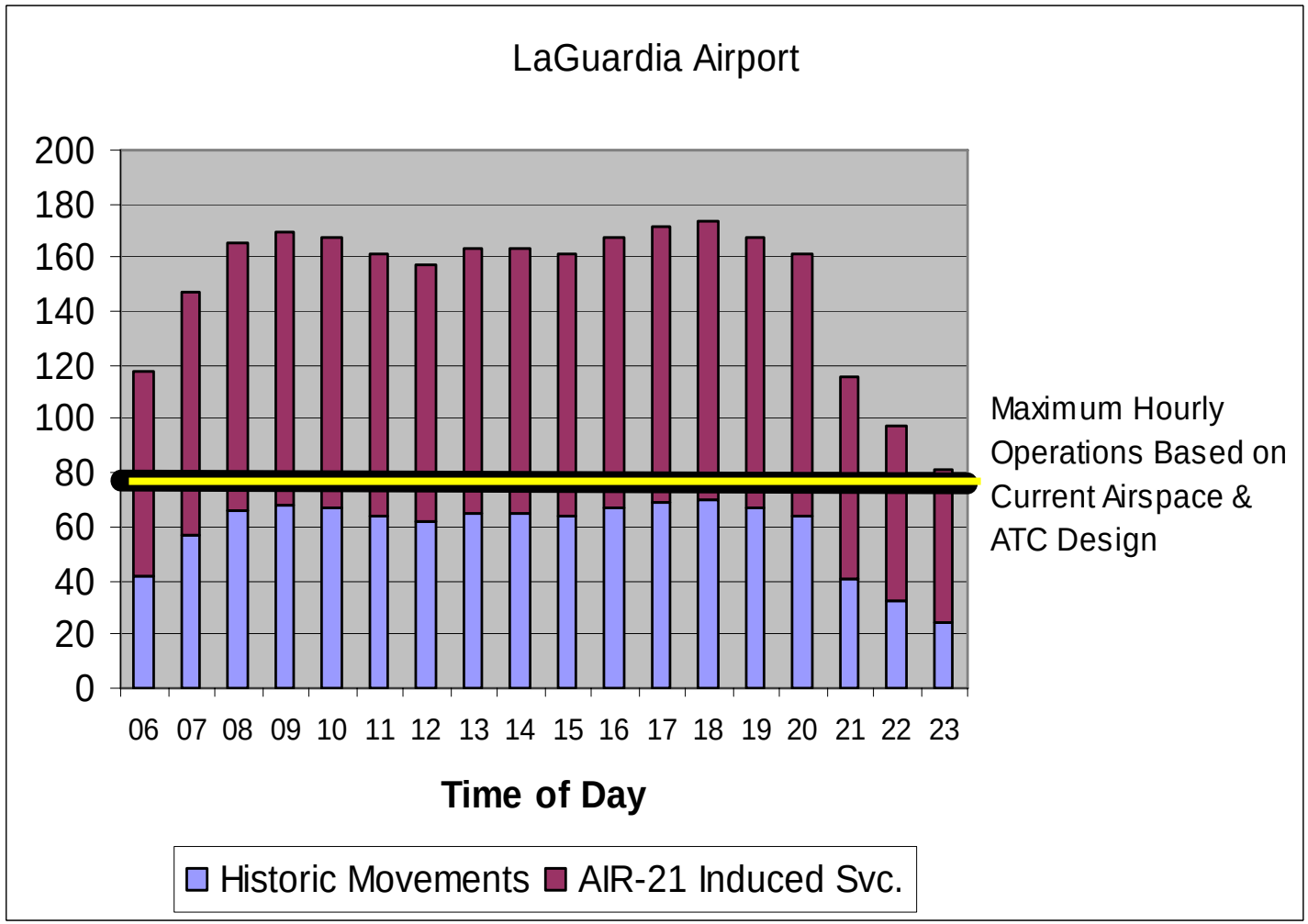


Historically Transition Driven by Catalytic Accidents

What is Capacity Analogue?

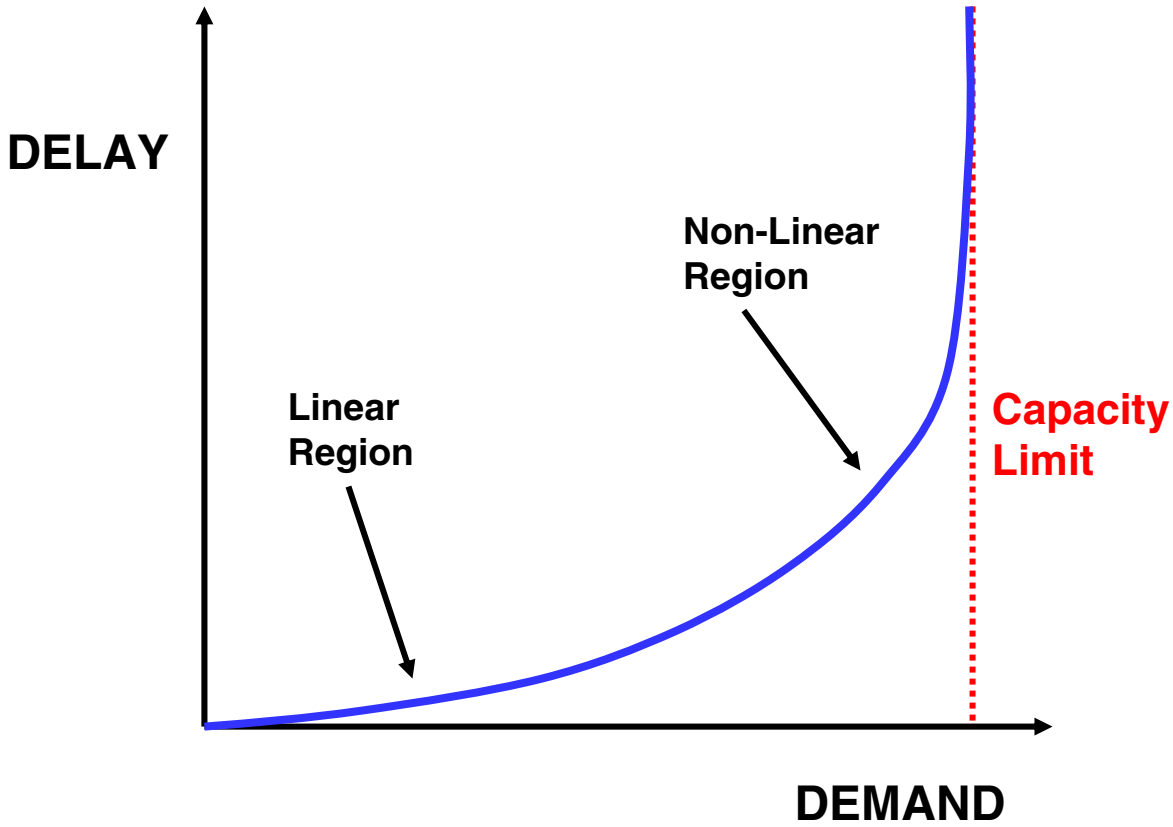
Source: Alexandra Mozdzanaowska

LGA Air 21 Impact



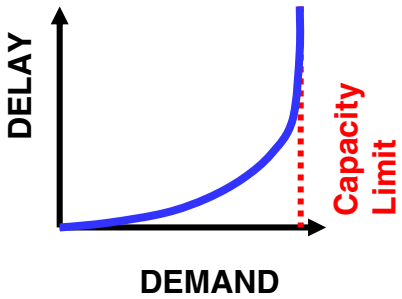
Source: William DeCota, Port Authority of New York

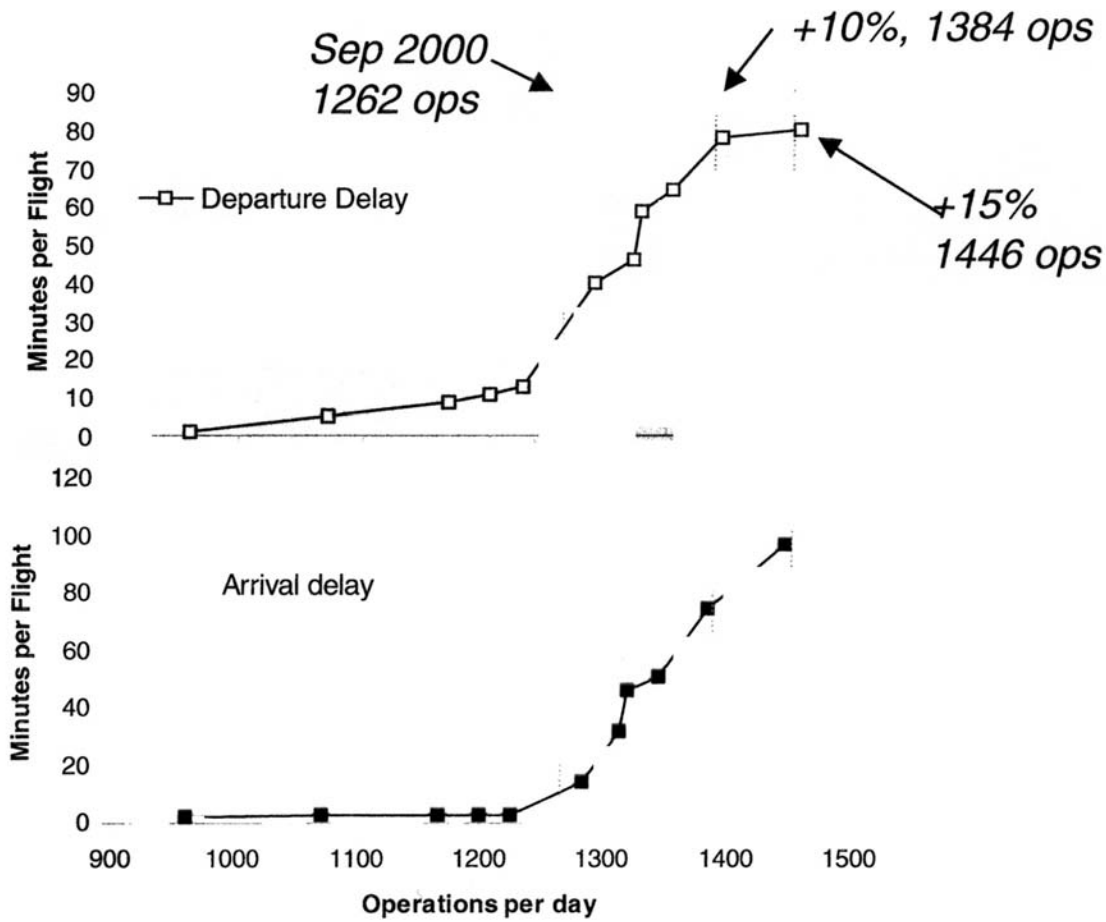
Classic Delay vs Demand Curve



LGA

Average Arrival and Departure Delay





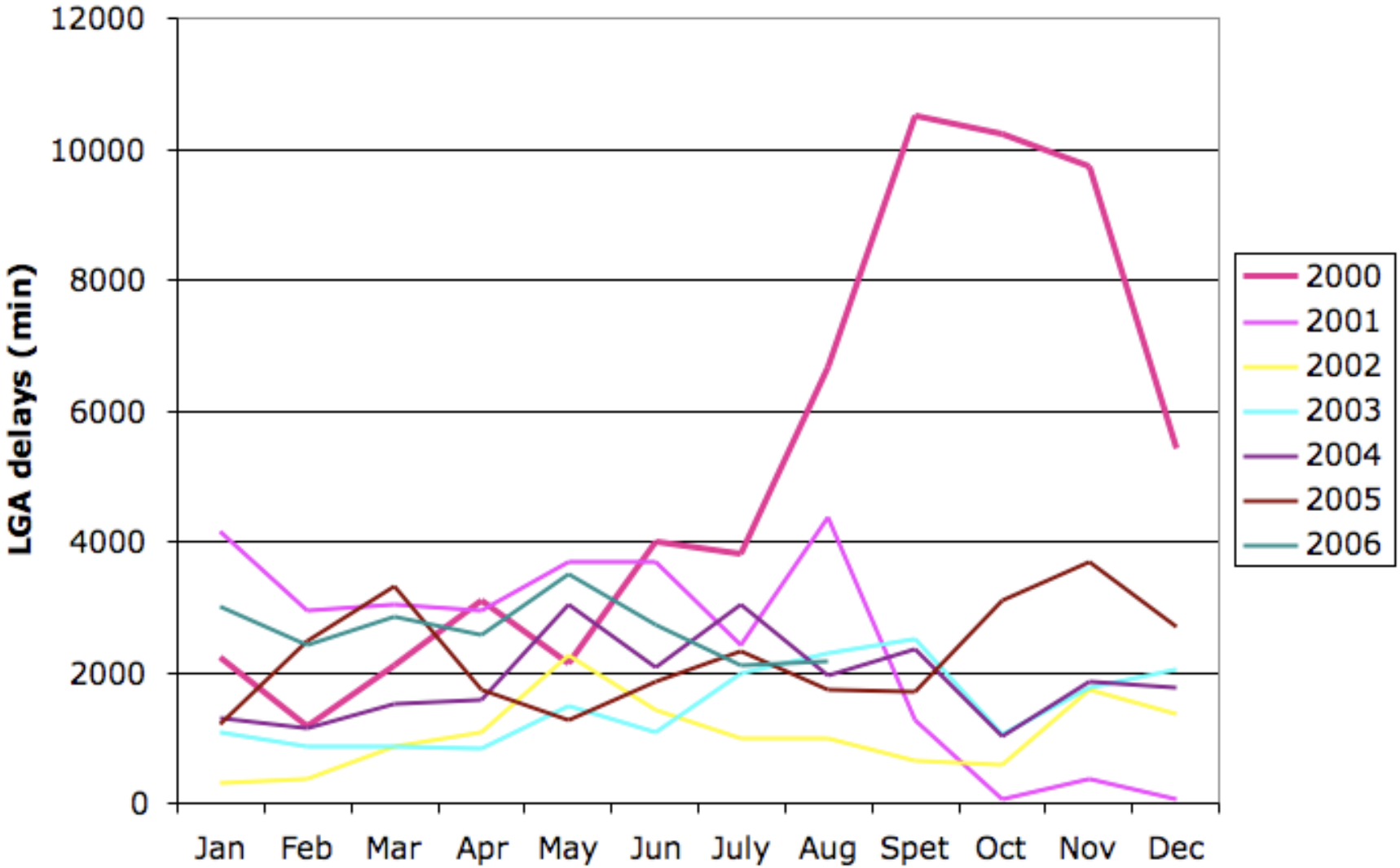
Departure Delay: (Actual - scheduled pushback time)+ (taxi-out time minus 10 minutes)

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

Internalized vs externalized costs

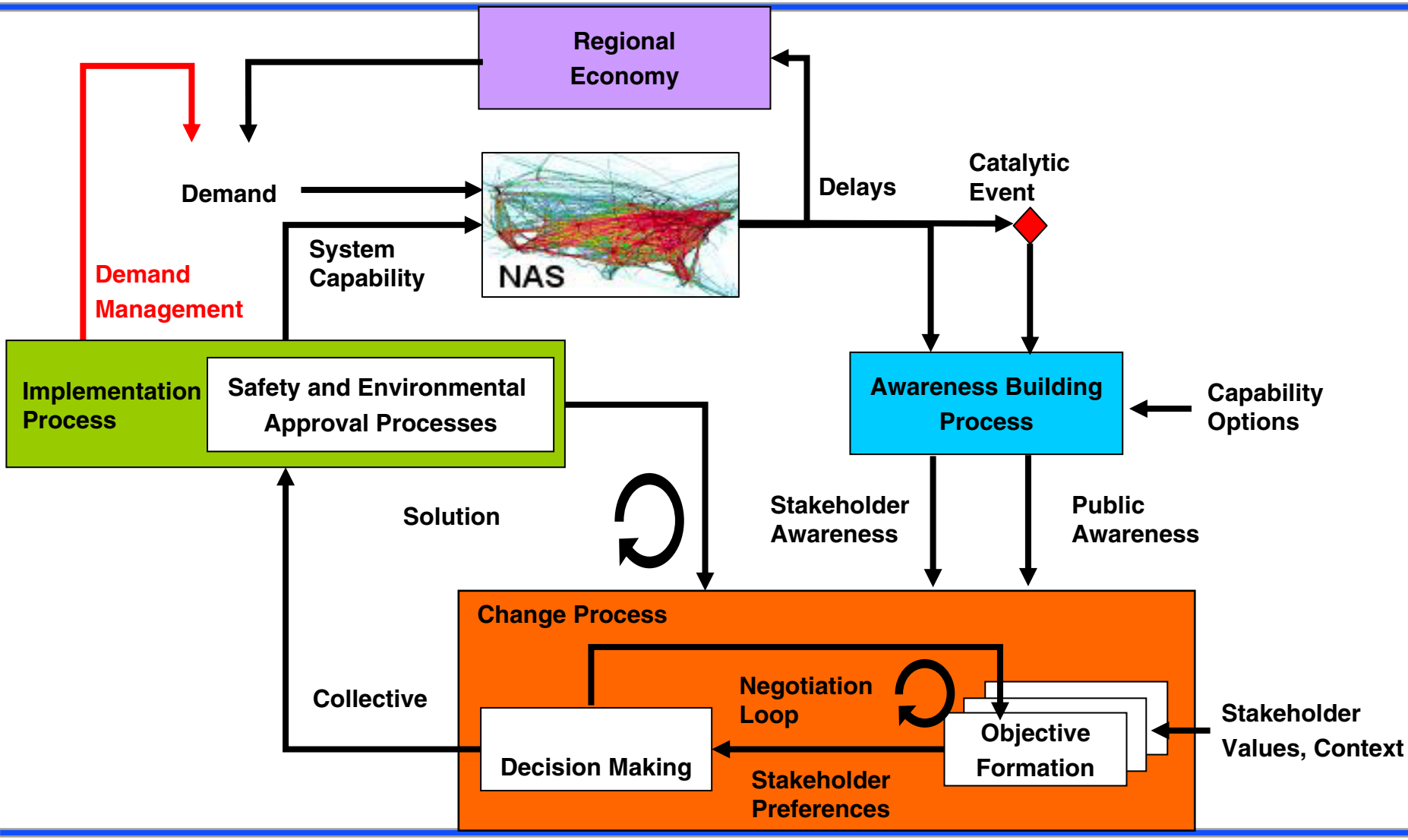
Source: William DeCota, Port Authority of New York

Flight Delays at LGA from 2000 to 2006

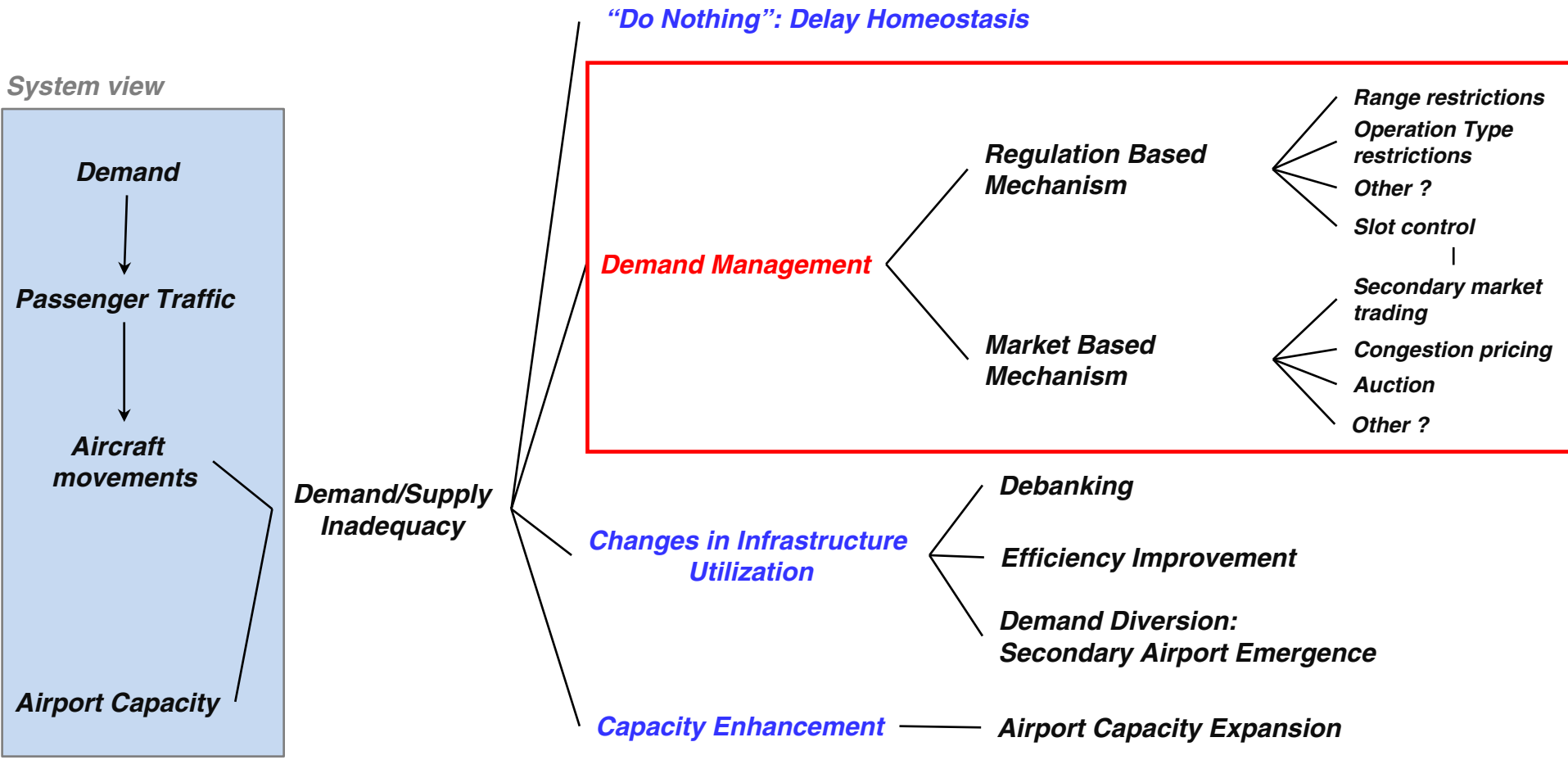


Source: FAA OPSNET data

Demand Management
Only Rapid Public Action



Solutions to Address Airport Demand/Capacity Inadequacy

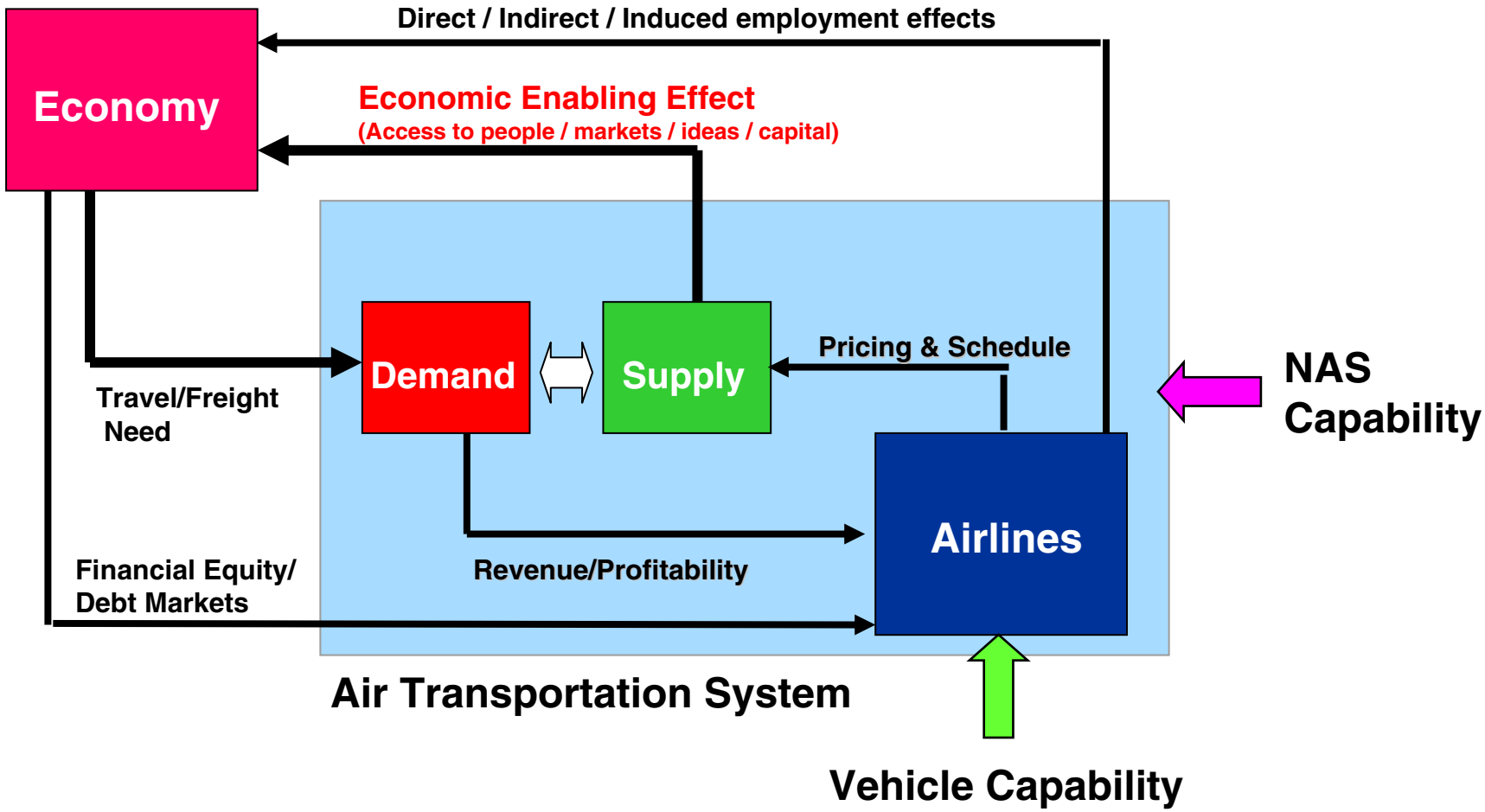


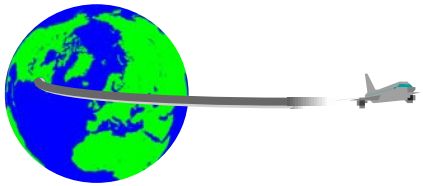
Source: Philippe Bonnefoy

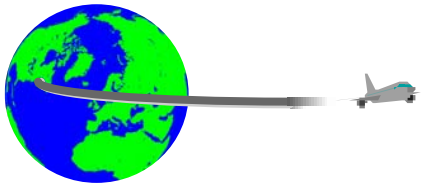
Conclusions

- **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







QuickTime™ and a
Animation decompressor
are needed to see this picture.