Predictability in Air Traffic Management

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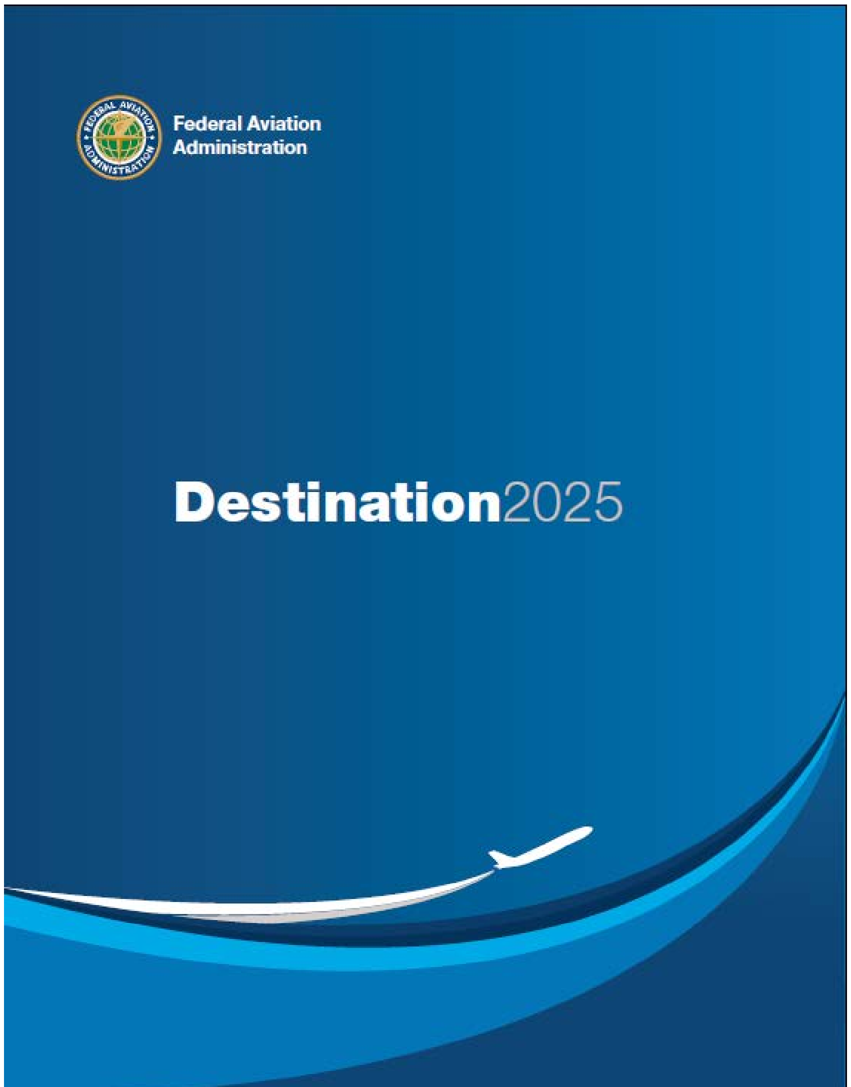
FAA NEXTOR Symposium

5/28/15

Outline

- Motivation
- Defining Predictability
- Measuring Predictability
- Valuing Predictability
- Achieving Predictability
- Conclusions

Motivation



- "One of our most complex challenges today is meeting the expectations for all system users for their operational needs, increasing capacity, efficiency, and predictability, while enhancing safety, mitigating environmental impacts, and operating in a seamless global environment." FAA, Destination 2025
- "Improve flight predictability by reducing variances in flying time between core airports based on a 2012 baseline." FAA, Destination 2025

Motivation

Stakeholder Outreach

4

Stakeholder Issues – Categorized

Predictability
- Block time growth
- Unpredictable taxi out times
- Lack of operational predictability
- Missed connections
- Push-back info not shared

Policy
- Current DOT on-time metrics incentivize bad behavior
- Excessive noise and emissions
- Airline slot mismanagement
- Piecemeal, non-integrated technologies at airports

Efficiency
- Surface congestion and queuing
- Taxi out delays
- "First-come-first-served" doesn't work
- Uncoordinated TMIs
- Limited use of RNAV/RNP
- Weather impacted departure routes
- Vectoring in climb and descent
- "Transactional friction" in ATC procedures
- Inefficient and unclear taxi routes
- Taxi in delays

Capacity & Throughput
- Over scheduling of departures by airlines
- Metering not used to its potential
- Reduced throughput in low visibility and weather
- Lost departure opportunities (e.g., missed EDCTs)
- Inefficient airspace design
- Insufficient airport capacity for demand
- Inadequate arrival/departure coordination
- Poor conformance with TMIs

Motivation

- Survey of Airline ATC Coordinators on criteria for assessing GDP performance
- 1 (Not at all important) to 5 (Extremely important)

Importance in evaluating GDP performance	Mean
GDP lead time	3.4
GDP duration	3.6
GDP scope	4.0
Number of GDP extensions	3.7
Average flight delay of non-exempted flights	3.7
Percentage of total delay that is taken in the air	3.0
Unrecoverable delay	4.1
Maximum fight delay	2.9
Accuracy of forecast on GDP end time	4.1
Accuracy of initial delay estimates	3.5
Accuracy of airport acceptance rate estimates in the initial plan	4.3
Number of revisions of AARs	4.1

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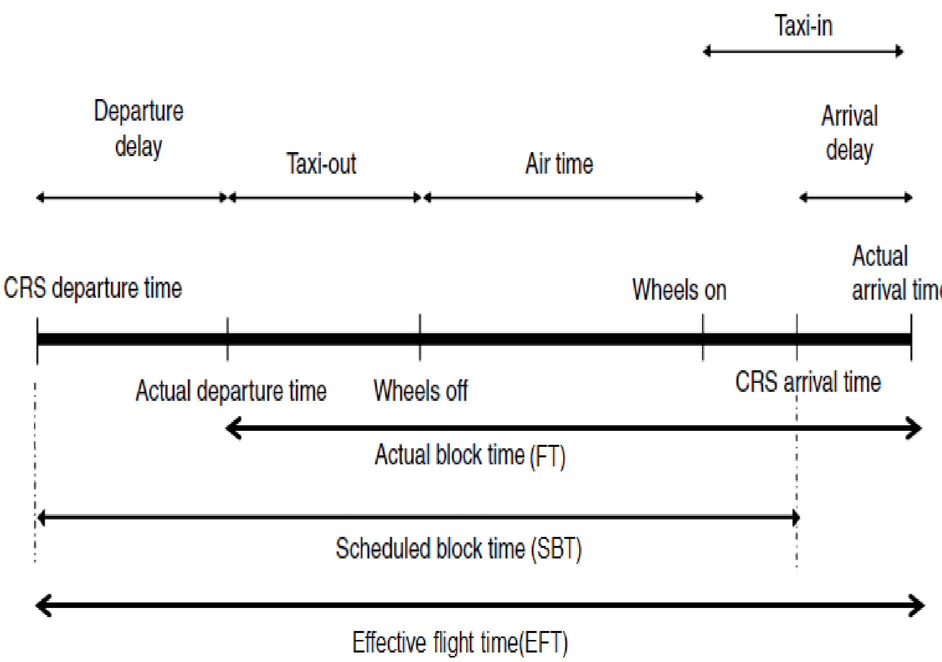
Predictability in ATM

- Ability to accurately predict ATM actions and operational outcomes
  - Realized Block times
  - Airborne times
  - “Effective flight time”
- Defined at different time scales
  - Strategic—several months out, when schedule is set
  - Tactical—day of operation, when flight plan is created



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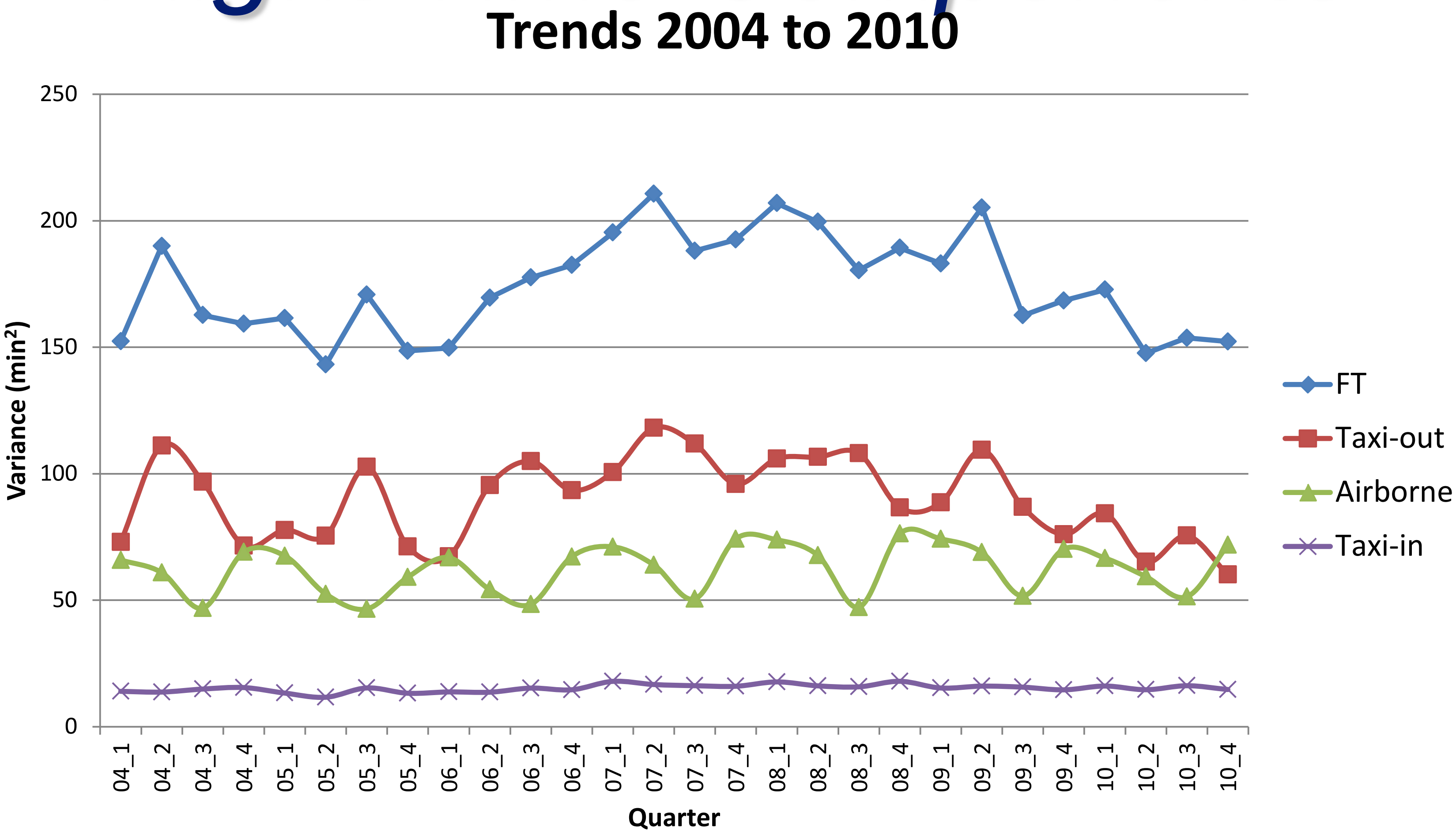
Approaches to Measuring Predictability

- Flight time variability
- Behavioral response
- Cognitive

Flight Time Variability

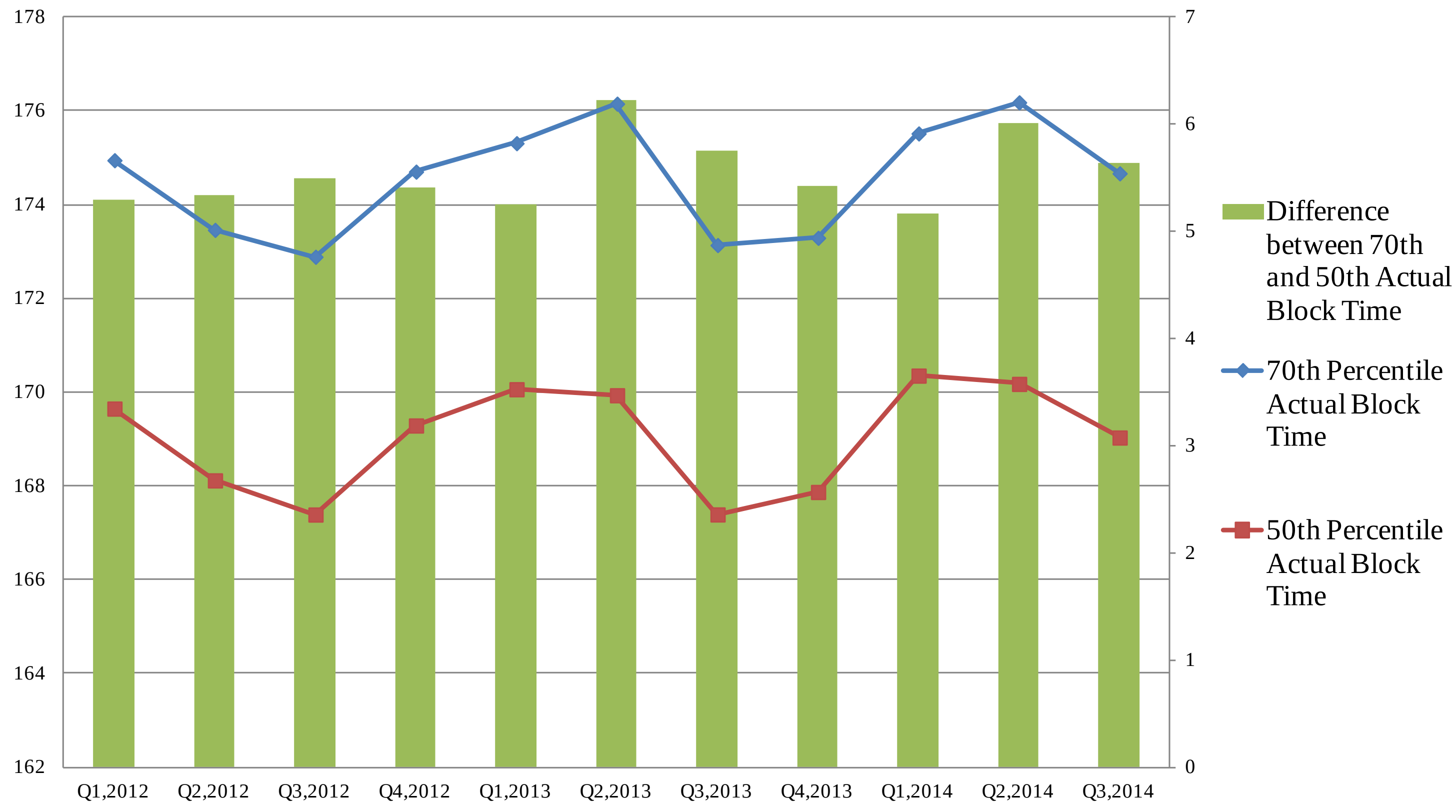
- What is a "flight"?
  - Airline, OD, Dep. Hr, AC Type
  - Airline, OD, Flt. No
- Flight time components to consider?
  - (Gate Delay), Taxi-out, Airborne, Taxi-in
- How to measure variability?
  - 2^{nd} Moment-based (variance and std. dev)
  - Percentile-based

Trends of Variance of Flight Time Components



Trends in 70th-50th Percentile ABT

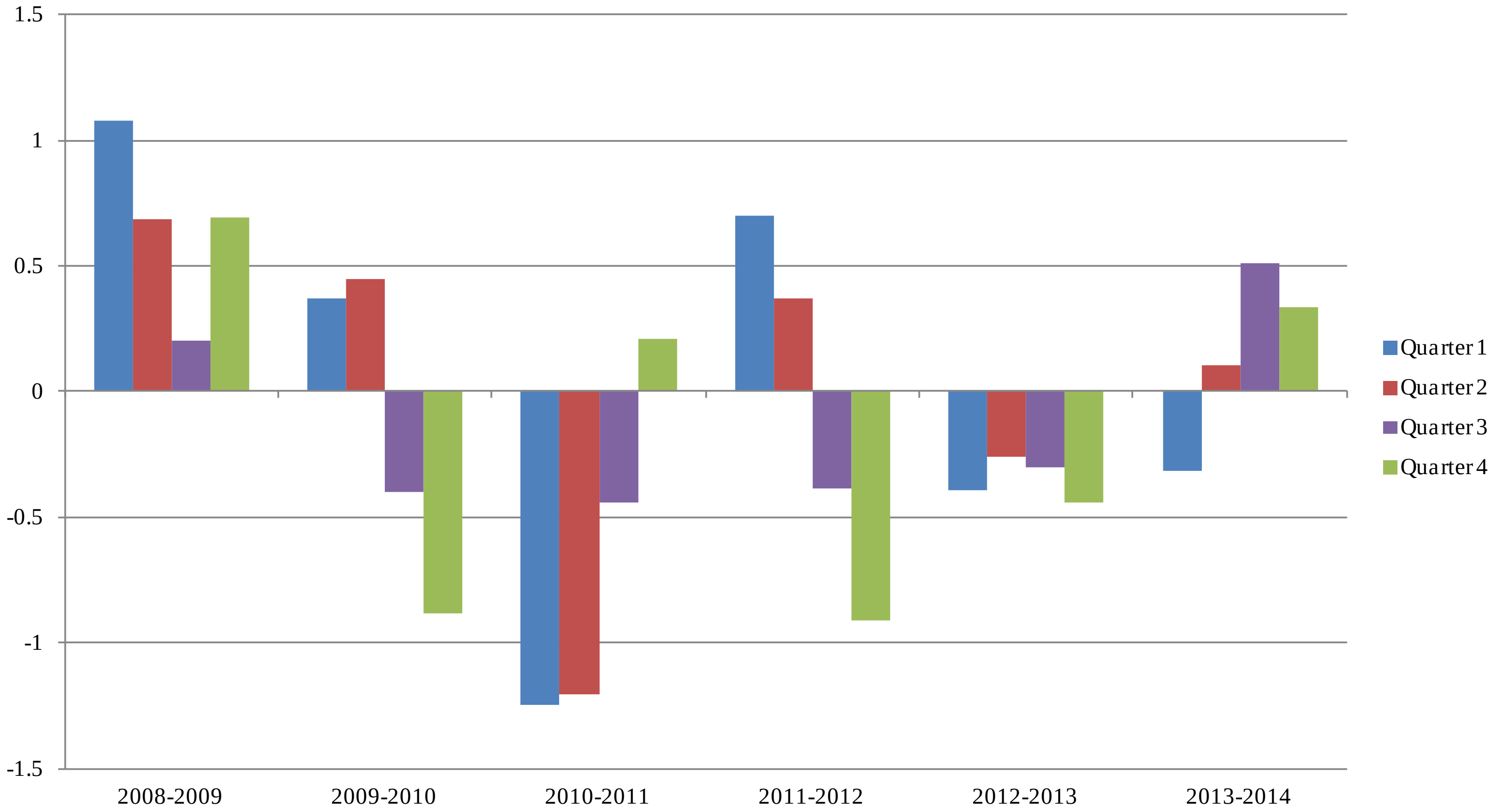
- Based on 586 unique combinations of Airline,O,D,Eq,Hr
- At least 10 flights in each quarter
- Benchmark OEP Airports



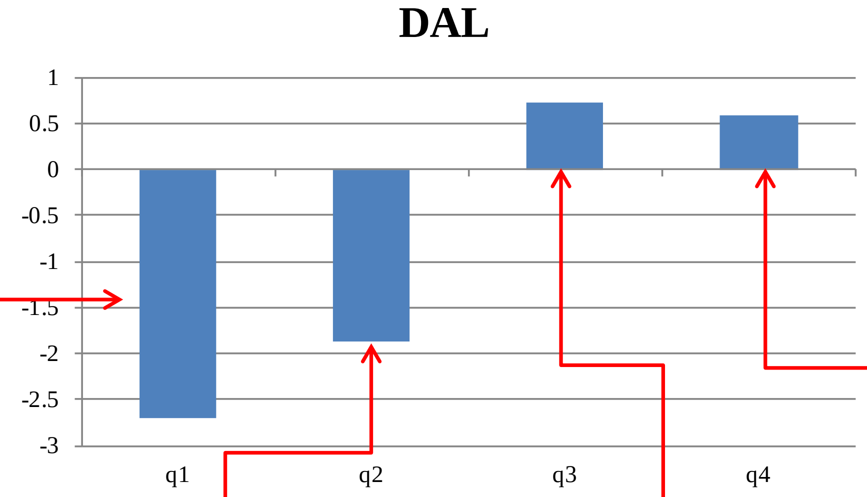
Behavioral Metrics

- Reflect flight operator adaptations to (un)predictability
- Lagging Metrics
- Scheduled Block Time
- Turn Times
- Fuel Loading

Overall Average SBT Change for Domestic and Weekdays Flights



Delta SBT change Top 15 Major Drivers (2013-2014)



Dep	Arr	type	hour	Difference
JFK	SFO	B752	19	-12.1
DTW	PHX	B738	8	-11.3
ATL	SLC	B763	16	-10.4
ATL	FNT	MD88	9	-13.9
JFK	SLC	B738	12	-12.5
ATL	ORD	B752	19	-9.6
SAN	JFK	B738	6	-13.2
LAS	JFK	B738	16	-8.5
EWR	SLC	B738	17	-8.8
BUF	ATL	MD88	17	-9.8
ATL	MCI	MD90	17	-8.5
JFK	LAS	B738	10	-9.9
ATL	SLC	B738	21	-8.8
SFO	JFK	B752	21	-8.2
MSN	DTW	MD88	16	-7.9

Dep	Arr	type	hour	Difference
DTW	MSY	A319	15	-11.7
ATL	LAX	B752	21	-17.8
HNL	LAX	B753	21	-9.4
BNA	LAX	B738	17	-9.0
ATL	MLB	MD88	9	-8.5
ATL	ORF	MD88	14	-11.6
ATL	MLB	MD88	15	-8.2
JFK	SLC	B752	7	-9.4
ATL	GSO	MD88	14	-9.2
ATL	MCO	B752	17	-8.6
ATL	STL	B752	22	-7.3
ATL	PHX	B752	19	-8.7
ATL	PHX	B752	8	-10.1
MSY	LAX	A319	17	-7.4
ATL	PHL	MD88	17	-9.4

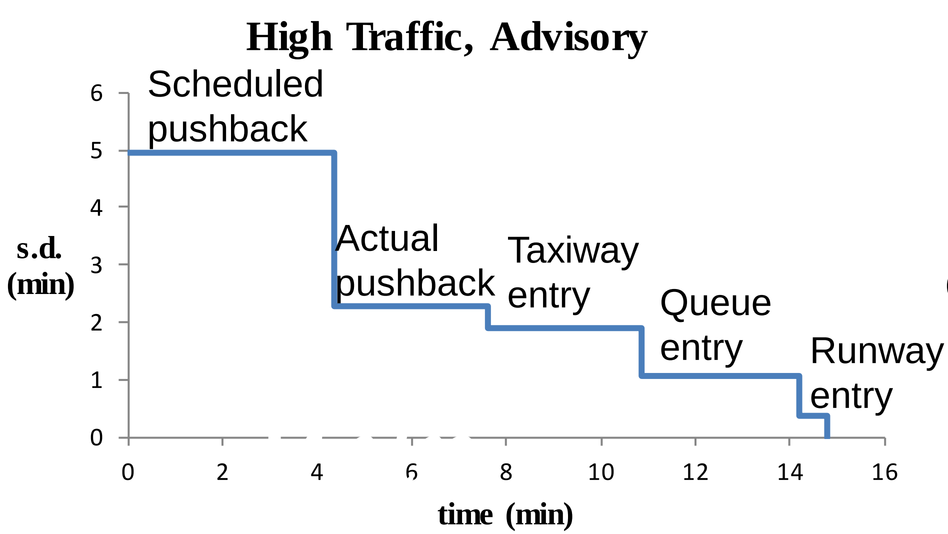
Dep	Arr	type	hour	Difference
ROA	ATL	A319	7	15.8
LGA	MSY	A319	18	19.8
LAX	BOS	B738	9	12.0
JFK	SFO	B752	7	11.5
SFO	JFK	B752	16	10.5
JFK	LAS	B738	10	10.3
JFK	LAS	B738	21	18.9
LGA	ATL	MD88	20	11.3
JFK	LAX	B763	15	9.7
CRW	ATL	A319	7	9.8
ATL	ROC	MD90	14	9.3
JFK	SFO	B752	16	9.2
ATL	MSP	B752	18	12.3
JFK	SFO	B752	19	7.5
MSP	SFO	B753	11	11.0

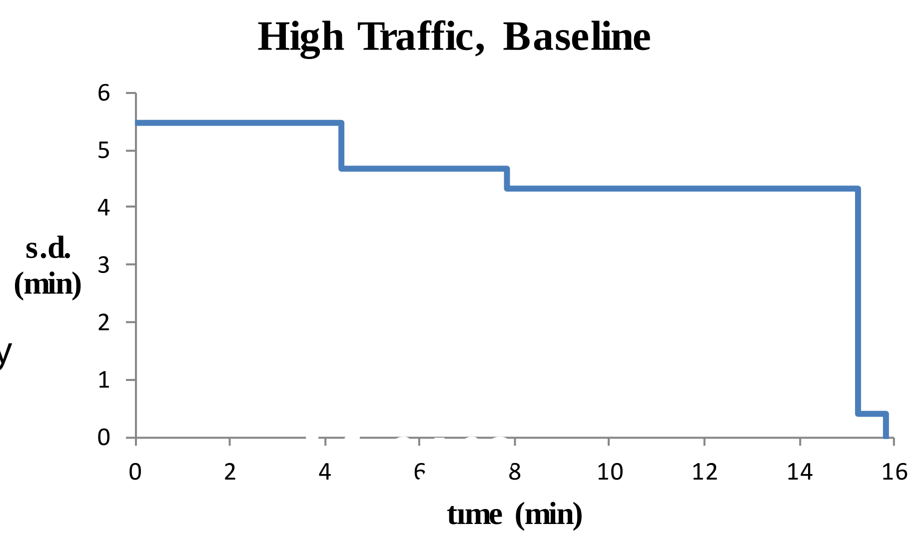
Dep	Arr	type	hour	Difference
PHL	ATL	B752	6	12.9
JFK	LAX	B763	7	11.8
PDX	JFK	B738	7	10.5
ATL	HNL	A333	10	12.5
JFK	AUS	B738	17	9.3
CRW	ATL	A319	7	10.2
DEN	ATL	MD90	6	8.7
ATL	LAX	B752	19	14.8
SEA	JFK	B752	7	7.7
JFK	SAN	B738	8	14.3
BDL	ATL	MD88	7	7.9
DTW	LAX	B739	12	7.0
BOS	MSP	B738	18	8.1
SJU	ATL	B752	8	10.1
CAK	ATL	MD88	17	10.7

Cognitive Metrics

- “What did they know and when did they know it”
- Important to flight operators but difficult to track
- Possible metrics
  - Wheels-off times
  - TMI lead times and revisions

Wheels-Off Time Predictability Change from Use of Spot and Runway Departure Advisor (SARDA)





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Scheduled Block Time (SBT) Model

- Investigate relationship between realized block times and scheduled block times
- Combine study of airline SBT setting process with econometric analysis

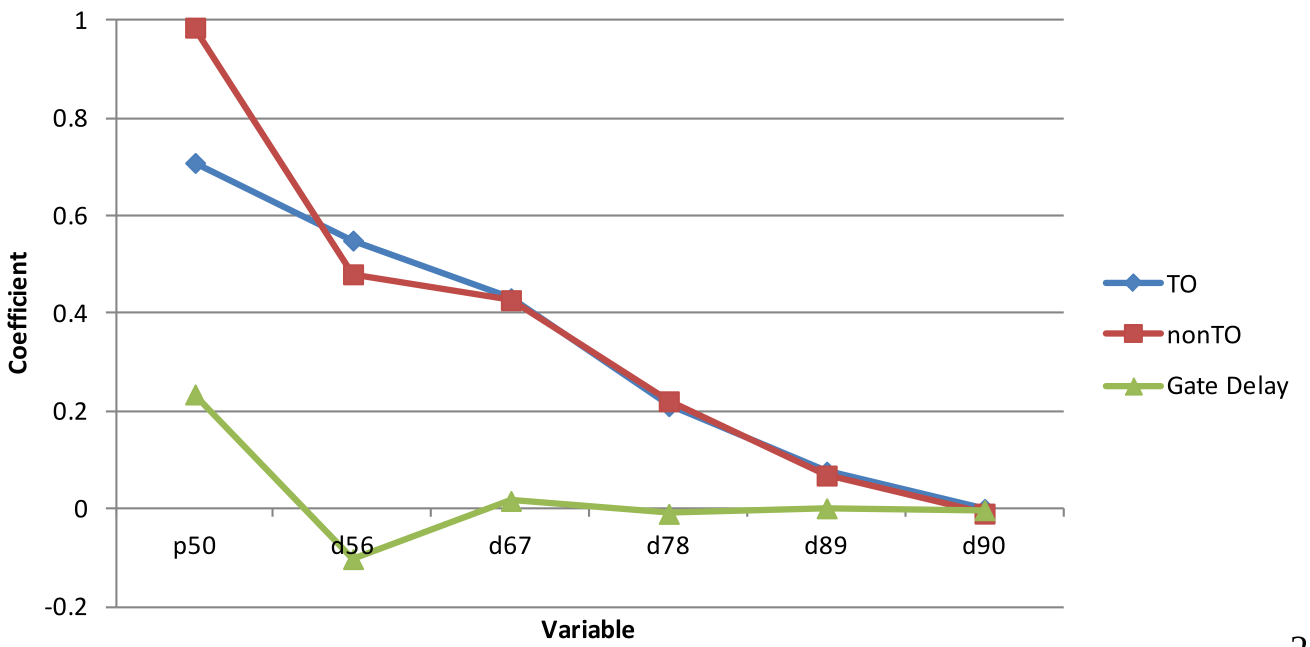
Hao and Hansen, Block time reliability and scheduled block time setting Transportation Research Part B: Methodological, Volume 69, November 2014, Pages 98-111

Percentile Model for SBT Setting

- Relate SBT to historical block time
- Predictability is depicted by segmenting the historical block time distribution
- Treat different segment of the distribution differently
- Allow for seeing the contribution of each segment

Percentile Phase-Specific Model

- Used percentiles by flight phase
- Included gate delay



Cost of Scheduled Block Time

- Statistical cost estimation: cost=g(output,factor prices, time variables,other)
- Airline quarterly data from Form 41, 1995-2007
- Time variables include
  - Positive delay against schedule
  - Schedule buffer

B. Zou and M. Hansen, "Impact of Operational Performance on Air Carrier Cost Structure: Evidence from US Airlines," *Transportation Research Part E*, Vol. 48, pp. 1932-1048.

Estimation Results

Estimation results of delay-buffer5/10/20 models.

	Delay-buffer5		Delay-buffer10		Delay-buffer20	
	Est.	Std. err.	Est.	Std. err.	Est.	Std. err.
Output (RTM)	0.4875^{***}	0.0369	0.4831^{***}	0.0362	0.4783^{***}	0.0356
Fuel price	0.2016^{***}	0.0016	0.2014^{***}	0.0016	0.2010^{***}	0.0016
Labor price	0.3858^{***}	0.0022	0.3856^{***}	0.0022	0.3853^{***}	0.0022
Materials price	0.4126^{***}	0.0032	0.4130^{***}	0.0032	0.4136^{***}	0.0032
Capital input	-0.0547^{***}	0.0009	-0.0546^{***}	0.0009	-0.0544^{***}	0.0009
Stage length	-0.2172^{***}	0.0837	-0.2071^{**}	0.0838	-0.1913^{**}	0.0835
Points served	0.6650^{***}	0.0573	0.6685^{***}	0.0571	0.6720^{***}	0.0569
Avg. pos. delay	0.0060^{***}	0.0014	0.0059^{***}	0.0014	0.0057^{***}	0.0015
Avg. buffer5	0.0070^{***}	0.0027				
Avg. buffer10			0.0066^{**}	0.0029		
Avg. buffer20					0.0057^{*}	0.0031
Time trend	0.0012^{**}	0.0006	0.0013^{**}	0.0006	0.0013^{**}	0.0006
R^2	0.9902		0.9901		0.9900	
RTS	0.9152	0.0439	0.9157	0.0441	0.9167	0.0444

Predictability and Fuel Loading

- In the flight planning process, airline dispatchers load discretionary (i.e., non-mission fuel) to hedge against uncertainty
  - Airport outages
  - Weather events
  - Possible re-routes
- What is the cost of carrying discretionary fuel?

Hao, Lu, M. Hansen, M. Seelhorst, and M. Smirti, “Impact of Operational Flight Predictability on Airline Fuel Cost”, TRB Annual Meeting, January, 2014, paper 14-5505_B.

What is Additional Fuel, and What is the Cost to Carry this Additional Fuel?

Two definitions of additional fuel

Fuel on arrival definition: Total Fuel on Arrival with Tankering, Reserve, and 1st Alternate Fuel Removed

Contingency fuel definition: "Additional" Contingency Fuel (fuel above SCF 99) plus 2nd Alternate Fuel

Cost to Carry Factors

- Convert additional fuel loaded into fuel burned
- Fuel burned per pound of fuel carried per mile using PIANO model
- Special recognition for: icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Annual Cost to Carry Across our Study Airline for All Domestic Flights

	Cost to Carry (lbs)	Cost to Carry @ \$2/gallon (\$)	Cost to Carry @ \$3/gallon (\$)	Cost to Carry @ \$4/gallon (\$)	CO_2 (lbs)
Fuel on Arrival	$1.86*10^8$	$5.56*10^7$	$8.35*10^7$	$1.11*10^8$	$5.81*10^8$
Contingency Fuel	$9.46*10^7$	$2.83*10^7$	$4.24*10^7$	$5.65*10^7$	$2.95*10^8$

- We aggregate the yearly cost to carry fuel across the entire domestic aviation system (assuming all other carriers behave like our study airline)
  - *The fuel on arrival benefit pool* is 1.9 billion lbs of fuel (~$835 million)
  - *The contingency fuel benefit pool* is 946 million lbs of fuel (~$424 million)

Flight Operator Survey

- Investigate flight operator preferences in traffic management initiative decision-making process
- 23 ATC coordinators from several airlines
- Stated preference questions

Stated Preference Analysis

- Airline ATC Coordinators asked to choose between a set of hypothetical GDPS
- Attributes of GDPs chosen to reveal utility functions
- Ordered probit model used for function estimation

Attributes	GDP A	GDP B
Average Delay per Flight (minutes)	50	35
Maximum Flight Delay (minutes)	250	270
Unrecoverable Delay per Flight (minutes)	15	0
Change in Delay per flight after Initial Plan (minutes)	-5	-20
Lead Time (minutes)	100	100
Number of Revisions	1	1

Strongly prefer A	Somewhat prefer A	No preference	Somewhat prefer B	Strongly prefer B
○	○	○	○	○

Estimation Results

- Unpredictability premium is about 15% (.012/.078)
- Other predictability effects have expected signs but are insignificant
- Maximum delay does not matter

Variable	Estimate	T-stat
Average delay per flight[a]	-0.078***[b]	-10.5
Maximum flight delay[a]	0.002	0.64
Negative change in delay per flight[a,c]	-0.011***	-3.11
Positive change in delay per flight[a,c]	-0.012***	-2.82
Lead time[a]	0.0001	0.05
Number of revisions[a]	-0.136	-0.58
Threshold 1	-1.472***	-5.03
Threshold 2	-0.259	-0.89
Threshold 3	0.189	0.65
Threshold 4	1.293***	4.42
Log-likelihood	-476.42	
Number of obs.	368	

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Achieving Predictability

- NEXTGEN
- Surface Traffic Management
- TMI Strategies
  - GDPs instead of Ground Stops
  - NAS Vision 15
  - Balance predictability and throughput objectives
- Sequencing policies that favor “right tail” flights

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Conclusions

- Predictability is a “thing”
- It has both a strategic and a tactical aspect
- It is measurable
- It is monetizable
- It can be improved