F066-B03-014

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Building a Timetable from the Bottom Up: A Microeconometric Approach

NEXTOR-FAA Conference

Virginia Tech Graduate Center

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Our Product: A Flight Timetable (or Schedule) Based on Projected Future Demand

Departure Airport	Arrival Airport	Equipment	Departure Time (GMT)	Arrival Time (GMT)
JFK	CUN	B752	3:40:00 PM	M
JFK	DCA	E145	3:50:00 PM	M
JFK	FLL	A320	3:45:00 PM	M
JFK	IAD	JS41		PM
HGR	TEB	PAY4		6:05:00 PM
JFK	IAD	CRJ1		4:31:00 PM
JFK	KIN	A343		7:05:00 PM
JFK				9:01:00 PM
JFK			3:10:00 PM	9:15:00 PM
JFK			3:30:00 PM	9:23:00 PM
JFK			3:45:00 PM	6:25:00 PM
JFK		B752	3:25:00 PM	6:11:00 PM
J		A320	3:40:00 PM	10:15:00 PM
J		A306	3:00:00 PM	6:53:00 PM
J		A320	3:30:00 PM	6:20:00 PM

Weekday 2004, Q4

Weekend 2006, Q3

Weekday 2018, Q2

Weekend 20xx, Qx

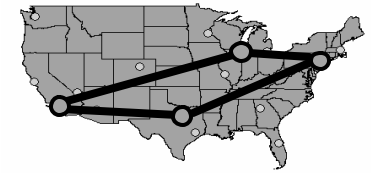
The Usual Method: Top-Down Forecasts

- Starts with national-level macro drivers, and allocates regional effects, if necessary.
- Straightforward process that works well in projecting long-term trends.
- However, because macro factors are the primary “drivers”, regional differences are often missed.
- No network effects.

Our Method: A Multi-Step Approach, Going from the Bottom Up

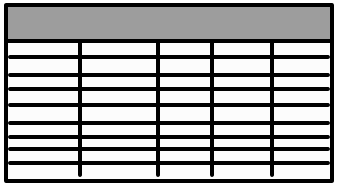
Estimate O&D Passenger Demand

Calculate Total "Segment" Passengers



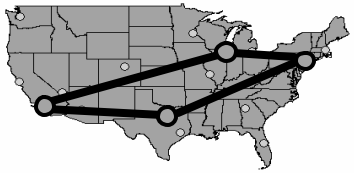
Estimate the Number & Size of A/C by Segment

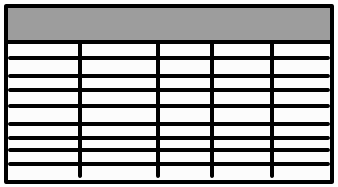
Create Timetable for Scheduled and Unscheduled



Step 1: Estimating O&D Demand

Estimate O&D Passenger Demand





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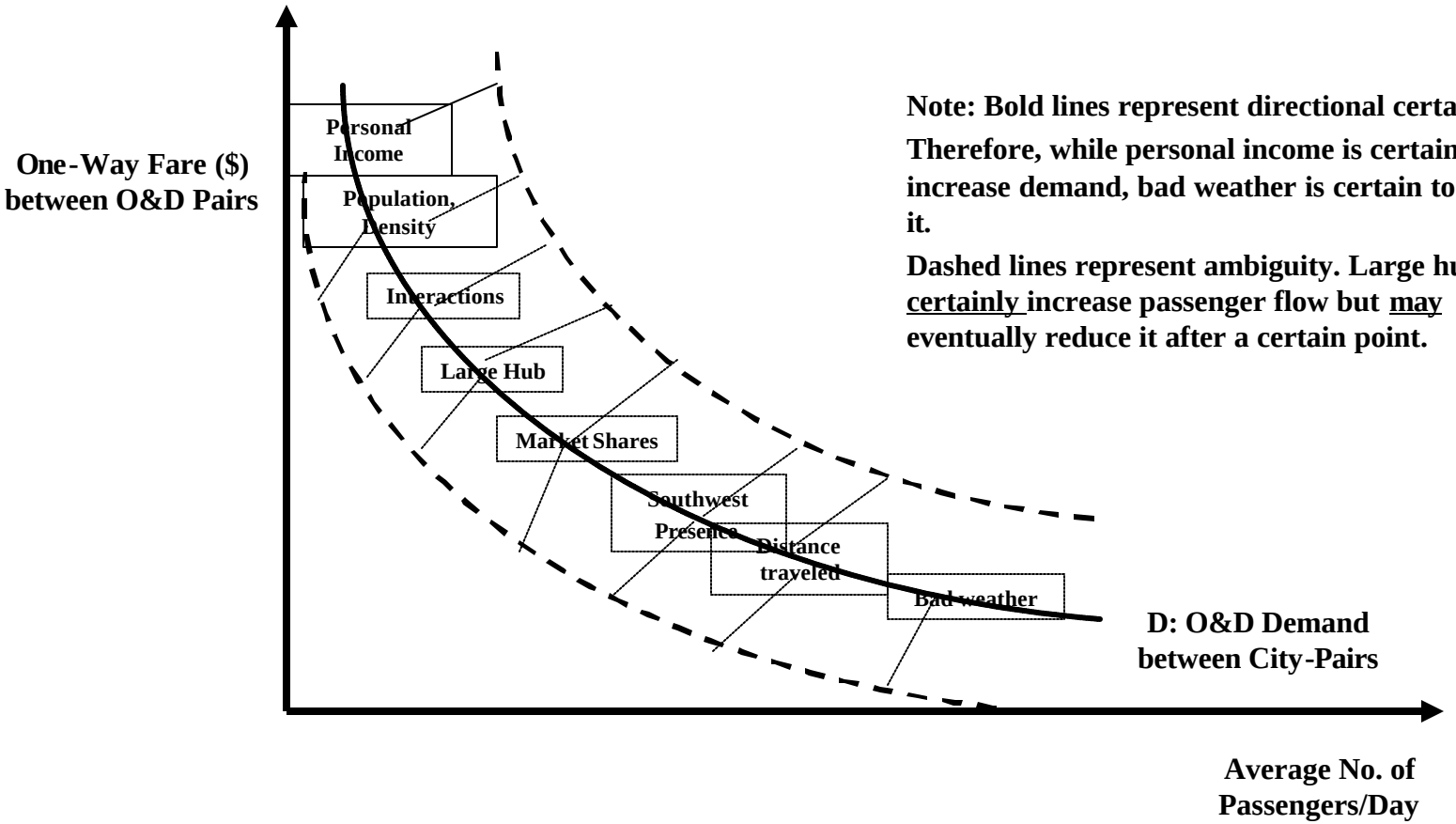
Determinants of Air Travel Demand Between O&D Pairs: Conceptual Framework



Note: Bold lines represent directional certainty.

Therefore, while personal income is certain to increase demand, bad weather is certain to reduce it.

Dashed lines represent ambiguity. Large hubs, will certainly increase passenger flow but may eventually reduce it after a certain point.

Source: Bhadra, D. (2003). "Demand for Air Travel in the United States: Bottom-Up Econometric Estimation and Implications for Forecasts by O&D pairs", *Journal of Air Transportation* (forthcoming).

Combining DOT Passenger Data with Local Economic and Demographic Forecasts

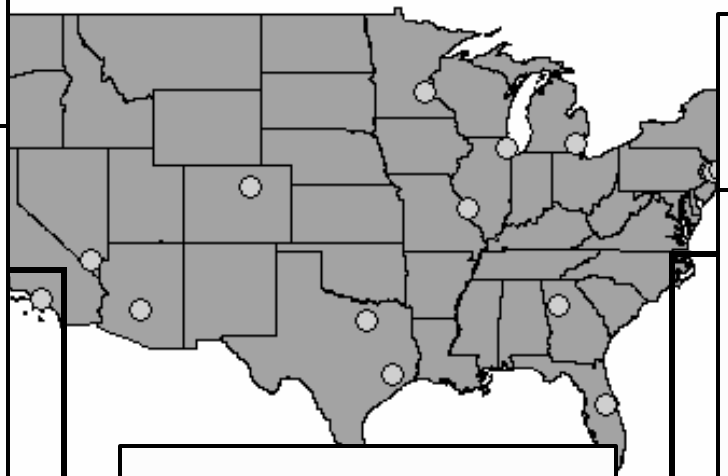
Airline Passenger Data

Local Economic Data

10% Ticket Sample

2000:1 - 2001:2

- Passengers
- Fare
- Carrier(s)
- Exact Itinerary
- Miles flown



- Airports
- Metropolitan Areas

Demographic Data

1975:1 - 2025: 4

- Population
- Income
- Employment

Basic Econometric Framework

Example of Data Set

Year	Qtr	Origin	Destination	Distance	Pax	Fare	Origin_pop
2000	1	ALBANY, NY, USA	BUFFALO, NY, USA	251	158	139	869,474
2000	1	BINGHAMTON, NY, U	PITTSBURGH, PA, US	251	14	220	
2000	1	CHICAGO, IL, USA	ST. LOUIS, MO, USA	251	2,503	88	8,008,507
2000	1	DENVER, CO, USA	DURANGO, CO, USA	251	76	161	1,978,991
2000	2	ALBANY, NY, USA	BUFFALO, NY, USA	251	155	154	869,474
2000	2	BINGHAMTON, NY, U	PITTSBURGH, PA, US	251	20	186	
2000	2	CHICAGO, IL, USA	ST. LOUIS, MO, USA	251	2,718	94	8,008,507
2000	2	DENVER, CO, USA	DURANGO, CO, USA	251	85	164	1,978,991

Basic Econometric Specification

Semi Log-Linear Specification
(Segmented by Observed Distances in the NAS)

$$\ln(\mathbf{P_{ij}}) = \alpha + \beta * \ln(f_{ij}) + \chi_i * \ln(PI_i) + \chi_j * \ln(PI_j) + \delta_i * \ln(Density_i) + \delta_j * \ln(Density_j) + \phi_i * \ln(Interactions_i) + \phi_j * \ln(Interactions_{ij}) + \eta * \ln(Market\ Power^{D}_{ij}) + \iota * \ln(Market\ Power^{ND}_{ij}) + \kappa^{D} * (Southwest_{ij}) + \kappa^{ND} * (Southwest_{ij}) + \gamma_i * (hub\ statusOrigin) + \gamma_j * (hub\ statusDestination) + \varphi * \ln(Distance_{ij}) + \rho * (season) + \varepsilon_{ij}$$

Comparison with Top-Down Forecasting

Market Features	Existing & FAA work	Our Research
Price Elasticities	uses one general number	effects are evaluated by distance bands
Income Elasticities	economy-wide(GDP) general number	effects are evaluated by distance bands
Distance Elastiticities	does not incorporate	effects are evaluated by distance bands
Seasonality	does not incorporate	effects are evaluated by distance bands
Low-cost carriers	part of anti-trust evaluation procedure	effects are evaluated by distance bands
Industry concentrations	part of anti-trust evaluation procedure	effects are evaluated by distance bands
Local economies, & demographies	does not incorporate	effects are evaluated by distance bands

leads to

Improved benefit assessment

Evaluation of future infrastructure for a particular airport

Evaluations of spring/ summer on scheduled air transportation

Assessment of policy changes, e.g., demand mgmt policies on airports

Evaluations of effects of low-cost carriers by market distances

Evaluations of market structures on scheduled air transportation

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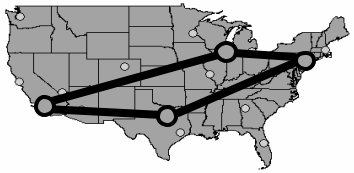
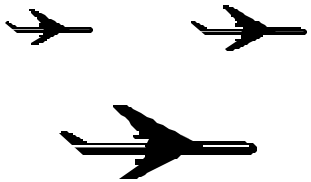
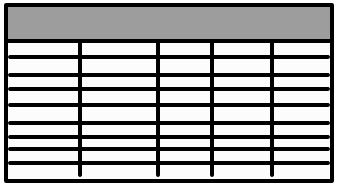
Step 2: Estimating Segment Demand

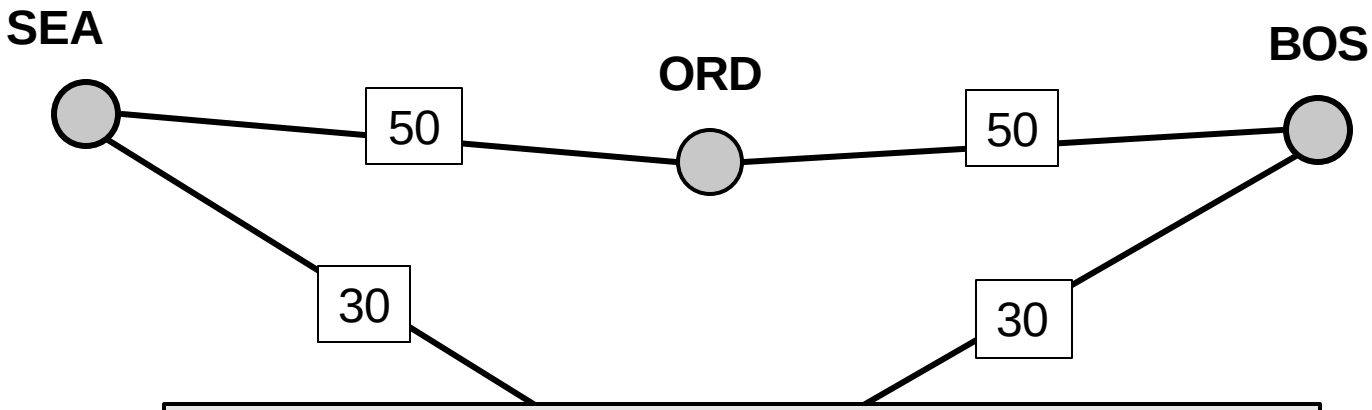
Calculate Total "Segment" Passengers







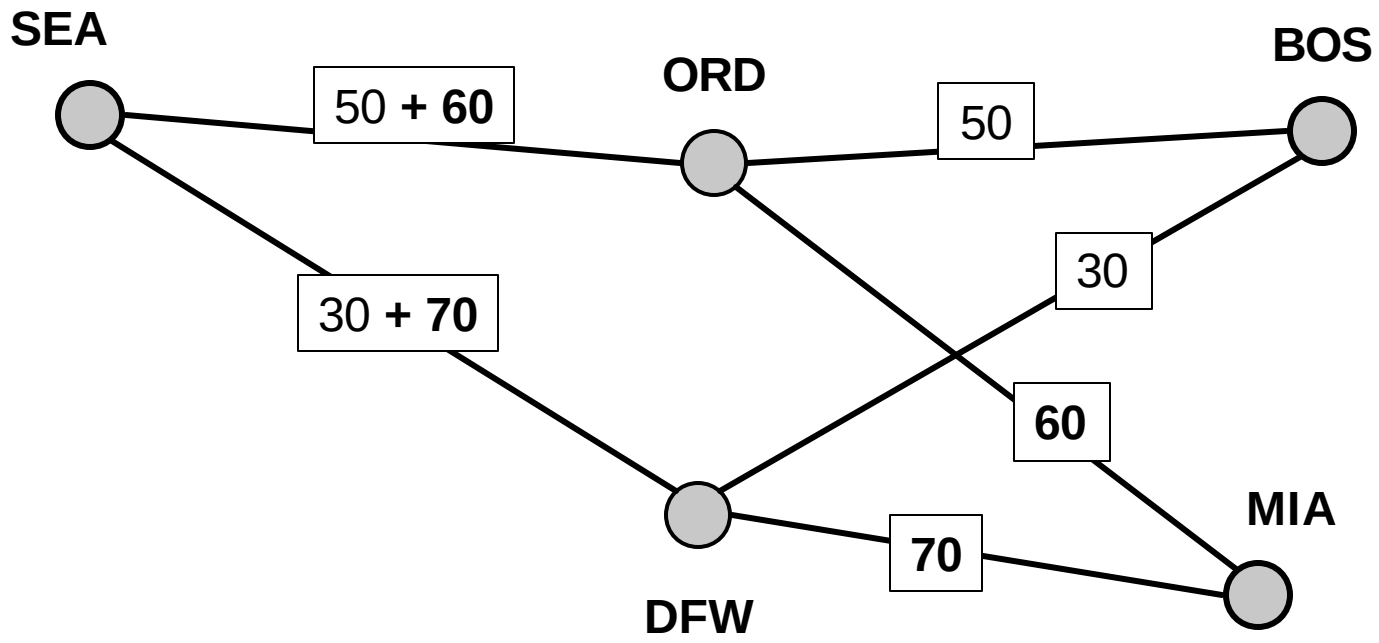
Assign OD Passengers to Routes Based On Relative Desirability



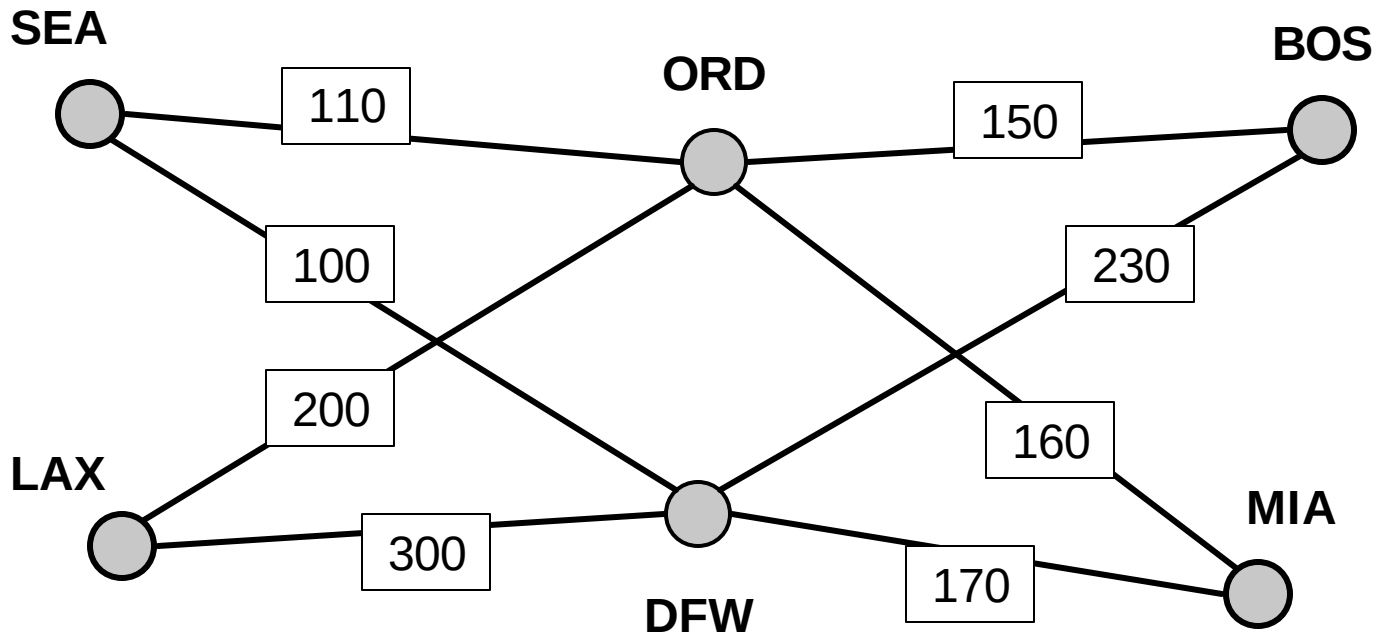
"Desirability" is based on route characteristics, such as block time and number of stops.

We calibrate passenger choice by applying a "Logit" model to data from the 10% Ticket Sample.

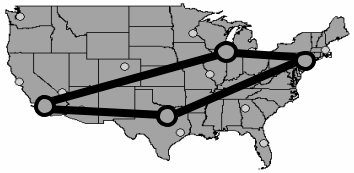
Estimate Each Market in Turn, Adding Up Passengers on Each Segment



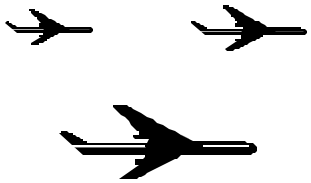
At the End, We Arrive at an Estimate of Total Passengers by *Airport* Pair

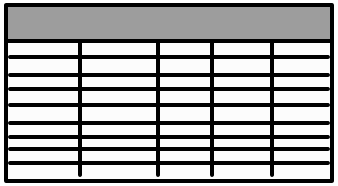


Step 3: Estimate Aircraft Used by Segment

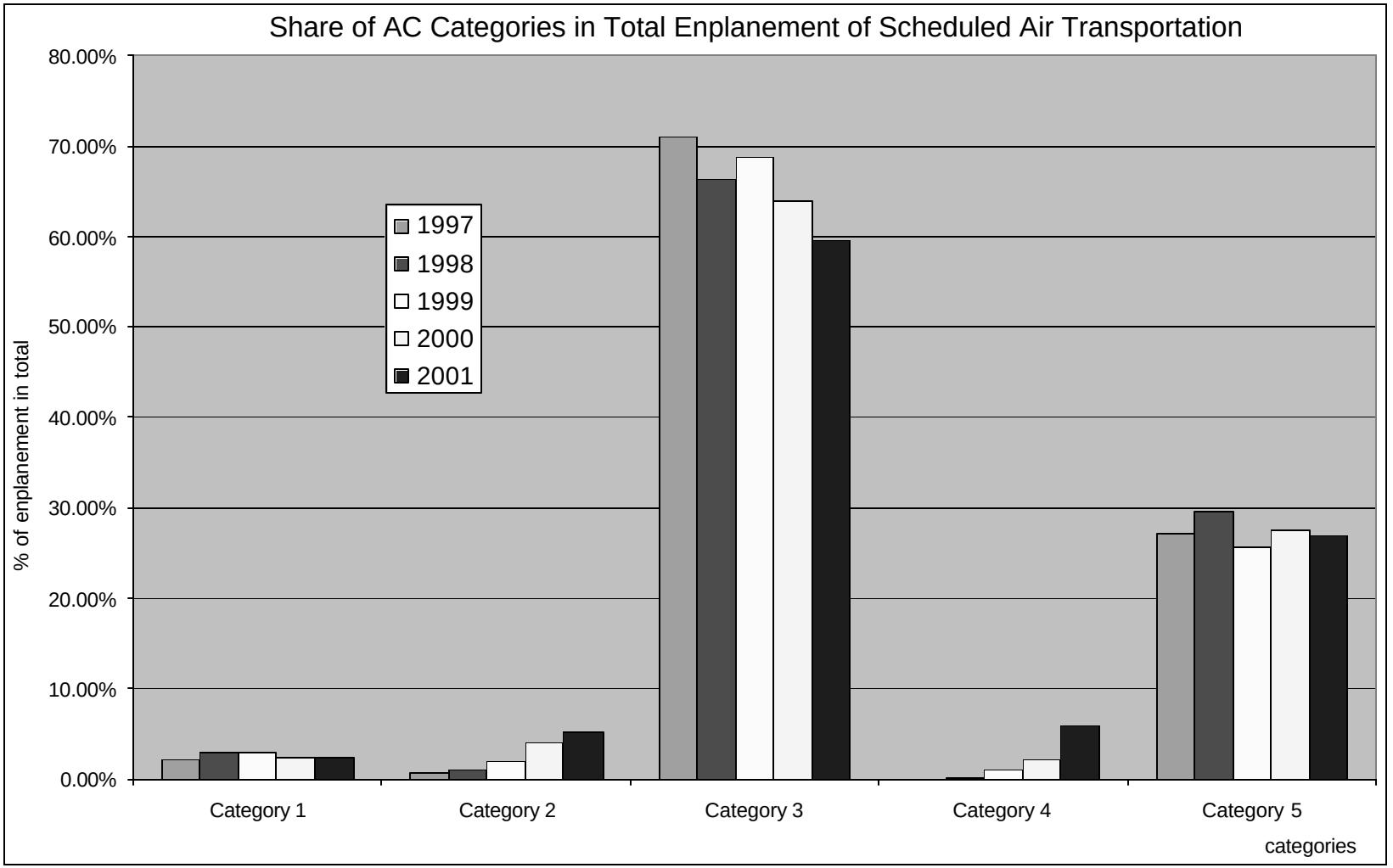


Estimate the Number & Size of A/C by Segment





Distribution of Passengers by A/C Category
(Cumulative total > 90%)



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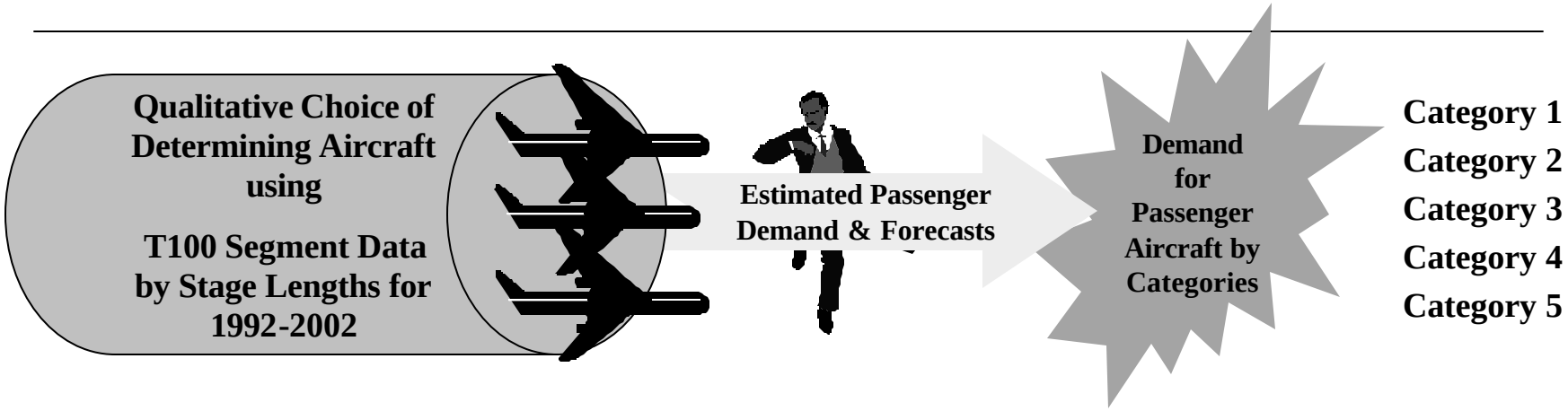
Source: T-100 Segment Data; DOT/BTS

Type of Aircraft in Each of Five Categories

Types of A/C	Types of Equipment	Broad Category	Avg. Distance (miles)	Avg. Size Range (no. of pax)	Best Cruise Speed (MPH)	Service Status
TurboProps	SF-340 SAAB-Fairchild 340		< 250	30-37	328	Production Terminated
TurboProps	ATR-72 ATR-72 Aerospatial	Category 1	< 250	60-72	319	--
TurboProps	ATR-42 ATR-42 Aerospatial		< 250	43-53	345	--
Narrow Body	EMB-145 Embraer EMB-145		250-500	45-55	566	in service
Narrow Body	DC-9-50 Douglas DC-9-50	Category 2	250-500	122-148	586	Production terminated
Narrow Body	RJ-145 Canadair RJ145-200		250-500	45-55	566	in service
Narrow Body	B-737-3/7 Boeing B-737-300		500-750	114-138	566	--
Narrow Body	MD-80 MD-80 & DC-9-80 Al		500-750	122-148	576	
Narrow Body	B-727-2 Boeing B-727-200/2		500-750	131-156	600+	Production terminated
Narrow Body	B-737-1/2 Boeing B-737-100/	Category 3	500-750	93-113	586	Production terminated
Narrow Body	DC-9-30 Douglas DC-9-30		500-750	91-121	586	Production terminated
Narrow Body	B-737-5 Boeing B-737-500		500-750	91-121	566	
Narrow Body	B-737-4 Boeing B-737-400		500-750	132-162	566	
Narrow Body	A319 Airbus Industrie A		750-1500	112-136	590	1996
Narrow Body	B737-7/LR Boeing B-737-700/	Category 4	750-1500	113-139	600	--
Wide Body	B-747-4 Boeing B-747-400		> 1500	416-568	700	April, 1988
Wide Body	B-757-2 Boeing B-757-200		> 1500	178-239	600+	
Wide Body	B-767-2/ER Boeing B-767-200	Category 5	> 1500	162-199	700	
Wide Body	B-777 Boeing 777		> 1500	305-365		
Wide Body	B-767-4 Boeing B-767-400		> 1500	245-303		
Wide Body	L-1011-5 Lockheed L-1011-50		> 1500	?		

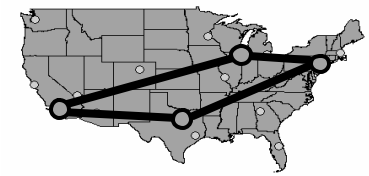
From Passenger Demand to Aircraft Operations by Market Segment: A Qualitative Choice Framework

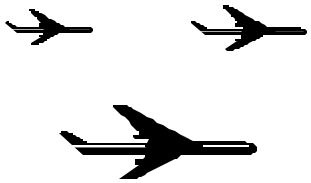


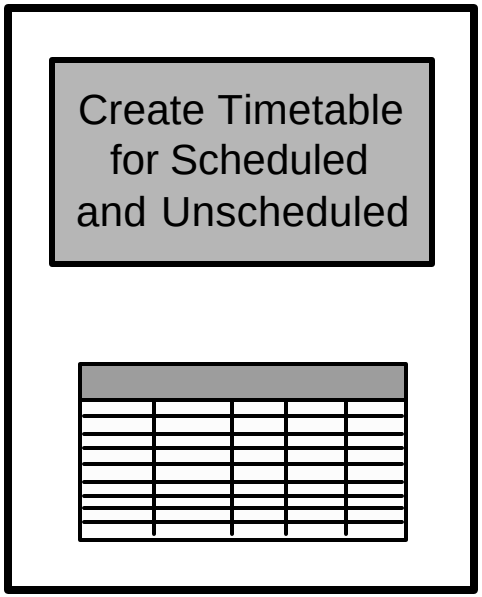
Process of Demand Generation: Passengers to A/C Movements by Market Routes and Stage Lengths

1. **Define the markets by stage lengths, i.e. short-haul (≤1200 miles), medium-haul (≤2000 miles) and longer hauls.**
2. **Classify aircraft into categories from the disaggregated list of almost 70 distinct A/C types over the last 5 years.**

Step 4: Create a Timetable of Flights







Final Timetable: Description of components

Departure Airport	Arrival Airport	Equipment	Departure Time (GMT)	Arrival Time (GMT)
JFK	CUN	B752		7:47:00 PM
JFK	DCA	E145		5:05:00 PM
	FLL	A320		6:40:00 PM
	IAD	JS41	3:57:00 PM	5:26:00 PM
JFK	IAD	CRJ1	3:15:00 PM	4:31:00 PM
JFK		A343	3:15:00 PM	7:05:00 PM
JFK		B752	3:30:00 PM	9:01:00 PM
JFK	LAX	B762	3:10:00 PM	9:15:00 PM
JFK	LAX	B763	3:30:00 PM	9:23:00 PM
	MCO	A320	3:45:00	6:25:00 PM
	MCO		3:25:00	6:11:00 PM
	OAK		3:40:00 PM	10:15:00 PM
		A306	3:00:00 PM	6:53:00 PM
		A320	3:30:00 PM	6:20:00 PM
		B732	3:25:00 PM	6:28:00 PM
JFK	IAD	JS41	3:57:00 PM	5:26:00 PM
HGR	TEB	PAY4	4:00 PM	6:05 PM
JFK	PHX	A320	3:00:00 PM	8:24:00 PM

Time of Day

Airport D

Airport A

Frequency

Block Time

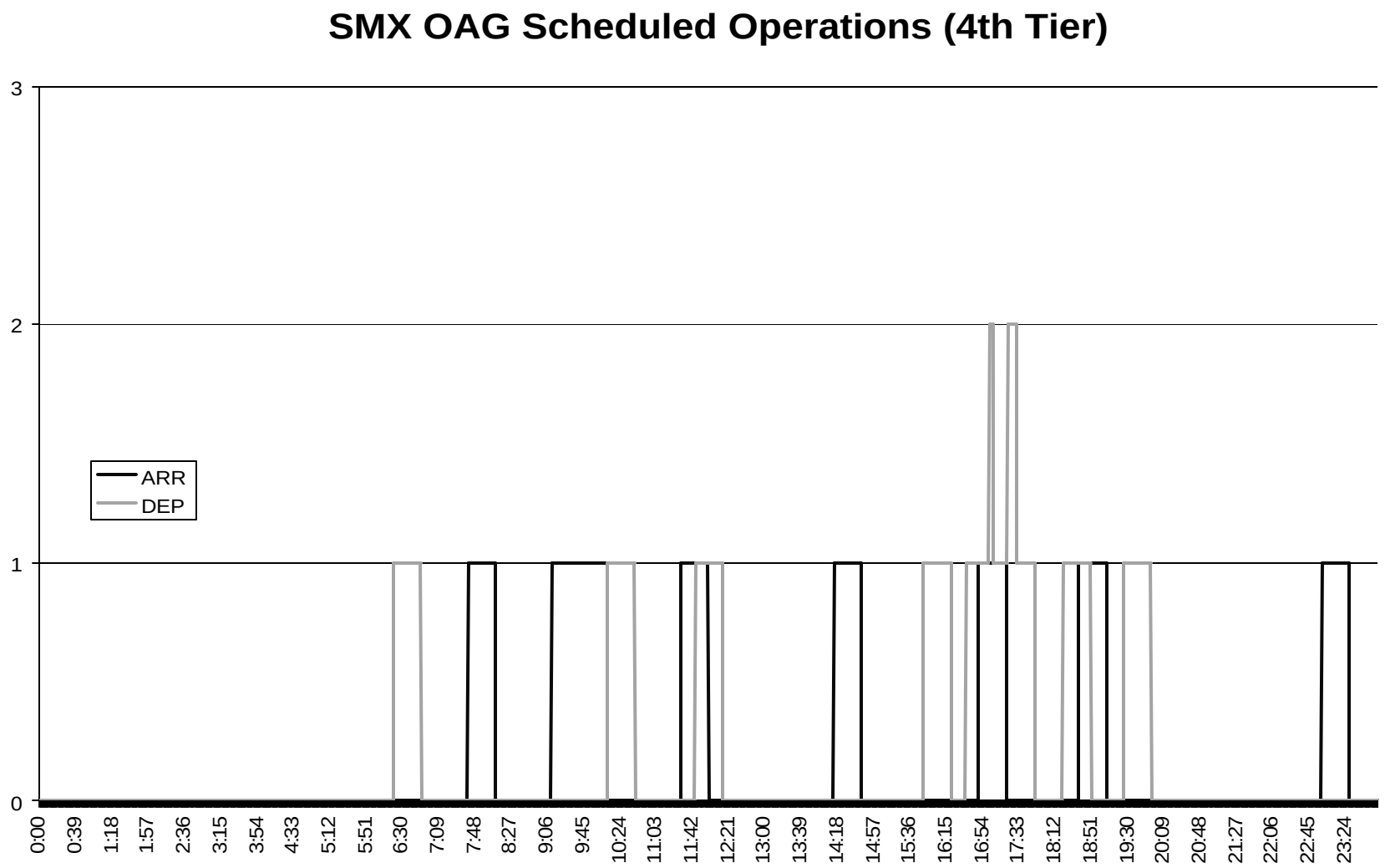
Aircraft

Flight Segments

291 Airports – 63% of TAF Airports, 95% of 2000 Enplanements (remainder primarily non-CONUS), 80% AC and AT operations in 2000

Schedules are Different - December 12, 2002

Count on Y Axis is the Number of Operations in Next 30 Minutes



Creating a Timetable for Scheduled Flights

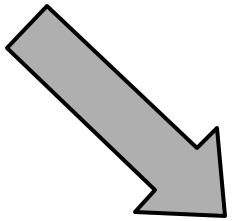
Forecast Future Flights

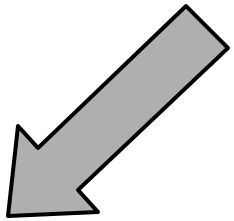
- Origin, Dest, A/C Type
- Need times added to complete schedule

+

Past OAG Schedule

- Includes flight time info





Scheduled Traffic Timetable

JFK	CUN	Cat 5	3:40:00 PM	7:47:00 PM
JFK	DCA	Cat 2	3:50:00 PM	5:05:00 PM
JFK	FLL	Cat 4	3:45:00 PM	6:40:00 PM
JFK	IAD	Cat 2	3:57:00 PM	5:26:00 PM

Finally We Add Unscheduled Flights

Forecasted Future Flights

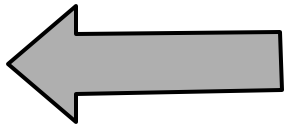
Past OAG Schedule

Unscheduled Traffic

- IFR
- VFR

Final Traffic Timetable

JFK	CUN	Cat 5	3:40:00 PM	7:47:00 PM
JFK	DCA	Cat 2	3:50:00 PM	5:05:00 PM
JFK	FLL	Cat 4	3:45:00 PM	6:40:00 PM
JFK	IAD	Cat 2	3:57:00 PM	5:26:00 PM
HGR	**TEB**	**Cat 1**	**4:00 PM**	**6:05 PM**



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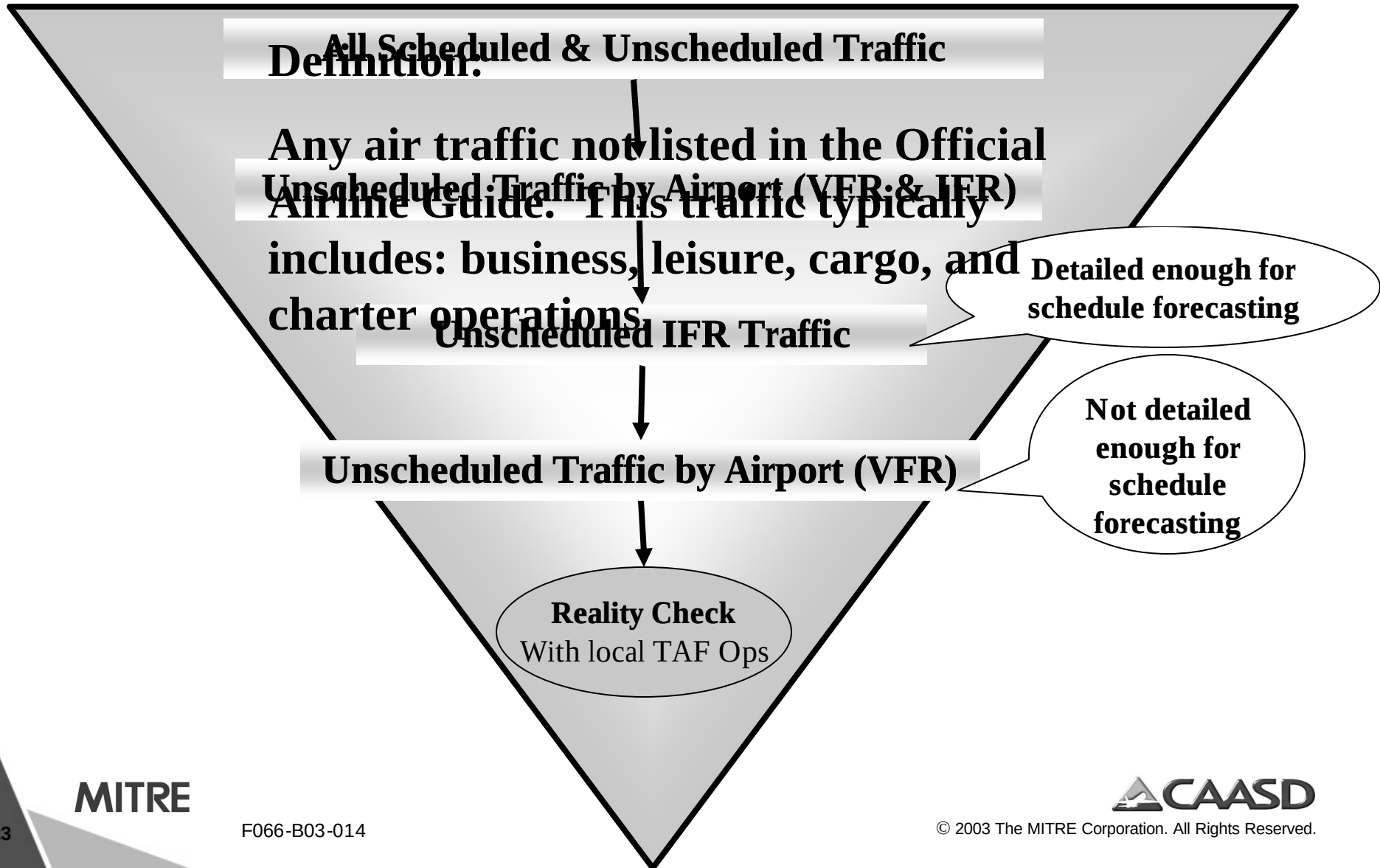
Unscheduled Traffic Timetable Development



Definition:

Any air traffic not listed in the Official Airline Guide. This traffic typically includes: business, leisure, cargo, and charter operations.

Our Product: A Flight Timetable (or Schedule) Based on Projected Future Demand

Departure Airport	Arrival Airport	Equipment	Departure Time (GMT)	Arrival Time (GMT)
JFK	CUN	B752	3:40:00 PM	M
JFK	DCA	E145	3:50:00 PM	M
JFK	FLL	A320	3:45:00 PM	M
JFK	IAD	JS41		PM
HGR	TEB	PAY4		6:05:00 PM
JFK	IAD	CRJ1		4:31:00 PM
JFK	KIN	A343		7:05:00 PM
JFK				9:01:00 PM
JFK			3:10:00 PM	9:15:00 PM
JFK			3:30:00 PM	9:23:00 PM
JFK			3:45:00 PM	6:25:00 PM
JFK		B752	3:25:00 PM	6:11:00 PM
J		A320	3:40:00 PM	10:15:00 PM
J		A306	3:00:00 PM	6:53:00 PM
J		A320	3:30:00 PM	6:20:00 PM

Weekday 2004, Q4

Weekend 2006, Q3

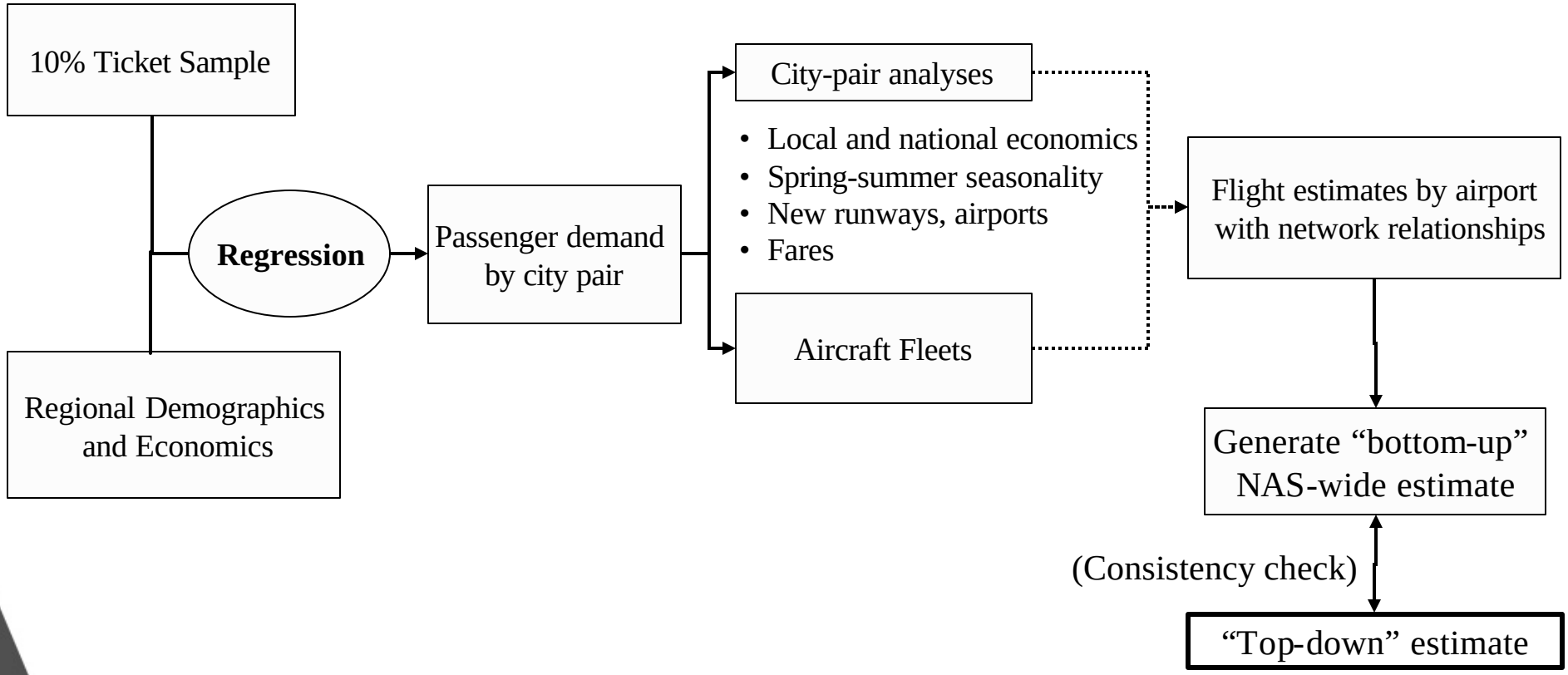
Weekday 2018, Q2

Weekend 20xx, Qx

Backup Slides

"Bottom-up" city-pair approach reveals network effects. Aggregates can be compared with forecasts from TAF.

Economists have advised the FAA to use O-D ticket data to capture network effects.



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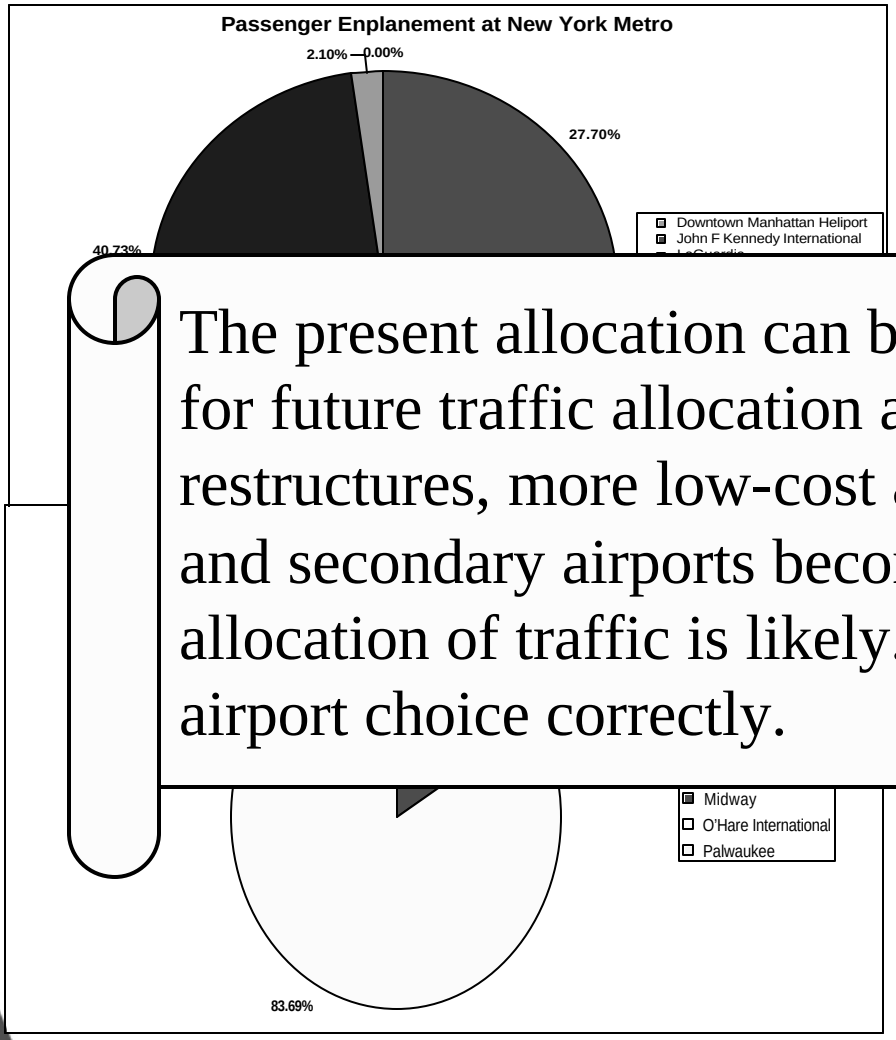
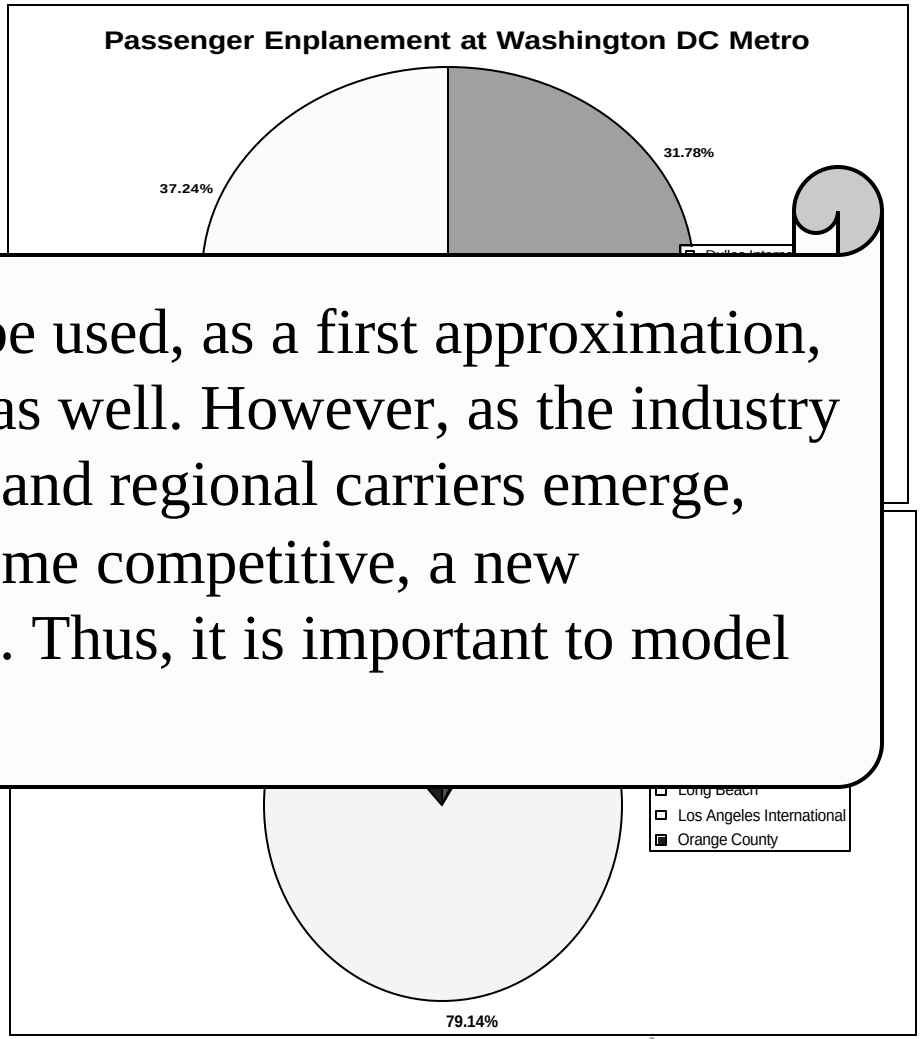
Nation's top MSAs: How are passengers allocated at multi-airport MSAs?

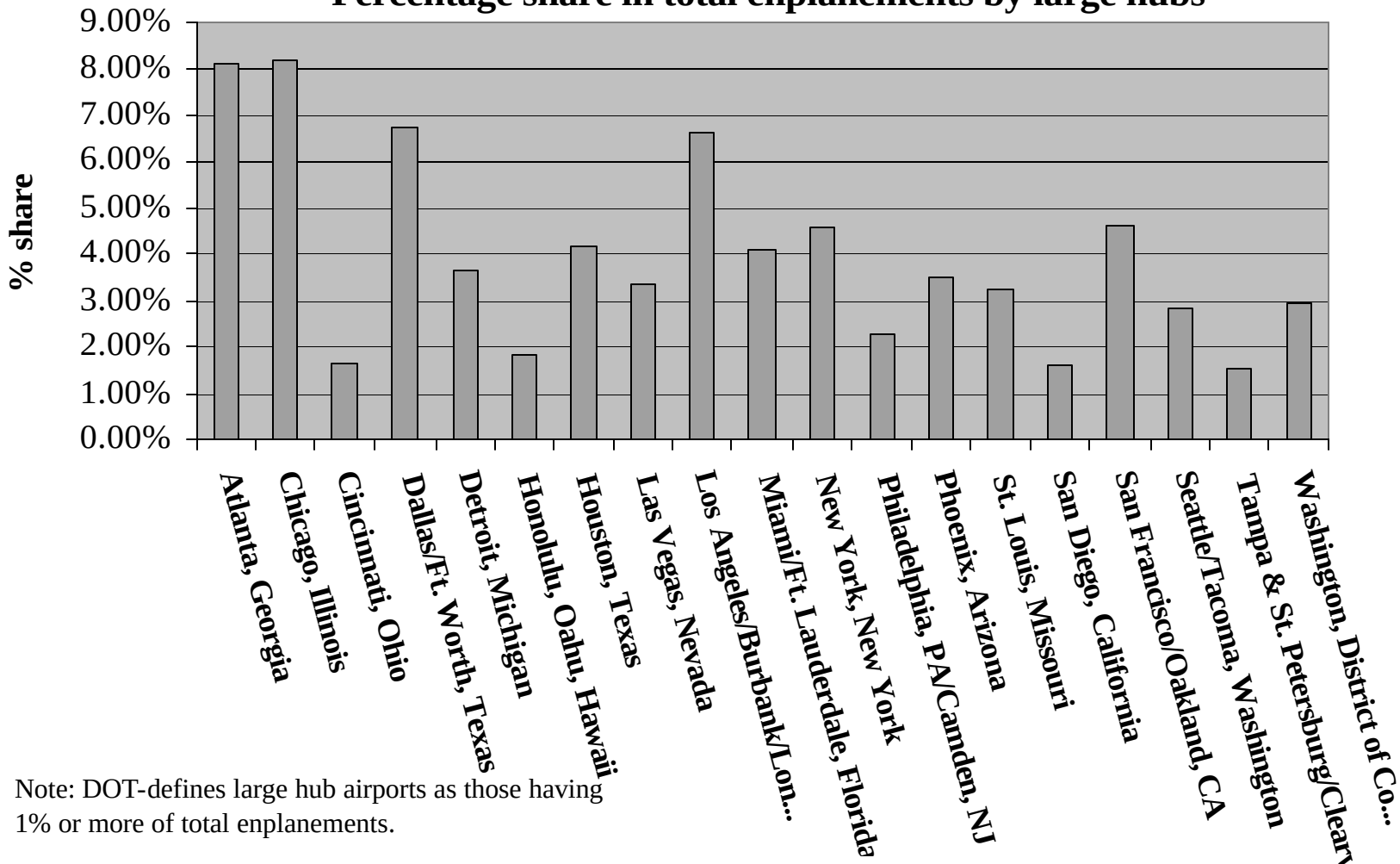




The present allocation can be used, as a first approximation, for future traffic allocation as well. However, as the industry restructures, more low-cost and regional carriers emerge, and secondary airports become competitive, a new allocation of traffic is likely. Thus, it is important to model airport choice correctly.

Airport Assignments

Rules for 1st Approximation: 27 MSAs together account for 75% of ALL scheduled enplanements today; 19 of those MSAs have multiple airports. Together they account for 60% of ALL scheduled enplanements

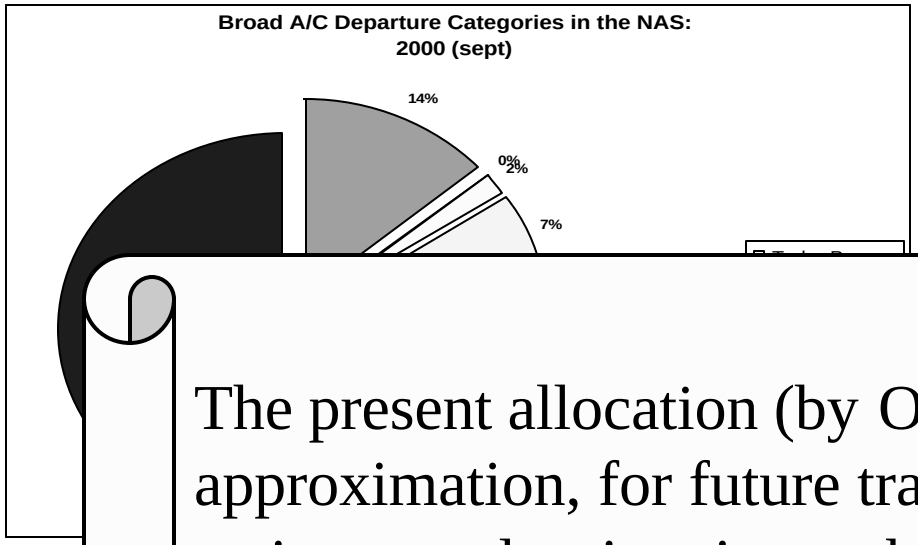


Note: DOT-defines large hub airports as those having 1% or more of total enplanements.

Source: http://www.bts.gov/publications/airactstats/tables/AirportTable3.htm

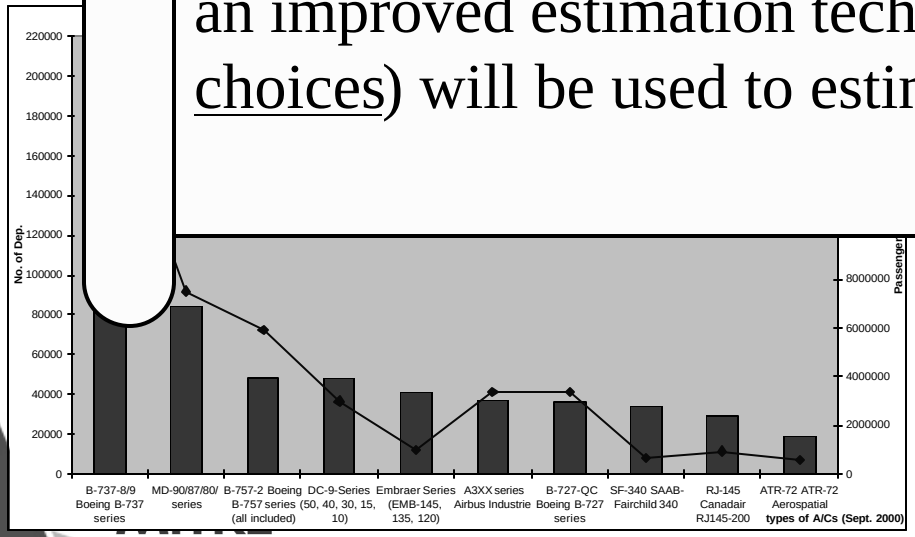
MSAs with multiple airport nodes

Aircraft Assignments by O&D pair: How are passengers allocated today?



Rank	A/C type	Departures Perfomed by Broac A/C category	Total No. of Passengers	Avergare Distance (miles)
1	B-737-8/9 Boeing B-737 series	199,297	16,060,781	675
2	MD-90/87/80/ series	84,302	7,508,323	598
				1152
				525
				359
				1034
				672
				205
				435
				215
				1344
				206
				343
				206
				238
				399
				1635
				1571
				1258
				1745
				142
22	C-208 Cessna 208	187	50	80
23	FALCON Dassault Falcon	164	0	583
24	MD-11 Douglas MD-11	146	20,515	2035
25	L-188A Lockheed L-188A-08	131	2,797	361
	Total	**628,070**	**46,505,752**	**721**

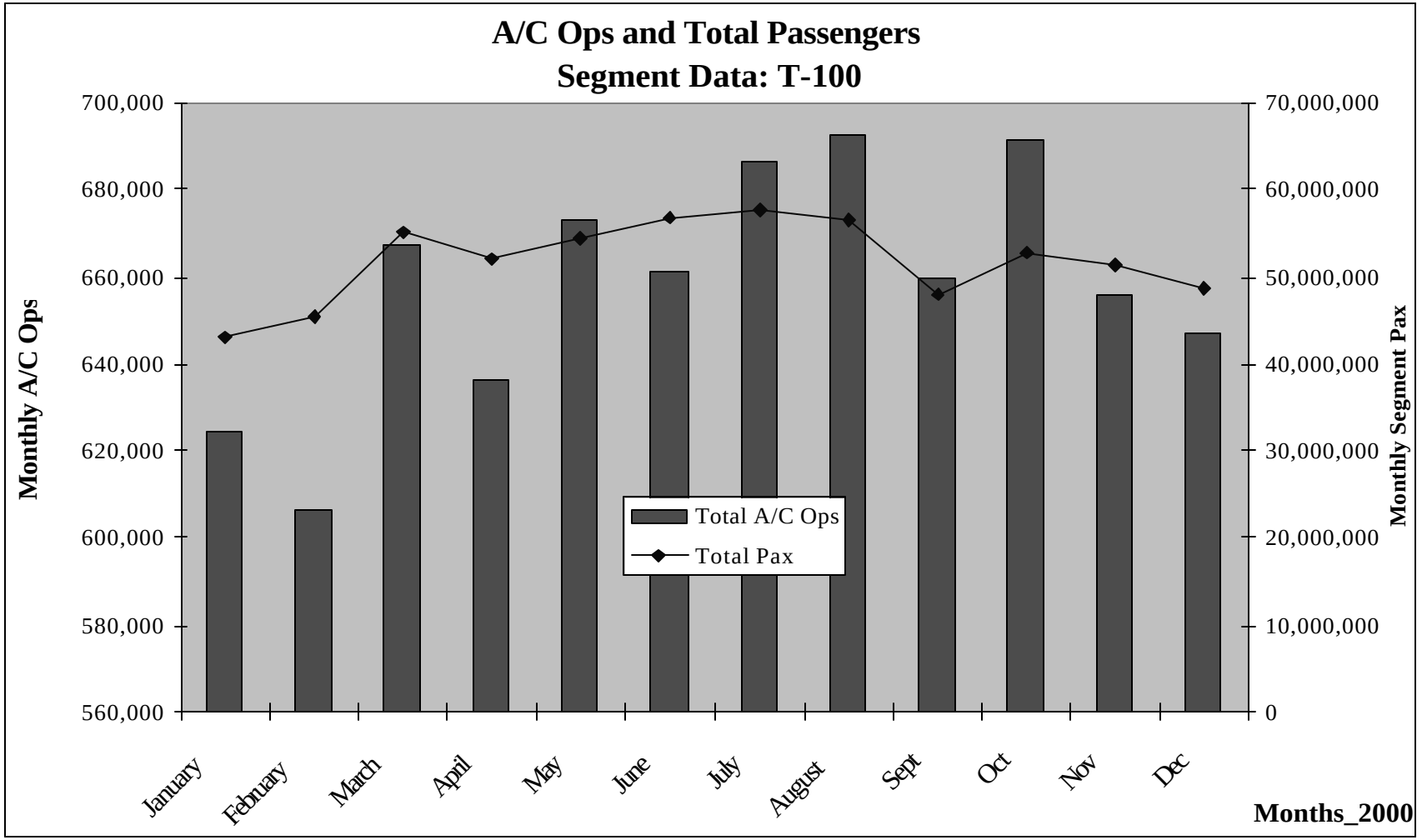
The present allocation (by O&D) can be used, as a first approximation, for future traffic allocation as well. However, an improved estimation technique (based on probabilistic choices) will be used to estimate fleet choice by O&D pairs.



Total A/C Types = 68
year = 2000; Month = 9;
Source Data: T-100 segment data

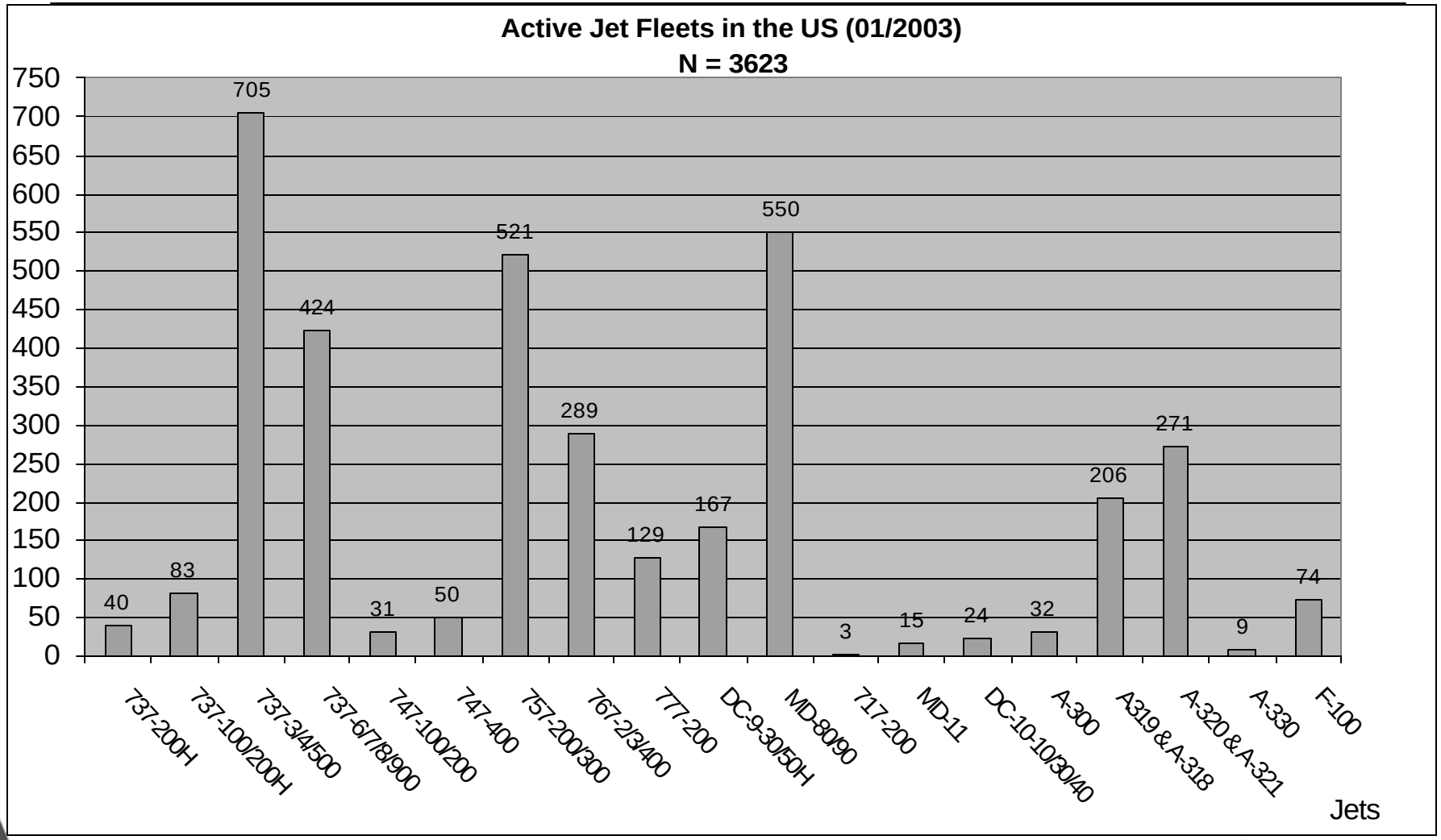
CAASD

Total passengers that are flown in the NAS by different aircraft



F066-B03-014

Distribution of active jets fleets



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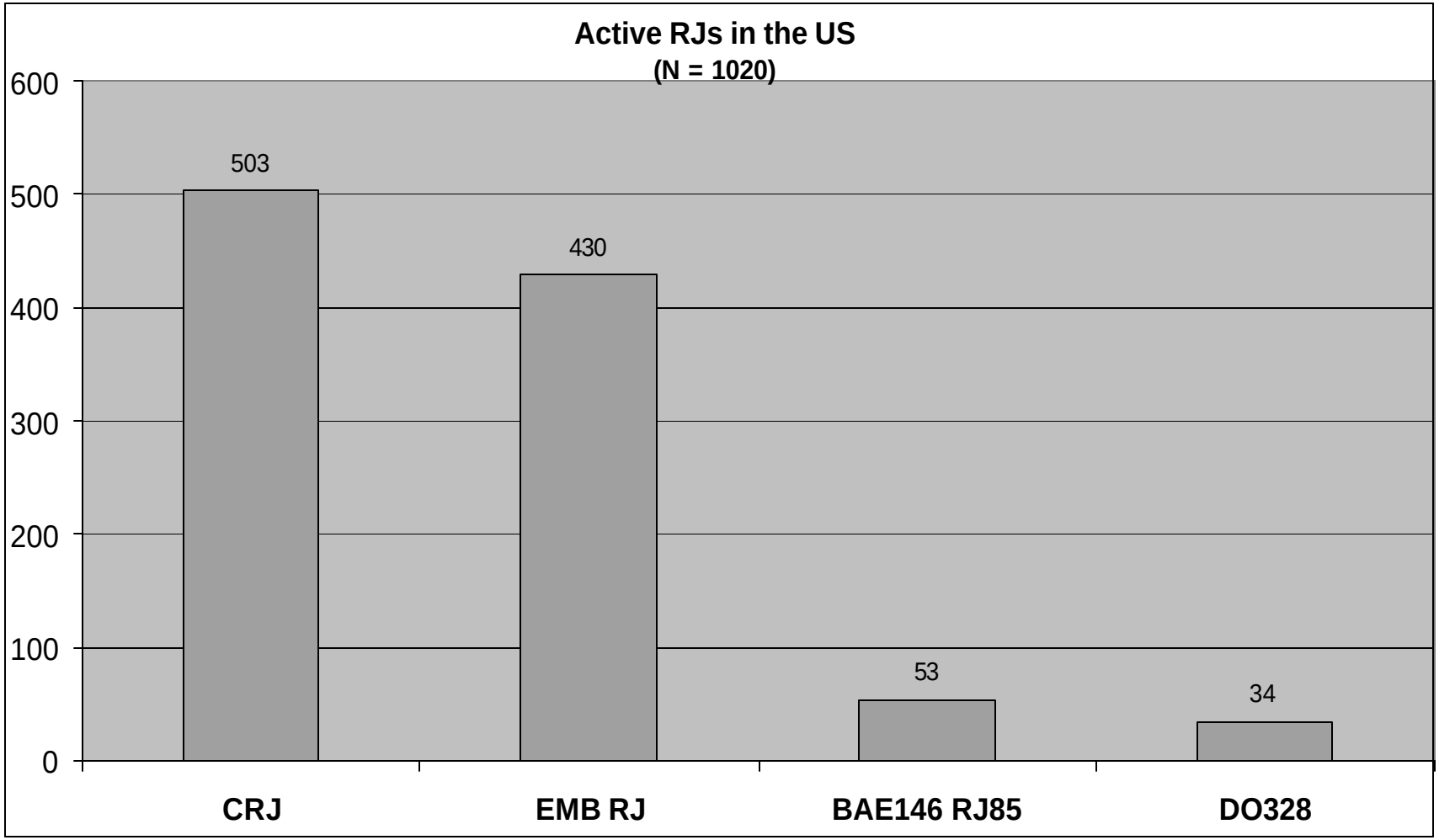
F066-B03-014

Source: Airline Monitor: February/March, 2003

Distribution of active RJ fleets



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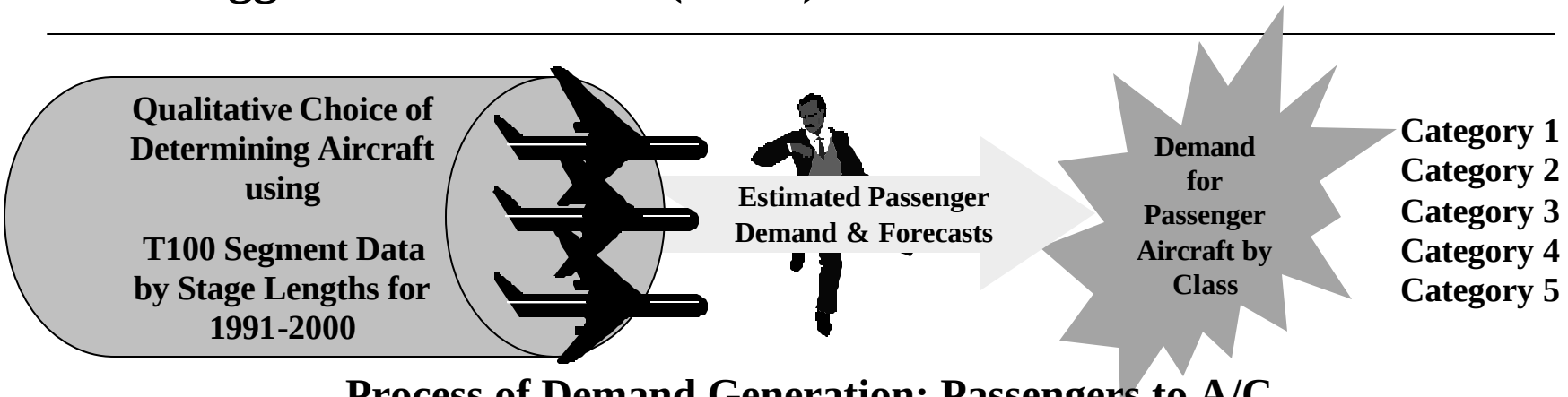
CAASD

F066-B03-014

Source: Airline Monitor: February/March, 2003

From Passenger Demand to Demand for Aircraft Operations by Market Segments: A Suggested Framework (*contd.)*



Process of Demand Generation: Passengers to A/C Movements by Market Routes and Stage Lengths

3. Based on the data (> 2 million records for 1992-2001), i.e., T100 segment data, we ask the qualitative question:

(a) What is the probability that one category of aircraft will be chosen over others given airline characteristics, market characteristics, no. of passengers, proportion of non-passengers (i.e., mail, freight) to passengers, and other performance indicators, such as departure scheduled and performed, elapsed time ramp-to-ramp and airborne, distance, year, and quarter.

(b) From these statistical estimates of probabilities of 5 qualitative choices, we determine the number of aircraft by O&D pairs.

(c) We also evaluate the effects of different factors (e.g., effects of market or airline characteristics, or quarters, or performance) in the probabilistic choices of aircraft.

(d) Finally, we use the forecasted passenger numbers, holding all other factors constant, to generate the forecast of aircraft (i.e., Future Demand).