NAS Strategy Simulator– Fleet Mix Module

Chieh-Yu Hsiao

Mark Hansen

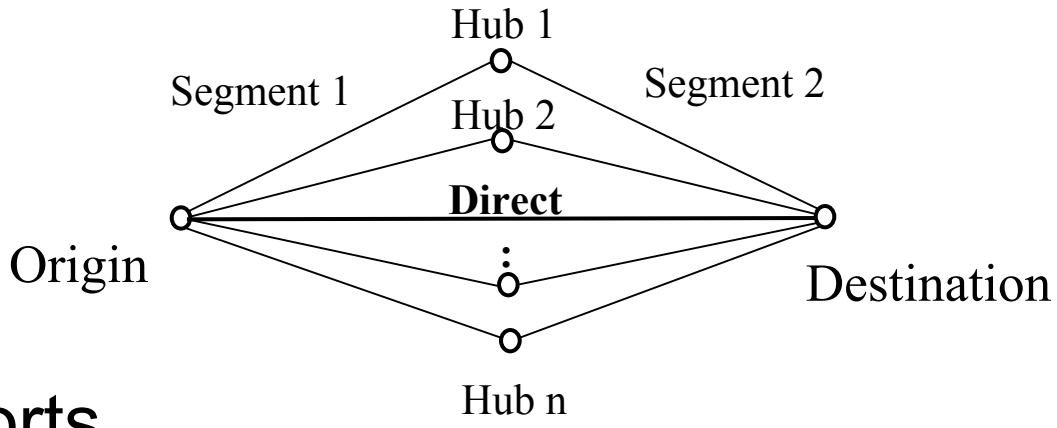
10/20/03

Outline

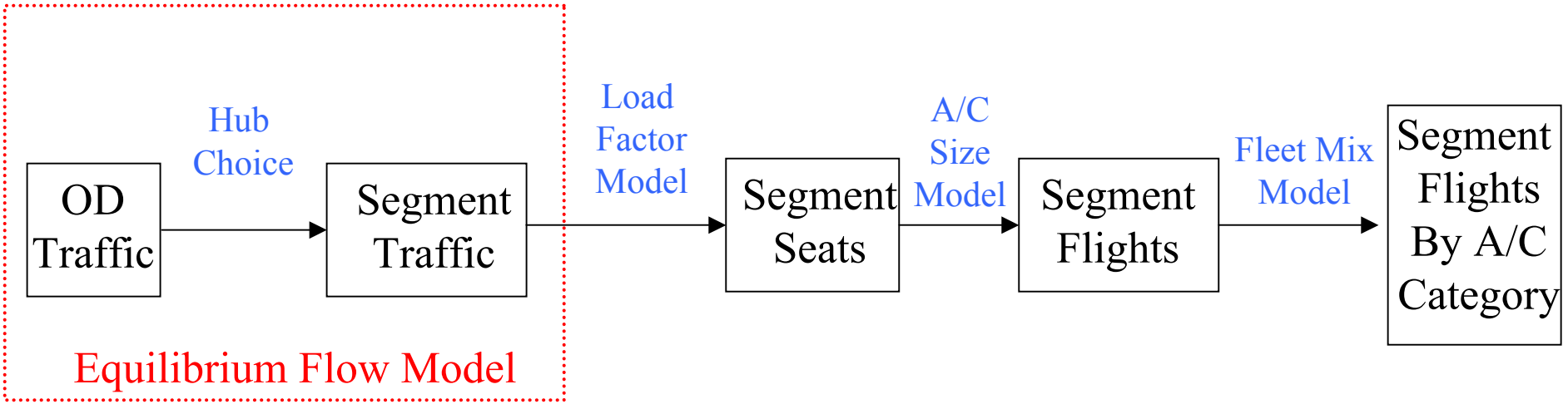
- The Problem
- Approaches
  - Framework
  - Four models
    - ✓ Equilibrium Flow Model
    - ✓ Load Factor Model
    - ✓ Aircraft Size Model
    - ✓ Fleet Mix Model
- Future Research

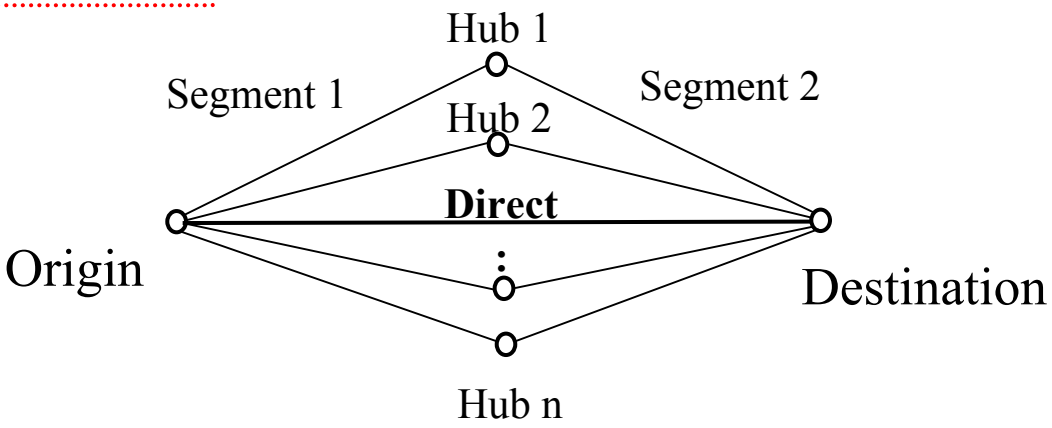
Problem

- Given the OD demand, predict
  - Segment traffic
  - Fleet mix
- Scope: 31 Benchmark Airports

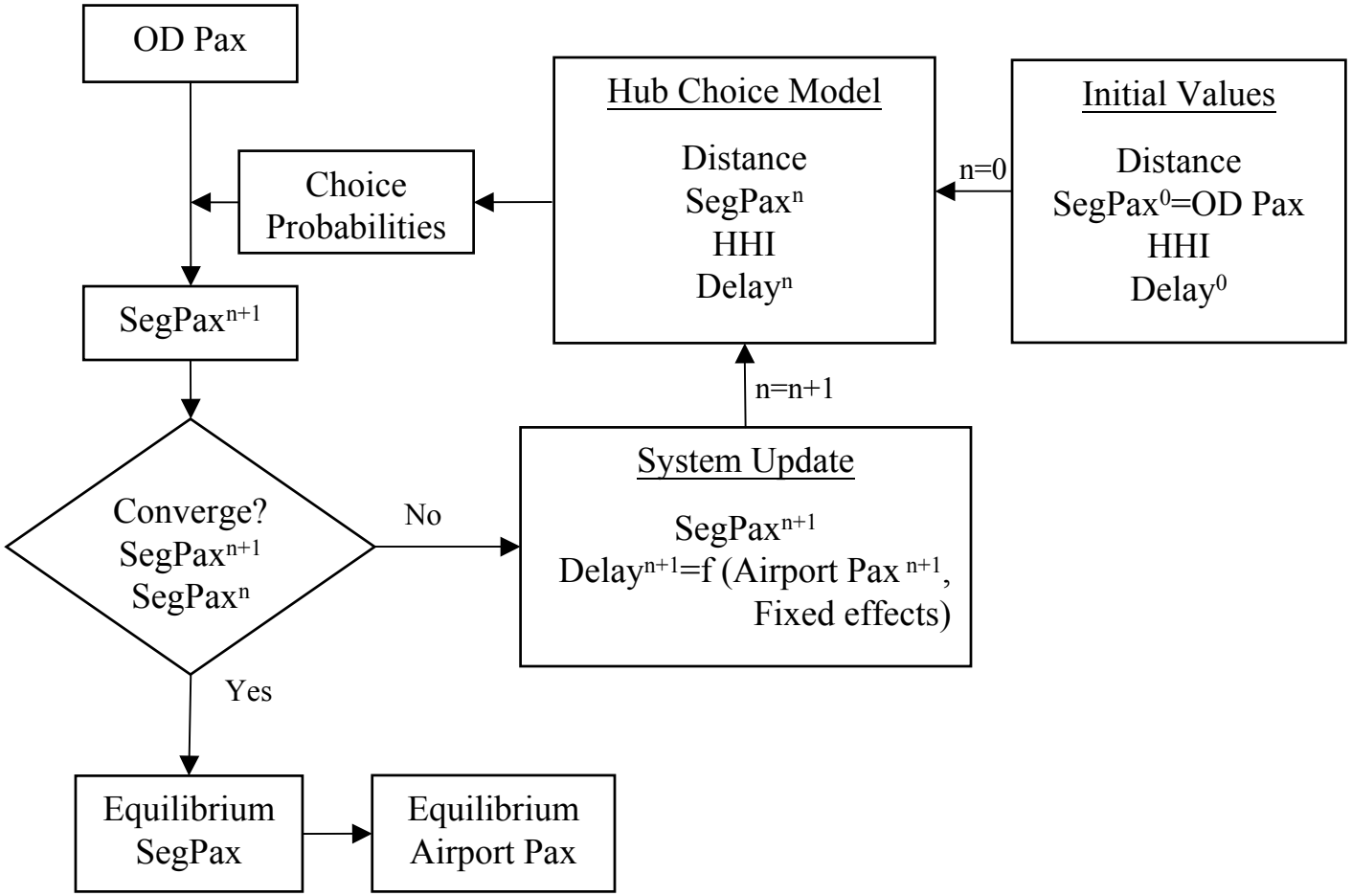


Framework


OD Traffic
Hub Choice
Segment Traffic
Load Factor Model
Segment Seats
A/C Size Model
Segment Flights
Fleet Mix Model
Segment Flights By A/C Category
Equilibrium Flow Model

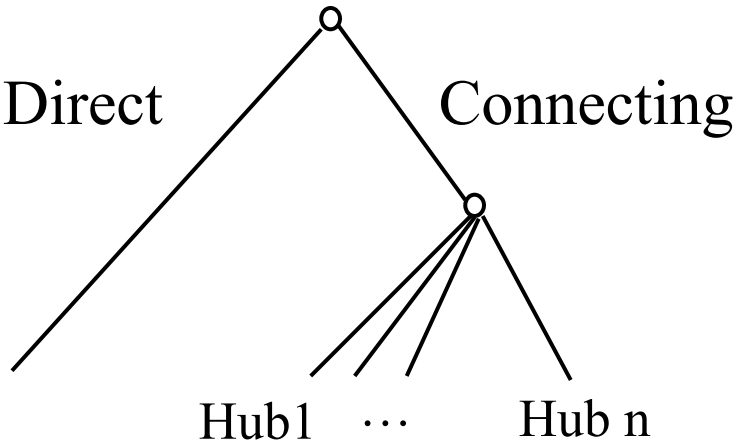

Hub 1
Segment 1
Segment 2
Hub 2
Direct
Origin
Destination
Hub n

Equilibrium Flow Model



Hub Choice Model

- Allocates OD Traffic to Segment Traffic—Route (hub) Choice
- Nested Logit Model
  - Direct or one-stop connecting
  - Conditioned on connecting, choose the connecting airport(hub)



Model Specification

$$P_{od}(Direct) = \frac{\exp(V_{direct})}{\exp(V_{direct}) + (\sum_i \exp(\beta V_{od,i}))^{1/\beta}}; P_{od}(Hub:i \mid Connect) = \frac{\exp(V_{od,i})}{\sum_i \exp(V_{od,i})}$$

$$V_{direct} = c_0 + b_{01}\ln(distD_{od}) + b_{02}\ln(paxD_{od}) + b_{03}\ln(HHI_{od})$$

$$V_{od,i} = b_1\ln(distC_{o-i-d}) + b_2\ln(\max pax_{oi/di}) + b_3\ln(\min pax_{oi/di}) + b_4\ln(Delay_i)$$

- distD/ distC : direct /connecting (O-hub-D) distance between OD
- paxD: # of pax of the direct segment
- maxpax: # of pax of the higher traffic segment
- minpax: # of pax of the lower traffic segment
- HHI: Herfindahl-Hirschman Index (0 to 1) of the direct segment od
- delay: the delay (the number of delayed operations per 1000 operations) of connecting airport i

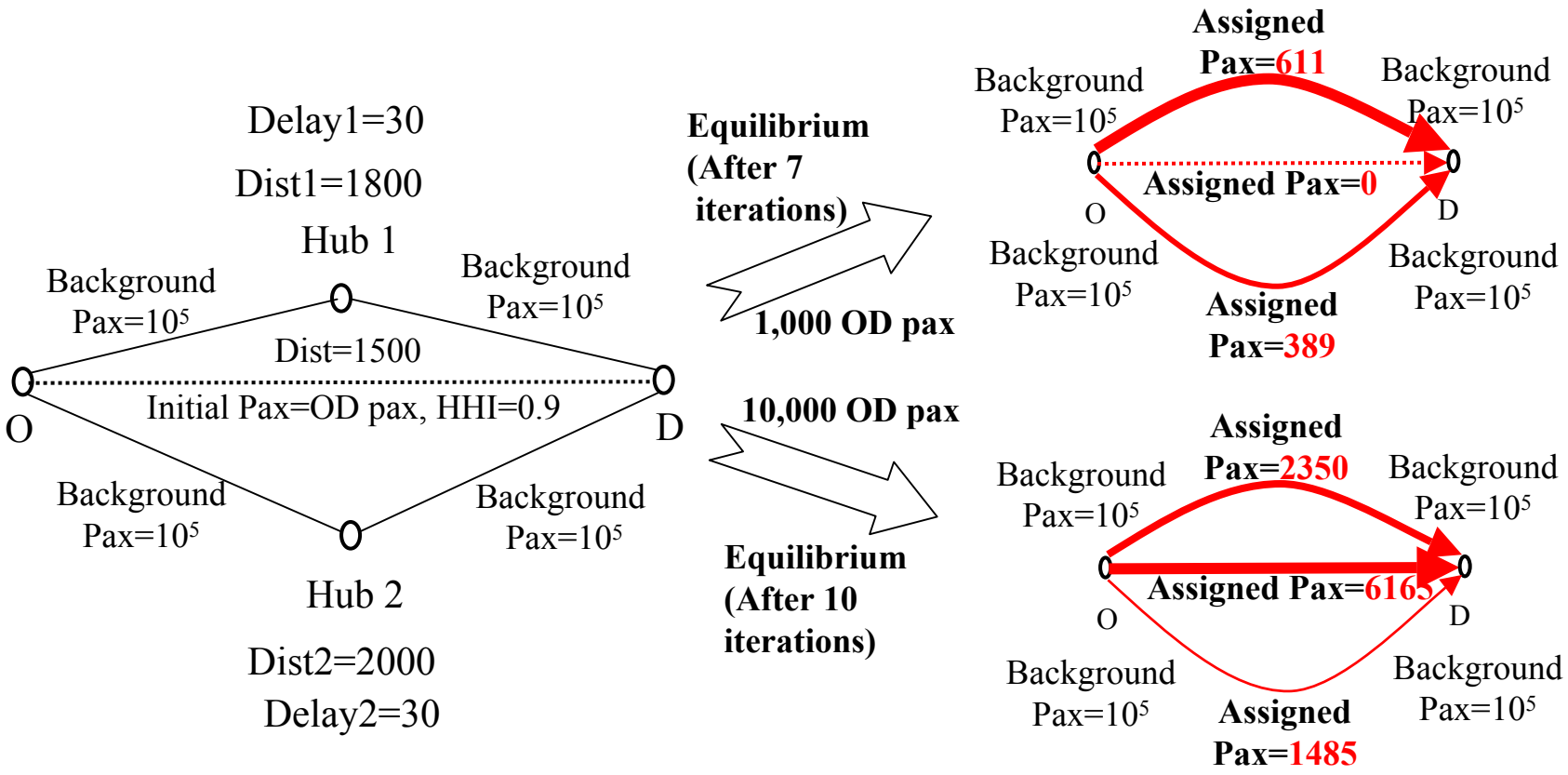
Model Estimation

Associated Factor	Estimate Parameter	Standard Error ($*10^{-4}$)	P-value
ln(Dist. of Connect)	-2.929	0.984	[.000]
ln(Max Pax of Connect)	0.226	0.179	[.000]
ln(Min Pax of Connect)	0.665	0.201	[.000]
ln(Delay of Connect)	-0.073	0.063	[.000]
β, 1/(inclusive value)	1.453	0.399	[.000]
Constant of Direct	2.386	2.295	[.000]
ln(Dist. of Direct)	-3.027	0.847	[.000]
ln(Seg. Pax of Direct)	0.986	0.127	[.000]
ln(HHI of Direct)	-0.272	0.294	[.000]

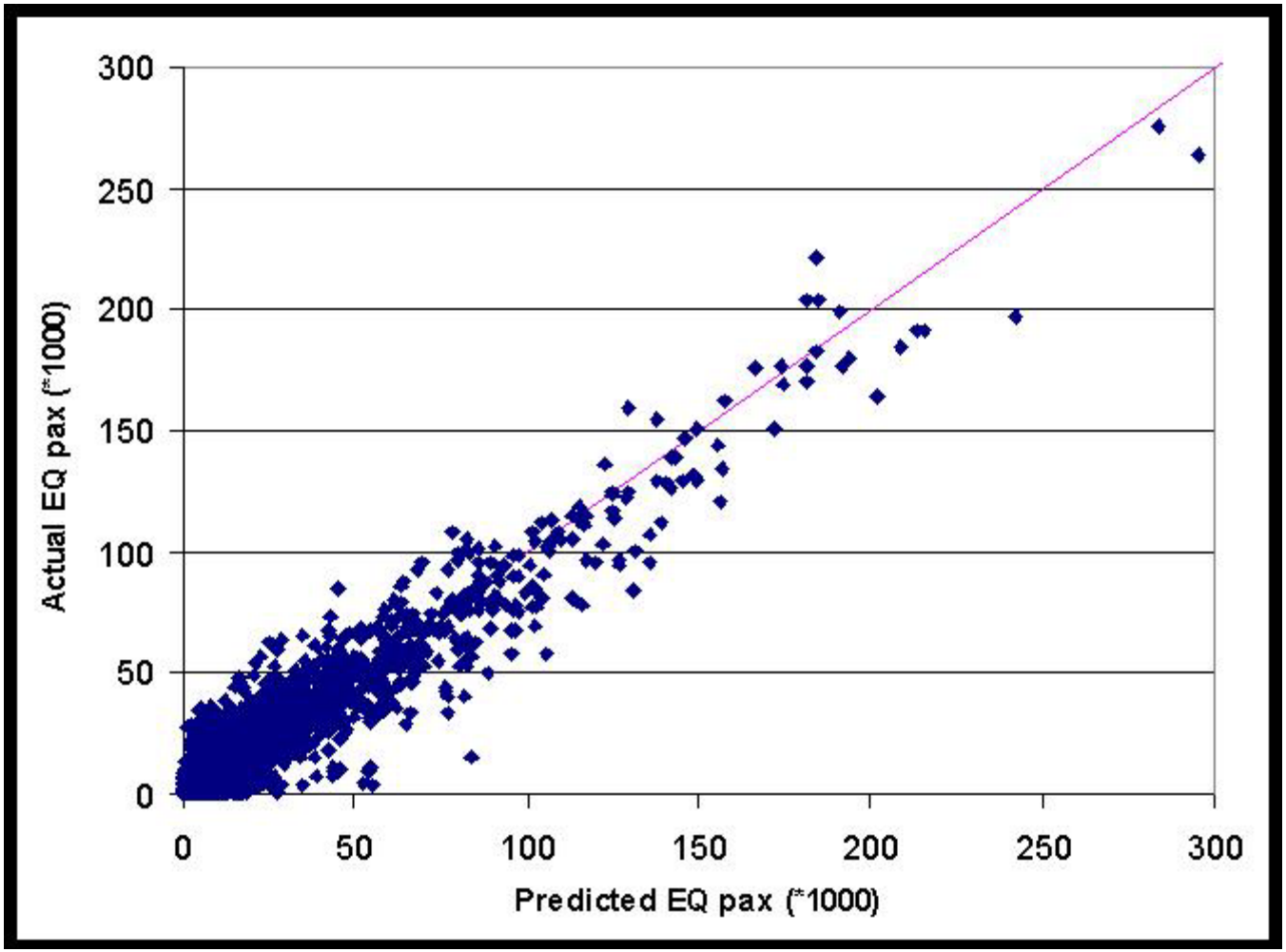
$\hat{\rho}^2 = 0.5555$ N=39,298,503 (100,951 routes)

Equilibrium Flow Example

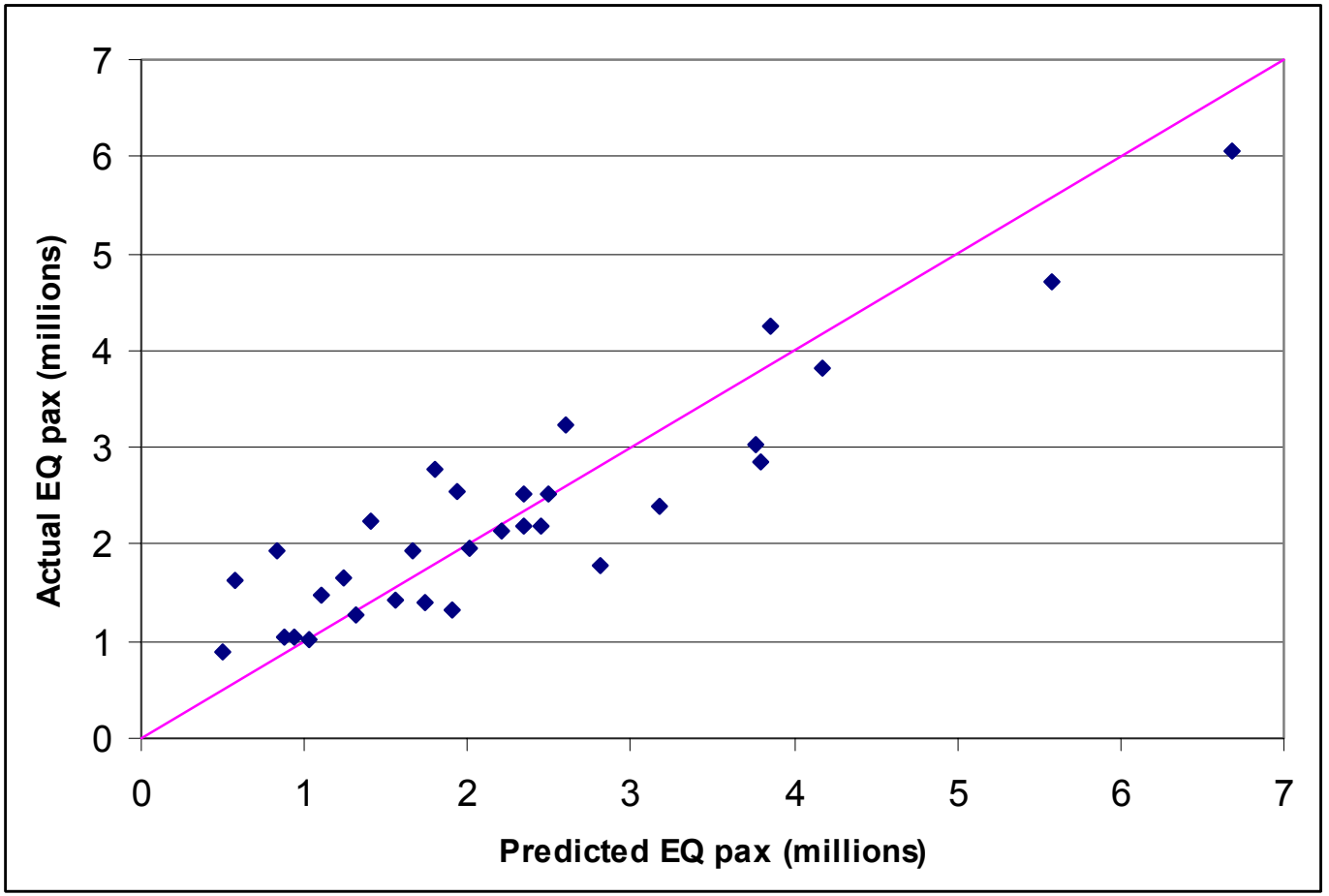
- Segment and OD density, and delay effects (segment pax are endogenous)



NAS Equilibrium- Segment Level



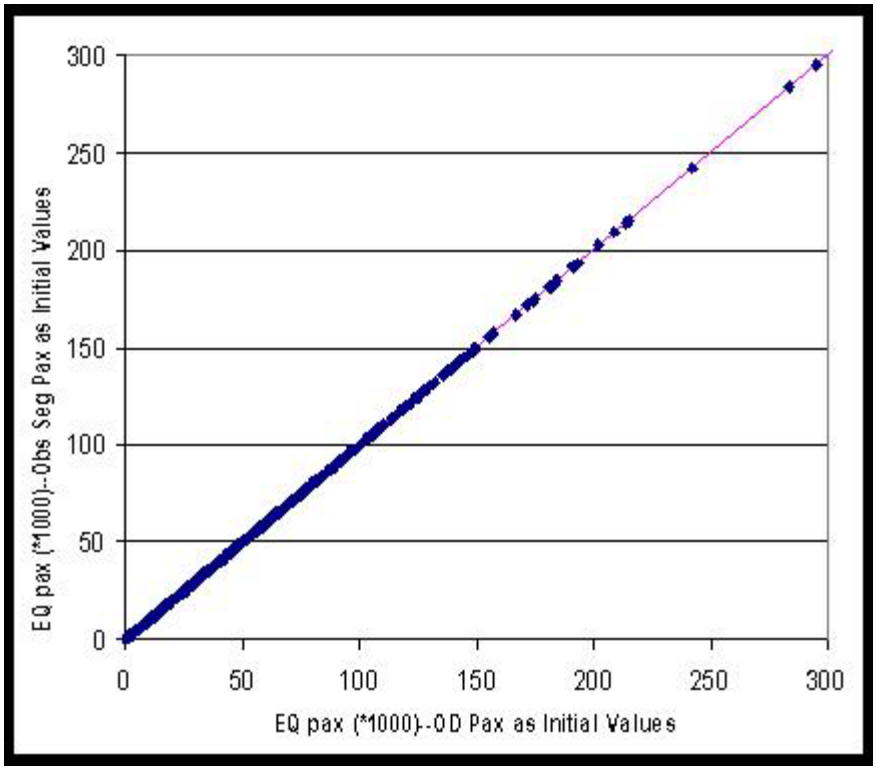
NAS Equilibrium- Airport Level



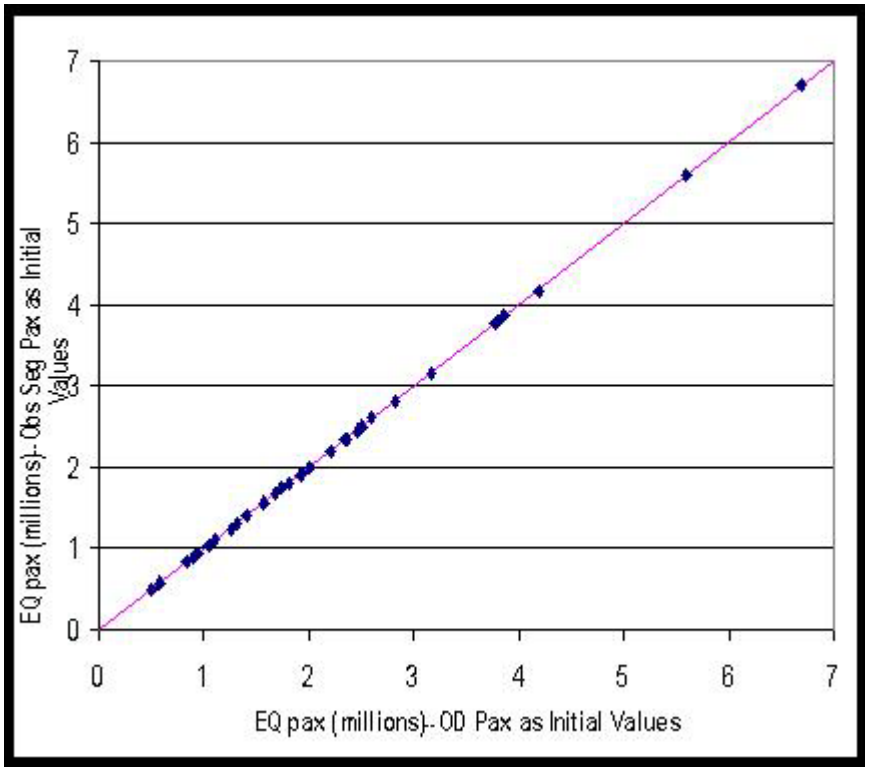
Equilibrium Prediction

- Possible situations:
  - Multiple Equilibria
  - May depend on the initial values and convergence criteria
  - Some equilibria may differ from the current status

Equilibria- initial values

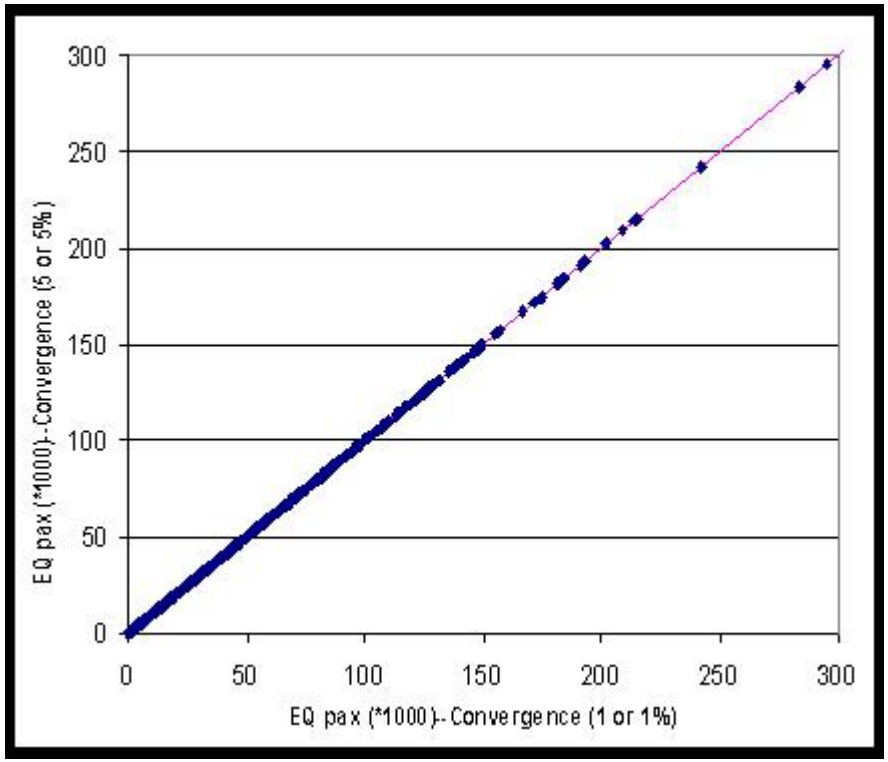


Segment Level

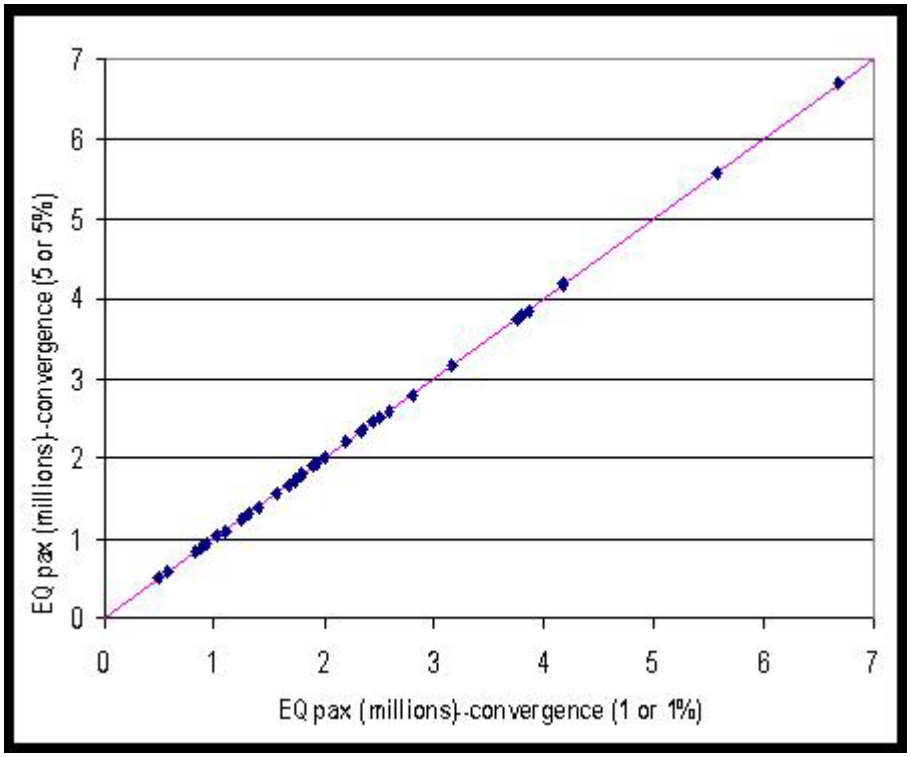


Airport Level

Equilibria- Convergence Rules



Segment Level



Airport Level

Policy Experiment— ORD Delay Improvement

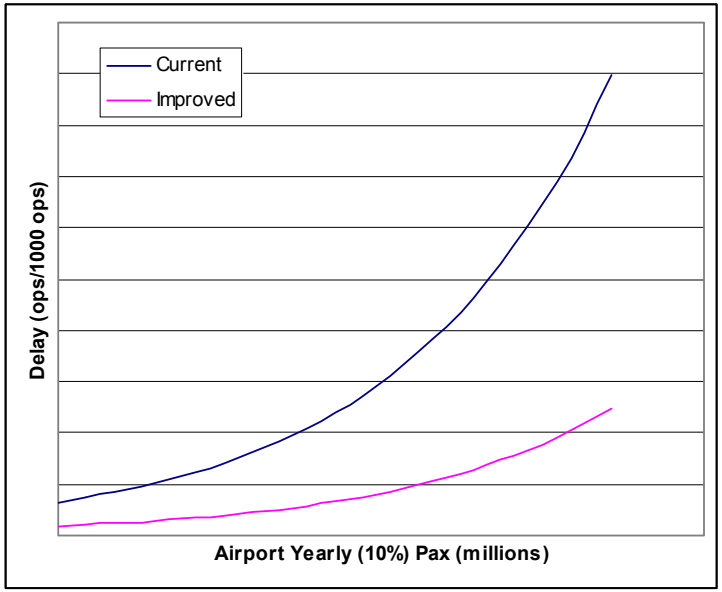
- Delay:

$$\ln(Delay_{it}) = \alpha_0 + \sum_{i=1}^{30} \alpha_i * C_i + \beta_1 * Pax_{it} + \varepsilon_{it}$$

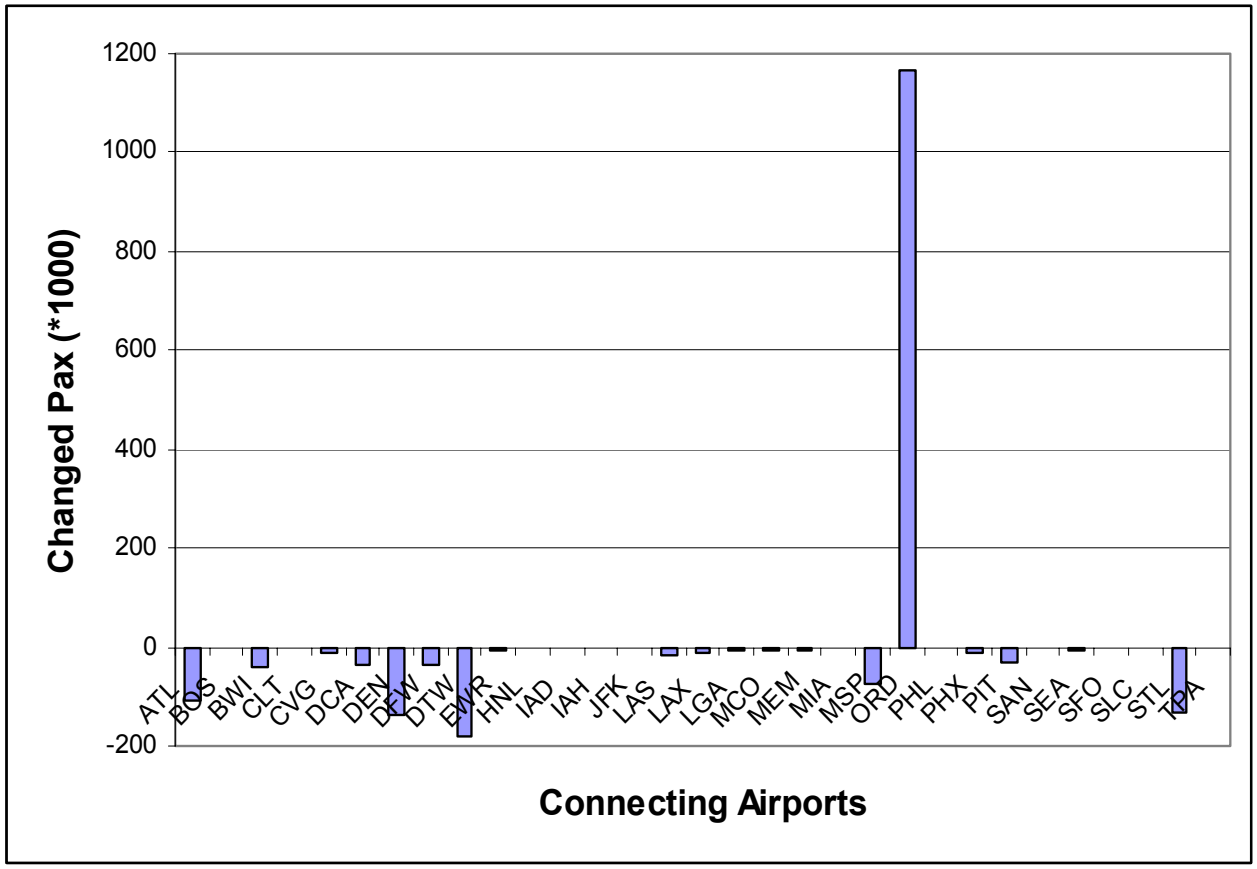
- Airport fixed delay effect improved:

$$\alpha_{ORD} = 1.70542 \rightarrow$$

$$\alpha_{ORD}' = \alpha_{DEN} = 0.42284$$



Policy Experiment— New Equilibrium Results



- ORD: +1,164,665
- Other hubs: -876,506
- Net effect on the system: +288,159
- ORD attracts:
  - ¾ from competing hubs
  - ¼ from "direct" routes

Conclusions—Hub Choice Model

- Conclusions
  - The equilibrium model reflects the economics of the route choice
  - Conserves OD traffic at airport level while allowing connecting traffic to vary
  - A tool for policy analysis

Future works (1/2)

- Model Structure (Better Equilibrium Estimation)
  - Positive Feedback system
  - Dynamics of the system
  - Travelers' behavior: flexible model form & Endogeneity
  - Computation efficiency

Future works (2/2)

- Affecting Factors Modeling
  - Delay
  - Market Concentration (HHI)
  - Other factors, for example, airport capacity
- System-wide Effects Estimation
  - Better Policy Analysis Tool

Questions?