Modelling Airline Network Routing and Scheduling under Airport Capacity Constraints

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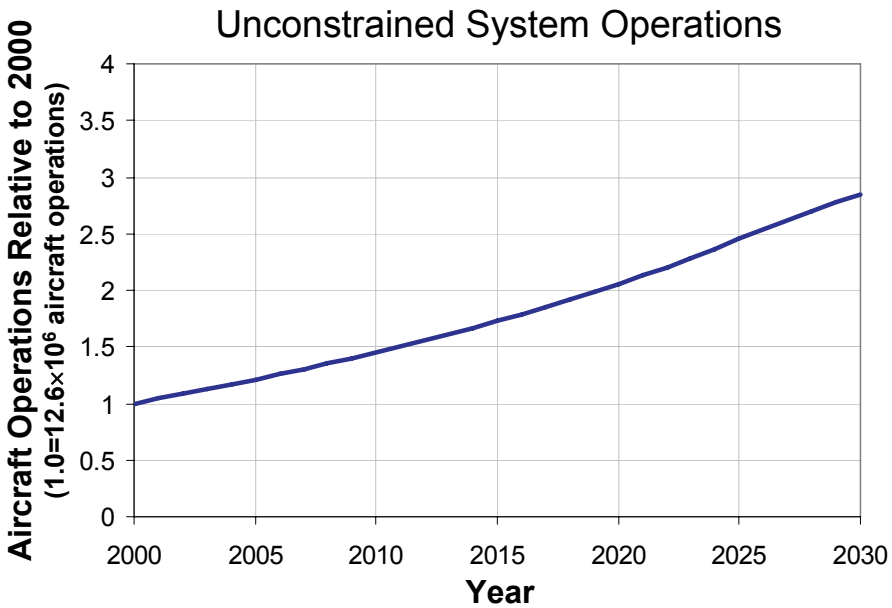
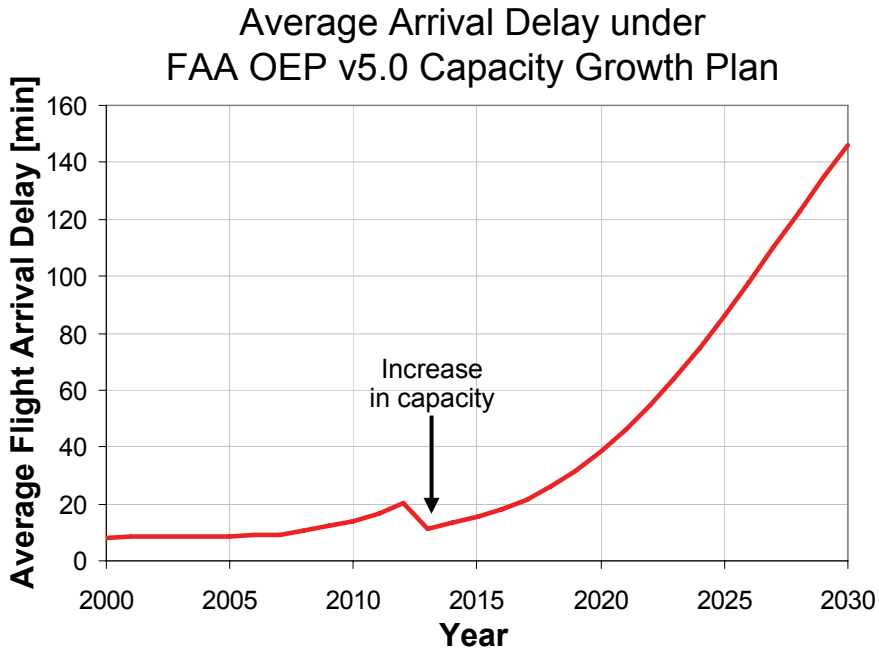
Motivation

Unconstrained US Air Transport System Growth - 50 primary airports





- Delay forecast unrealistic: Airlines and passengers would respond to delay
  - Potential impact on scheduling, aircraft operated, and routing network
  - Potential impact on air traffic growth, and emissions

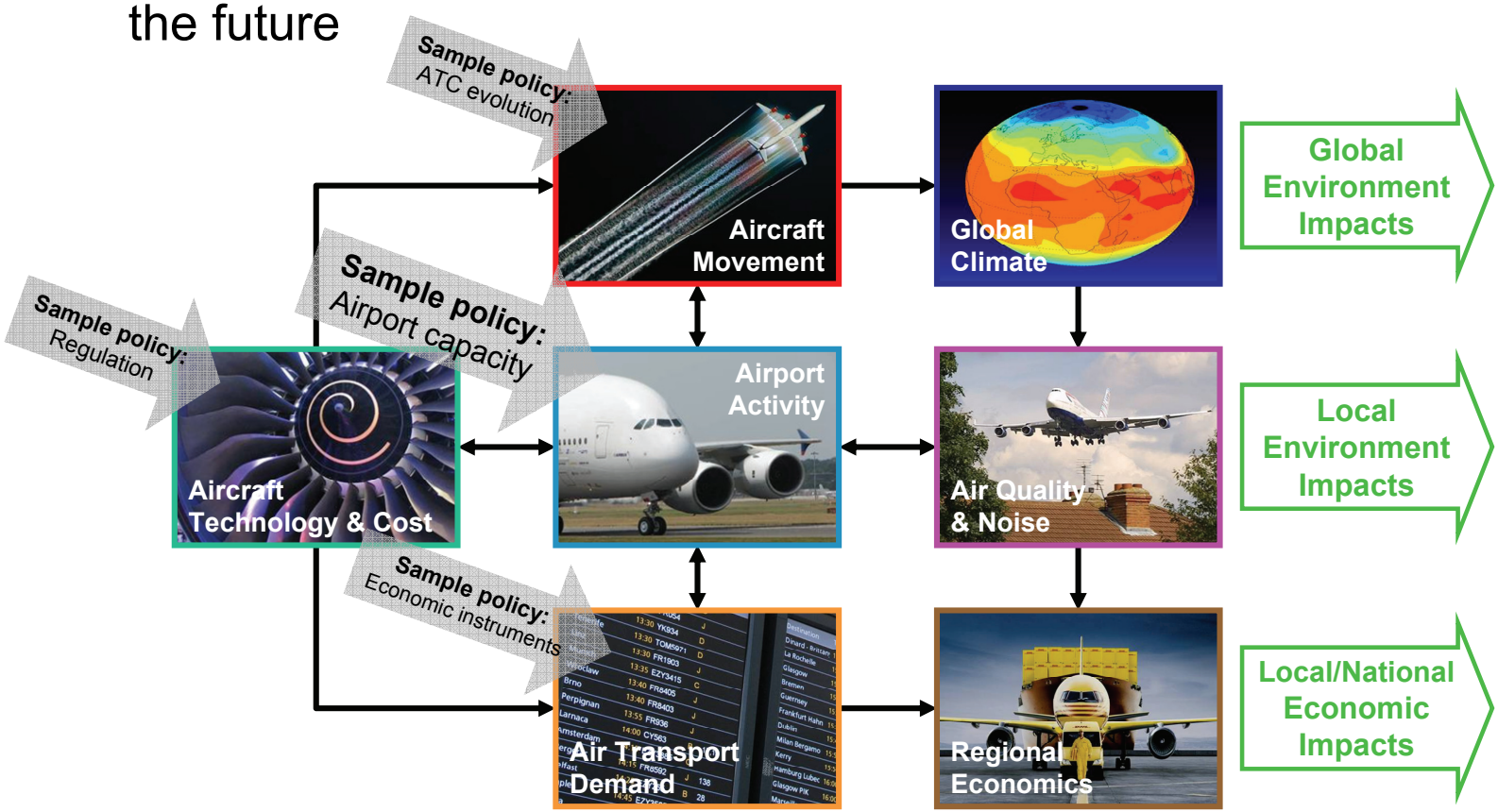
Research Objectives

- Develop model of airline network routing and scheduling responses to capacity constraints
  - Routing network changes (e.g. avoid congested hubs)
  - Changes in aircraft size
  - Schedule changes

- Model to an appropriate degree of detail to capture effect on air traffic growth and emissions
- Apply model to generate more representative estimates of traffic growth, and effects of policies relating to airport capacity

Context

- Aviation Integrated Modelling (AIM) Project
  - Goal: Develop policy assessment tool for aviation, environment & economic interactions at local & global levels, now and into the future



Methodology

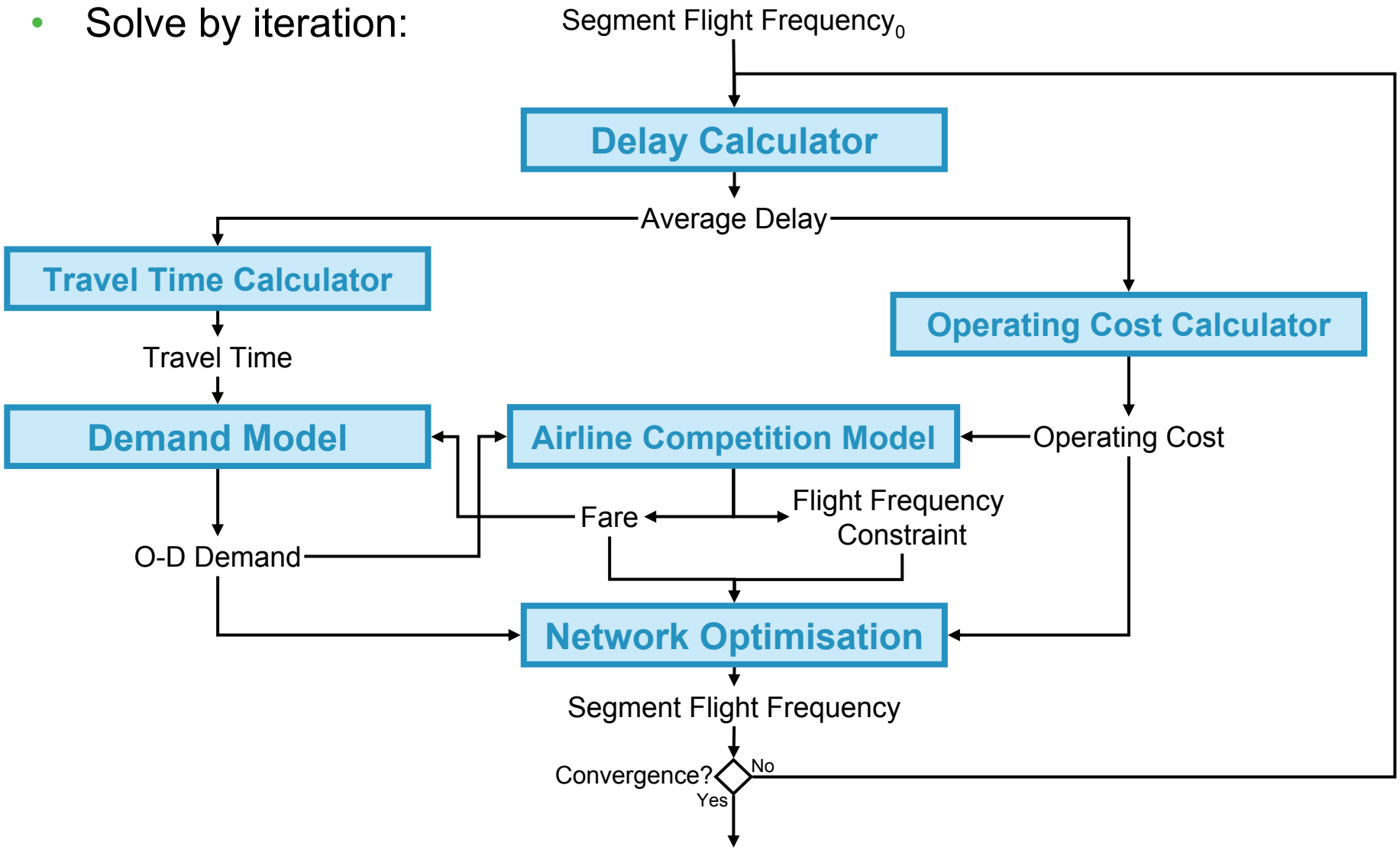
- Select schedule, aircraft and routing network to maximize airline system profit:

$$\max\left(\sum_{i,j}\sum_{p\in Itin_{i,j}}\overline{Fare}_{i,j}\cdot Pax_{i,j}^{p}-\sum_{m,n,k}Cost_{f\,m,n,k}\cdot Fltfreq_{m,n,k}-\sum_{i,j}\sum_{p\in P_{i,j}}Cost_{p\,i,j}\cdot Pax_{i,j}^{p}\right)$$

  - Passenger demand (Pax) a function (among others) of delay (travel time) and fare ($Fare$) – modelled by a Demand Model
  - Operating cost ($Cost_f$ & $Cost_p$) a function (among others) of delay – modeled by an Operating Cost Calculator
  - Delay (among others) a function of flight frequency ($FltFreq$) – modeled by a Delay Calculator
  - Fare ($Fare$) and flight frequency ($FltFreq$) constrained by competition – modeled by an Airline Competition Model

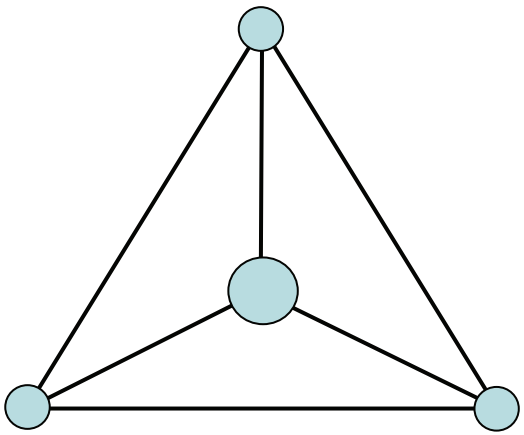
Methodology

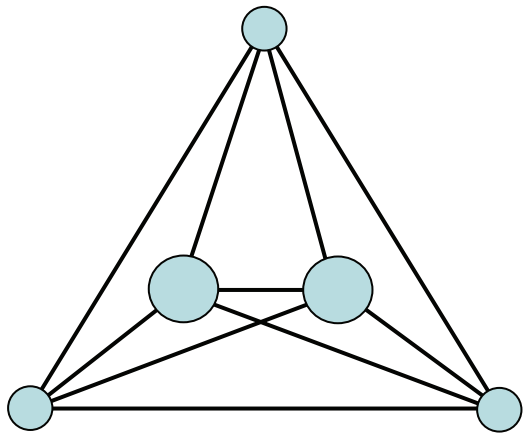
- Solve by iteration:

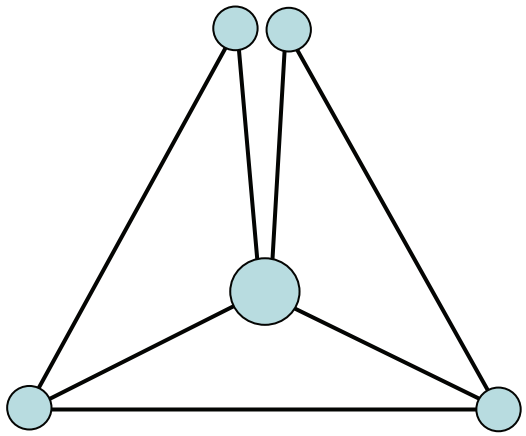


Sample Results

- Theoretical networks
  - Basic: Three spoke airports surrounding a hub
  - Multiple hubs: Three spoke airports surrounds two hubs
  - Secondary airports: Three spoke cities – one with two airports – surrounding a hub



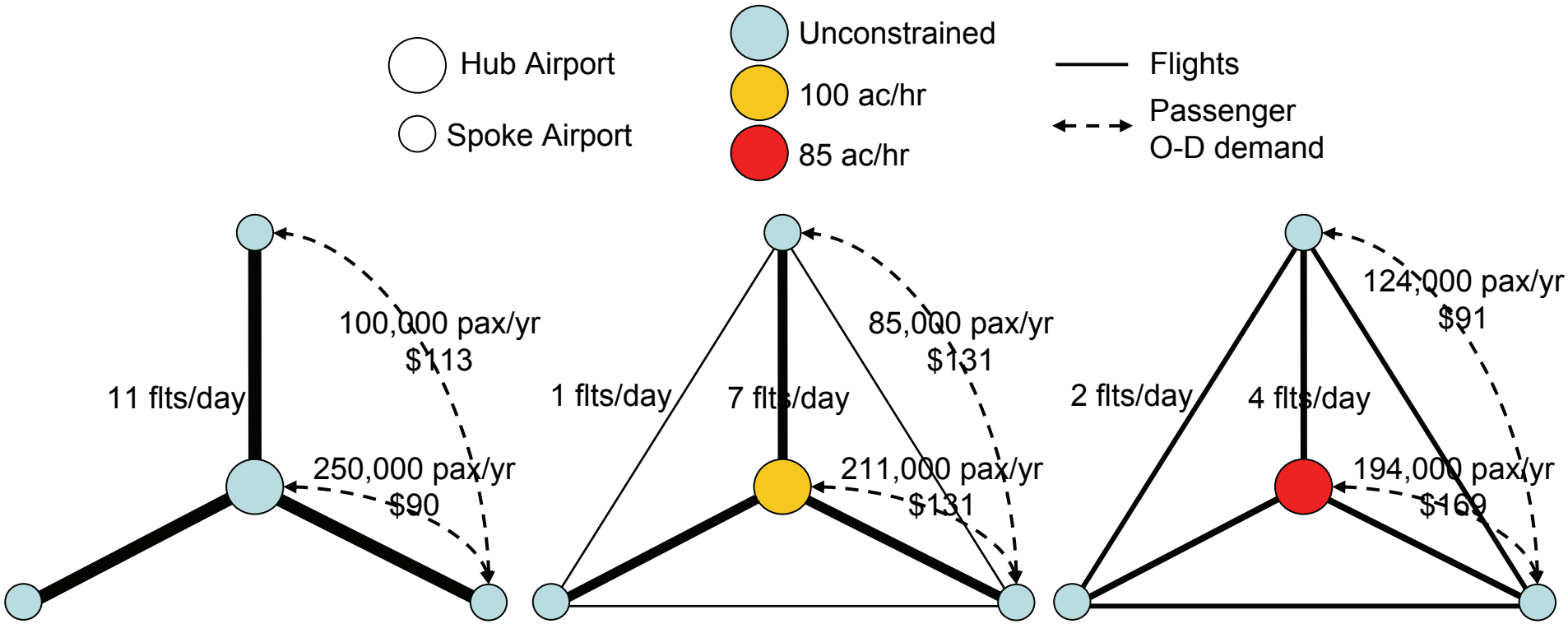




- Actual network
  - 10 busiest origin-destination cities in US

Hub and Spoke Networks

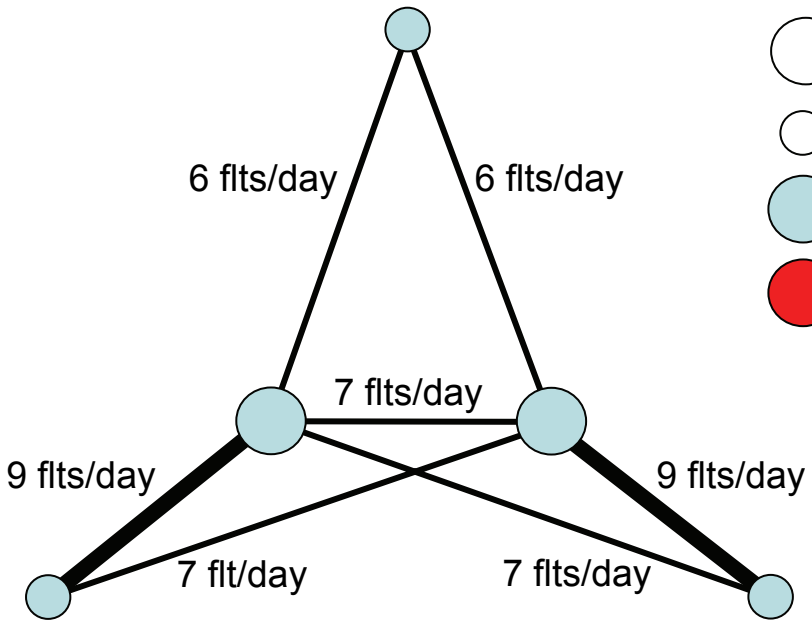
- Sample results for effects of delay on a simple hub and spoke network with **varying hub capacity constraints**



- As hub capacity constraint increases the system shifts from a pure hub-and-spoke network to a pure point-to-point network

Multiple Hubs

- Sample results for effects of delay on a theoretical hub and spoke network with **multiple hubs**



Unconstrained Scenario

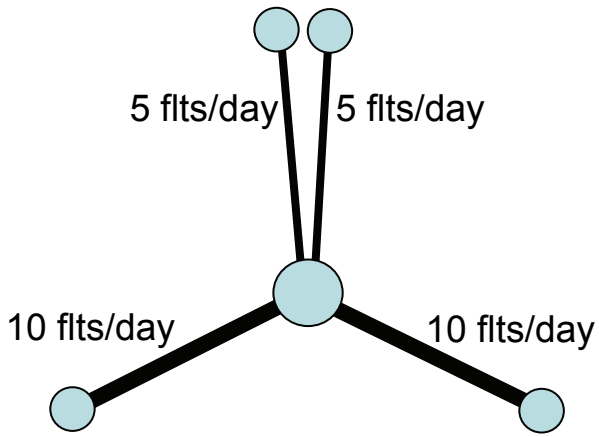
- Symmetry
- Extensive use of both hubs

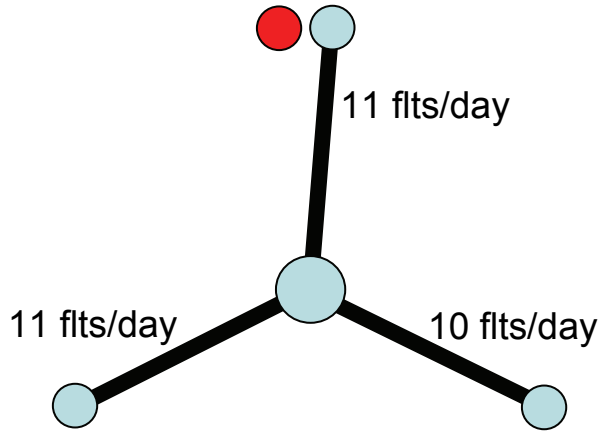
Single Constrained Hub

- All connections through unconstrained hub
- Point-to-point flights

Multi-Airport Systems

- Sample results for effects of delay on a theoretical hub and spoke network with **multiple airport cities**



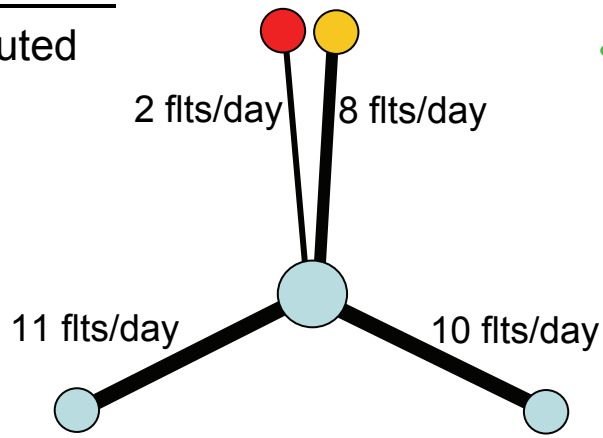


Unconstrained Scenario

- Flights evenly distributed between city airports

Single City Airport Constrained

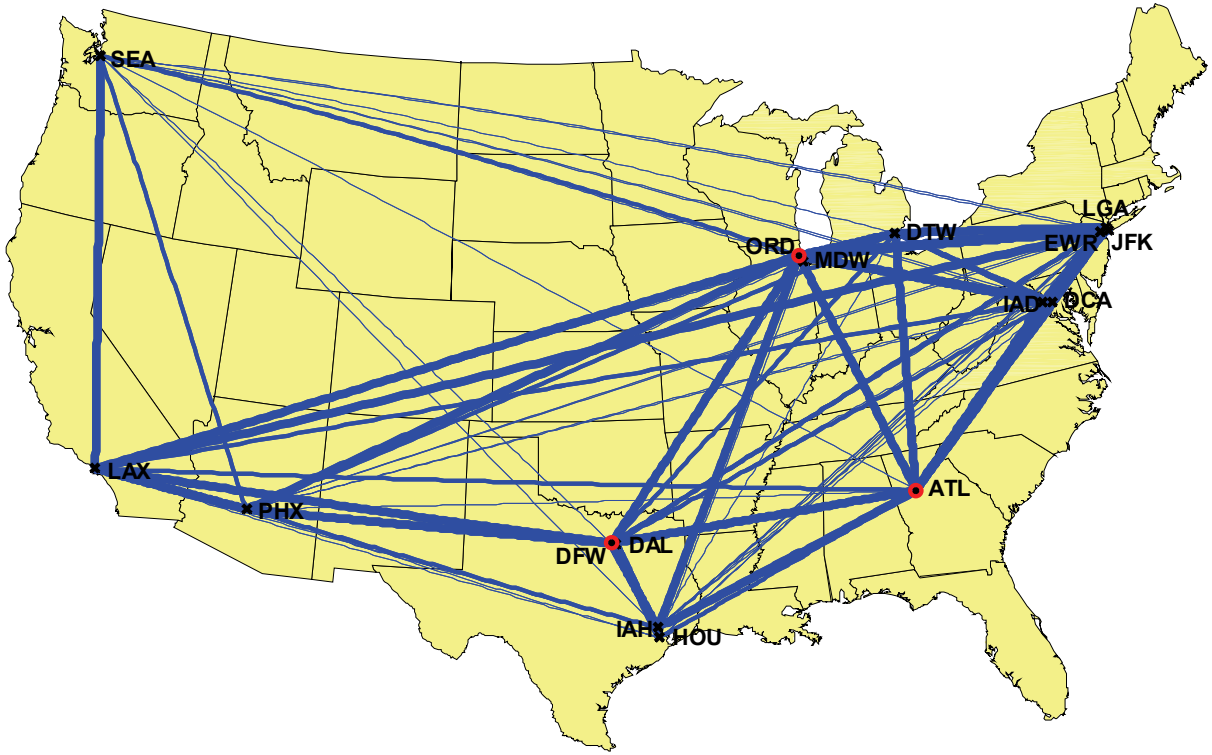
- All flights to unconstrained airport



City Airport Constrained Differently

- Flights distributed between city airports

Actual Network

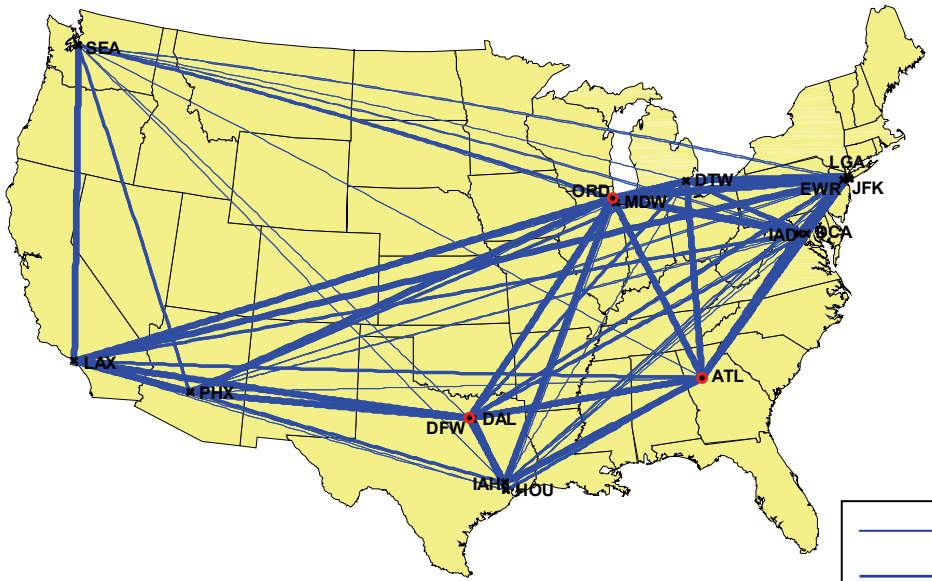


Actual Data
2005

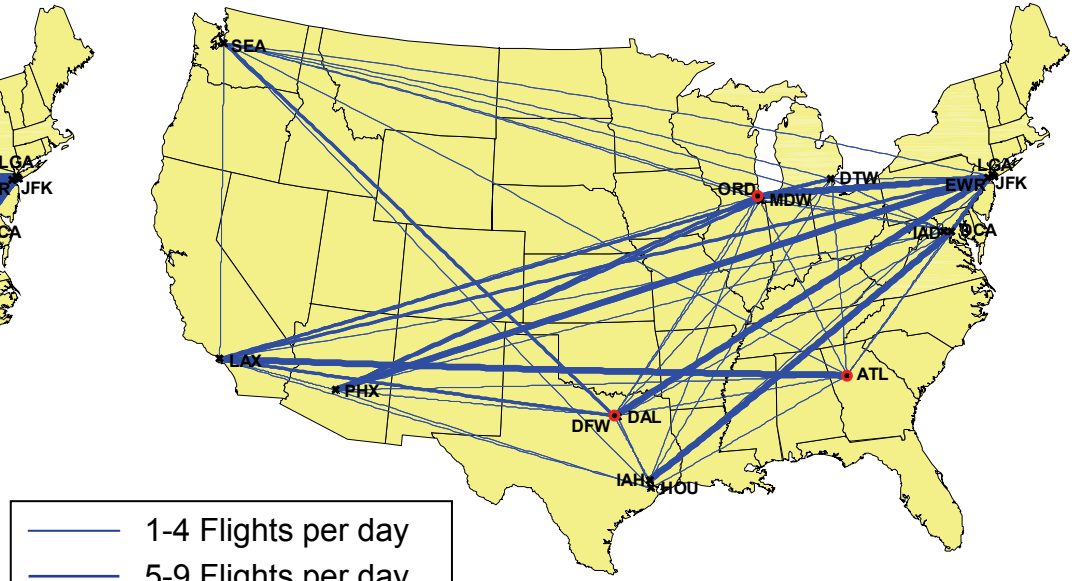
- 1-4 Flights per day
- 5-9 Flights per day
- 10-14 Flights per day
- >15 Flights per day

- 10 highest O-D passenger demand cities in US in 2005
- 16 airports modelled
- 3 hubs modelled (ORD, ATL, DFW)

Actual Network applying Model



Actual Data
2005



Model Results
2005

1-4 Flights per day
5-9 Flights per day
10-14 Flights per day
>15 Flights per day

	Avg. % deviation by O-D market/segment
Flight Frequency	36% low
Fare	12% low
O-D pax demand	6% high

Future Work

- Improve model performance in predicting flight frequencies
  - Significant airline constraints not included?
    - Fleet, aircraft type restrictions, load factors, primary/secondary airport use, hub use
  - Artefact of modeling simplifications?
    - no passenger choice modeling, not modeling leisure and business separately, no revenue management modeling
- Apply to forecast impact of capacity constraints in US in 2030/2050
- Apply to other regions, e.g. India