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CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

# **US Airline Network: A Framework of Analysis and Some Preliminary Results**

***Dipasis Bhadra and Brendan Hogan***

***Paper to be presented at the Airline Evolution and Change:  
Deregulation and Beyond Session  
of the 46th Annual Forum of the Transportation Research Forum***

***Aviation Institute, Marvin Center  
George Washington University***

***March 7, 3:30-5:00***



# The Airline Industry is Undergoing Structural Change

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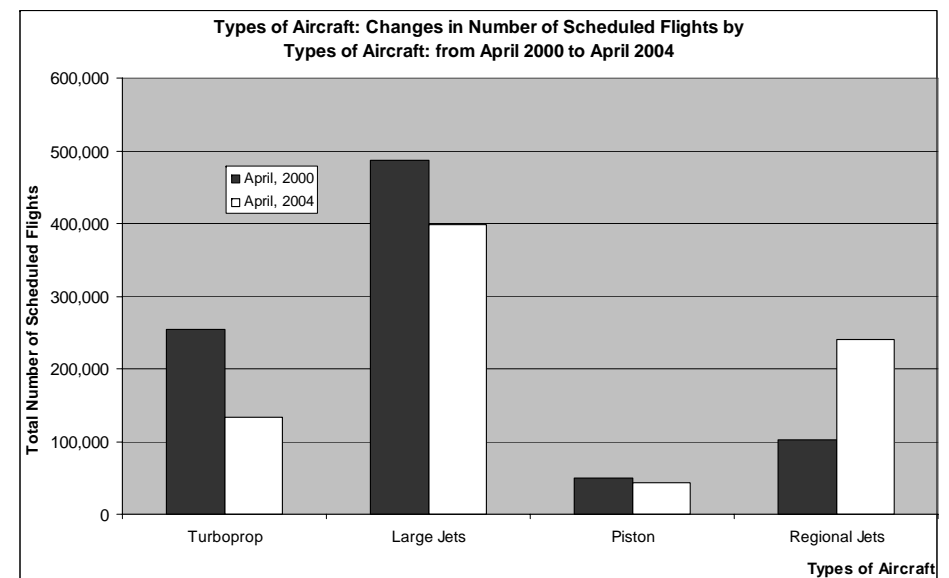
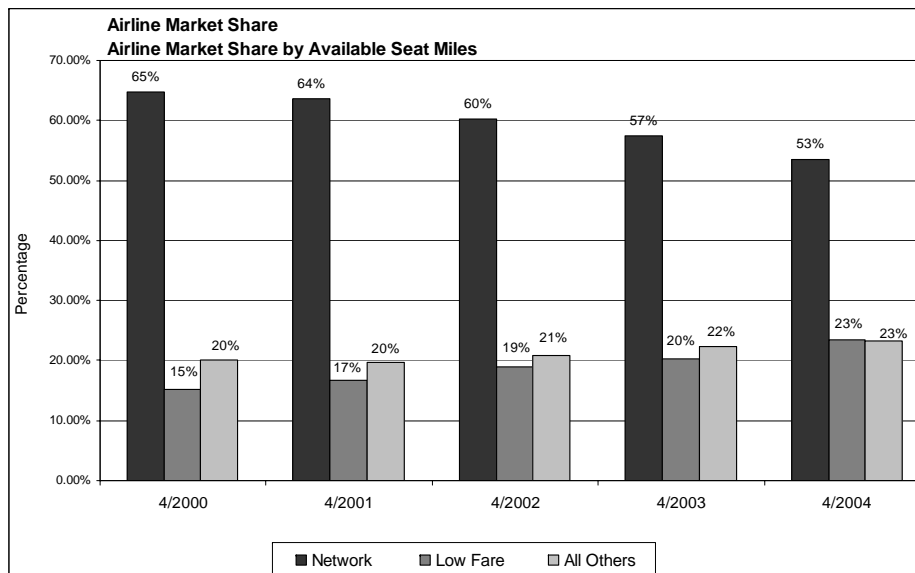
“What ails the airlines...was evident before 9/11, and goes well beyond the current downturn in the economy, to something more fundamental.”

Donald Carty, Chairman and CEO American Airlines  
September 6, 2002

**But what will the  
“restructured”  
future look like?**

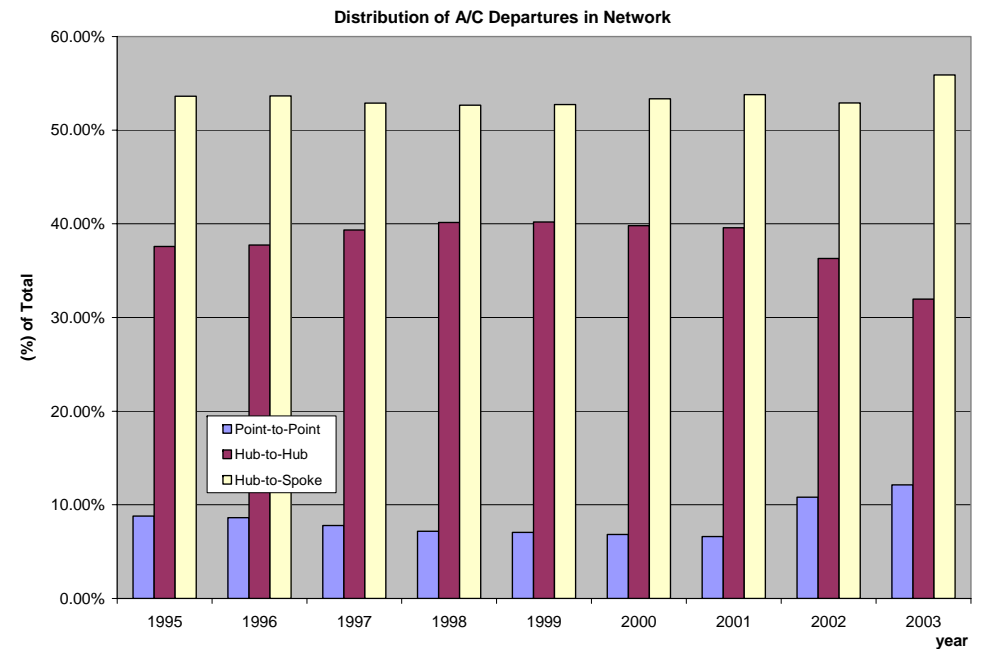
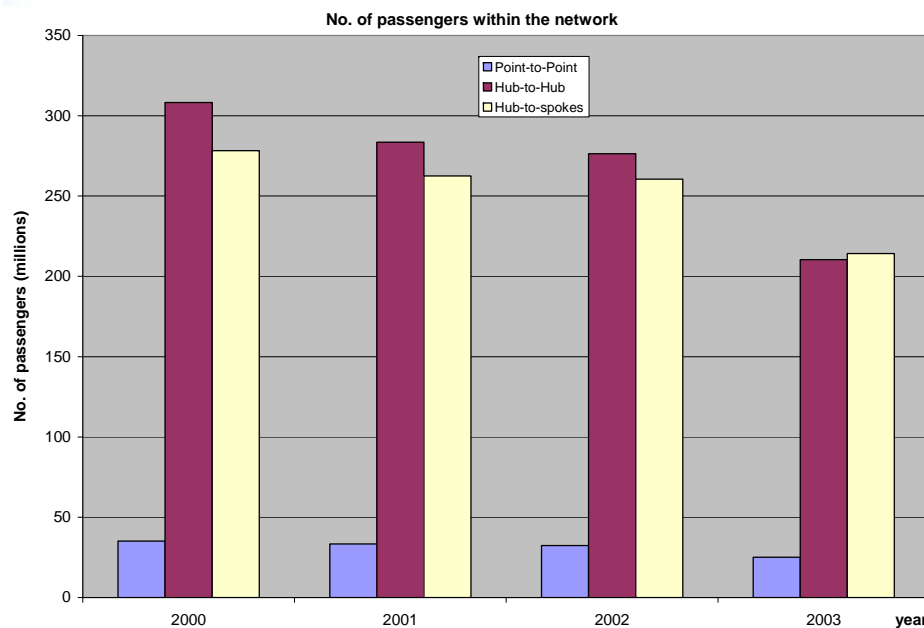


# Declining Share of Network Carriers are Being Filled up By LCCs and Regional Carriers; More RJs Substitute for Large Jets and Turbo Props



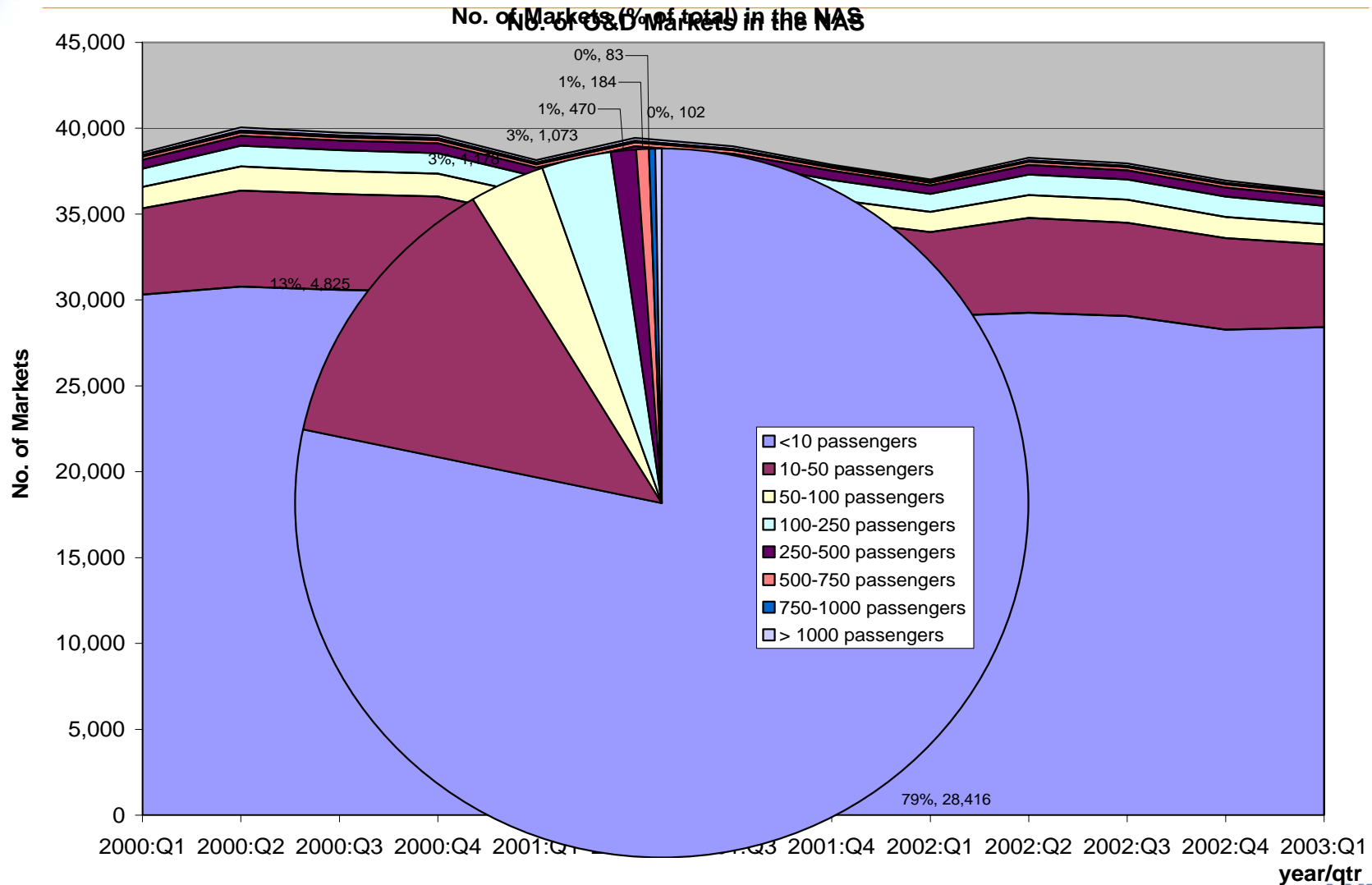


## While Large Hub Airports (i.e., OEP 35) Lose Relative Importance, Smaller Airports Gain



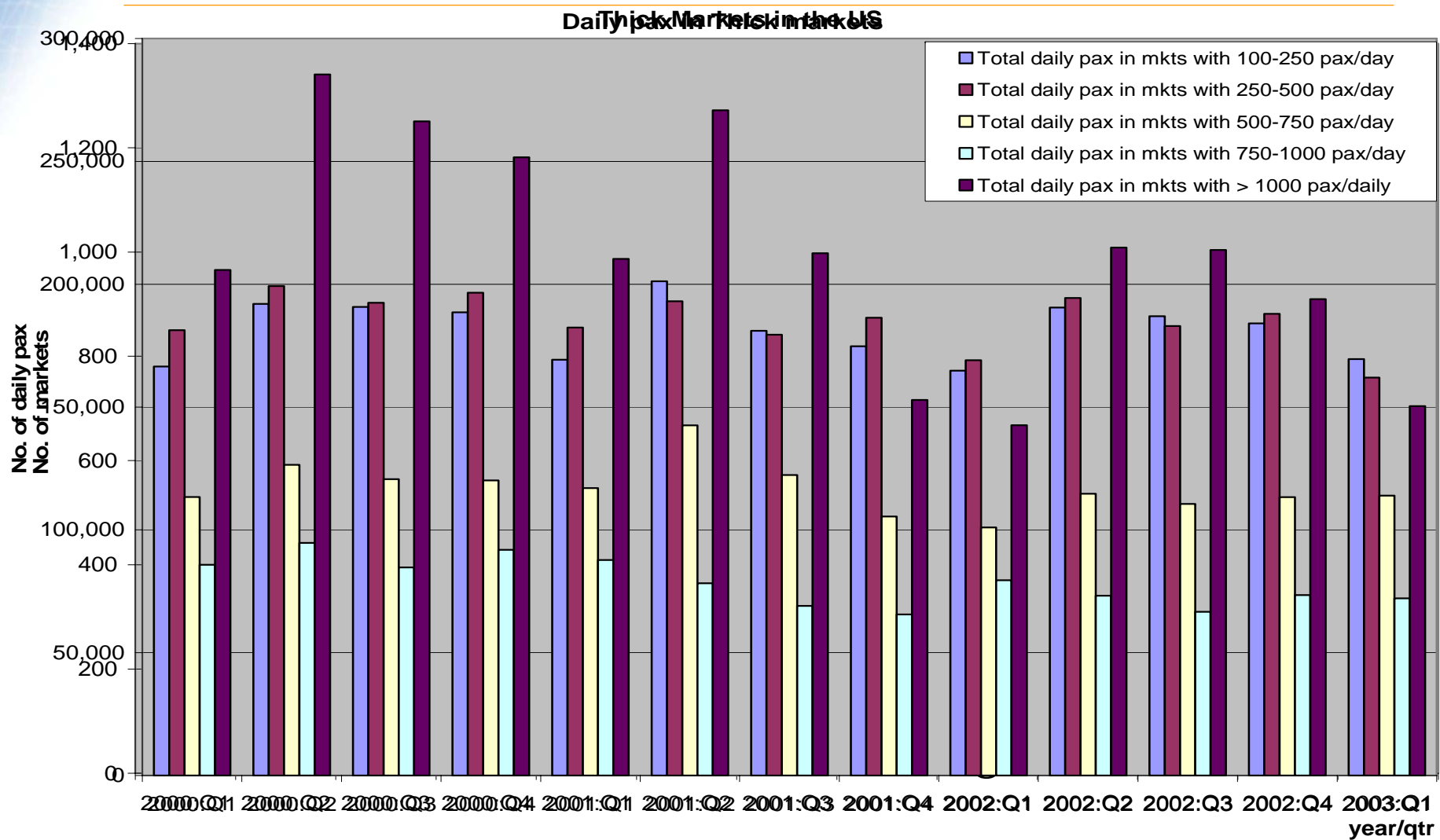


## Although the Underlying Market Structures Have Not Changed Fundamentally





# Upper End of the O&D Markets (Both in Terms of Numbers and Passengers) Appear To Be Fairly Stable Over Time

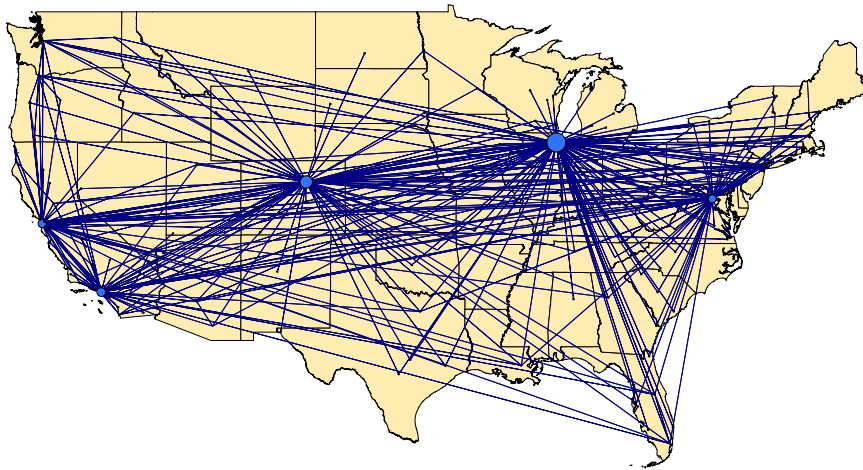


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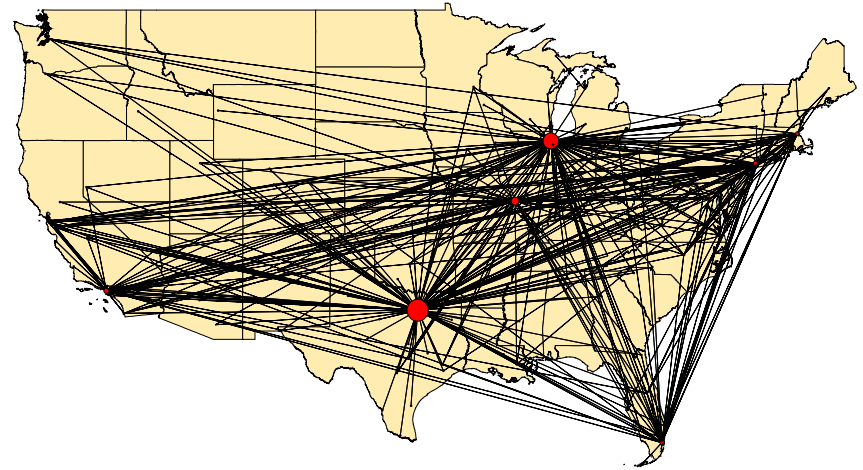


# Airline Network Used To Be Primarily Hub-and-Spoke

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 **UNITED**



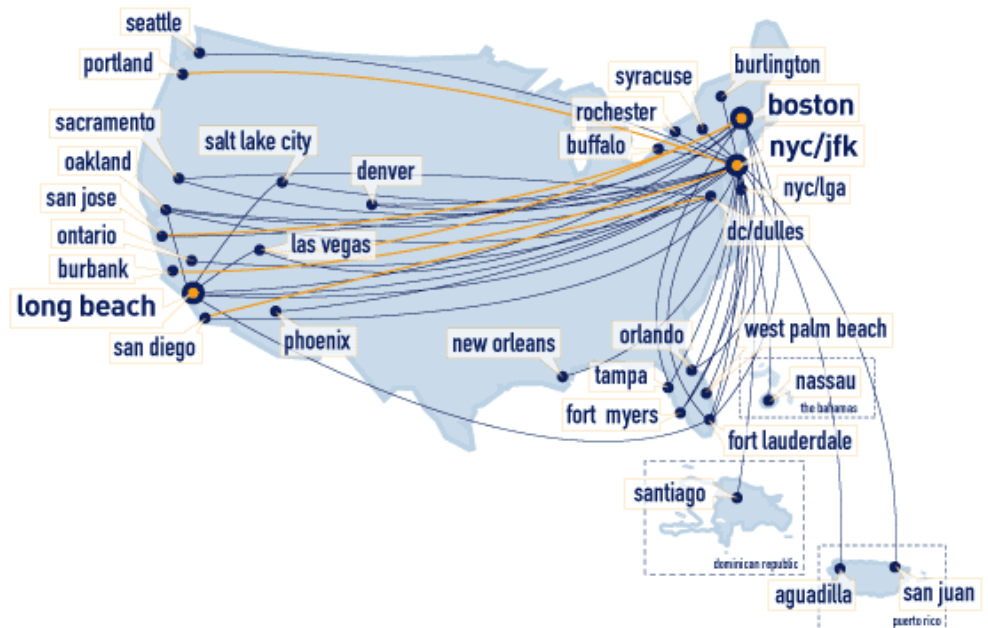
**American Airlines**

January 03, 2003 (Domestic)



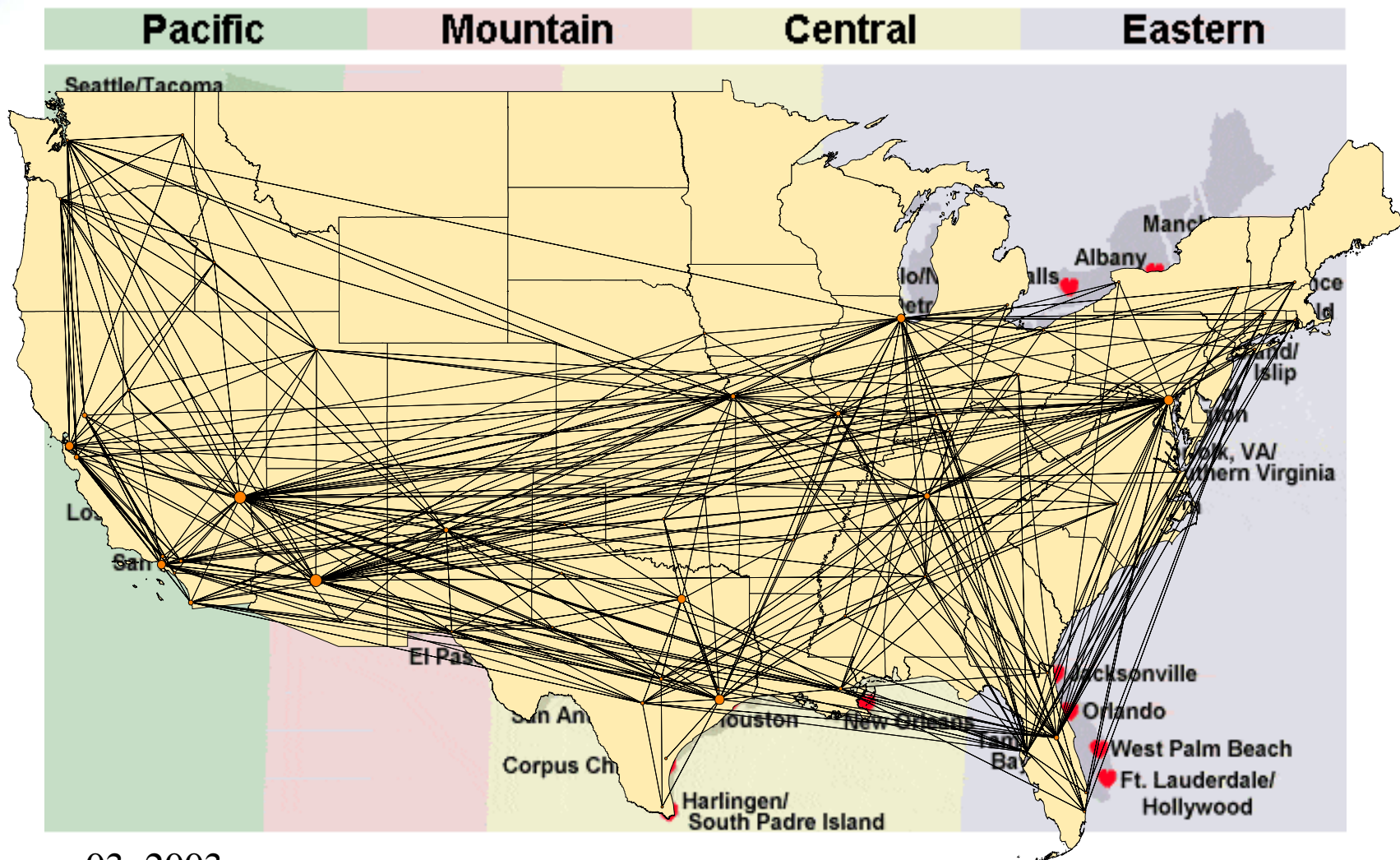


# Some of the Leading LCCs are also Hub-and-spoke Network Carriers





## However, with Increasing Importance of Southwest, Network Has become Far More Distributed

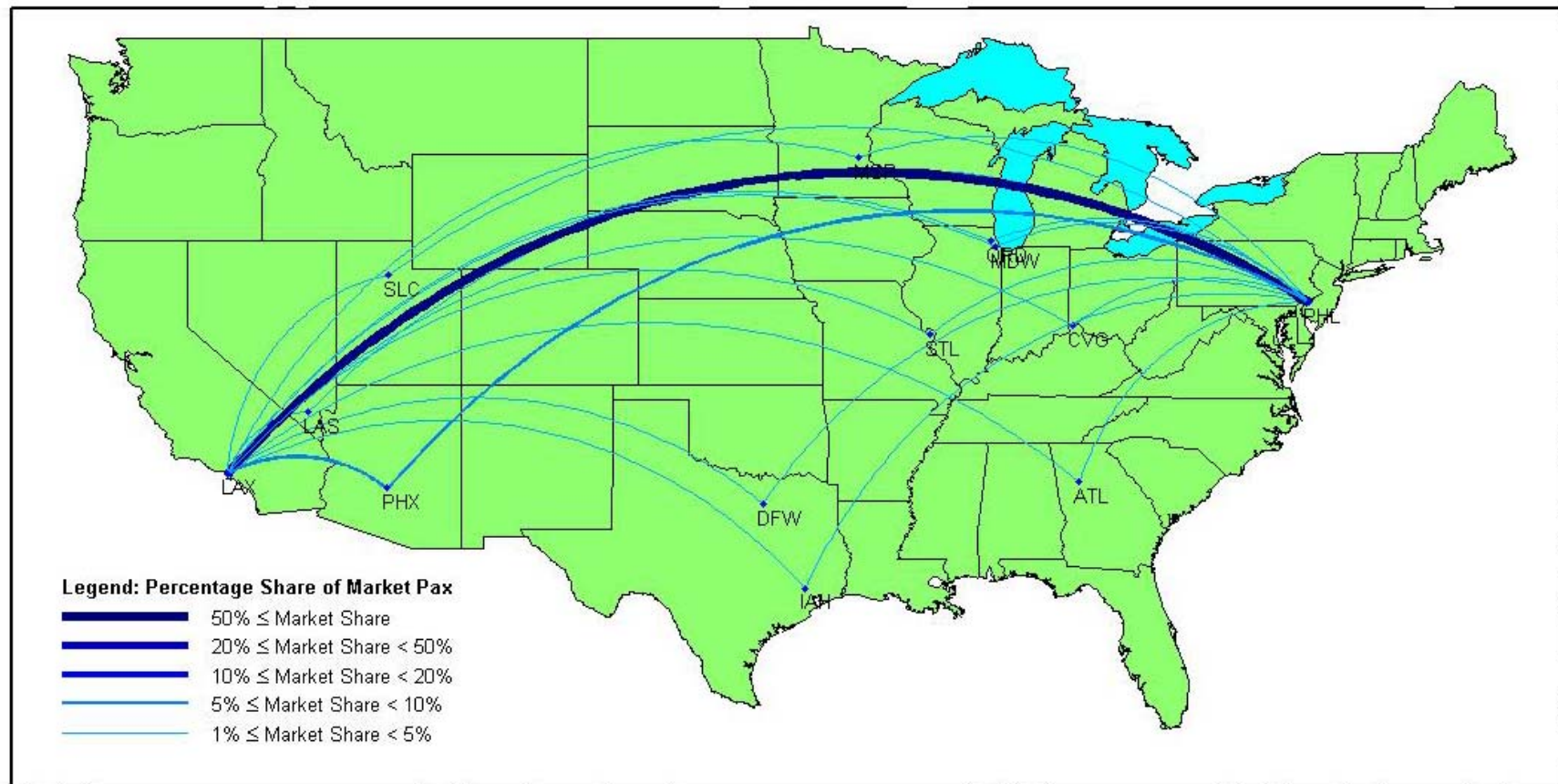


January 03, 2003



# Visual Example of a Centralized Market

## Market Share by Itinerary: 2003 Q2 PHL to LAX

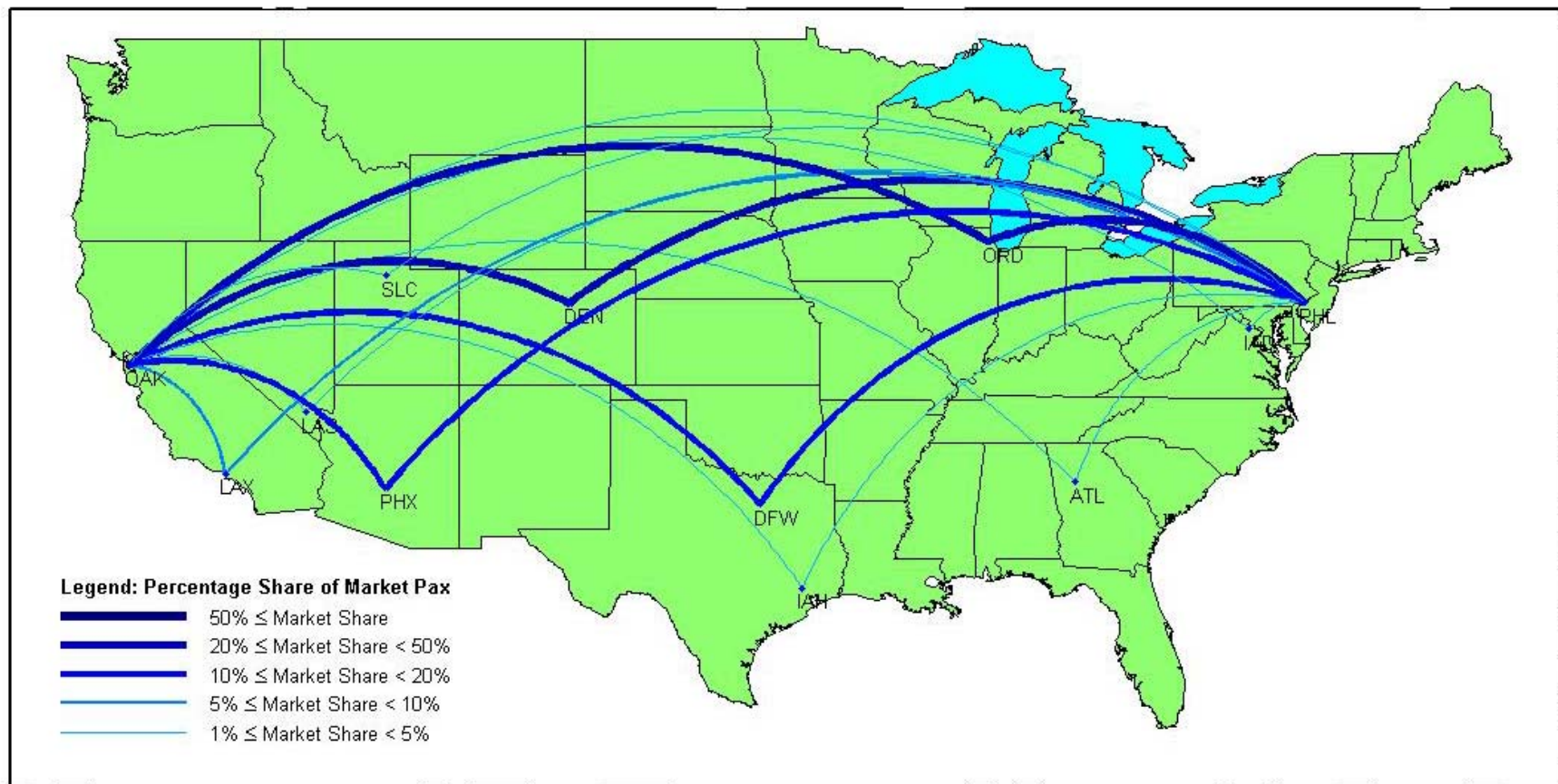






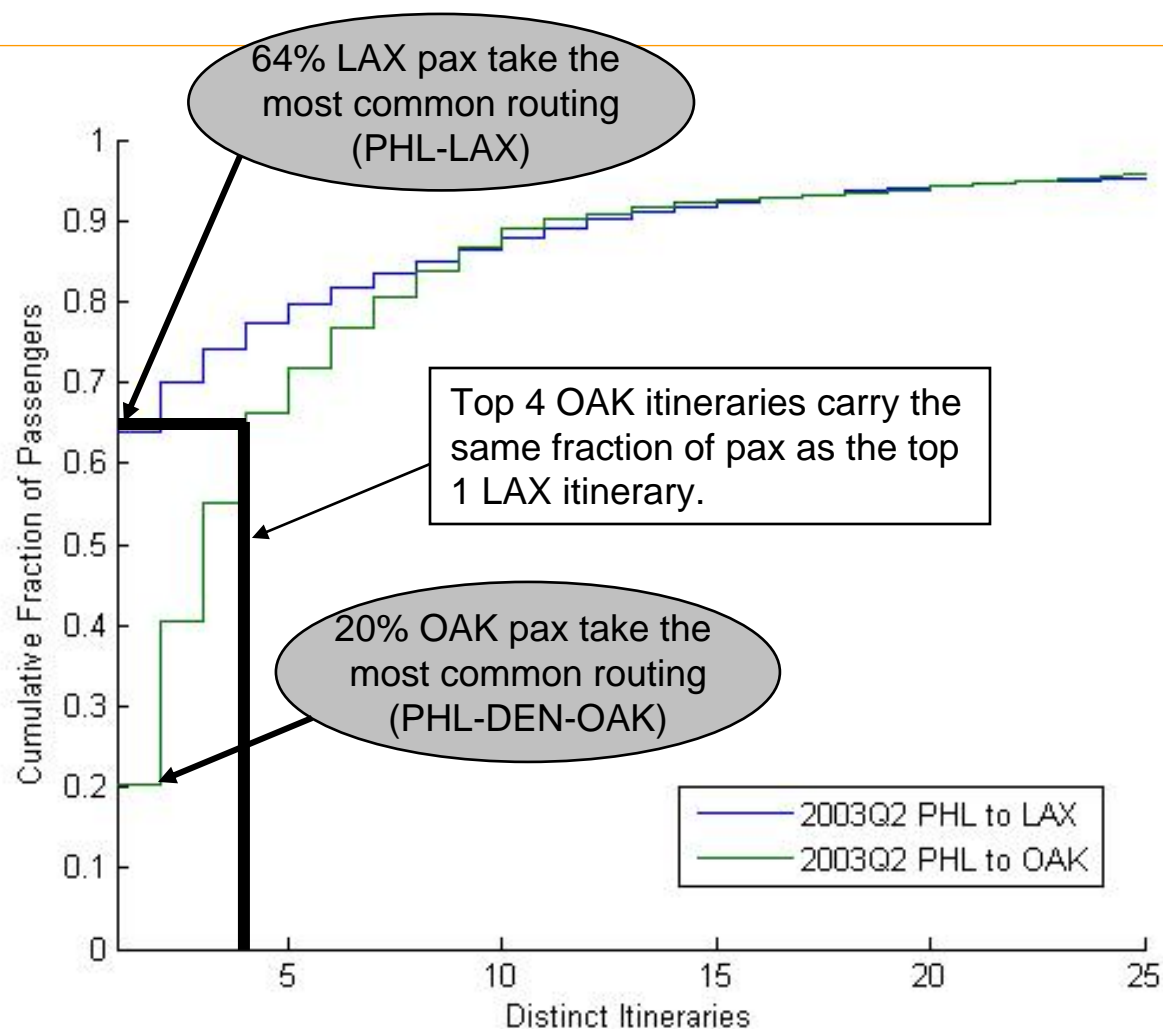
# Visual Example of a Distributed Market

## Market Share by Itinerary: 2003 Q2 PHL to OAK





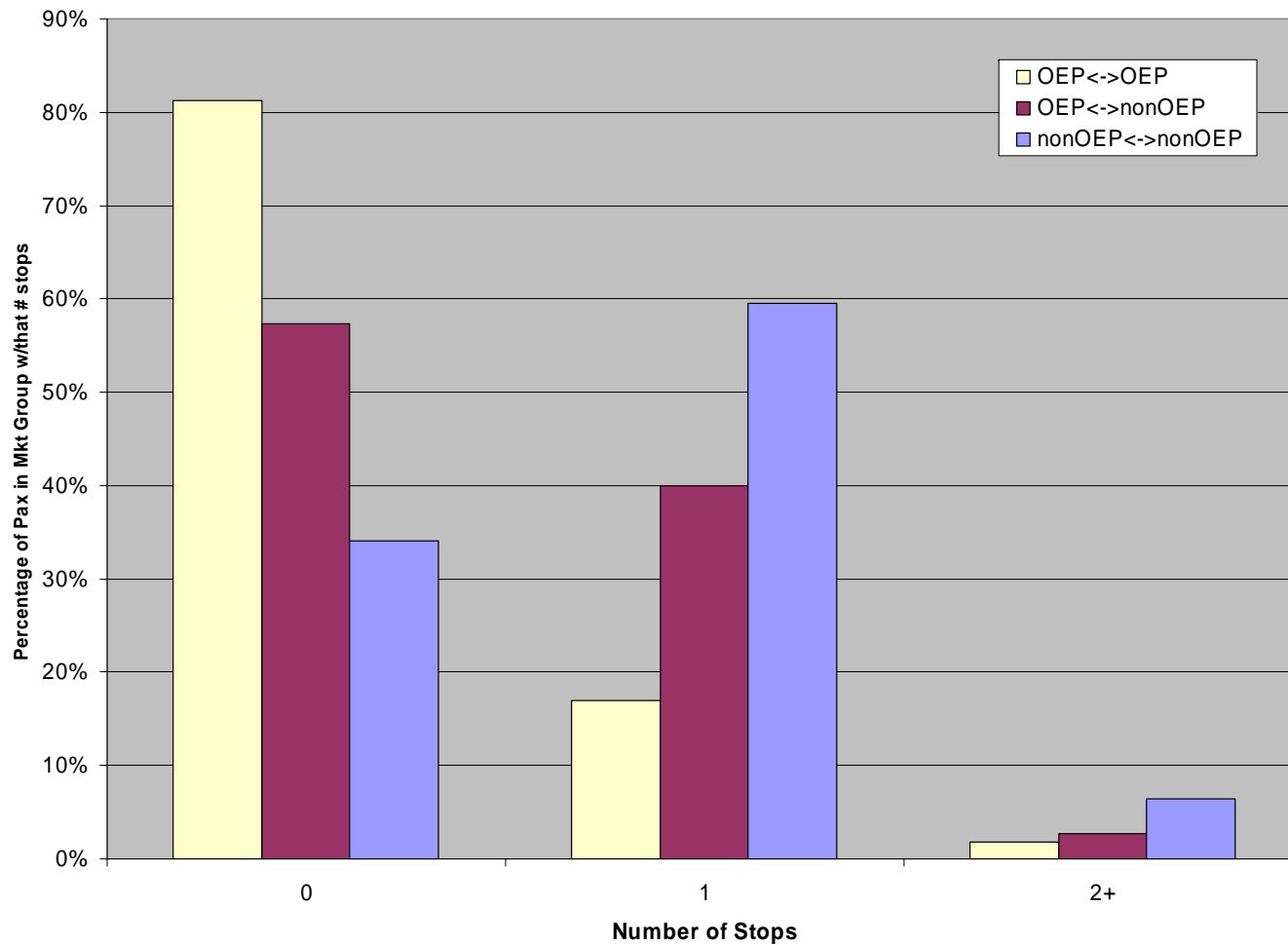
## Quantitative Difference between Example Distributed and Centralized Markets





# Number of stops observed to vary by market type

Passenger Distribution by Number of Stops, DB1B Market Data 2003 Q2





## Analytical Model to Determine Itinerary Number of Stops by Market

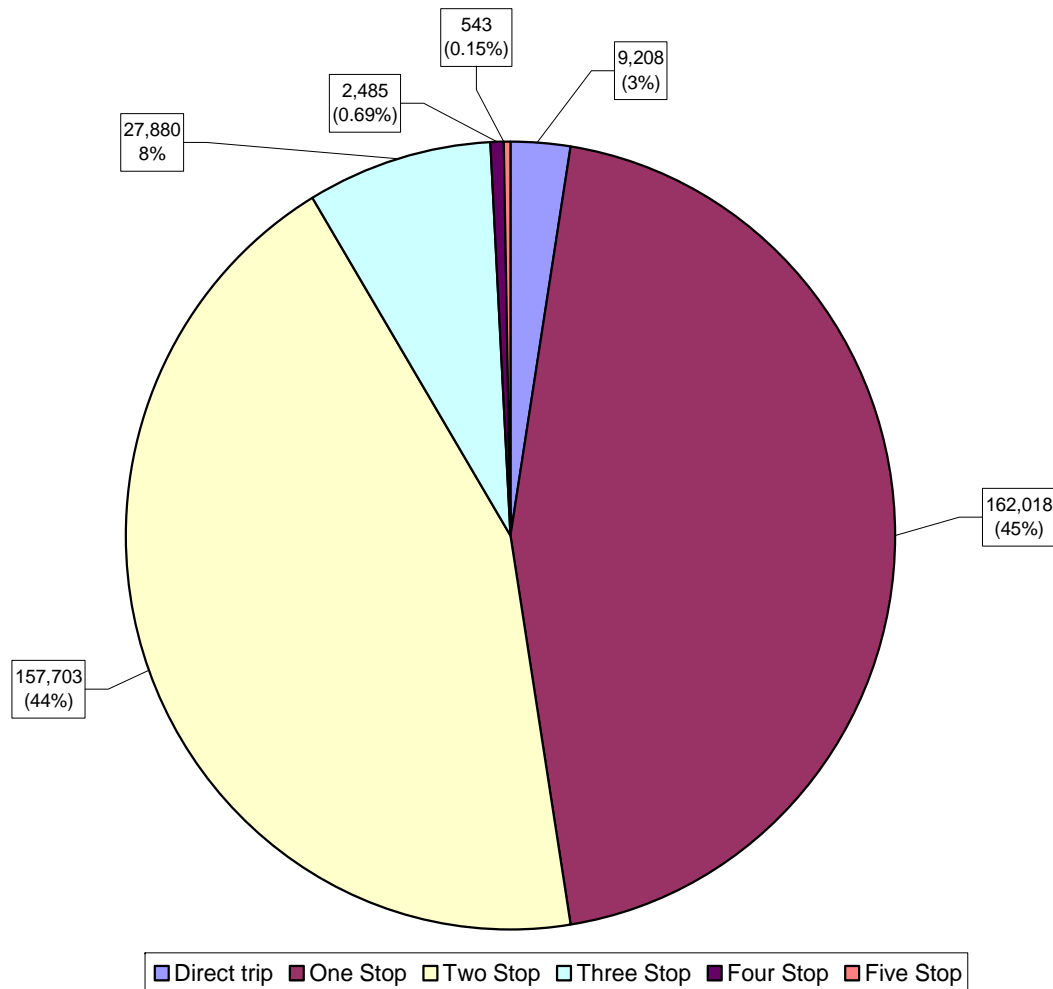
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$$\begin{aligned} P_i (y_i = j | x_i, \beta) \\ (j = 1, 2, \dots, 6) \end{aligned} = \alpha_{ij} + \beta_1 (\text{passengers\_Inline}) + \beta_2 (\text{Average Distance}) \\ + \beta_3 (\text{Passengers\_O\&D Market}) + \beta_4 (\text{Weighted Average Fare}) + \beta_5 (\text{Presence of Network Carriers}) + \\ \beta_6 (\text{Presence of LCC Carriers}) + \varepsilon_i \quad (E.1)$$



# Network Information from Itinerary Data

Types of Itinerary in the NAS: Aggregated by Origin and Destination (O&D)  
2nd Quarter, 2003: N=359,837







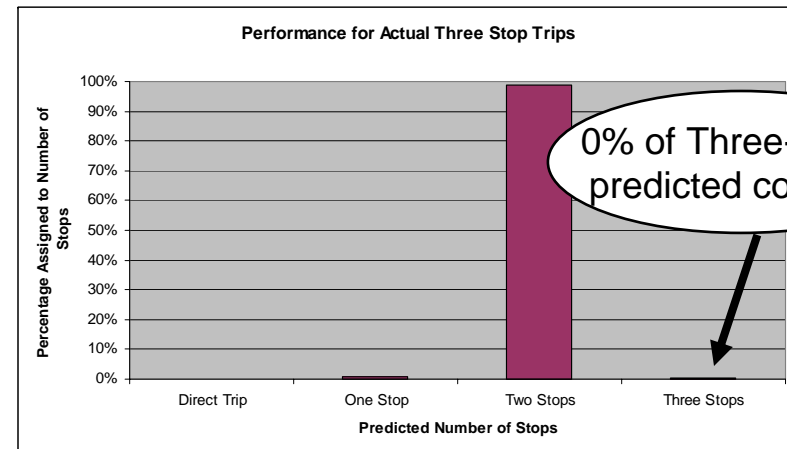
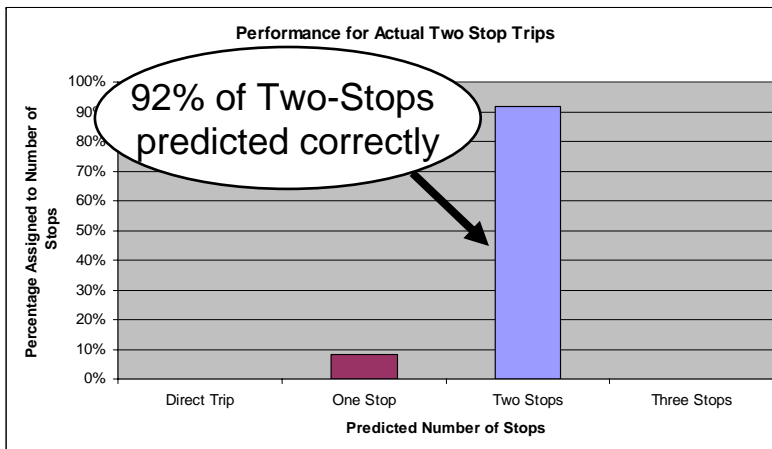
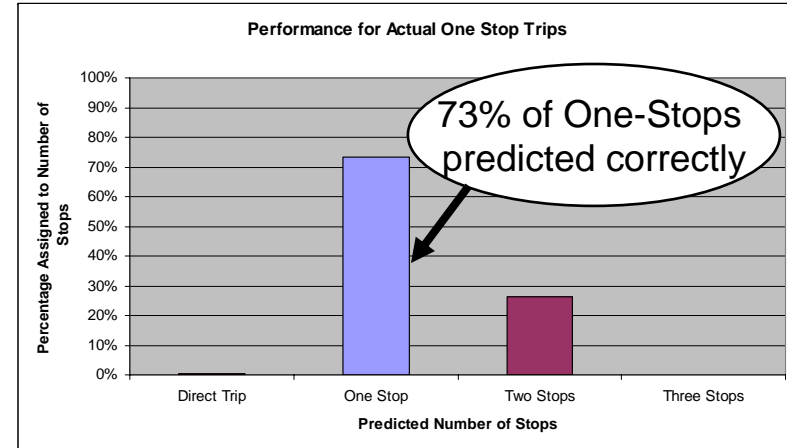
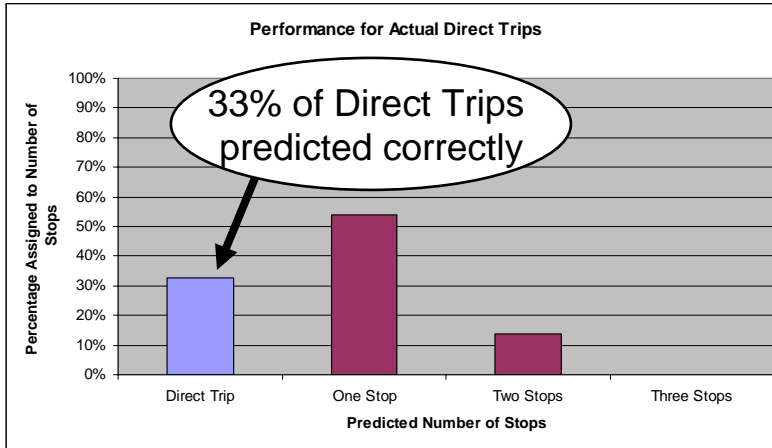
## Estimated Results from Multi-nomial Logit

Parameters*	One Stop Vs. Direct Route	Two Stop Vs. Direct Route	Three Stop Vs. Direct Route	Four Stop Vs. Direct Route	Five Stop Vs. Direct Route	Direct Route Vs. All Non- Direct Routes**
Intercept	1.3093	1.7519	0.8474	-1.3892	-2.2153	-1.5764
Passengers_Inline	-0.0129	-0.4963	-1.8749	-2.9525	-2.6818	0.0154
Passengers_O&D Market	0.00177	0.00187	0.00192	0.00196	0.00199	-0.00182
Weighted Average Fare	0.00616	0.00496	0.00460	0.00538	0.00502	-0.00586
Average Distance	0.000282	0.00128	0.00161	0.00176	0.00181	-0.00062
Presence of Network Carriers	0.4609	0.4126	0.6635	1.0609	-0.00869	-0.4640
Presence of LCC Carriers	-0.7429	-1.4307	-1.4664	-1.5098	-2.7836	0.9311

‘\*’ : All parameters are statistically significant at greater than 99% level of significance ; ‘\*\*’ : There are two ways of deriving this. First, we can rerun logit program using different base and derive the parameters; and/or use all non-direct routes (i.e., itinerary stops  $\geq 1$ ) as a choice against the alternative of direct route as a binary model. We run the latter to extract the model parameters for direct route.



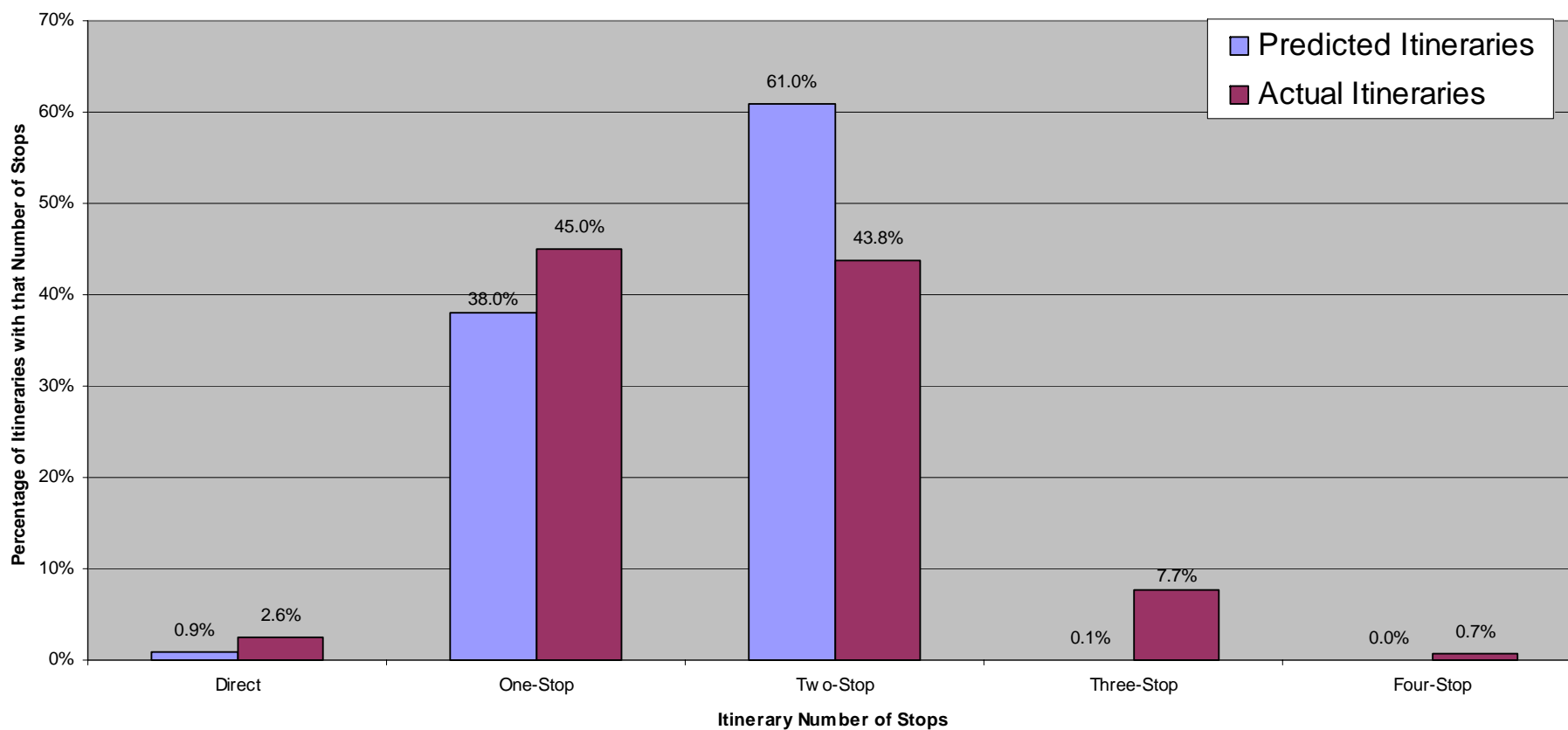
# Predictive Performance of Logit Model





# Overall Allocation of Number of Stops

Distribution of Itinerary Number of Stops





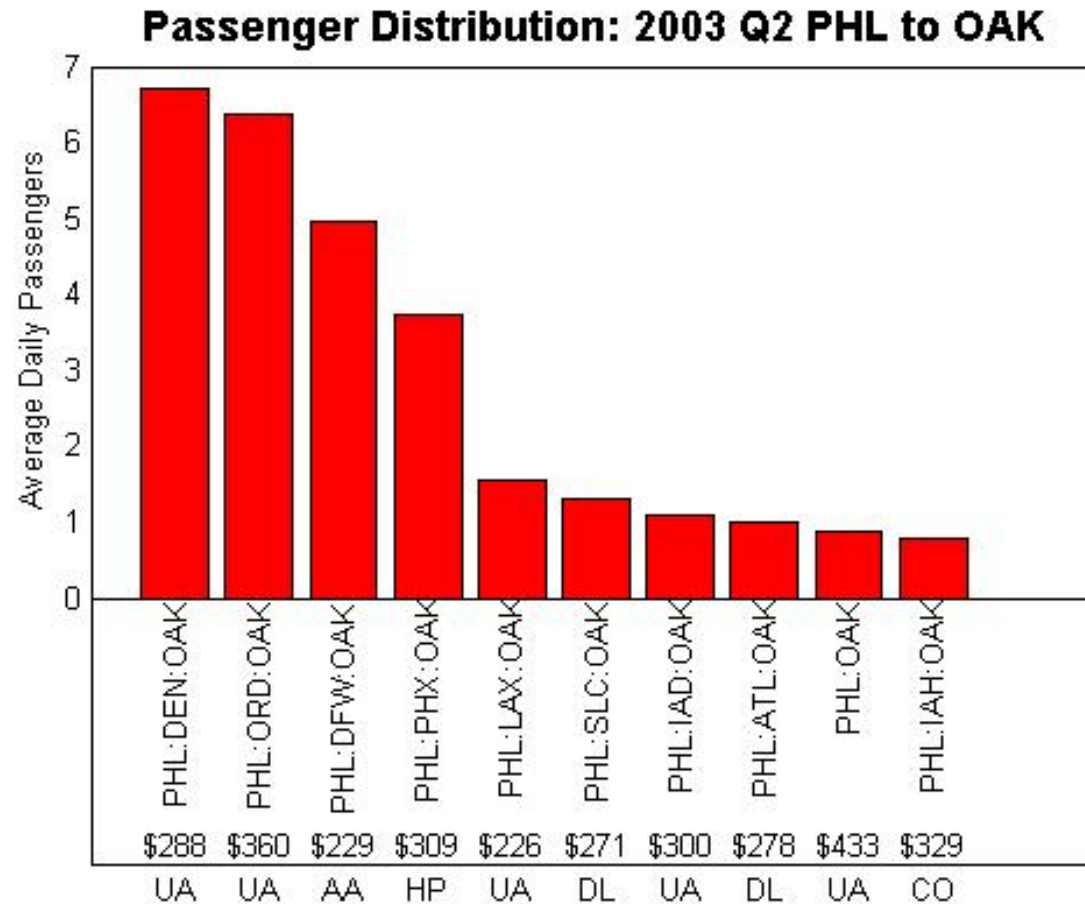
## Recap...and Next Steps

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- **We have developed a model for the number of stops between an OD pair**
  - Carriers have been aggregated together to do this
- **It remains to determine where they will stop**
- **The economics of hubs and the cost advantages between carriers must be built into the model**

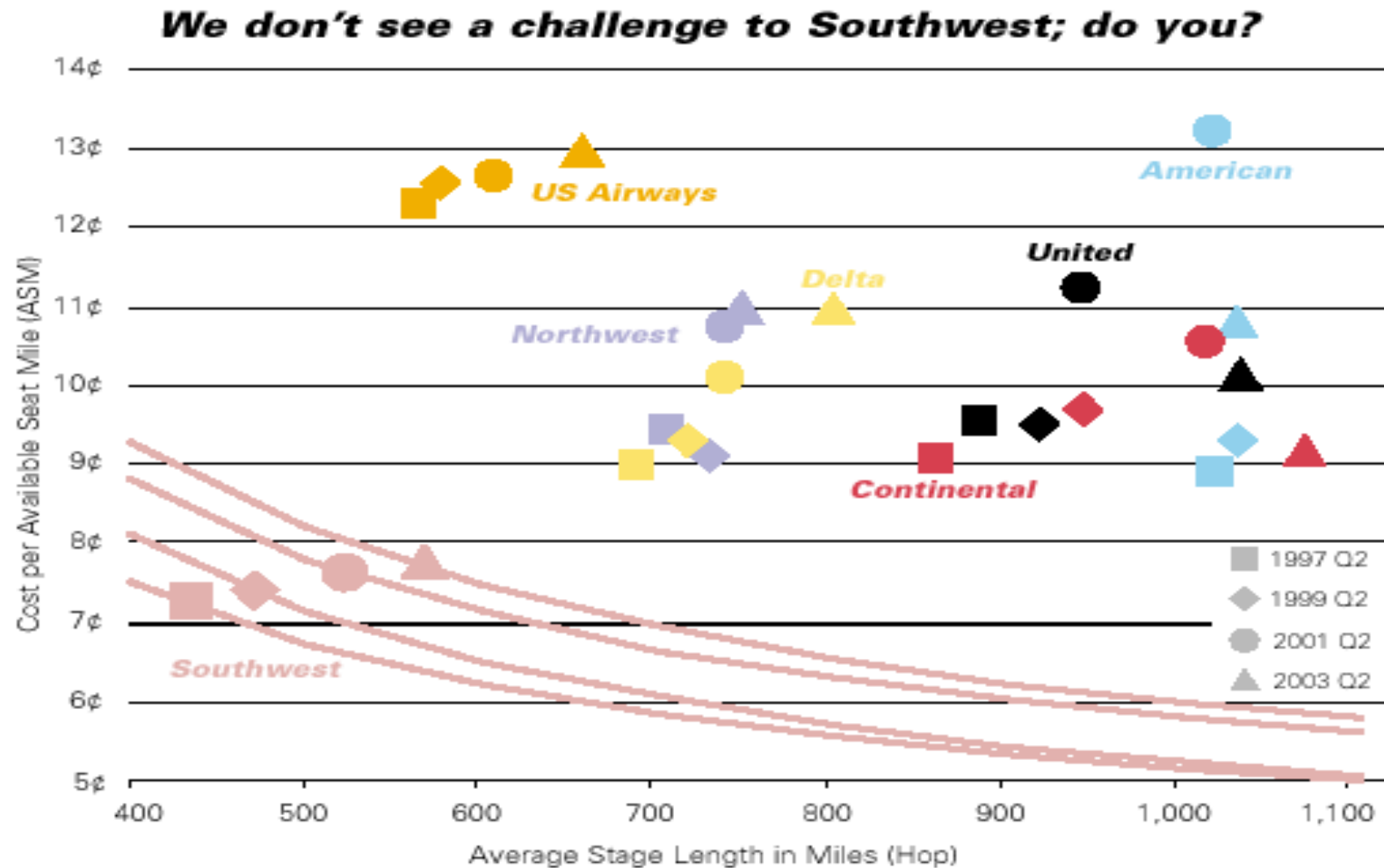


# Passenger Routings Give Insight into Airline Cost Advantages



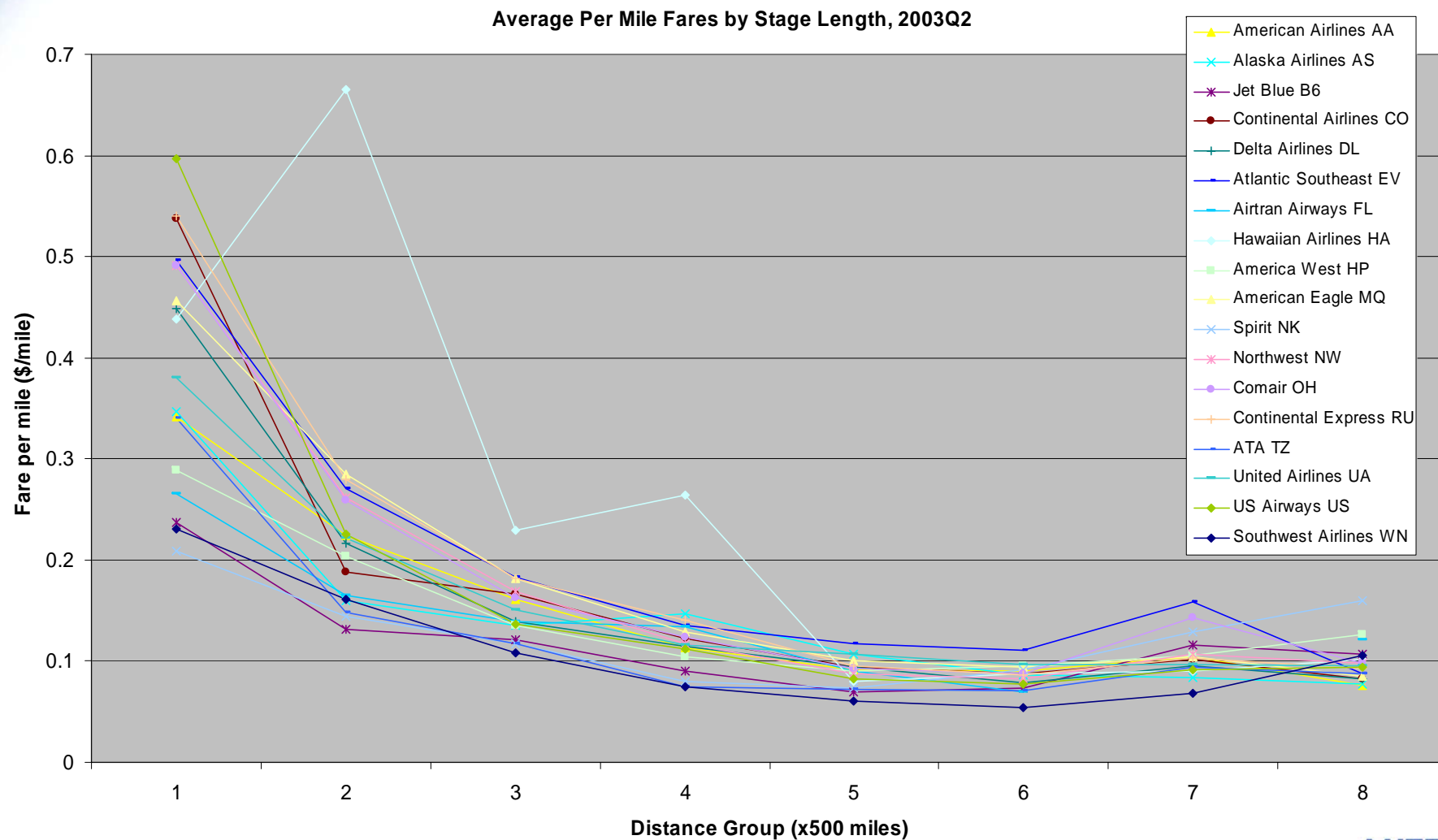


# Southwest's cost advantage over others





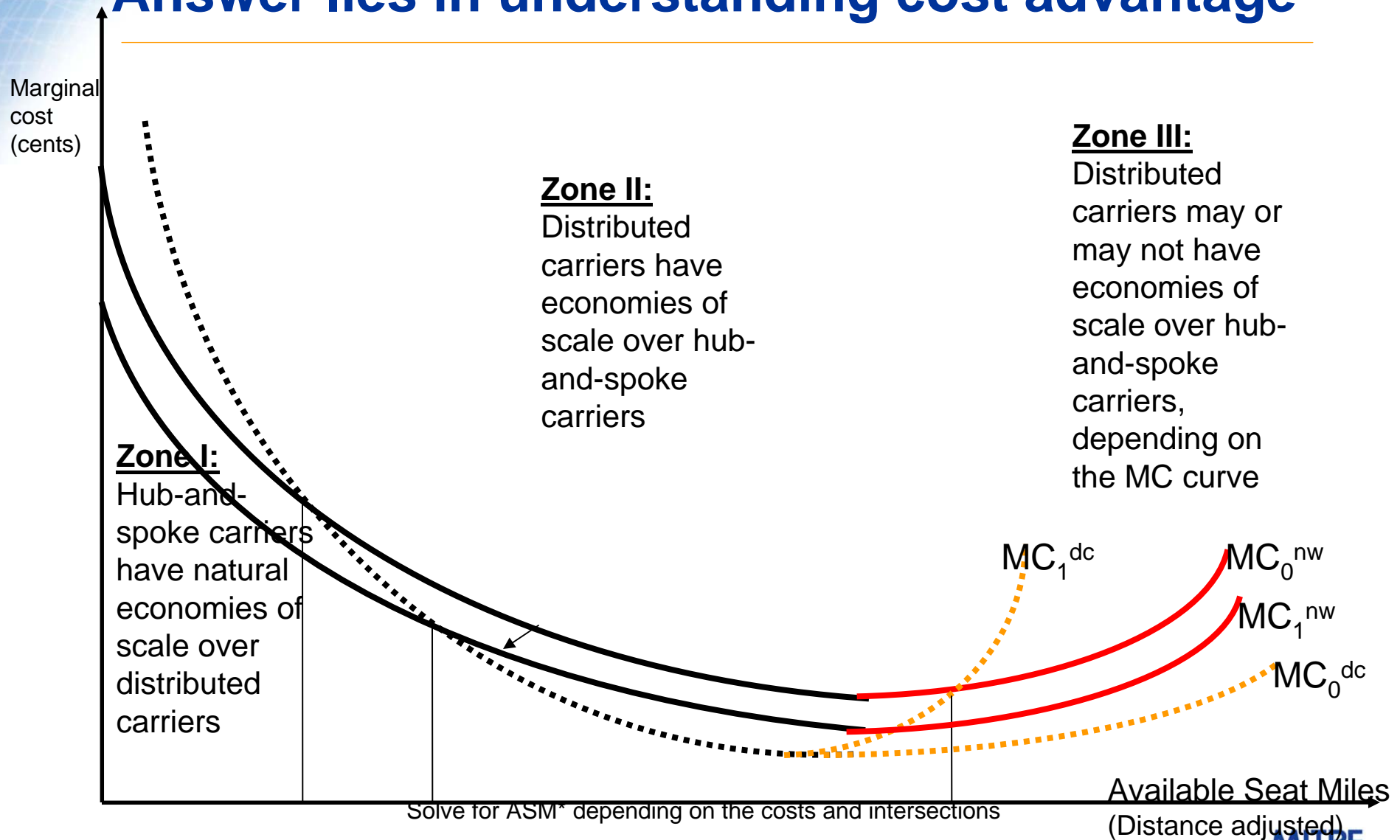
# Carrier Average Fares by Distance Group





# Will low-cost carriers and hence their network structure inherit the earth?

## Answer lies in understanding cost advantage







## Please leave us your contacts for details and a revised paper

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- Dipasis Bhadra: [dbhadra@mitre.org](mailto:dbhadra@mitre.org)
- Brendan Hogan: [bhogan@mitre.org](mailto:bhogan@mitre.org)
- Visit us at: [www.mitrecaasd.org](http://www.mitrecaasd.org)

***Thank you***



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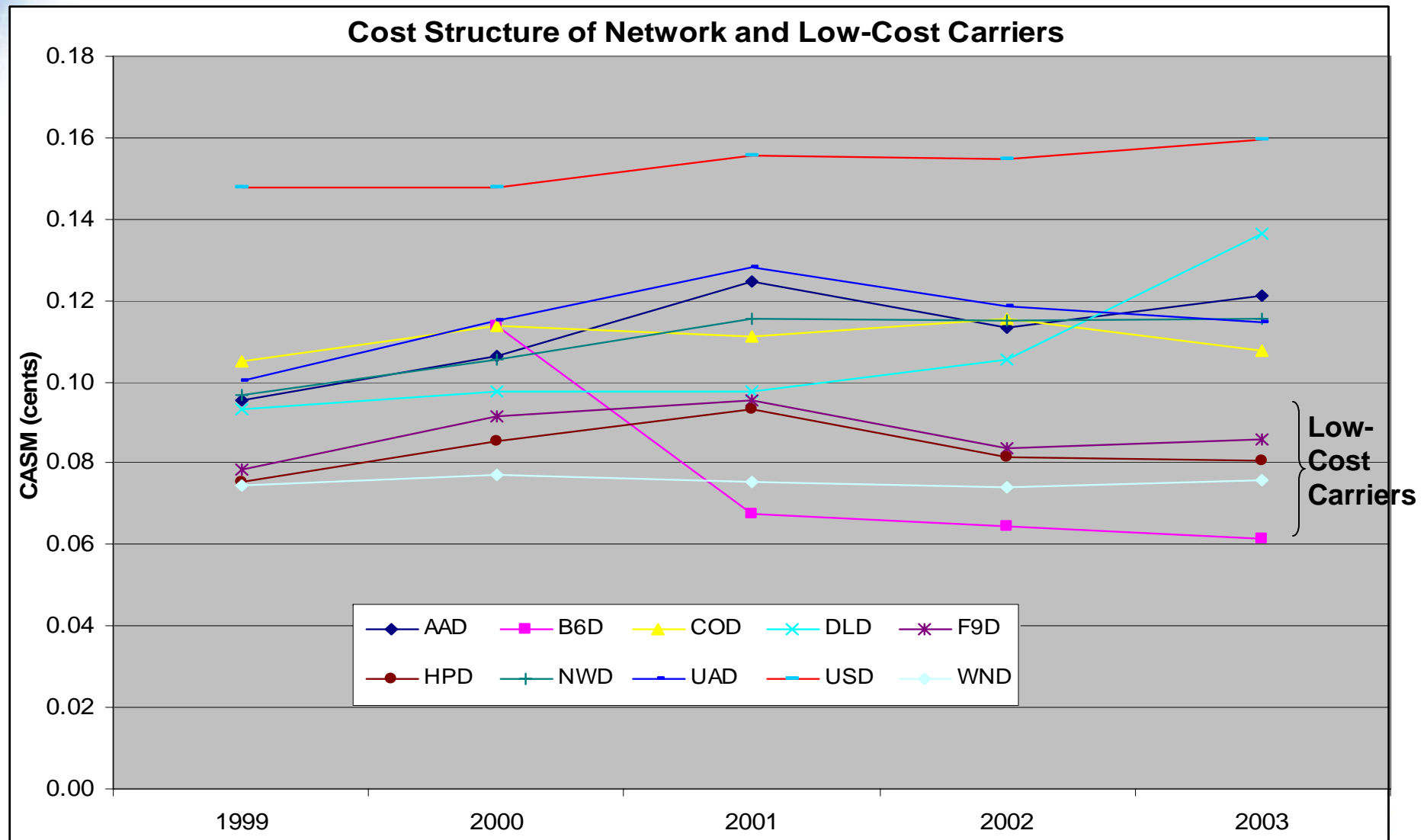
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## Back Up Slides

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# Relative cost advantage of low-cost carriers have been maintained over time





# Airline Network: Our Definition for this Analysis

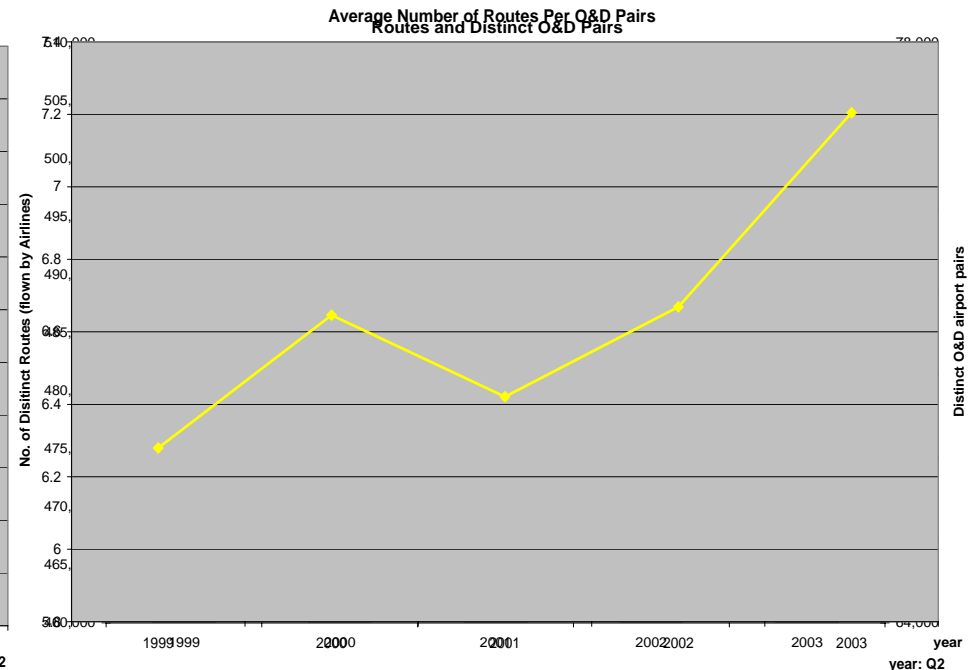
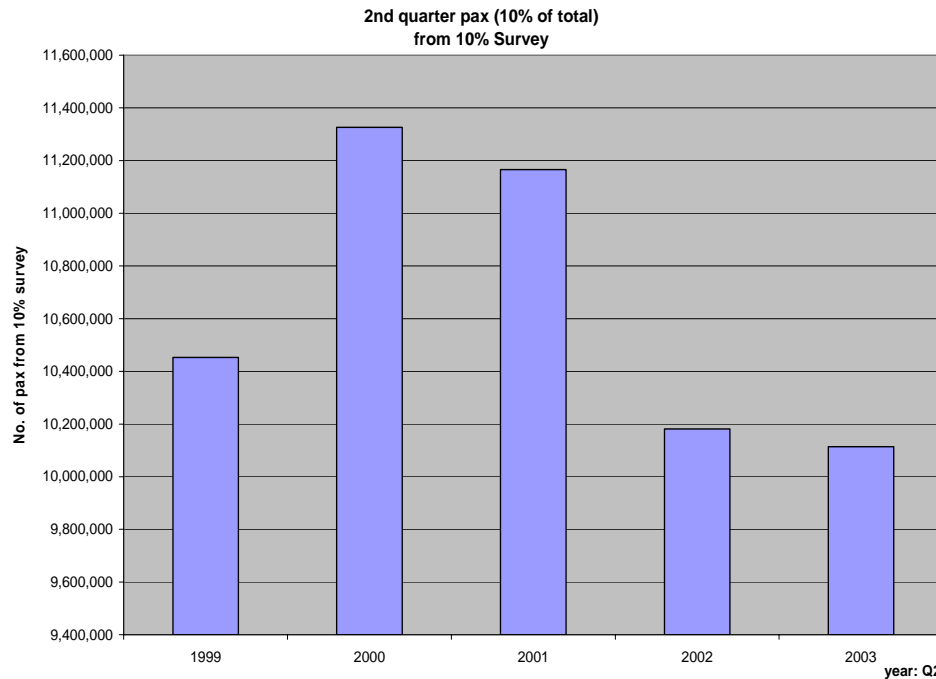
- **Spoke Network**: Travel is between non-major hubs and airports;
  - example: TEB-HGA; *network = 0*;
- **Hub Network**: Travel is between major hubs;
  - example: travel between ATL-BOS; *network = 1*;
- **Outbound**: Origin is a major hub but destination is not a major hub, i.e., variation of HS;
  - example: ATL-TEB; *network = 2*;
- **Inbound**: Origin is not a major hub but destination is a major hub, i.e., variation of HS;
  - example: TEB-ATL; *network = 3*;
- Major Hubs (35), according to the last OEP Definition:  
  
ATL; BOS; BWI; CLT; CVG;  
DCA; DEN; DFW; DTW;  
EWR; HNL; IAD; IAH; JFK;  
LAS; LAX; LGA; MCO;  
MEM; MIA; MSP; ORD;  
PHL; PHX; PIT; SAN; SEA;  
SFO; SLC; STL; TPA;  
MDW; FLL; PDX; and CLE;



# Analytical Model to Determine Itinerary Number of Stops by Market

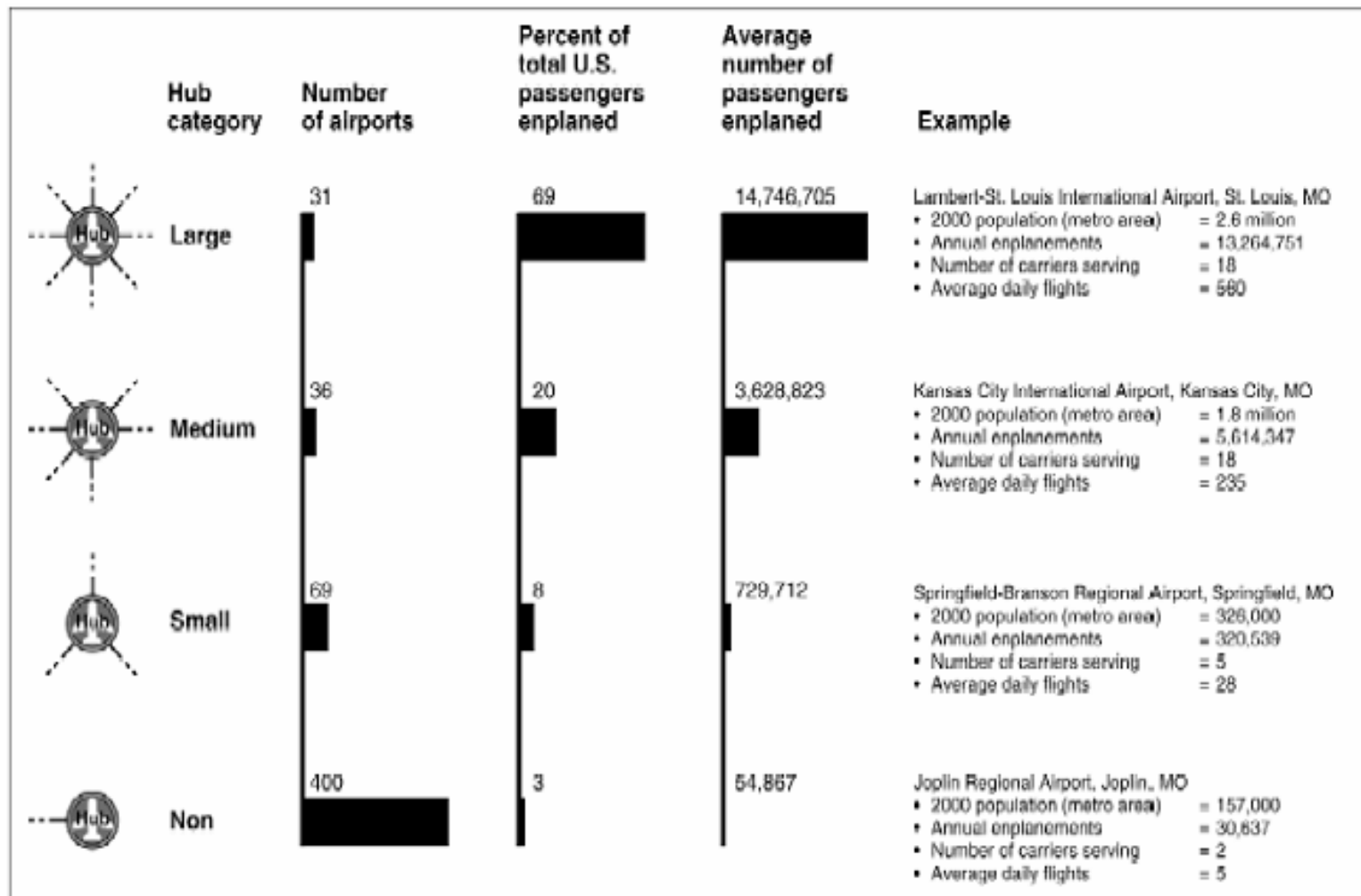
$$P_i (y_i = j | x_i, \beta) = \alpha_{ij} + \beta_1 (\text{passengers\_Inline}) + \beta_2 (\text{Average Distance}) + \beta_3 (\text{Passengers\_O\&D Market}) + \beta_4 (\text{Weighted Average Fare}) + \beta_5 (\text{Presence of Network Carriers}) + \beta_6 (\text{Presence of LCC Carriers}) + \varepsilon_i \quad (\text{E.1})$$

(j = 1, 2, ..., 6)



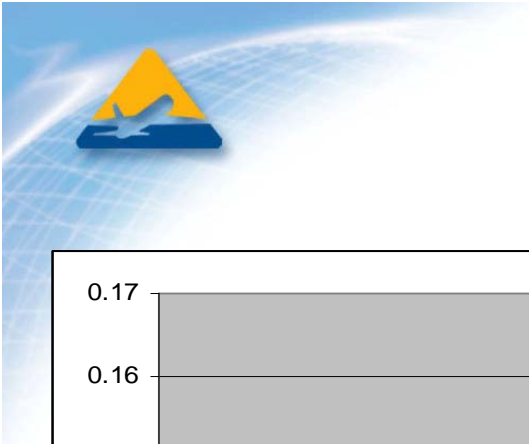


# Airline Network Used To Be Primarily Hub-and-Spoke

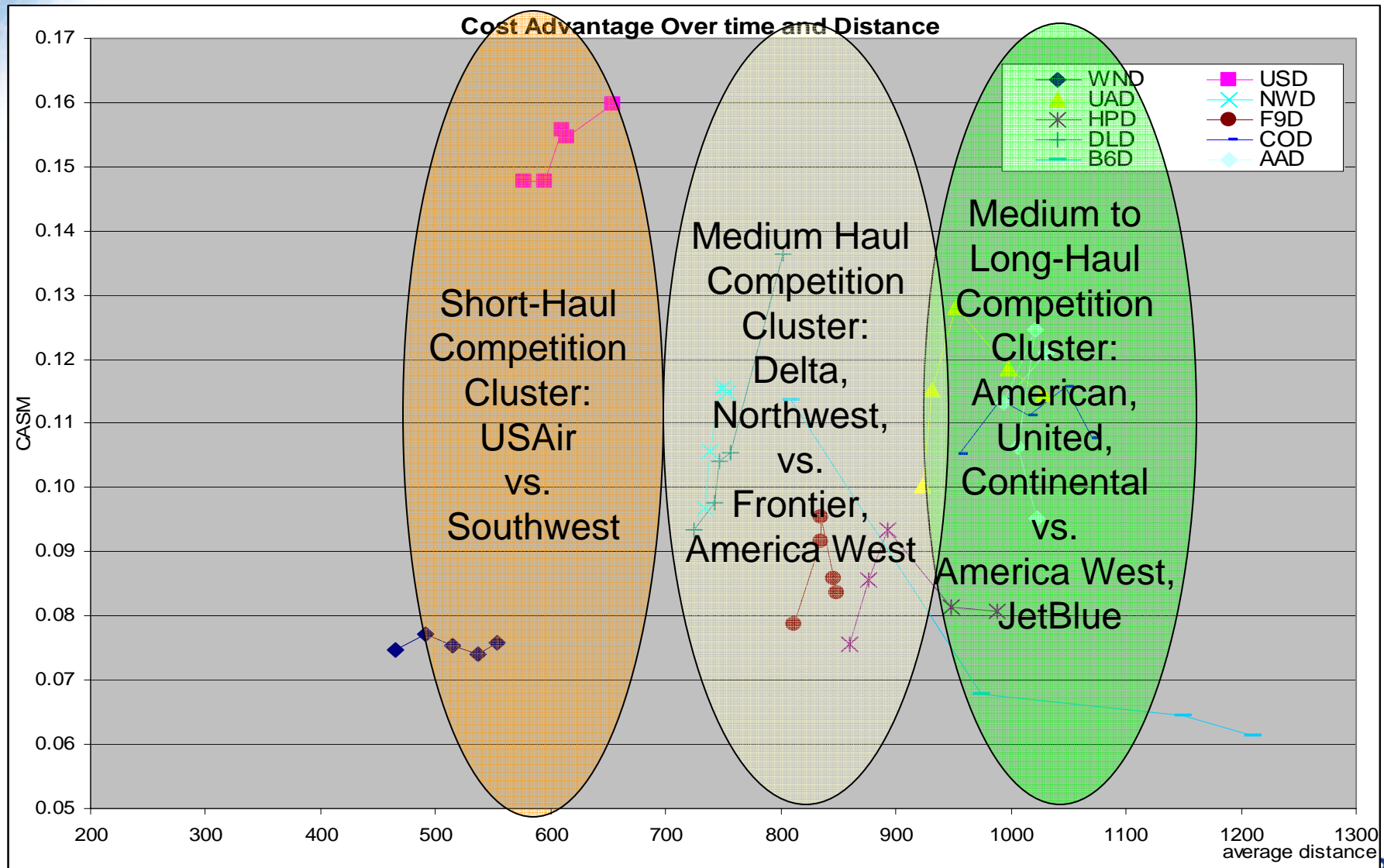


Source: GAO (analysis), FAA (data), Seabrook (data), and U.S. Census Bureau (data).





# Competition Cluster



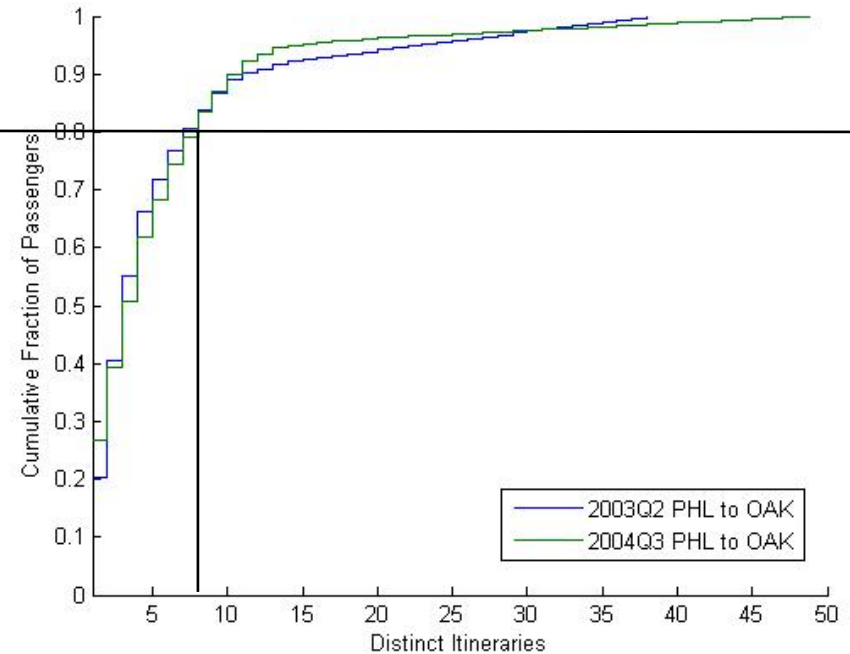
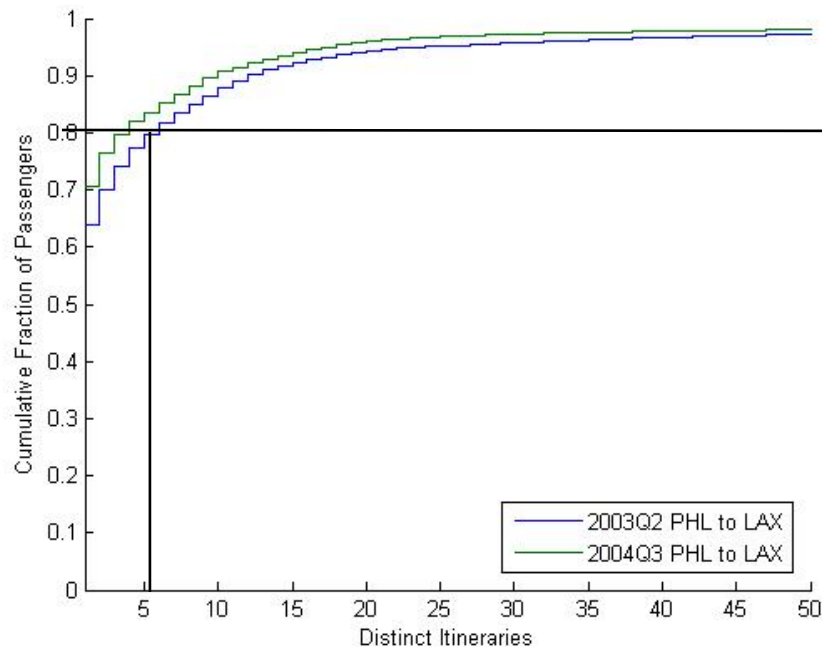




# Quantitative Difference between Distributed and Centralized Markets

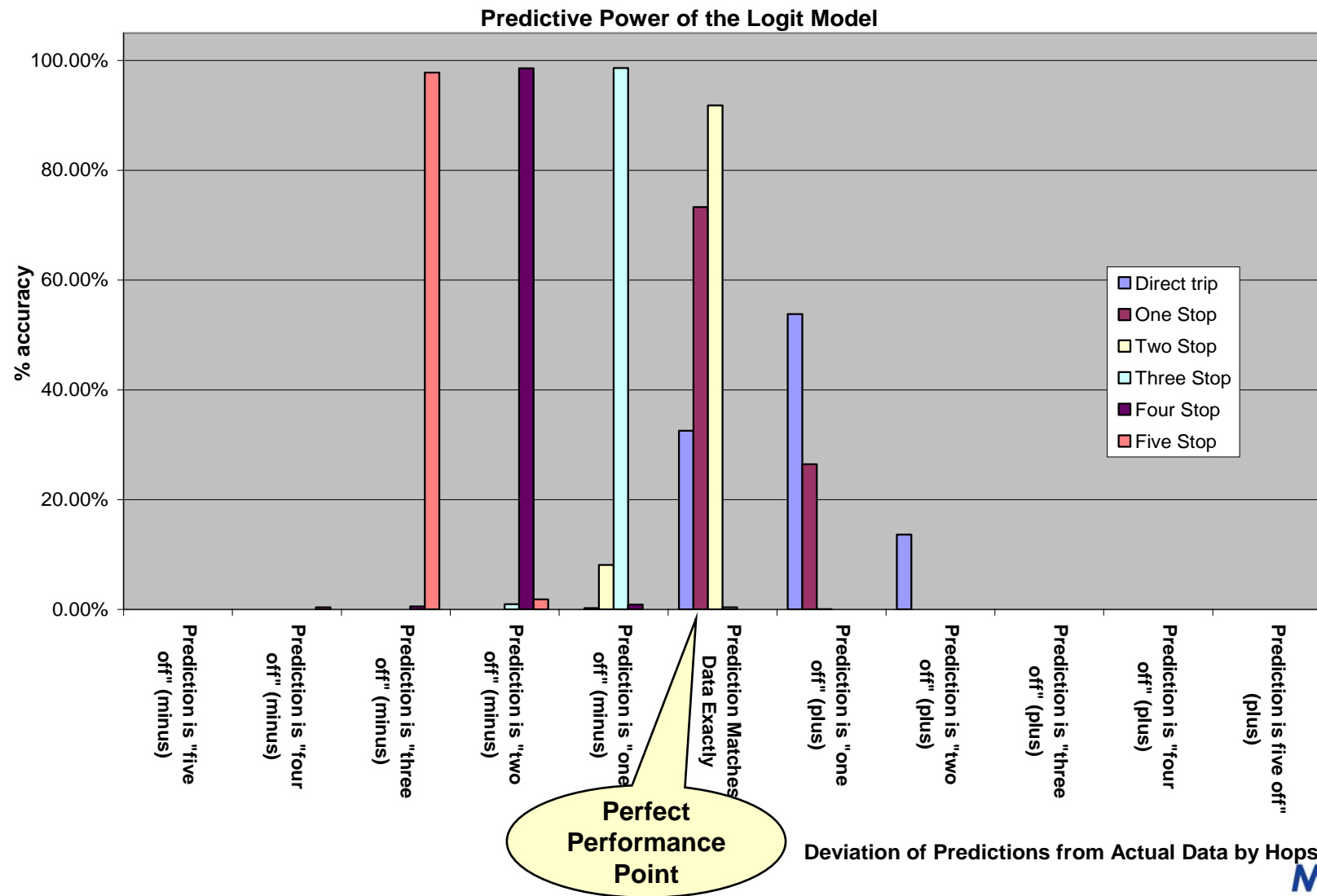
70% take the most common routing (direct)

20% take the most common routing (direct)



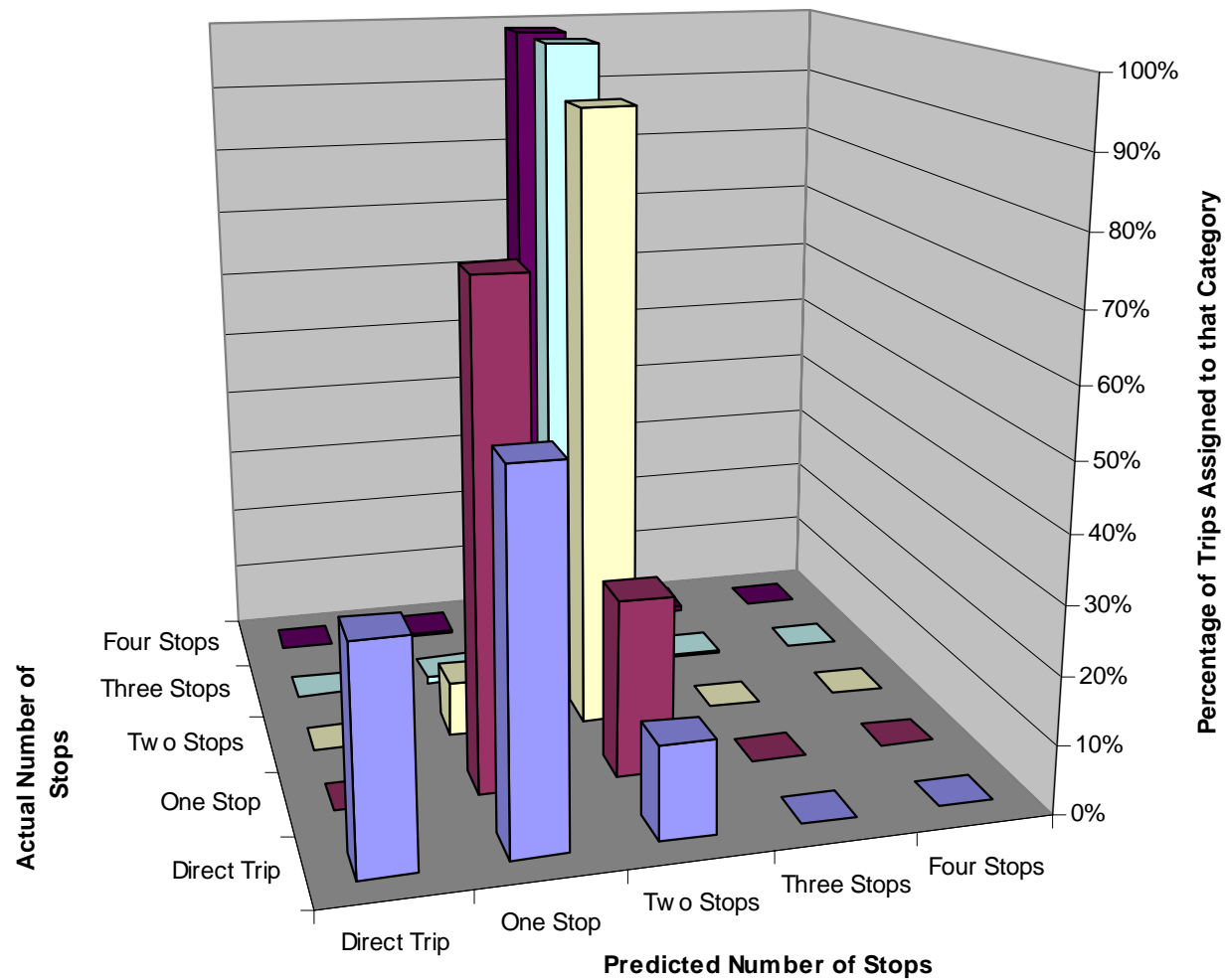


# How Well Does the Model Perform?





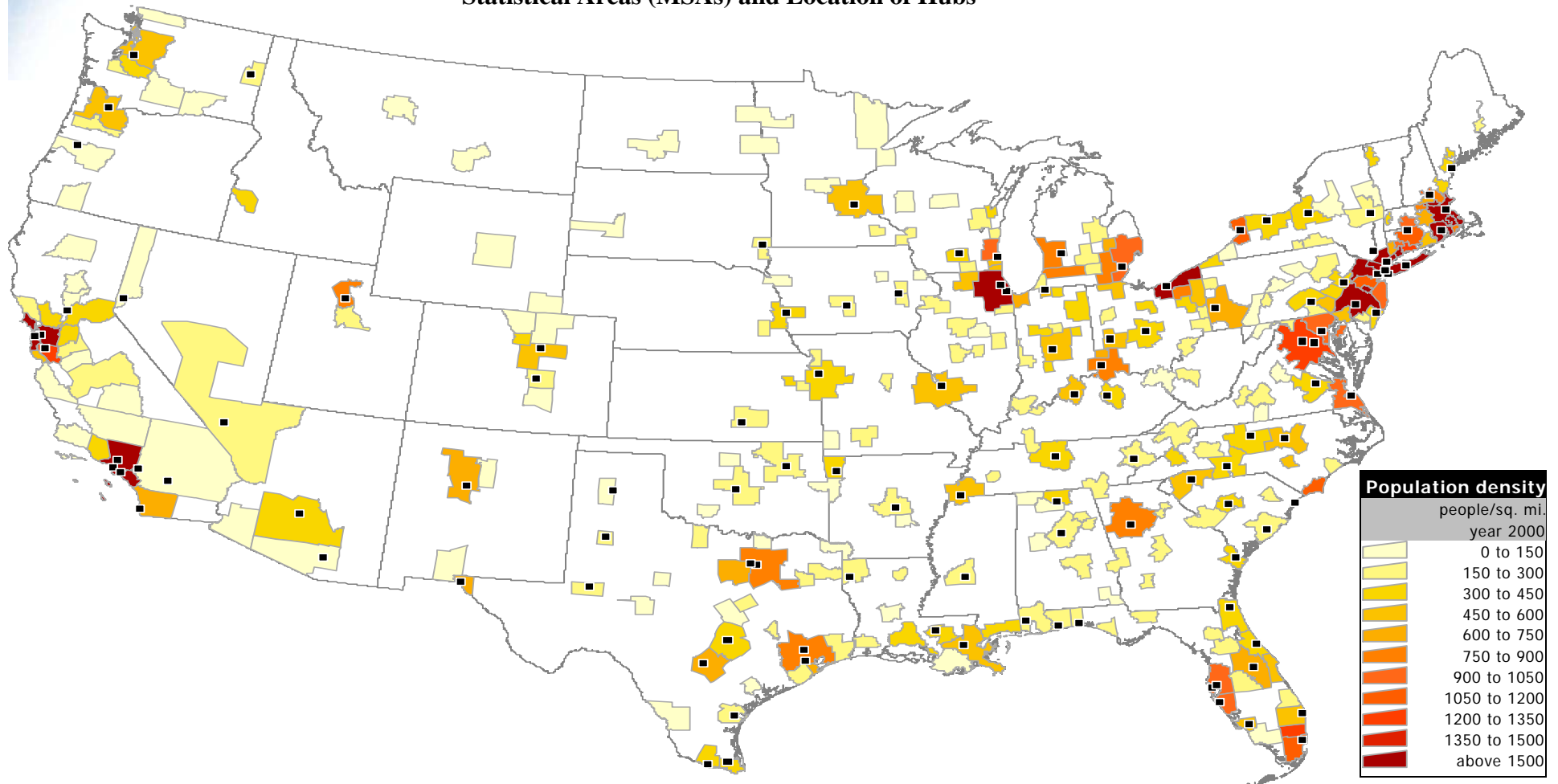
## Predictive Performance of Model Across Itinerary Types





**We observe that major US airports are located where the population centers are....**

**Density Distribution in Metropolitan  
Statistical Areas (MSAs) and Location of Hubs**

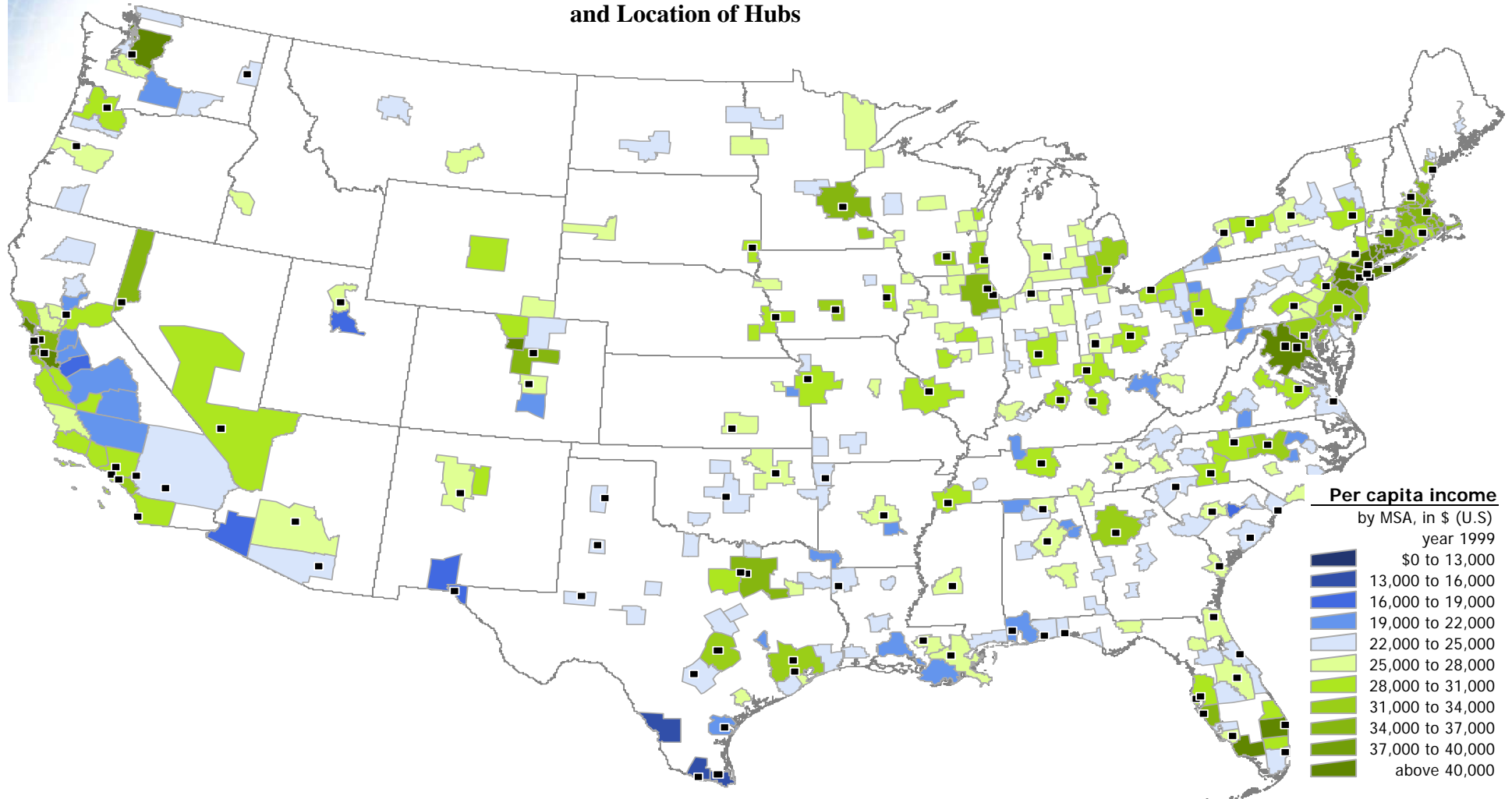


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and....higher the per capita income, the greater the likelihood of major airports

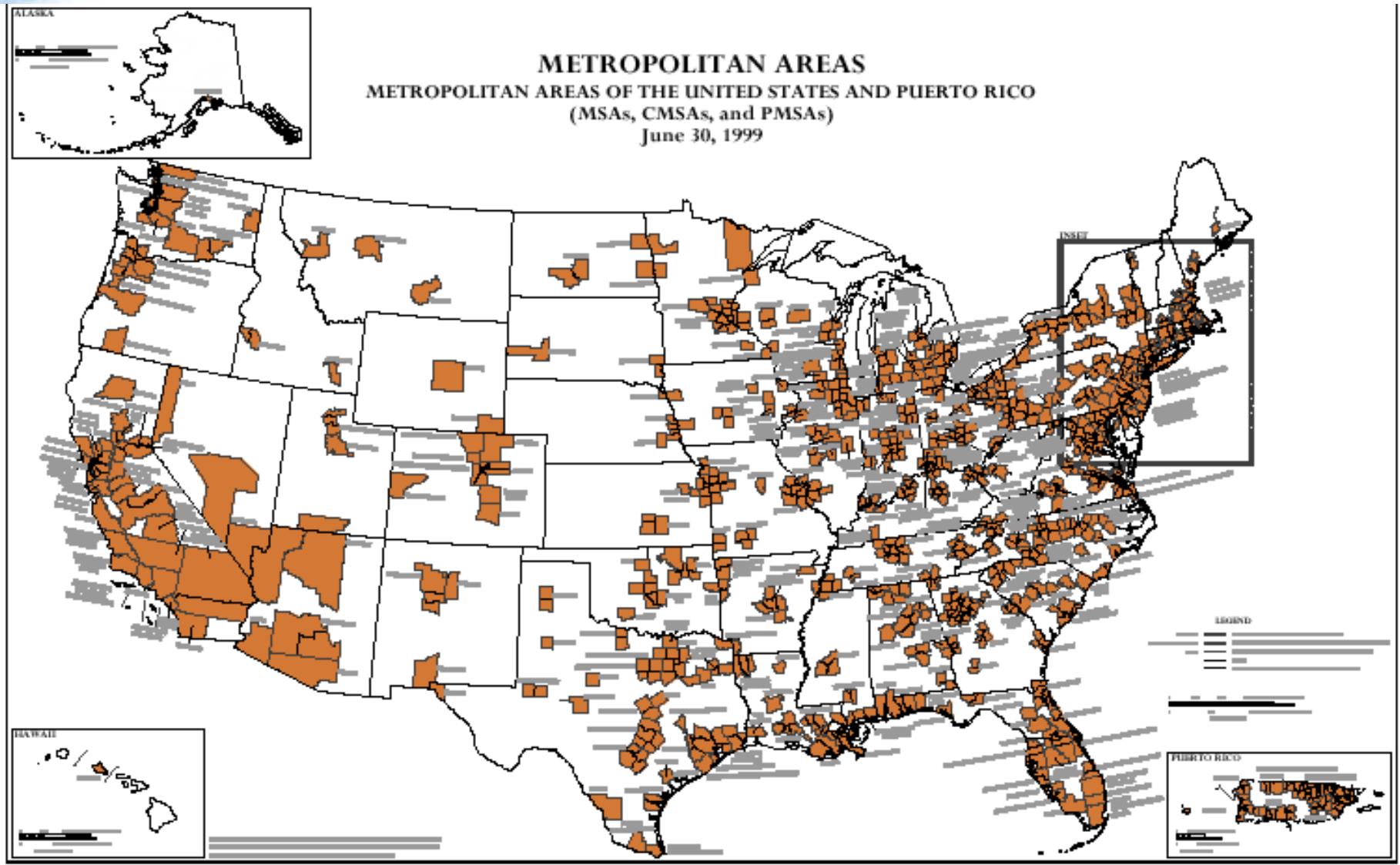
Income Distribution in MSAs  
and Location of Hubs



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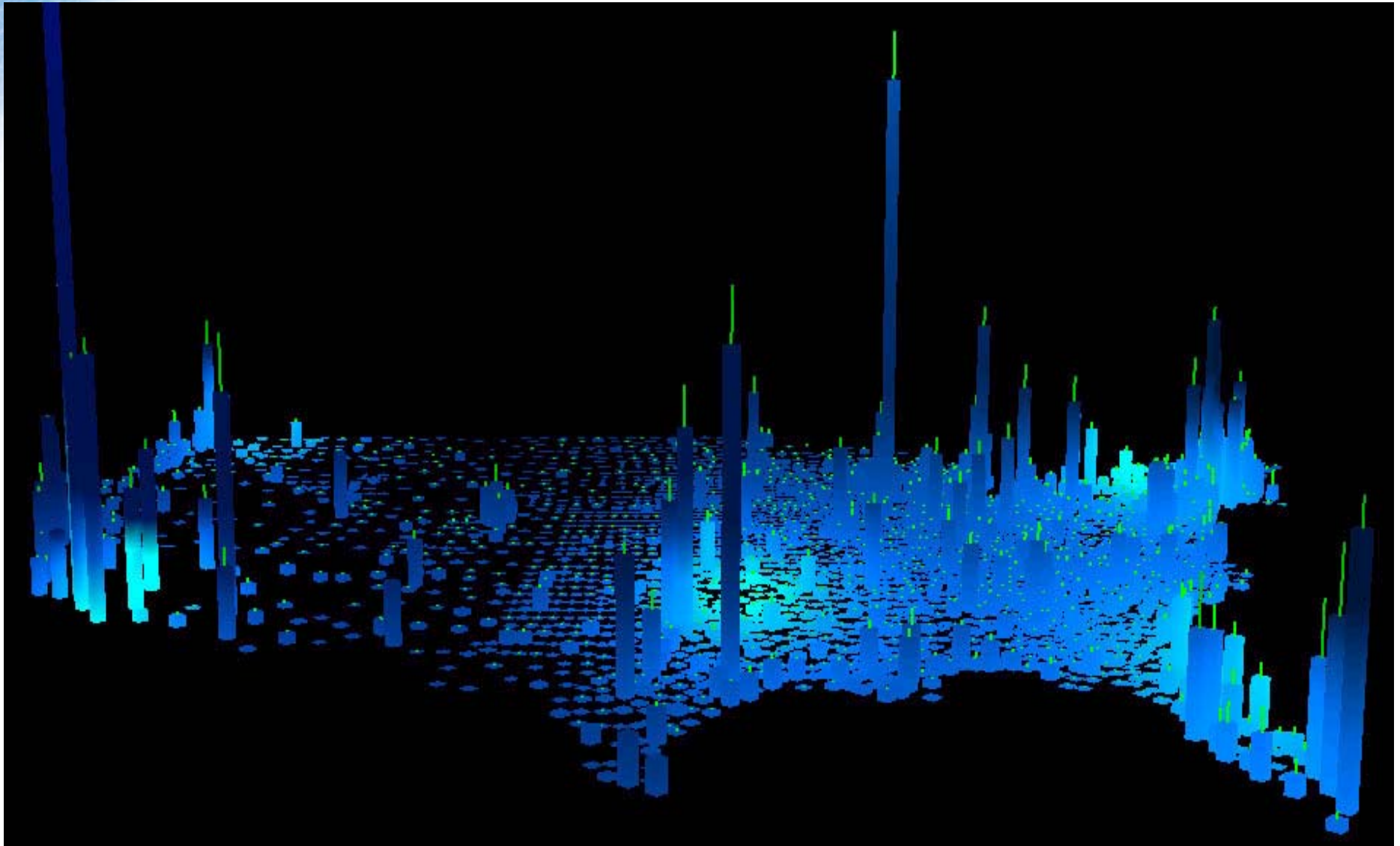
## Aviation activities result from economics and demographics: Metropolitan areas as engine of growth







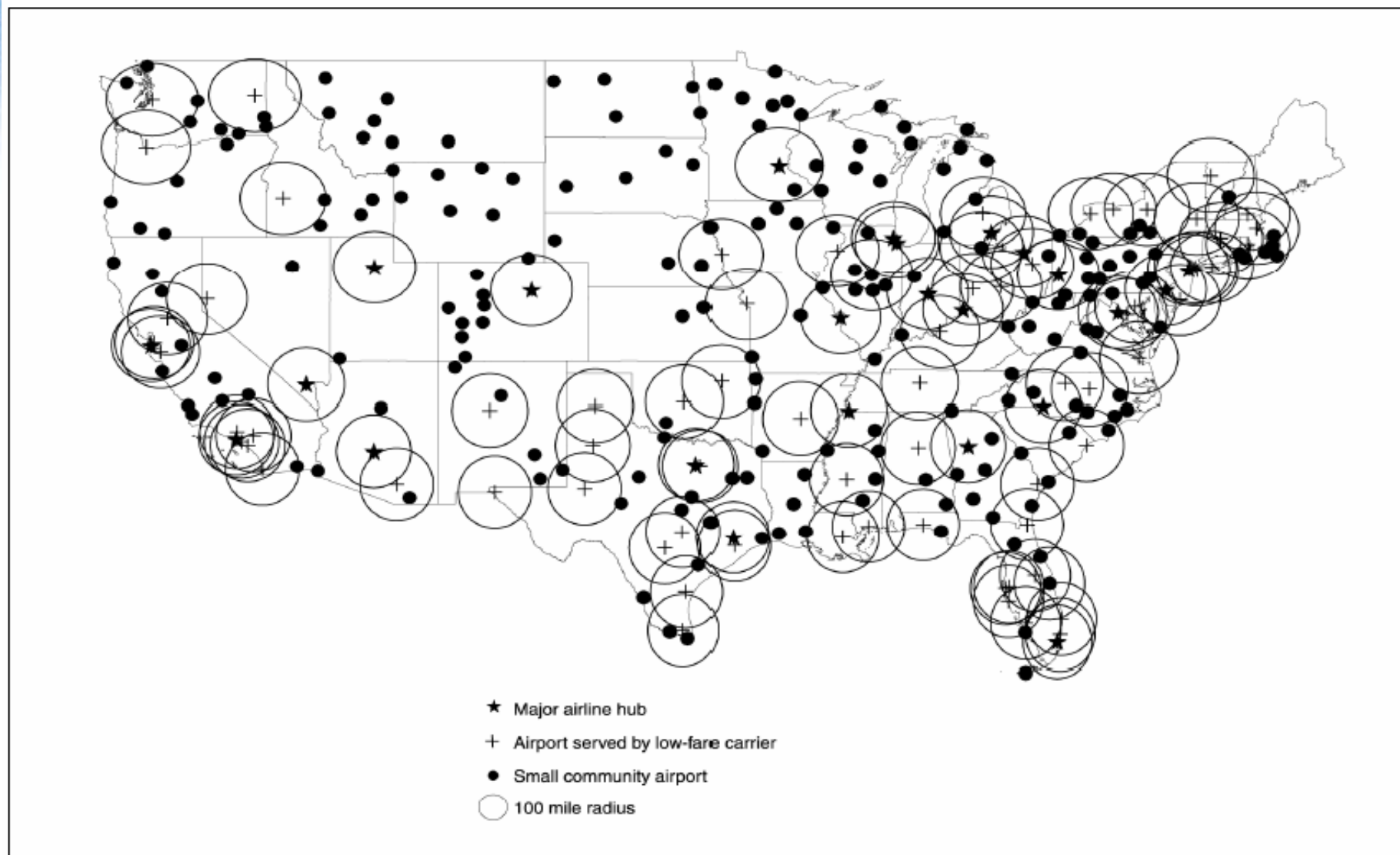
## Uneven density results from uneven economic and demographic activities



Source: [http://www.manifold.net/press/us\\_pops\\_scrn.jpg](http://www.manifold.net/press/us_pops_scrn.jpg)



## Airports and airlines serve peoples' needs







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