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Institute for Aviation and the Environment

How are Airlines Likely to Respond to Congestion?

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MIT Portugal AirNets Workshop

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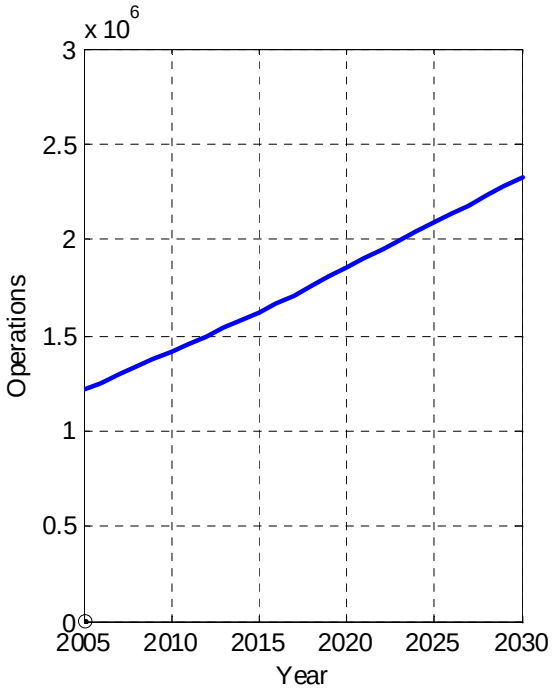
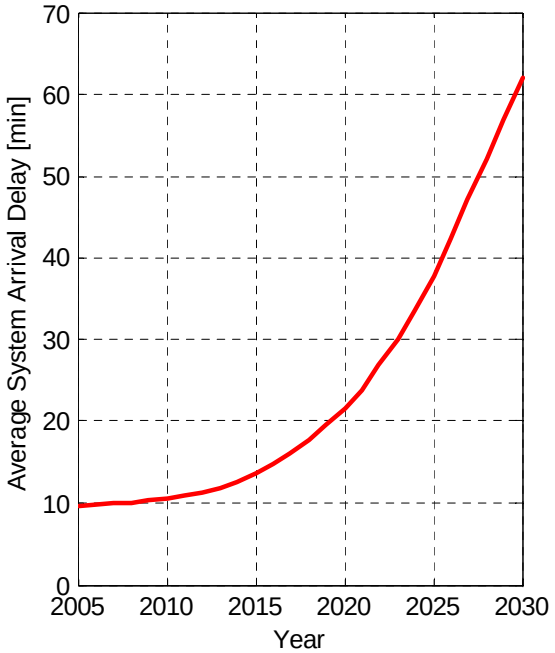
Motivation

Unconstrained forecast of US domestic air transport system growth
Network of 22 primary airports

System Operations



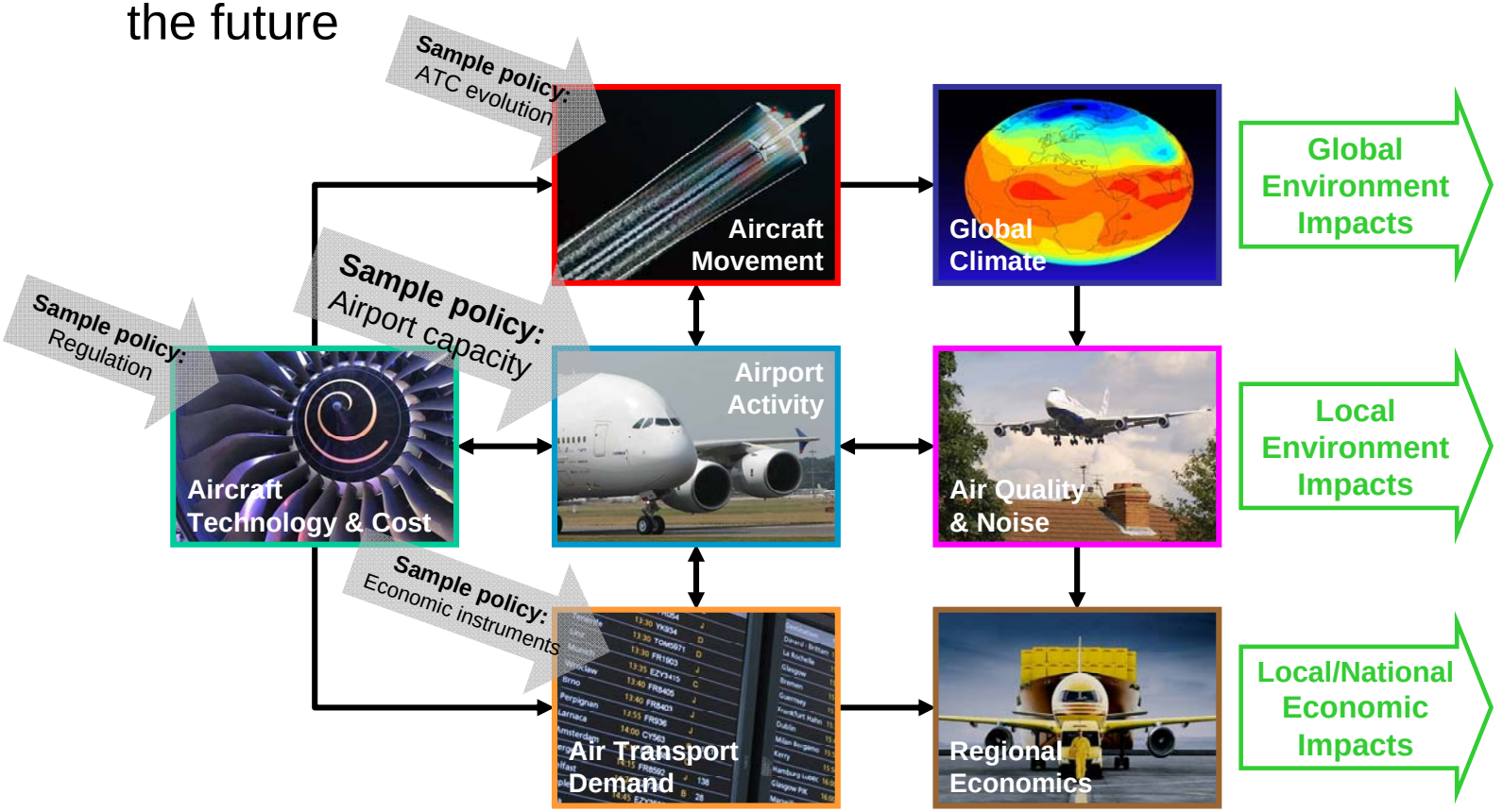
Average Airport Arrival Delay



- 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

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



Objectives & Methodology

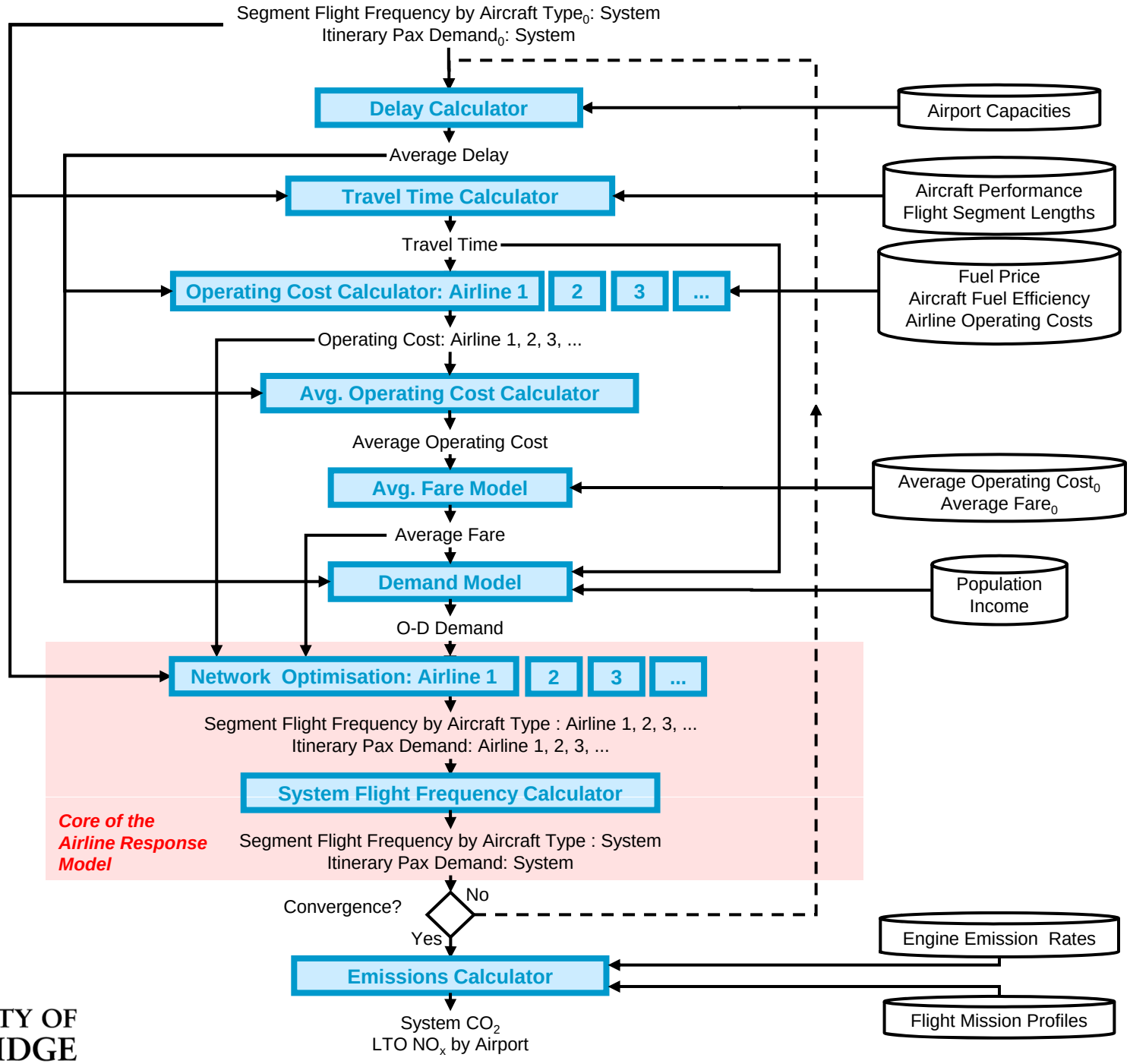
- Objective: Develop a model of airline operational responses to airport capacity constraints
  - Routing network changes
    - Avoiding congested hubs
    - Shift to secondary airports
  - Changes in flight frequency
  - Changes in aircraft size
- Methodology: Select each airline's routing network, flight frequencies, and aircraft to maximize individual profit
  - Simulate game between airlines to capture effects of competition endogenously
  - Model effects of airport capacity constraints on airline costs and demand endogenously

Methodology

- Airline profit function:

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

- Decision variables: Segment flight frequency ($Fltfreq_{m,n,k,a}$), passenger itinerary demand ($Pax_{i,j,p,a}$)
- Constraints:
  - Demand constraint: $$\sum_{p\in Itin_{i,j}}Pax_{i,j,p,a}\le\frac{Fltfreq_{i,j,a}}{\sum_{a\in A}Fltfreq_{i,j,a}}\times D_{i,j}$$
  - Seat constraint: $$Pax_{m,n,k}<LF_{\max}\cdot Seats_{m,n,k}$$
  - Airport balance constraint: $$\sum_{n,k}Fltfreq_{m,n,k}=\sum_{n,k}Fltfreq_{n,m,k}$$
  - Only non-stop and single connection itineraries modeled



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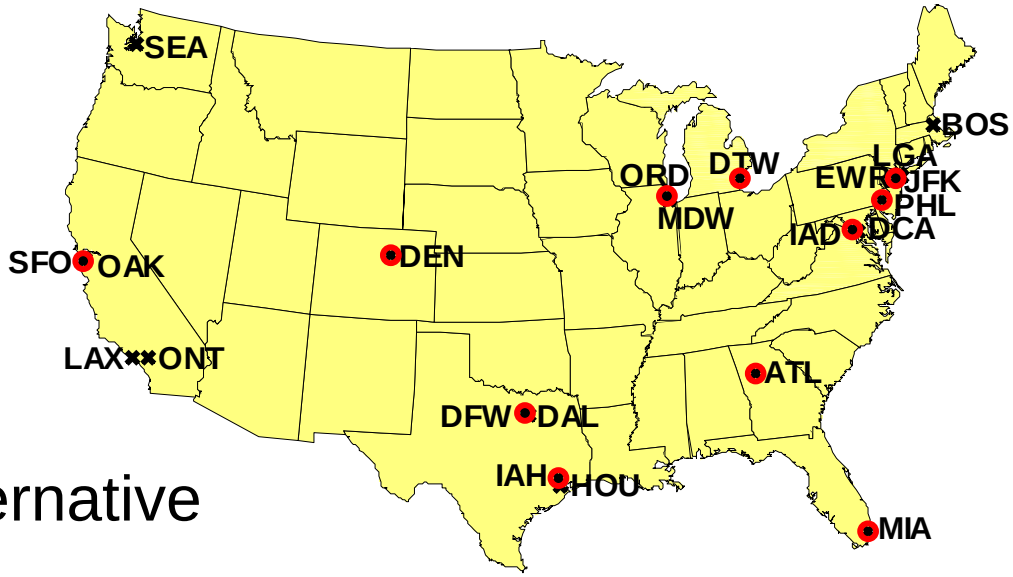
Sample Problem

- Model 5 airlines in 14 cities / 22 airports / 11 hubs in the US
  - Served 75% of scheduled flights in the domestic US in 2005

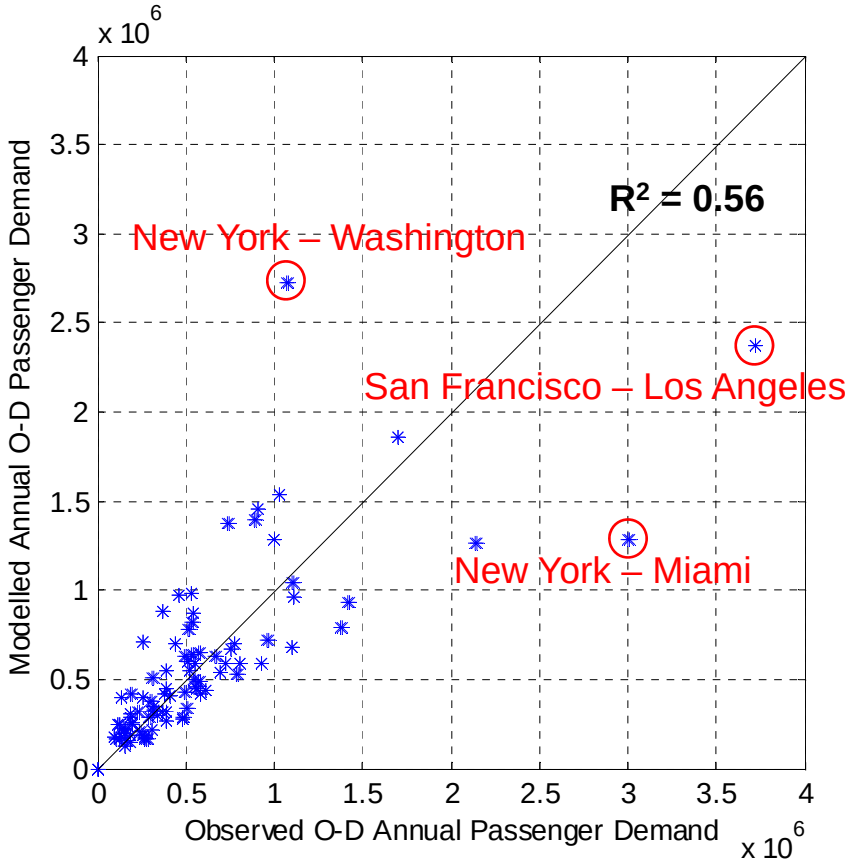
- Validate model by comparing results with 2005 input data to observed data for 2005



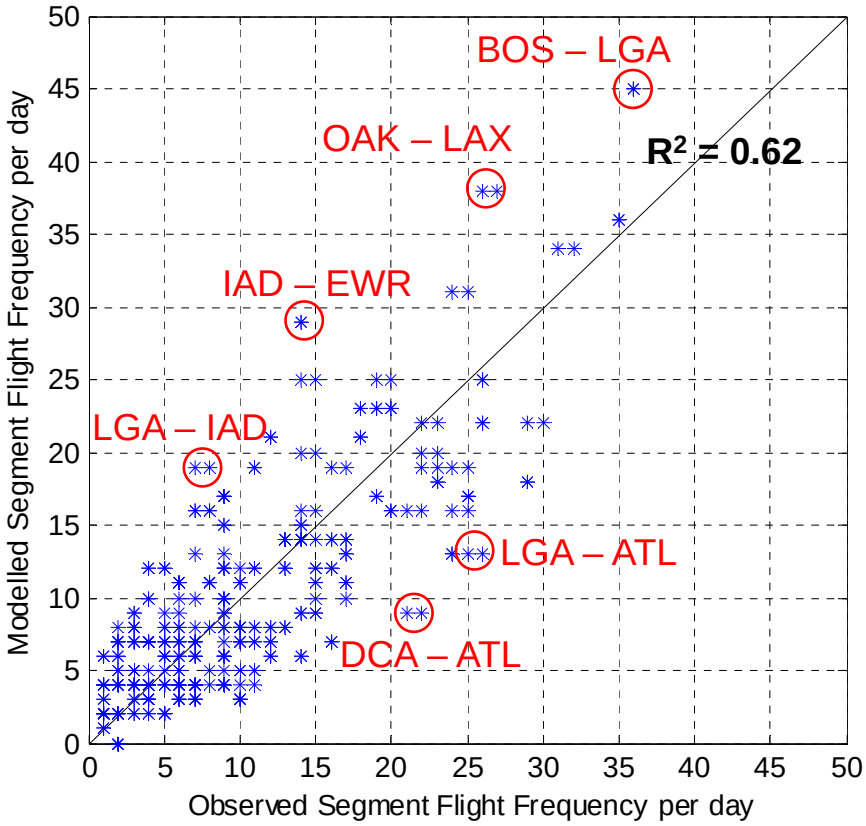
- Simulate to 2030 under alternative airport capacity scenarios
  - Proposed airport capacity expansion
  - No airport capacity expansion
  - No airport capacity expansion at ORD, proposed elsewhere

Model Validation

- Comparison of modelled and simulated passenger demand and flight frequencies: Outliers in multi-airport systems



% Difference across System = 1%



% Difference across System = 3%

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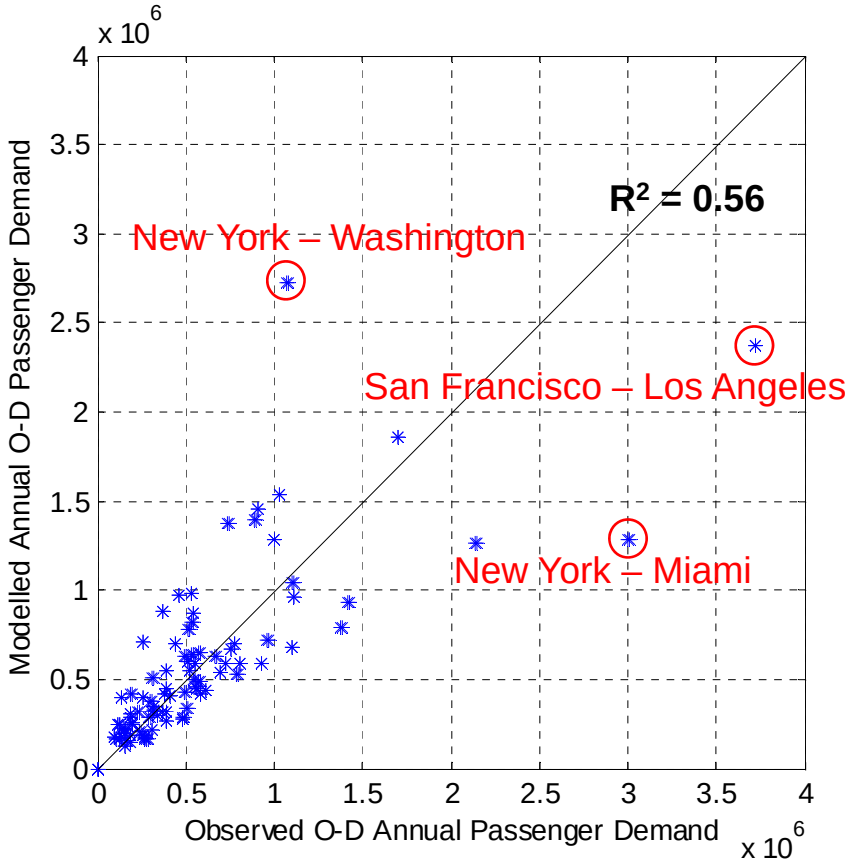

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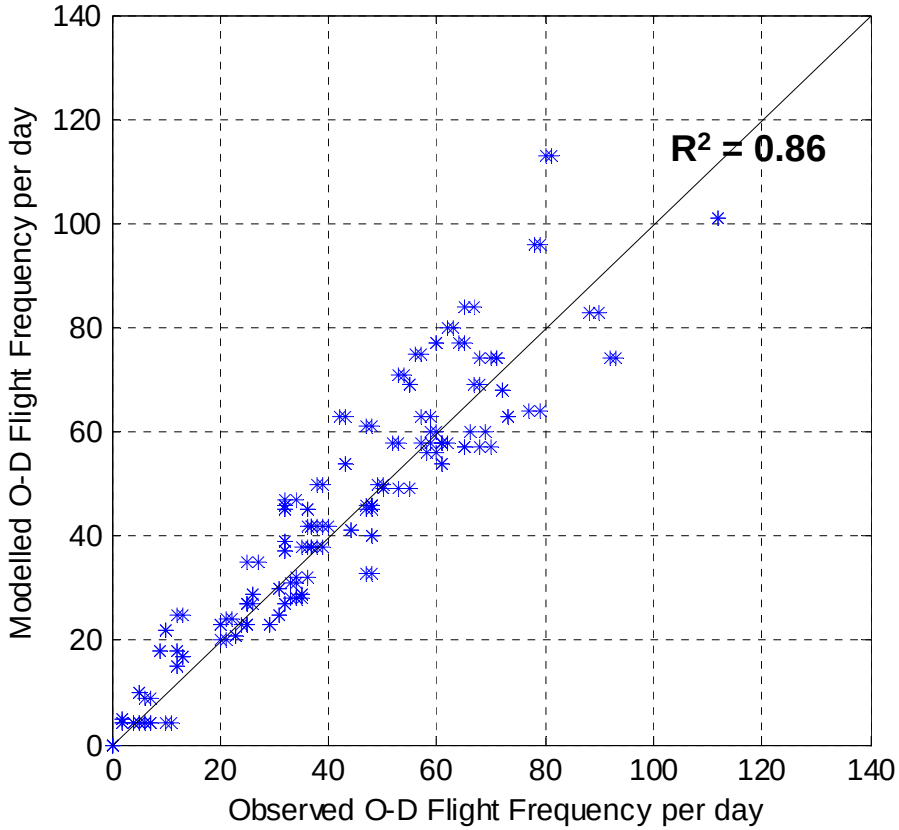
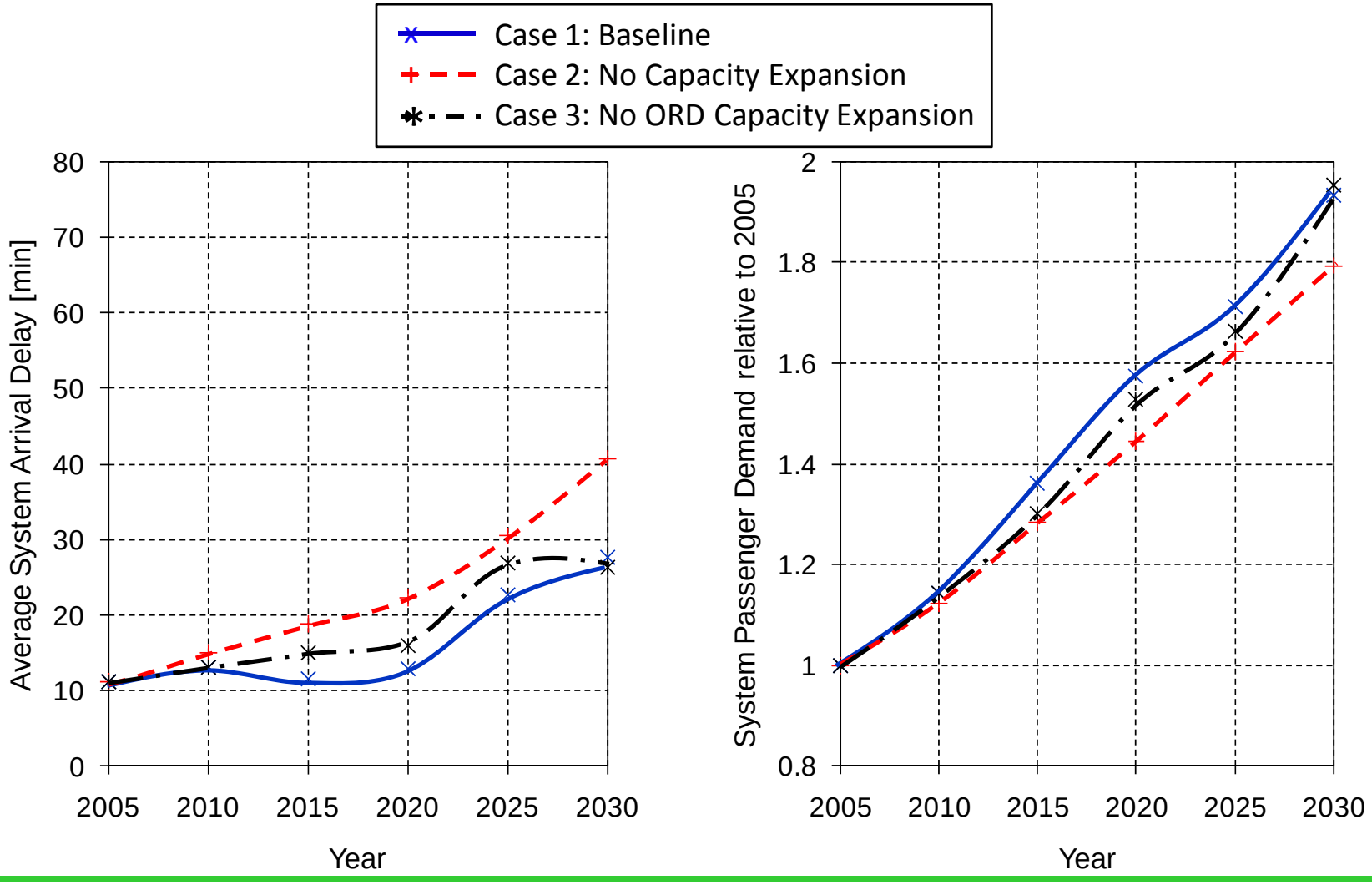


% Difference across System = 2%

Simulating to 2030: System-Wide

- Population, income, oil price based on MIT CCSP (2007) IGSM scenario



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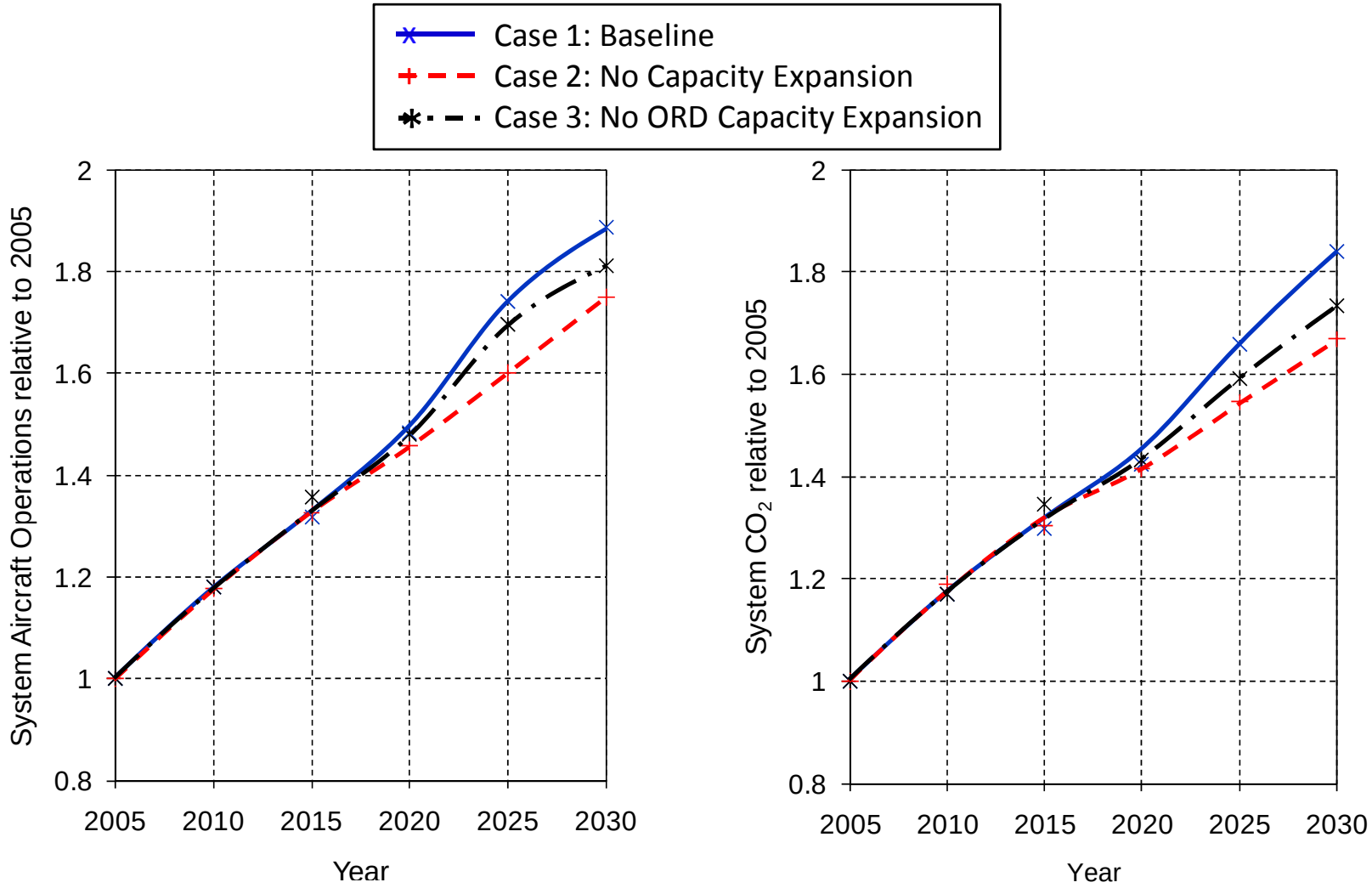
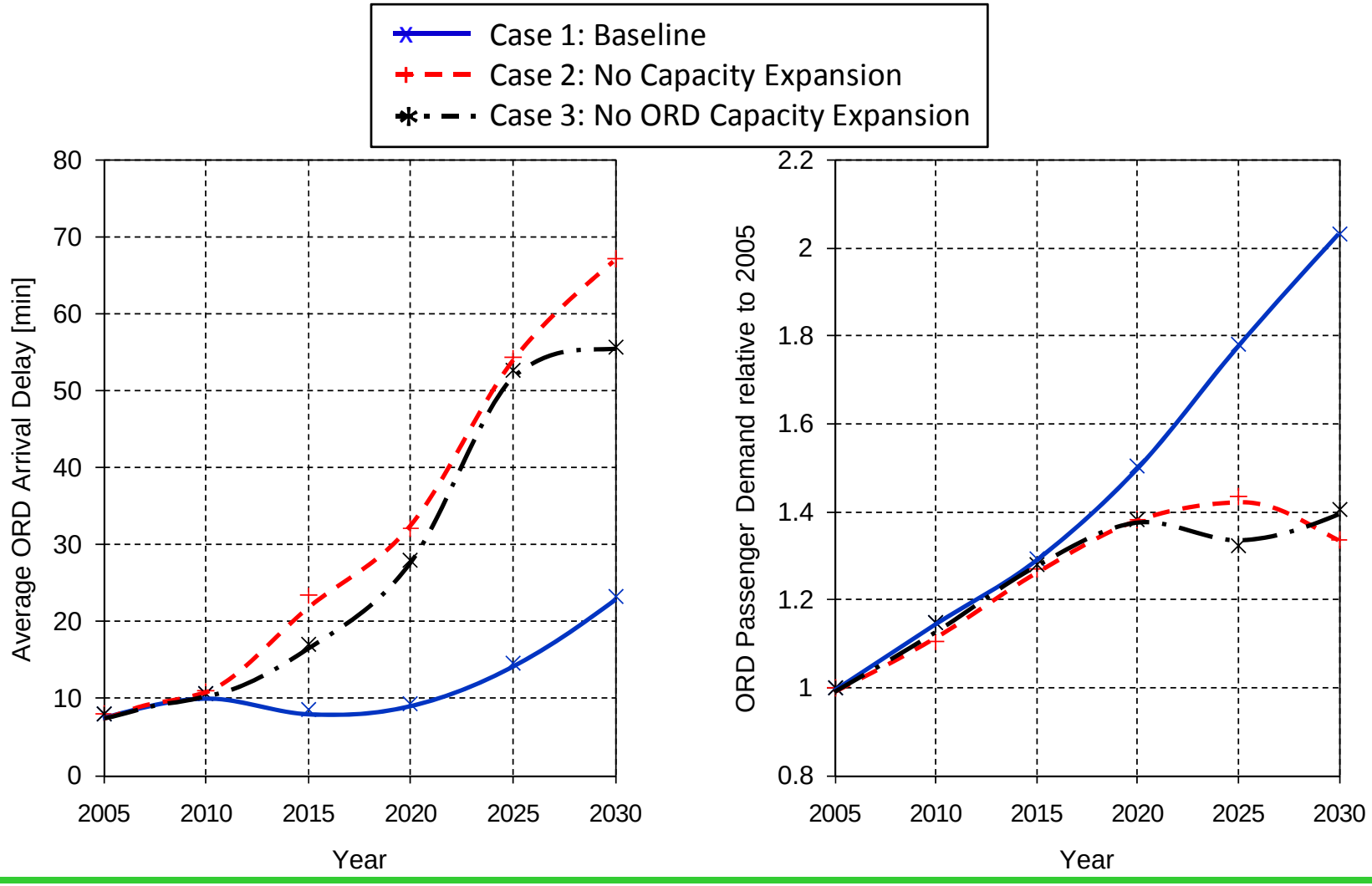


Simulating to 2030: ORD

- Local effects of airport capacity constraints are significantly greater



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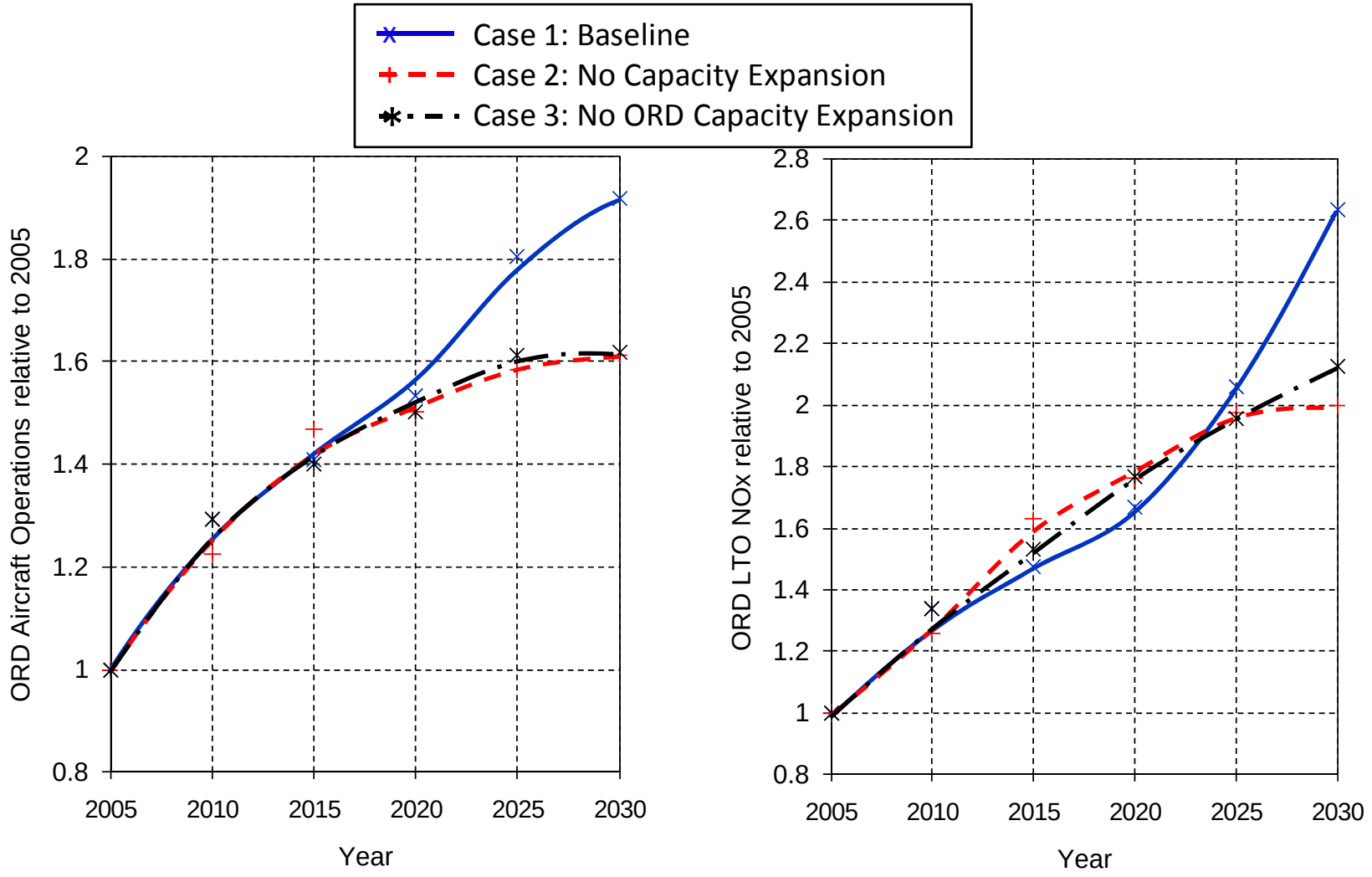
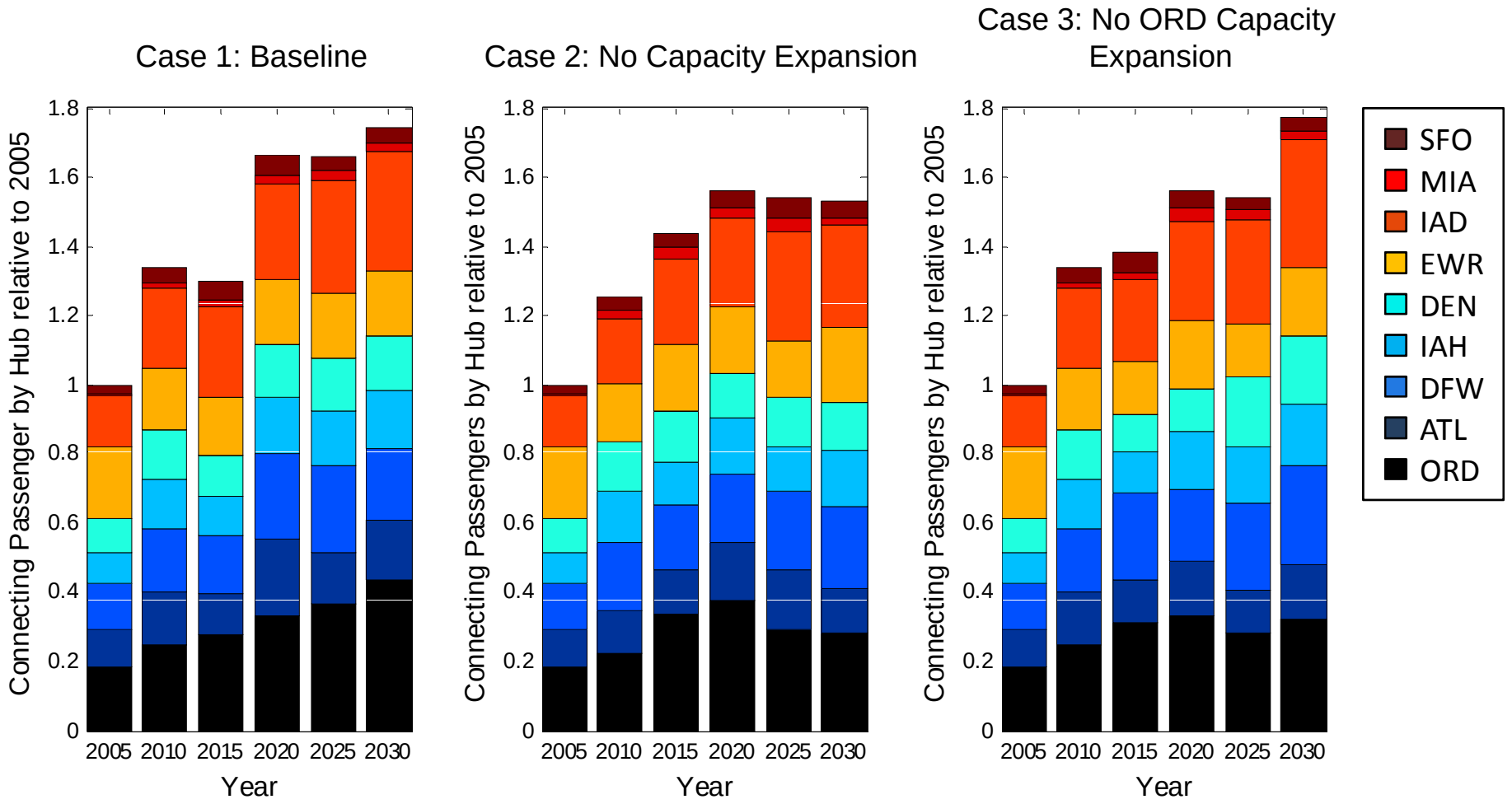


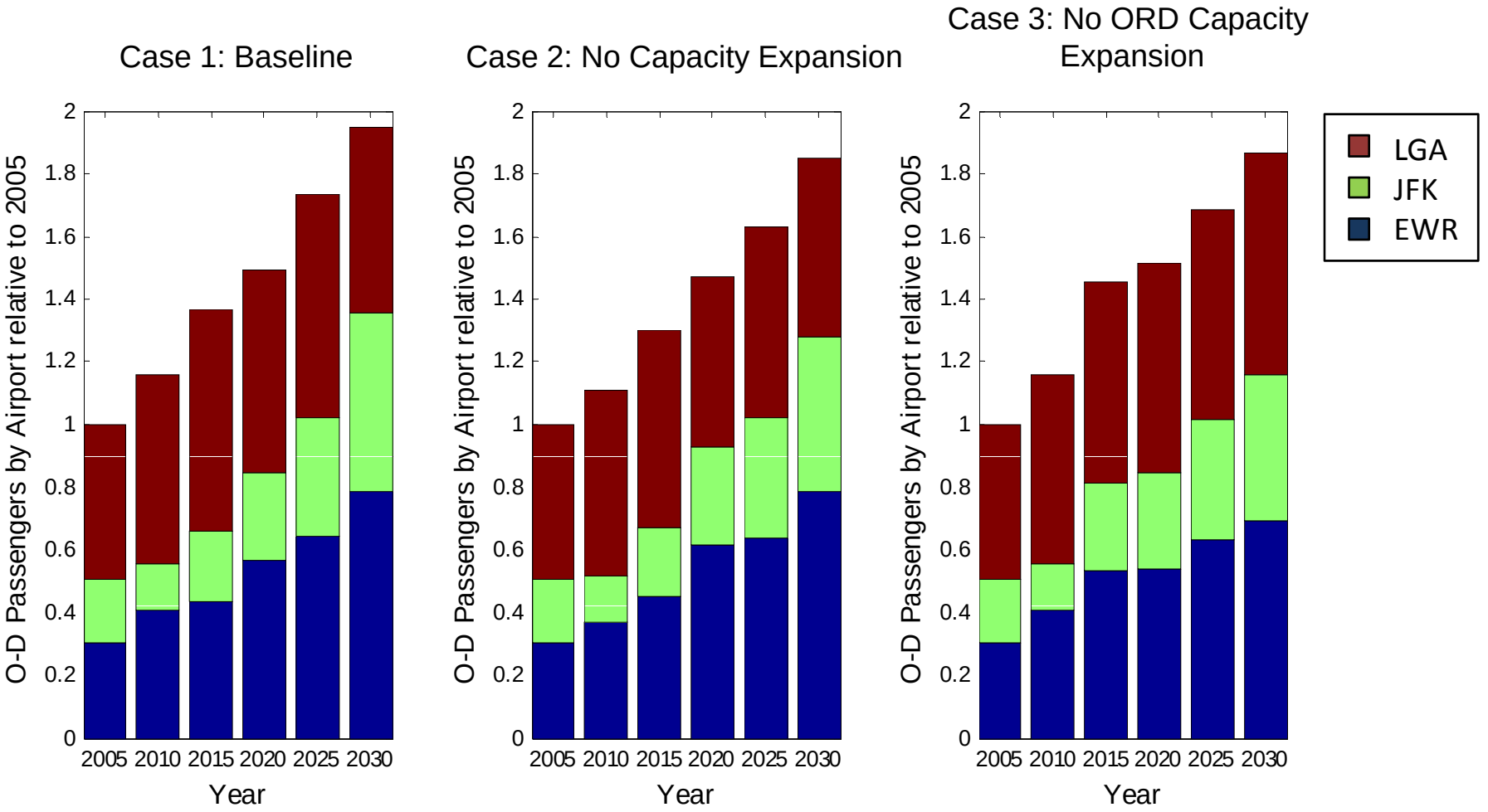
Simulating to 2030: Hubs

- Airport capacity constraints can induce a shift in traffic to other hubs, if capacity is available elsewhere



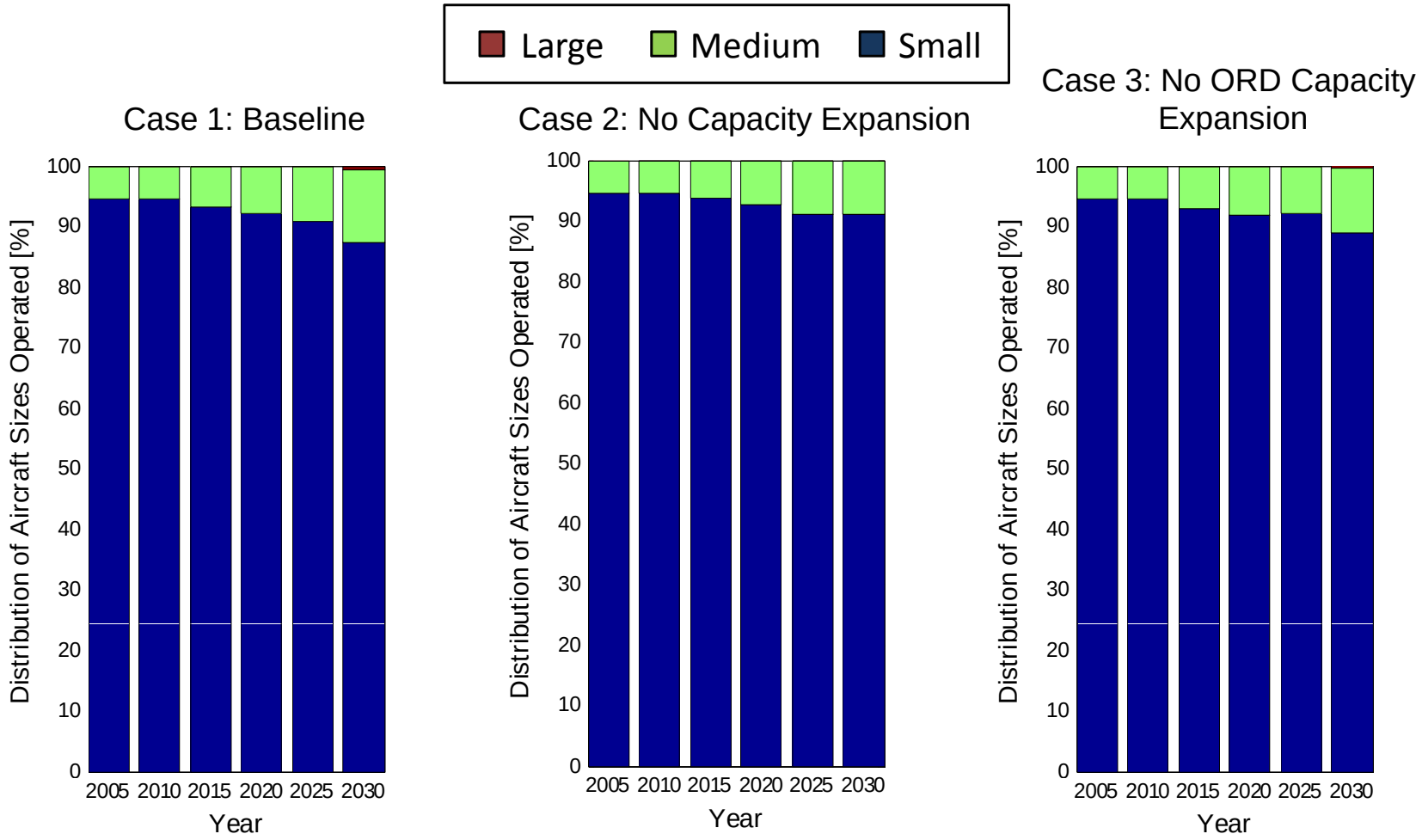
Simulating to 2030: Multi-Airport Systems

- Airport capacity constraint can induce a shift in traffic between airports in multi-airport systems



Simulating to 2030: Aircraft Size

- Because of frequency competition effects, airport capacity constraints may lead to little change in aircraft size.



Conclusions

- A model was developed that simulates airline operational responses to airport capacity constraints
- The model was validated by applying it to a network of 22 airports and 14 cities in the United States in 2005
- The model was applied to simulate what the likely airlines responses would be to congestion in the US through 2030:
  - The most significant airline response to congestion is likely to be a reduction in flight frequencies in response to reductions in passenger demand
  - Airlines are likely to shift connecting passengers to less congested hubs
  - Airlines are also likely to shift traffic between airports in multi-airport systems
  - Because of frequency competition effects, airlines may not increase aircraft sizes
- Increased airport capacity is required in the US to maintain delays at manageable levels, either through existing airport capacity expansion or the development of new airports.