Post-Deployment Assessments Using Daily and Flight Level Performance Metrics

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Performance Metrics TIM

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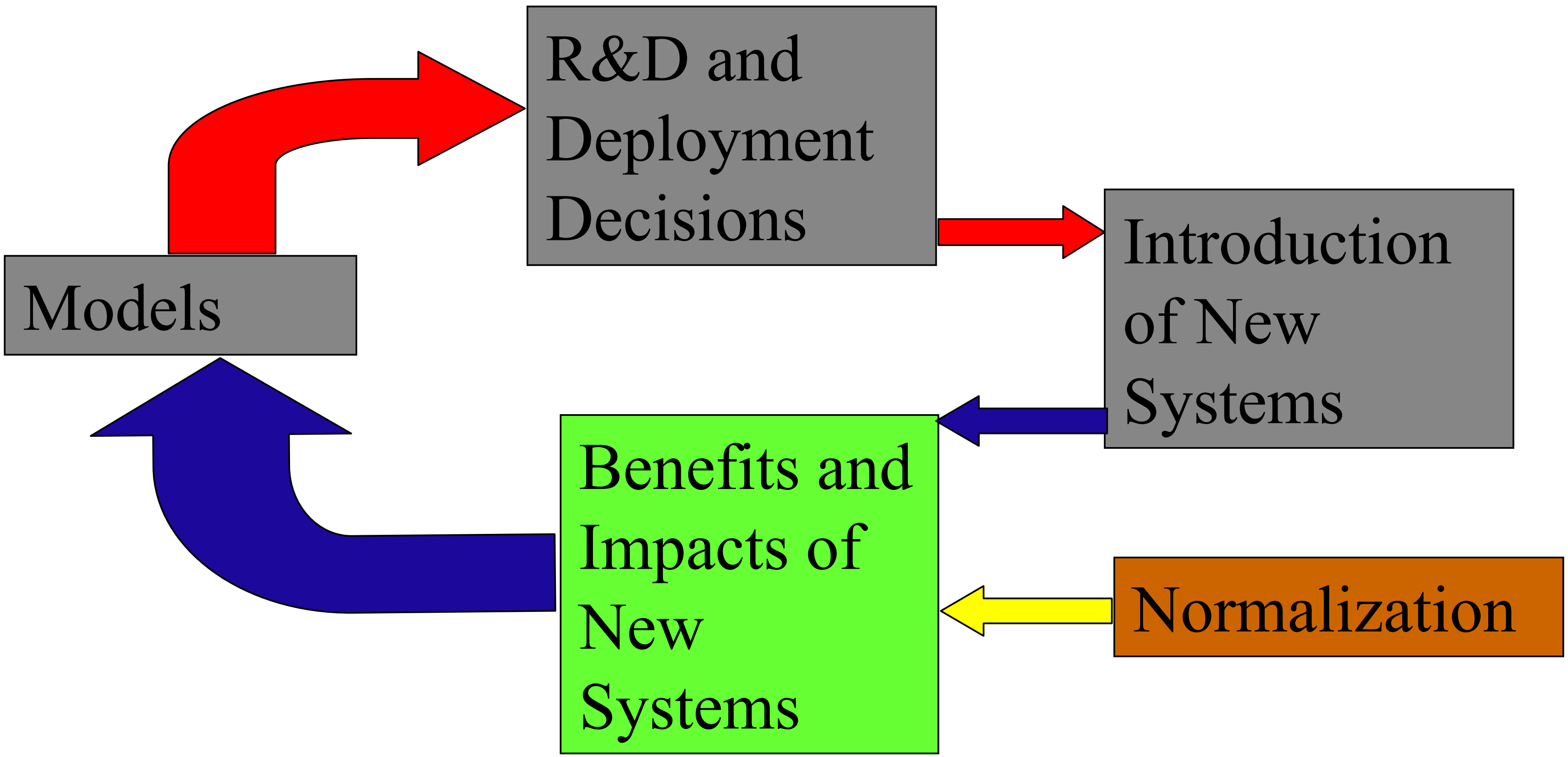
National Center of EXcellence in AviaTiOn Research

R&D Modeling Cycle



NEXTOR Metrics Research

- Effects of FFP1 on Terminal Area and En Route Performance
- Use Statistical Inference to Capture Impacts that may not be Directly Observable
- Focus on Delays and Time-in-System Metrics
- Normalize for Weather and Demand
- Presented Here
  - Effect of TTMA at LAX
  - Effect of URET

Final Approach Spacing Tool

- Decision support tool for TRACON
- P(assive)FAST advises on runway assignment and landing sequence
- Active FAST provides speed and turn advisories
- Advisories incorporated into ARTS display
- Prior PFAST implementation at DFW

FAST at LAX

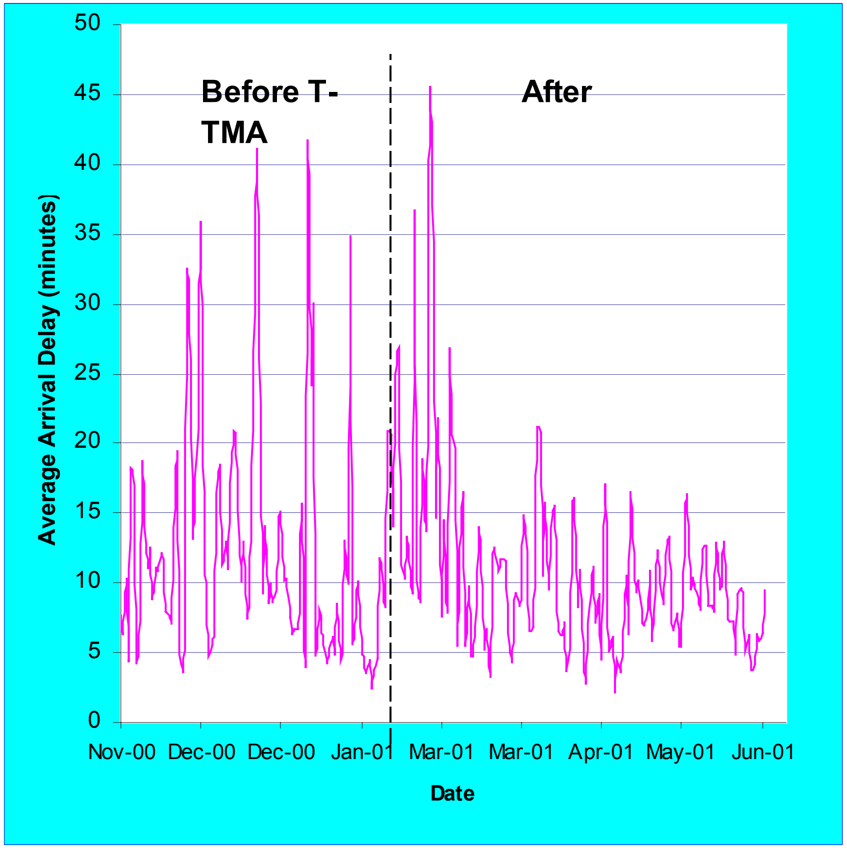
- “Passive Passive FAST” (P^2FAST) or “T-TMA”
- No advisories
- Separate displays depict traffic up to 300 nm out using combination of HOST and ARTS data
- A situation-awareness tool instead of a decision automation tool

Impacts of TTMA at LAX

- Average Delay Analysis
  - Model Average Daily Arrival Delay
  - Control for Demand-Capacity
- Daily Flight Time Index
  - Model Flight Times and their Components
  - Control for Demand, Weather, and Congestion at Up-line Airports

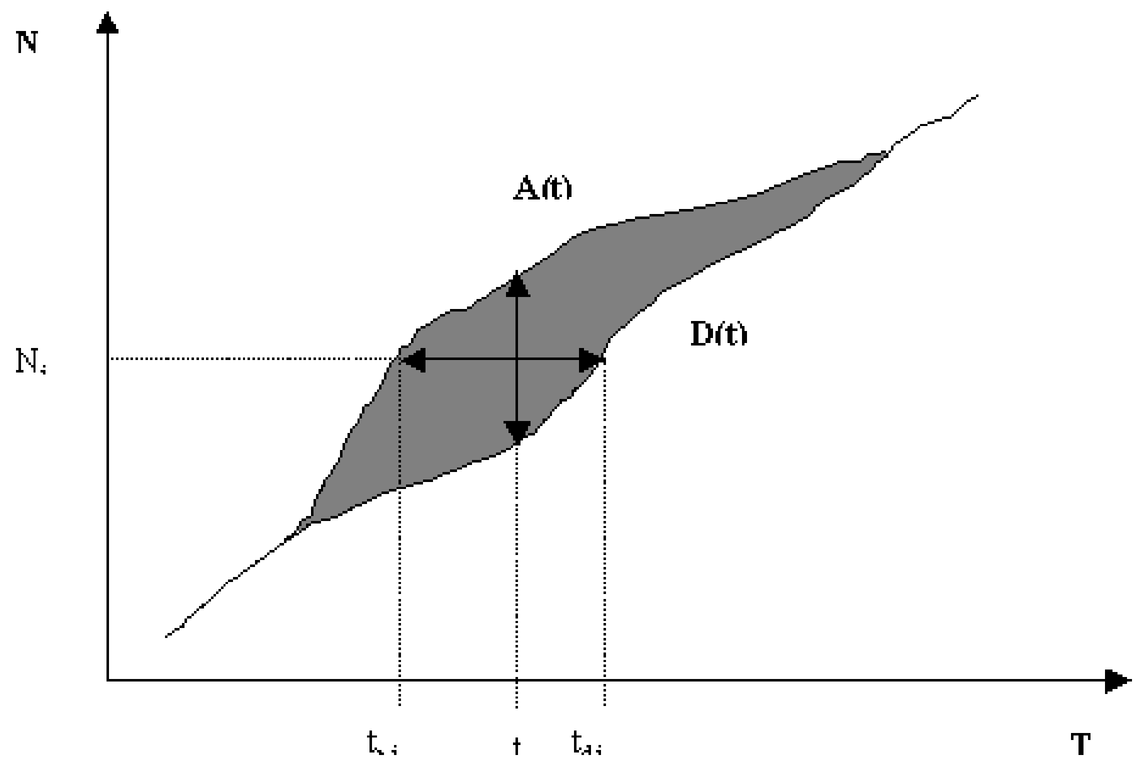
Arrival Delay at LAX

- High day to day variability due to varying weather conditions and demand
- Need to normalize the effect of the external factors

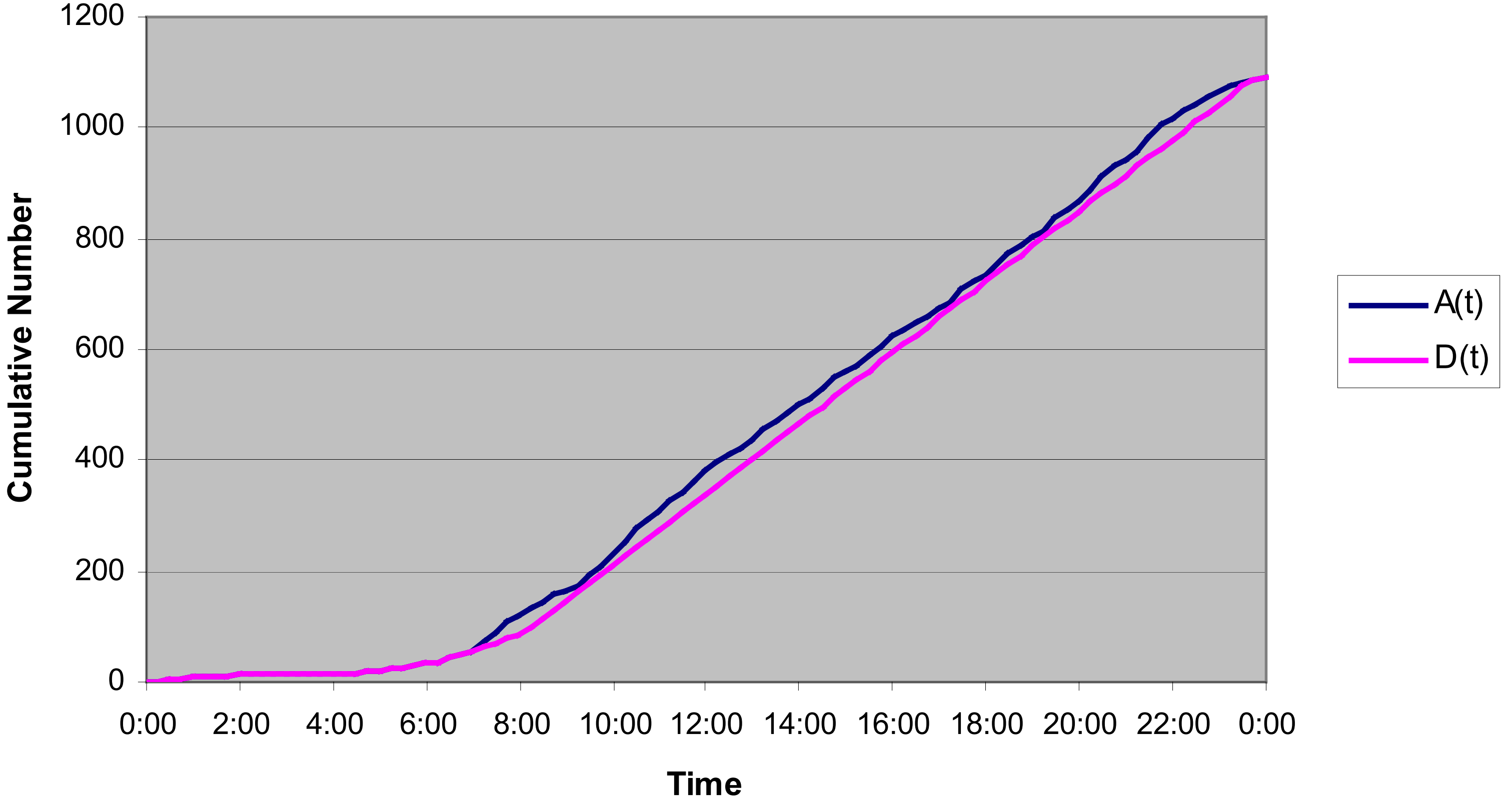


Predicted Delay Metric

- Arrival demand curve *A(t)* based on “on time” arrival according to OAG schedule
- AAR sets an upper bound for actual arrival curve *D(t)*
- Shaded area under the curves gives total delay
- Delay: *predicted* and *hypothetical*



Example: Queuing Diagram for December 1, 2000 (A Bad Day)



The Linear Regression Model

- *Study period:* Nov 1, 2000 – Jun 30, 2001
- Model estimated using OLS
- Assumes Acceptance Rates not Affected by TTMA

$$DELAY_t = \beta_0 + \beta_1 HDD_t + \beta_2 TTMA_t$$

- Where,

$DELAY_t$	is the average arrival delay for LAX arrivals of day t;
HDD_t	is the predicted average arrival queuing delay for LAX on day t;
$TTMA_t$	is a dummy variable set to 0 for days before T-TMA initial daily use at the SOCAL TRACON, and 1 after

Results

- T-TMA reduces arrival delay by 2.1 minutes
- Amount of non-queuing delay incurred by LAX arrivals: 9.29 minutes
- 1 minute of predicted queuing delay increases arrival delay by 0.89 min

Parameters	Estimates and Significance Level
β_0	9.29 (0.0001)
β_1	0.89 (0.0001)
β_2	-2.08 (0.0024)
R-Square	0.50

Impact on Days with Flow Control

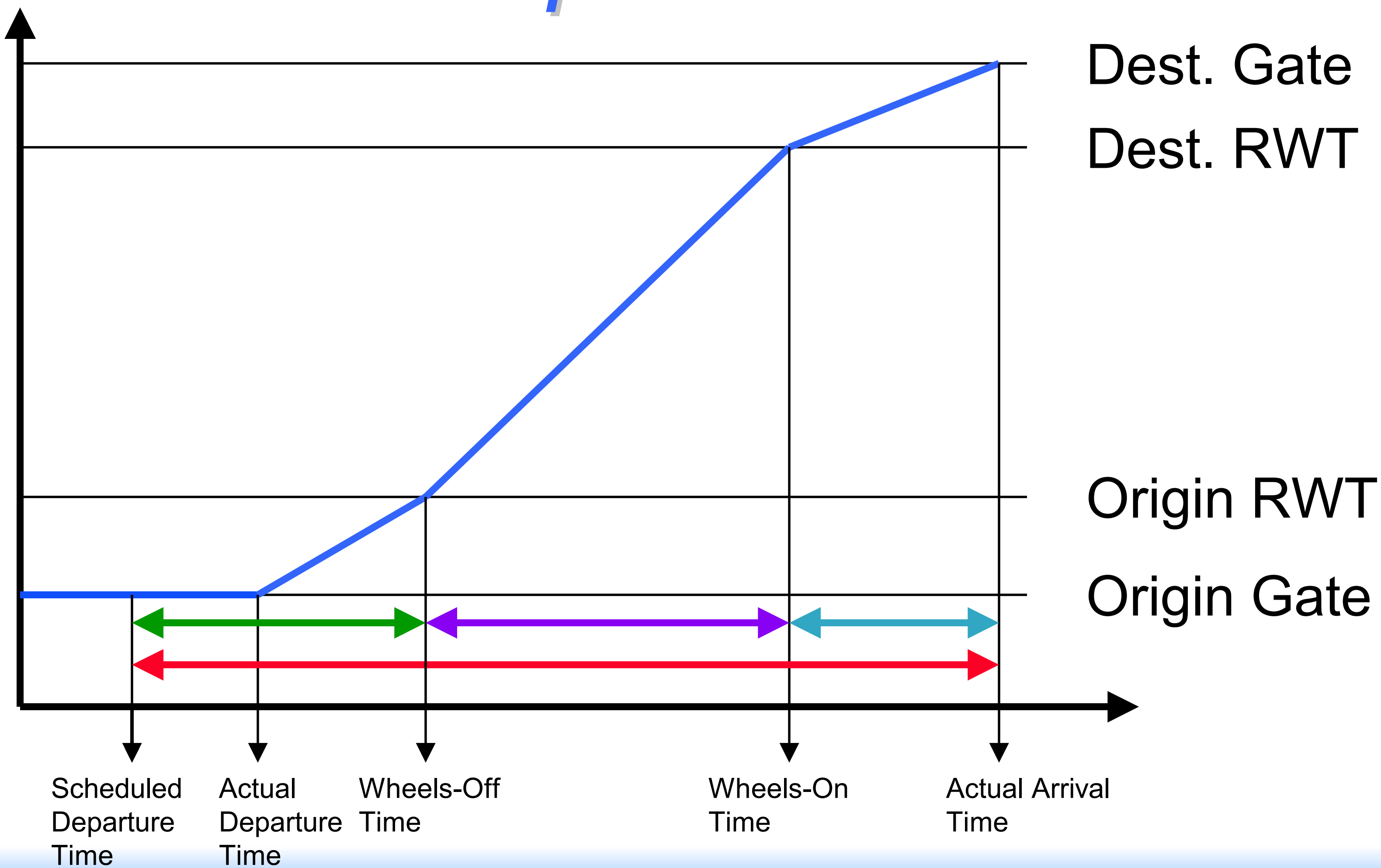
- Reduced average arrival delay by 7.57 minutes in days with flow control
- Effect on days without flow control low and insignificant

Parameters	Estimates and Significance Levels	
	Days Without Flow Control	Days With Flow Control
β_0	7.59 (0.0001)	17.62 (0.0001)
β_1	0.96 (0.0001)	0.64 (0.0001)
β_2	-0.64 (0.2410)	-7.57 (0.0010)
R-Square	0.23	0.48

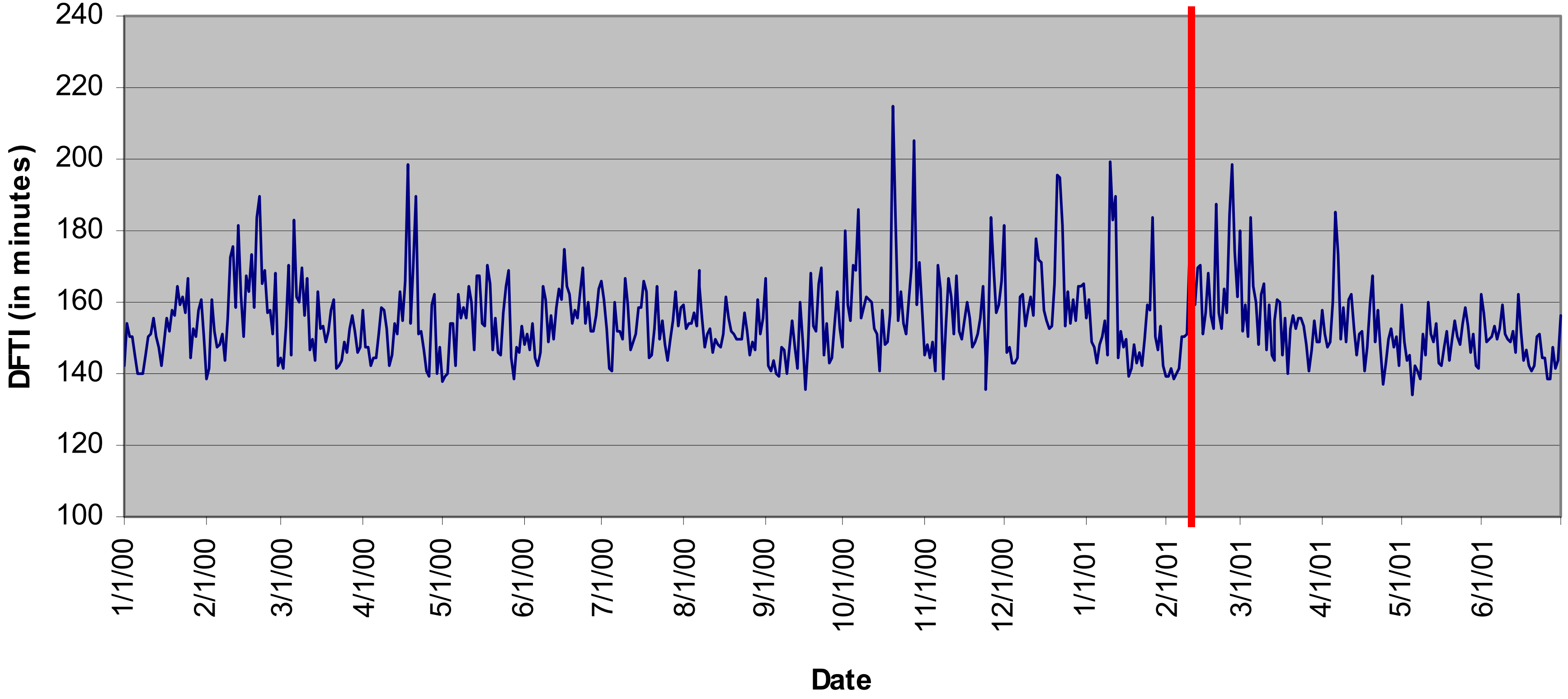
Daily Flight Time Index (DFTI)

- Daily weighted average of flight times to a given airport from a set of origins
- Analogous to a Consumer Price Index
- Origins in “market basket” have at least one completed flight in each day of sample
- Weights reflect origin share of flights to study airport over study period

Flight Time and Its Components



DFTI Before and After Implementation



Weather Normalization

- Based on CODAS hourly weather observations for LAX
- Factor analysis of weather data
  - Create small number of factors that capture variation in large number of variables
  - Factors are linear combinations of original variables
  - Factors correspond to principal axes of N-dimensional data elipse

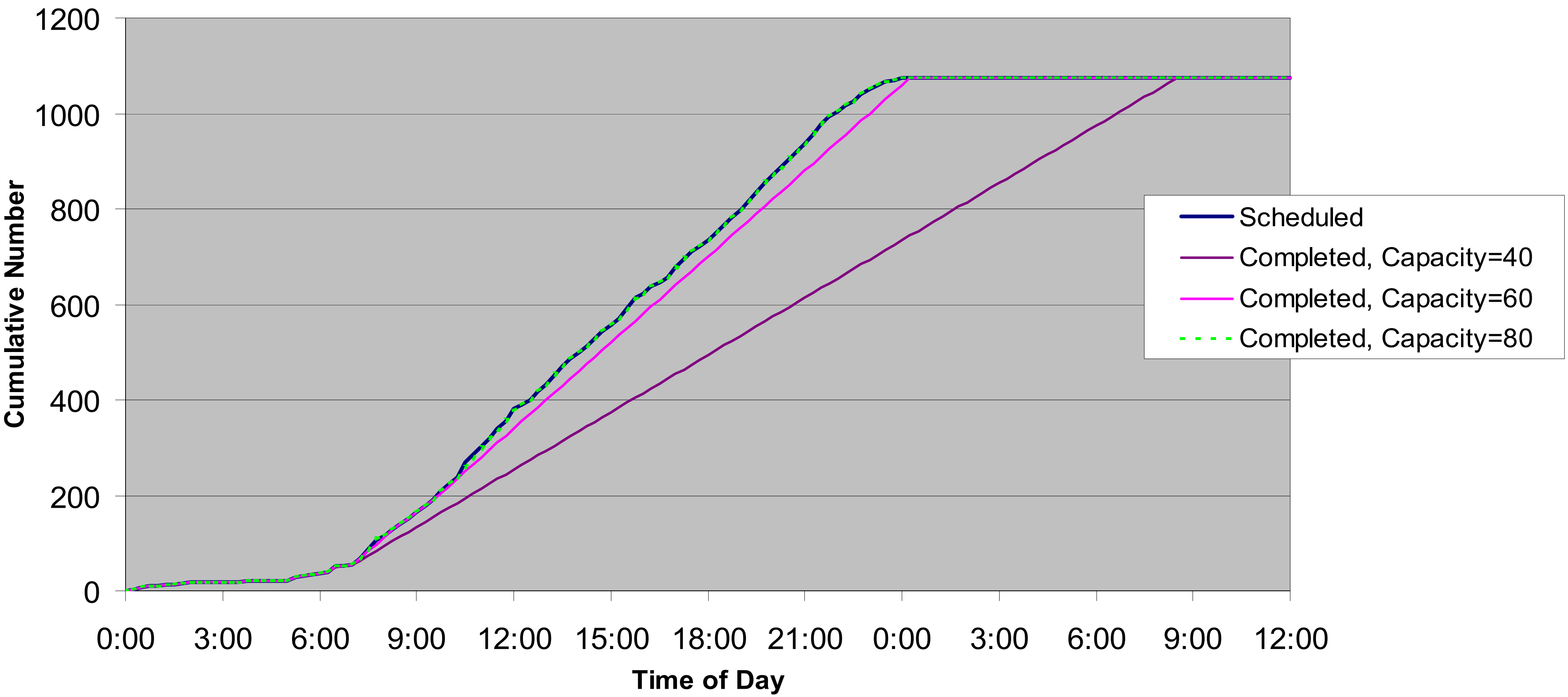
LAX Weather Factor Interpretations

Factor	Interpretation
1	High temperature throughout the day
2	High cloud ceiling and VFR conditions in the afternoon and evening
3	High cloud ceiling and VFR conditions in the morning
4	High visibility throughout the day
5	High wind speed in the afternoon and evening
6	Medium cloud ceiling in the evening
7	Medium cloud ceiling in the morning hours

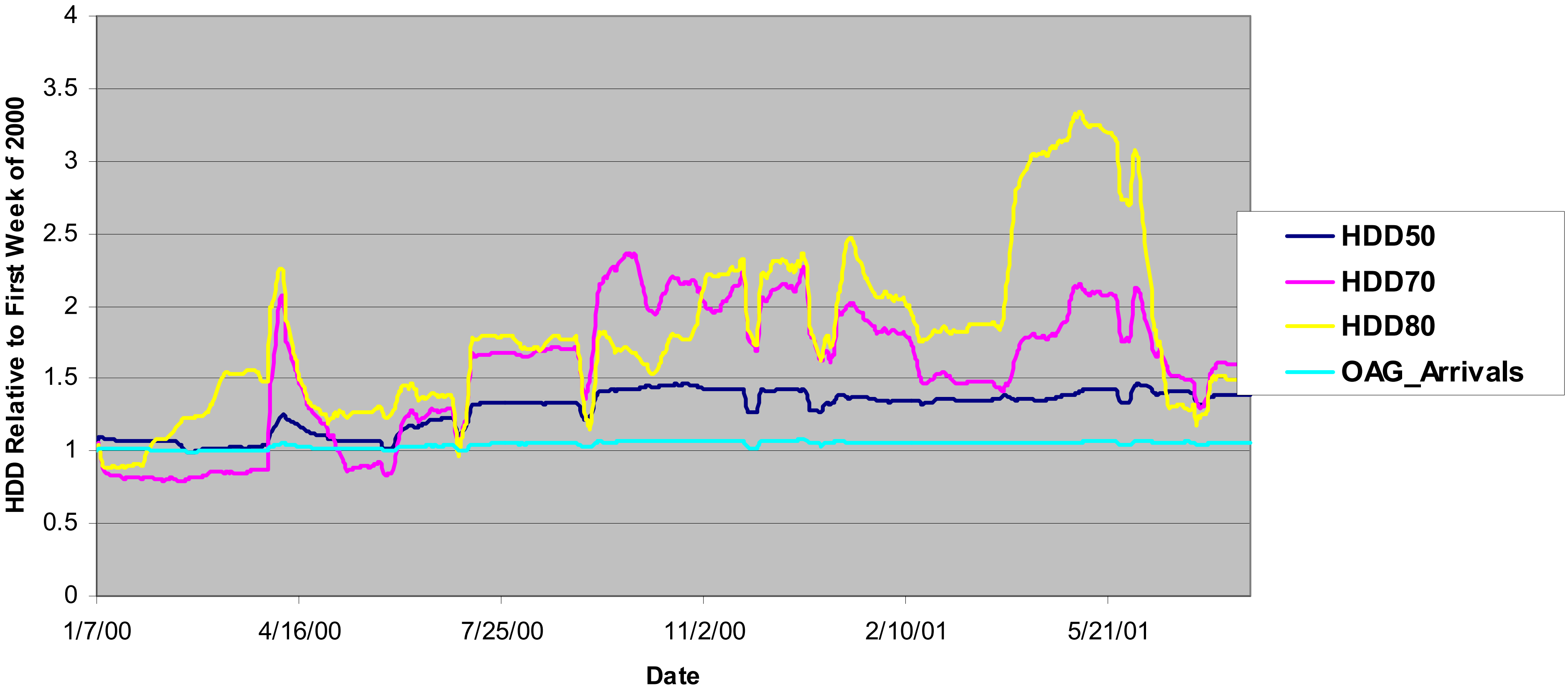
Demand Normalization

- Deterministic Queuing Analysis
- Arrival Curve from Official Airline Guide
- Departure Curves and Average Delays Calculated Assuming Range of Hypothetical Capacities
- Factor Analysis Applied to Obtain Reduced Set of Demand Factors

Queuing Diagrams



Trends in HDD Parameters for the Study Period (7-Day Moving Average)

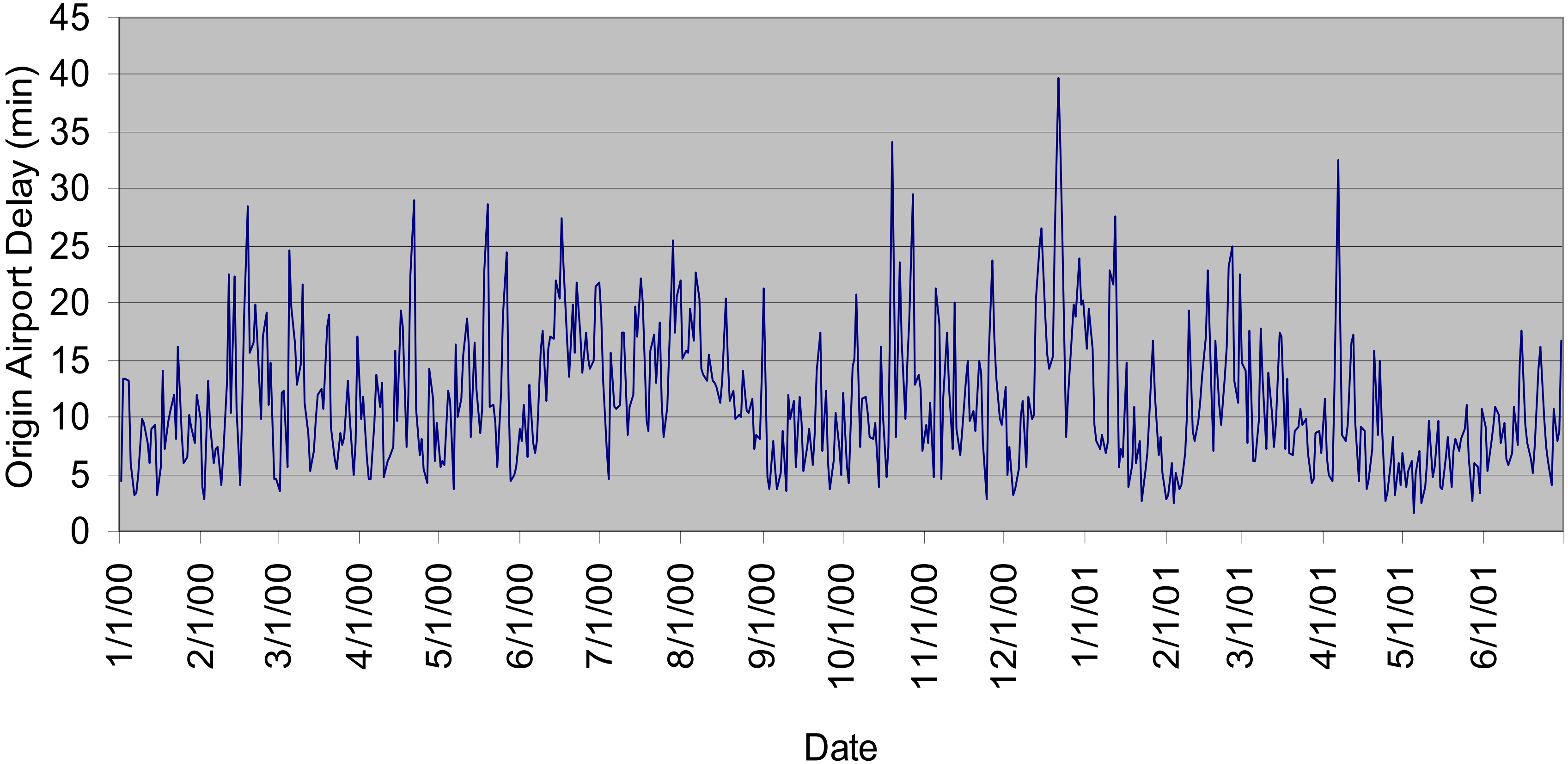


Normalization for Conditions at other Airports

- Consider airports included in DFTI average
- For each compute daily average departure delay for flights not bound to LAX region
- Average airport departure delays using DFTI weights

NEXTOR

Trends in Origin Airport Congestion



Performance Models

$$Y_t = f(WX_t, DMD_t, ODEL_t) + \varepsilon_t$$

Where:

Y_t is DFTI or DFTI component for day t;

WX_t is vector of weather factors for day t;

DMD_t is vector of demand factors for day t;

$ODEL_t$ is average origin departure delay for day t;

ε_t is stochastic error term.

TTMA Normalization Results

Variable	Parameter Estimates			
	DFTI	At Origin	Airborne	Taxi-in
intercept	***139.29***	***15.23***	***115.9***	***8.11***
TTMA	***-1.99***	***-1.71***	-0.19	-0.07
OAC	***1.39***	***1.29***	**0.03**	***0.06***
Peak Demand	-0.35	-0.1	***-0.24***	-0.01
Base Demand	***0.97***	***0.74***	0.04	***0.19***
Weather Factor1	***-3.37***	***-0.89***	***-2.63***	***0.14***
Weather Factor2	***-2.66***	***-1.8***	***-0.75***	***-0.12***
Weather Factor3	***-1.88***	***-1.36***	***-0.48***	**-0.04**
Weather Factor4	0.19	-0.24	***0.49***	***-0.07***
Weather Factor5	***1.48***	***0.73***	***0.79***	-0.03
Weather Factor6	***0.46***	0.12	***0.31***	0.02
Weather Factor7	***0.64***	0.27	***0.29***	***0.81***
Adjusted R-Square	0.79	0.83	0.55	0.39

Significant at 5% level **Significant at 10% level**

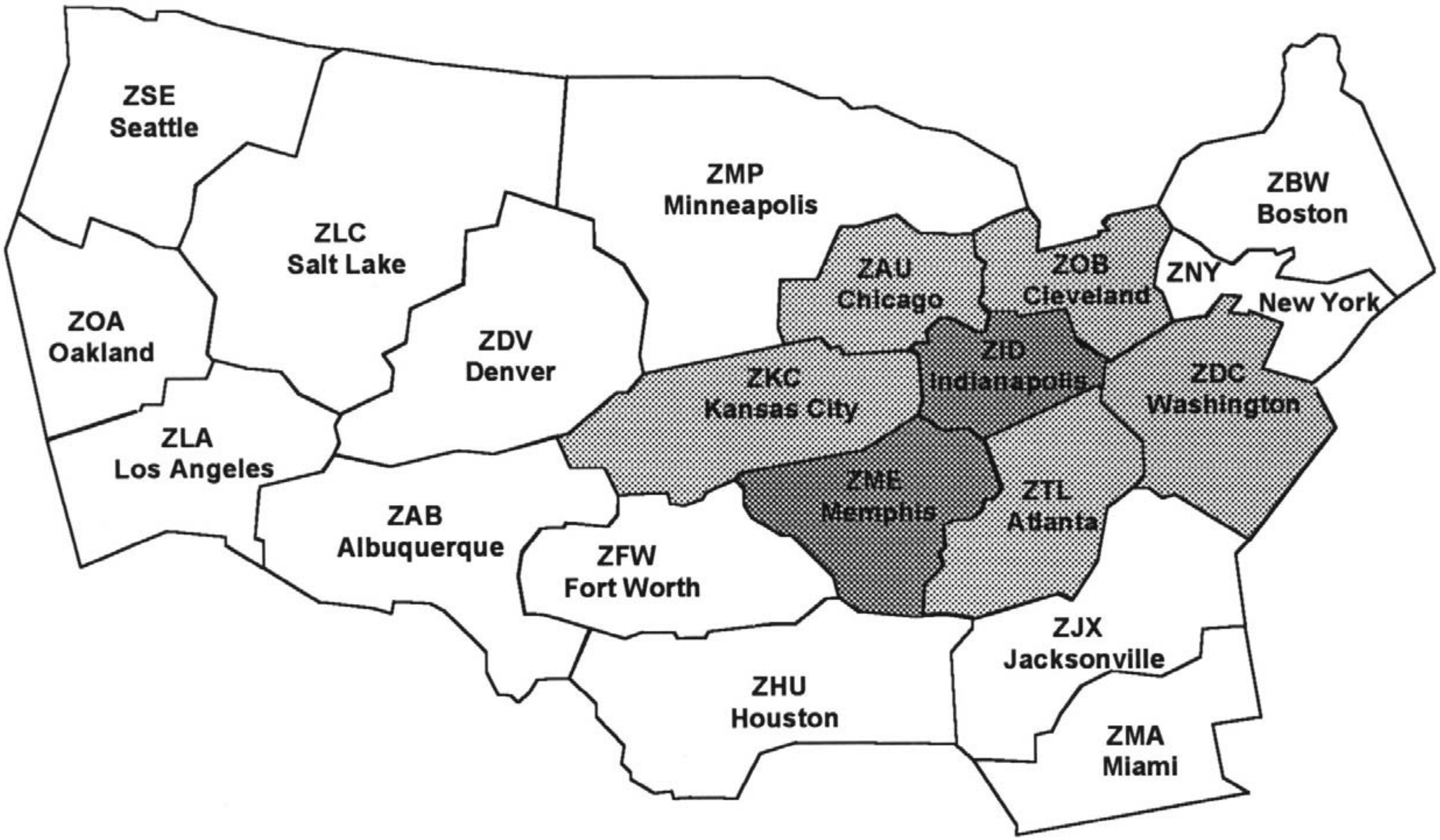
LAX T-TMA Key Findings

- Delay reduction 2 min/flight
- Effect concentrated on
  - Departure delay
  - Days with flow control programs for LAX
  - Short Duration Flights
- Also evidence of
  - Higher throughput
  - Reduced cancellations

User Request Evaluation Tool

- En Route Decision Support Tool
- Automated Conflict Detection
- Trial Planning
- Automated Coordination
- Allows More Direct Routings and Increases En Route Sector Capacity

URET Sites


ZSE
Seattle
ZLC
Salt Lake
ZMP
Minneapolis
ZBW
Boston
ZOA
Oakland
ZAU
Chicago
ZOB
Cleveland
ZNY
New York
ZDV
Denver
ZID
Indianapolis
ZKC
Kansas City
ZDC
Washington
ZLA
Los Angeles
ZAB
Albuquerque
ZME
Memphis
ZTL
Atlanta
ZFW
Fort Worth
ZJX
Jacksonville
ZHU
Houston
ZMA
Miami

URET Deployment

January 1995	January 1996	February 1996	May 1996
Prototype development begins	1st prototype in ZID	Evaluations begin	Continuous probing added

November 1996	December 1996	June 1997	October 1997
Sector notification logic added	Integrated at a D-side in ZID	Installed in ZME	Daily use in ZID

November 1997	Beginning 1998	July 1999	February 2000
Daily use in ZME	Interfacility capability added	**Two-way communication with HCS added**	22 hours a day operational use begins at both ZID and ZME

URET Impact

- Performed Flight Level Analysis
- Observed Airborne Time for ASQP Flights for Corresponding Months Before and After URET (about 800,000 per analysis)
- Effects Estimated
  - Before vs After URET
  - Use URET Sectors vs Don’t Use
  - Use URET Sectors*After URET
- Control for Distance, Direction, and Originating Airport and Destination Airport

Individual Flight Times Model

$$FlightTime = \tau + \sum_{\ell} \alpha_{\ell} L_{\ell} + \beta_{lat} \cdot X_{lat} + \beta_{lon} \cdot X_{lon} + \sum_{i=1}^{40} [\delta_{ai} \cdot A_i + \delta_{di} \cdot D_i] +$$

$$\mu \cdot URET + \pi \cdot AFTER + \theta \cdot AFTER \cdot URET$$

Relation between Time Period, Center, and URET Effects

	Year 1999	Year 2000
Don't Fly Through URET Centers	Base Case	Time Period Effect
Fly Through URET Centers	Center Effect	URET Effect

Individual Flight Times Model for April

Coefficient	Description	Estimate	Standard Error	P-Value
τ	Intercept	24.470	0.3672	<0.0001
α_1	Distance in 0-200 nm range	0.169	0.0020	<0.0001
α_2	Distance 200-500 nm range	0.146	0.0005	<0.0001
α_3	Distance 500-1000 nm range	0.139	0.0003	<0.0001
α_4	Distance 1000+ nm range	0.131	0.0002	<0.0001
β_{lat}	Difference in latitude	3.426	0.5969	<0.0001
β_{lon}	Difference in longitude	21.890	0.2274	<0.0001
μ	*URET* dummy	4.172	0.0854	<0.0001
π	*AFTER* dummy	-1.322	0.1257	<0.0001
θ	*AFTER URET* interaction	-3.260	0.1506	<0.0001
Adjusted R^2		0.8168		
Number of Observations		~800,000		

Individual Flight Times Model

URET Influence on Flight Times (min)

Month	Flight Time	Airborne	Departure Delay	Taxiout	Adjusted R^2
February	**-1.643**	**-0.239**	**-1.392**	-0.011	0.8693
March	**-1.367**	**-0.512**	**-0.929**	**0.074**	0.8672
April	**-1.354**	**-0.452**	**-0.865**	-0.037	0.8591
May	**-1.099**	**-0.196**	**-0.929**	0.026	0.8445
June	**-3.260**	**-0.345**	**-2.828**	-0.086	0.8186
July	**-0.502**	**0.223**	**-0.751**	0.026	0.8225

The Coefficients in bold letters are statistically significant on 1% level.

URET Key Findings

- Flight times decreased 1-2 minutes after URET implementation in most months
- Airborne times decreased around 20 seconds
- Most flight time reduction is in departure delay
- Departure delay reductions focus on:
  - Bad weather days
  - Departure airports in/near URET centers

Conclusions

- Ex Post Analysis of Deployment Impacts Necessary to Close R&D Modeling Cycle
- Normalization Required to Isolate Impacts of Deployment
- Can be Done at Daily or Flight Level
- Results for T-TMA and URET Show Benefits but with Surprises