Evaluation of Predictability as a Performance Measure

Global Challenges Workshop
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Outline

1. Introduction
2. What is Predictability?
3. Trends in Predictability Indicators
4. Benefits of Predictability
   a) Scheduled Block Time Setting
   b) Fuel Loading
   c) Stated Preference Analysis

Goals of the Project

- Develop and validate predictability measures could be practically implemented by FAA as part of standard reporting of performance or for more routine use in cost benefit studies
- Address the following questions:
  - **Do predictability measures add value distinct from other performance measures?**
  - Can ATO influence a predictability measure?
  - Do FAA programs depend on predictability as measured by the recommended indicators?
  - **Can predictability be monetized for program benefit assessments?**

NEXTOR

Flight Predictability: Concepts, Metrics and Impacts

Final Report — February, 2014

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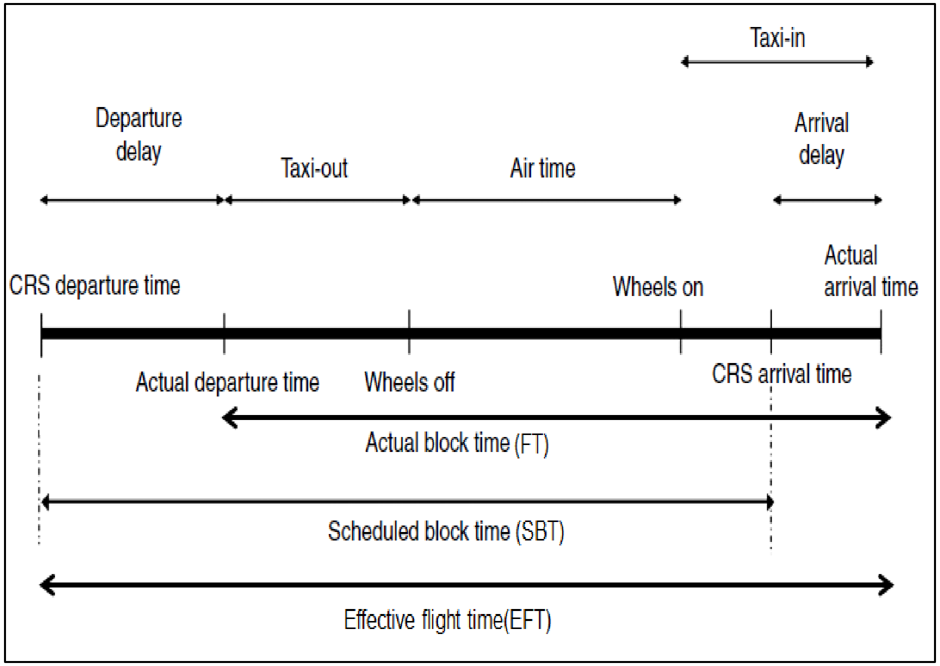
What is Predictability?

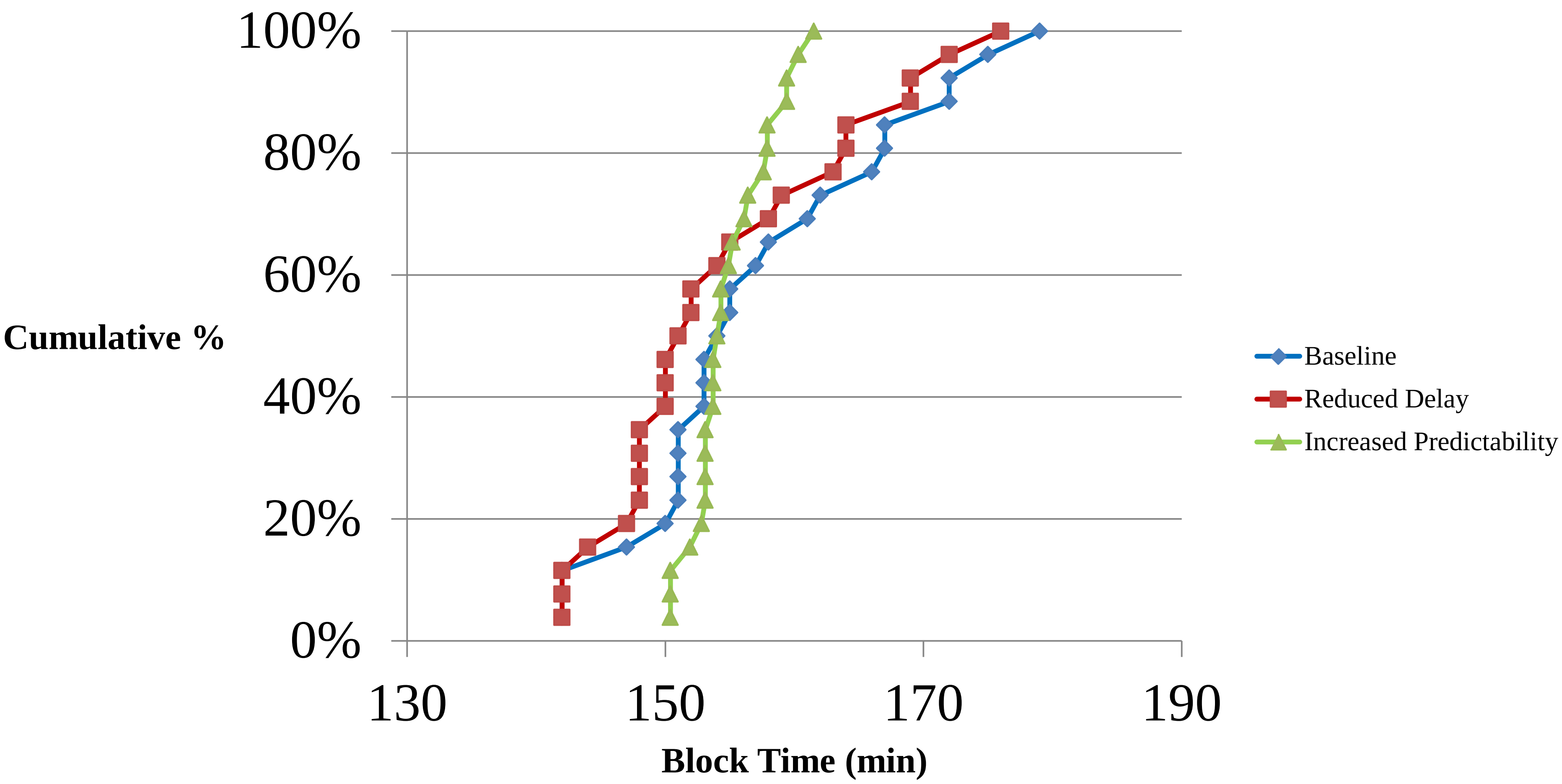
- Ability to accurately predict operational outcomes
  - Block times
  - Airborne times
  - “Effective flight time”
- Defined at different time scales
  - Strategic—several months out, when schedule is set
  - Tactical—day of operation, when flight plan is created



Predictability and Delay

- Delay—time above some criteria value
  - Block, taxi, or airborne time vs ideal conditions
  - Schedule arrival or departure time
- Predictability—variability in block time
- Operational improvements may change one or the other, or both

Example DFW-DCA, AA, 1900-1930, MD80, 2010-1



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Recent Trends in Predictability

- ATL-LGA-DL Case Study
- Compare January 13 and January 14
- Disaggregate by
  - AC Type
  - 1 hr departure window
- Predictability Indicators
  - Scheduled Block Time
  - 70% percentile Actual Block time
  - A14 (% of flights arriving less than 15 min late)

Dep Hr	AC-Type	# Flts 13	# Flts 14
6	B752	24	4
6	MD88	1	20
7	MD88	5	21
8	MD88	5	26
11	B752	29	21
12	MD88	6	26
13	B752	27	20
14	B752	30	1
15	MD88	3	26
18	B752	25	24
21	B752	30	1
21	MD88	1	4

Changes in Scheduled and Actual Block Times, ATL-LGA-DL, 1/13 and 1/14

Dep Hr	AC Type	SBT-13	50th Pct Act BT-13	70th Pct Act BT-13	A14 BT-13	SBT-14	50th Pct Act BT-14	70th Pct Act BT-14	A14 BT-14
6	B752	128	124	130	88%	129	123	124	100%
6	MD88	130	123	123	100%	129	120	126	80%
7	MD88	138	129	138	100%	137	128	134	90%
8	MD88	144	127	128	80%	135	132	144	65%
11	B752	137	124	128	93%	132	116	119	90%
12	MD88	141	125	131	100%	135	128	135	62%
13	B752	138	130	134	93%	134	125	132	70%
14	B752	135	122	126	87%	132	146	146	0%
15	MD88	139	129	133	100%	136	133	141	65%
18	B752	144	128	135	72%	135	120	123	67%
21	B752	139	127	130	93%	126	114	114	100%
21	MD88	140	121	121	100%	129	121	126	75%

System-wide Trends

- Method for calculating weighted average predictability metrics for each quarter (from Q1, 2010 to Q3, 2014) based on ASPM data (weekdays flights)
- Trends in metrics

Methodology of Calculating Weighted Average SBT for Each Quarter

Motivation:

- Remove block time changes that result from changes in the aircraft type and scheduled gate out time window

Procedures:

- Categorization
- Matching
- Calculate weighted average

Methodology of Calculating Weighted Average SBT for Each Quarter

1. Categorization
   - Dep, Arr, airline, aircraft type, scheduled gate out hour window
   - E.g.

ID	Departure	Arrival	Airline	Aircraft type	Hour window (from 0 to 24)	Q1, 2013		Q2, 2013	
						Number of flights	Mean SBT (in minutes)	Number of flights	Mean SBT (in minutes)
1	ATL	DCA	DAL	MD88	12	25	104	48	106
2	ATL	FLL	DAL	B752	16	40	117	26	113
3	DCA	MIA	AAL	B738	3	0	0	0	0
4	ATL	MCO	DAL	B752	15	0	0	5	88
5	ABQ	DAL	SWA	B733	2	24	96	18	105

Methodology of Calculating Weighted Average Metrics for Each Quarter

2. Matching

- Exclude “0 flights” combinations
- For example, total number of matched flights is 25+48+40+26+24+18=181
- Weights for combination 1 is (25+48)/181=0.40

ID	Departure	Arrival	Airline	Aircraft type	Hour window (from 0 to 24)	Q1, 2013		Q2, 2013		weights
						Number of flights	Mean SBT (in minutes)	Number of flights	Mean SBT (in minutes)	
1	ATL	DCA	DAL	MD88	12	**25**	104	**48**	106	0.40
2	ATL	FLL	DAL	B752	16	**40**	117	**26**	113	0.36
5	ABQ	DAL	SWA	B733	2	**24**	96	**18**	105	0.24

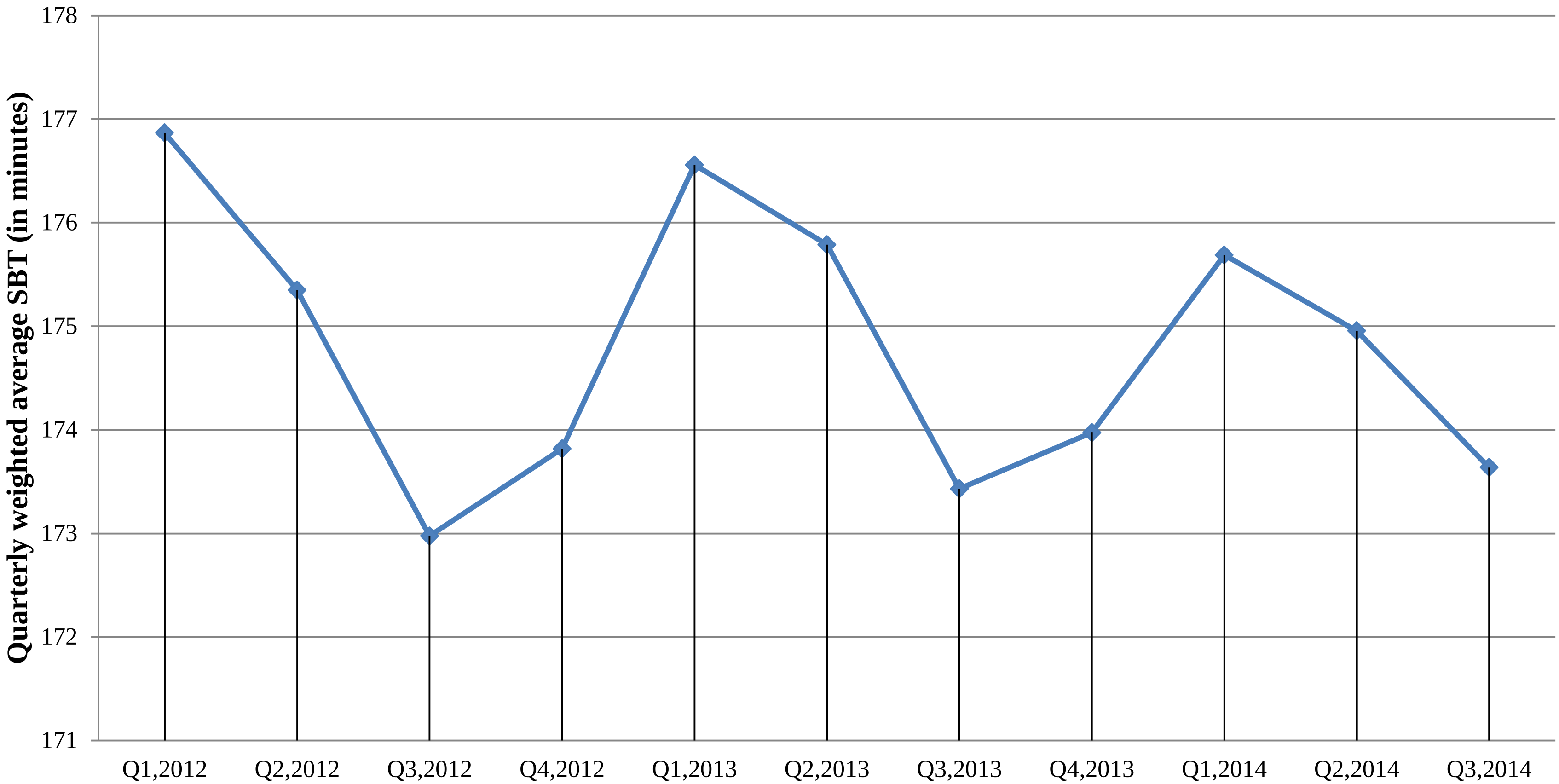
Methodology of Calculating Weighted Average Metrics for Each Quarter

3. Weighted average for each quarter
   - E.g. for Q1, 2013, the weighted average SBT=104*0.4+117*0.36+96*0.24=108

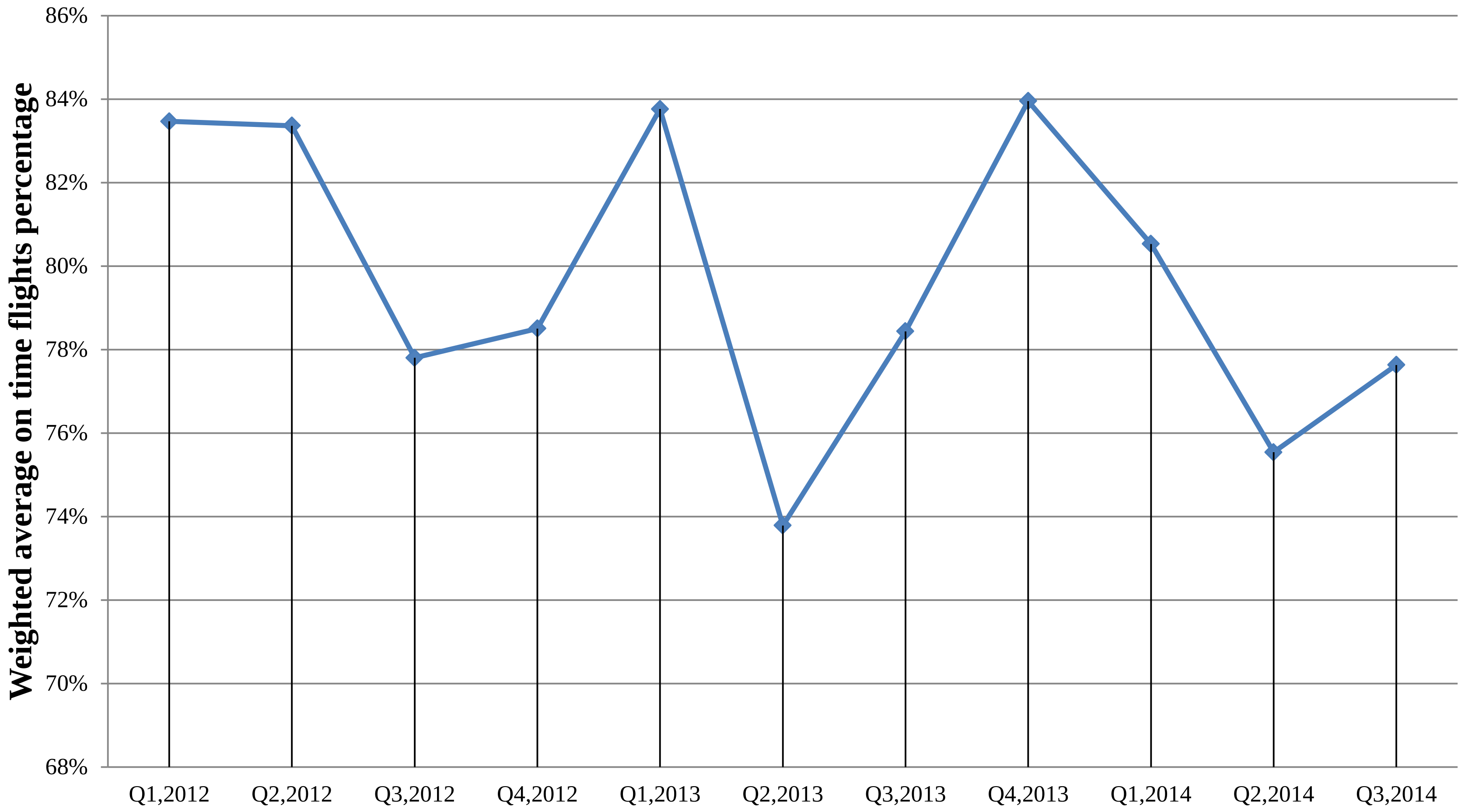
ID	Departure	Arrival	Airline	Aircraft type	Hour window (from 0 to 24)	Q1, 2013		Q2, 2013		weights
						Number of flights	Mean SBT (in minutes)	Number of flights	Mean SBT (in minutes)	
1	ATL	DCA	DAL	MD88	12	25	**104**	48	**106**	**0.40**
2	ATL	FLL	DAL	B752	16	40	**117**	26	**113**	**0.36**
3	ABQ	DAL	SWA	B733	2	24	**96**	18	**105**	**0.24**
Average quarterly SBT						**108**		**108**		

Trends of Weighted Average SBT for Major Airports and Airlines

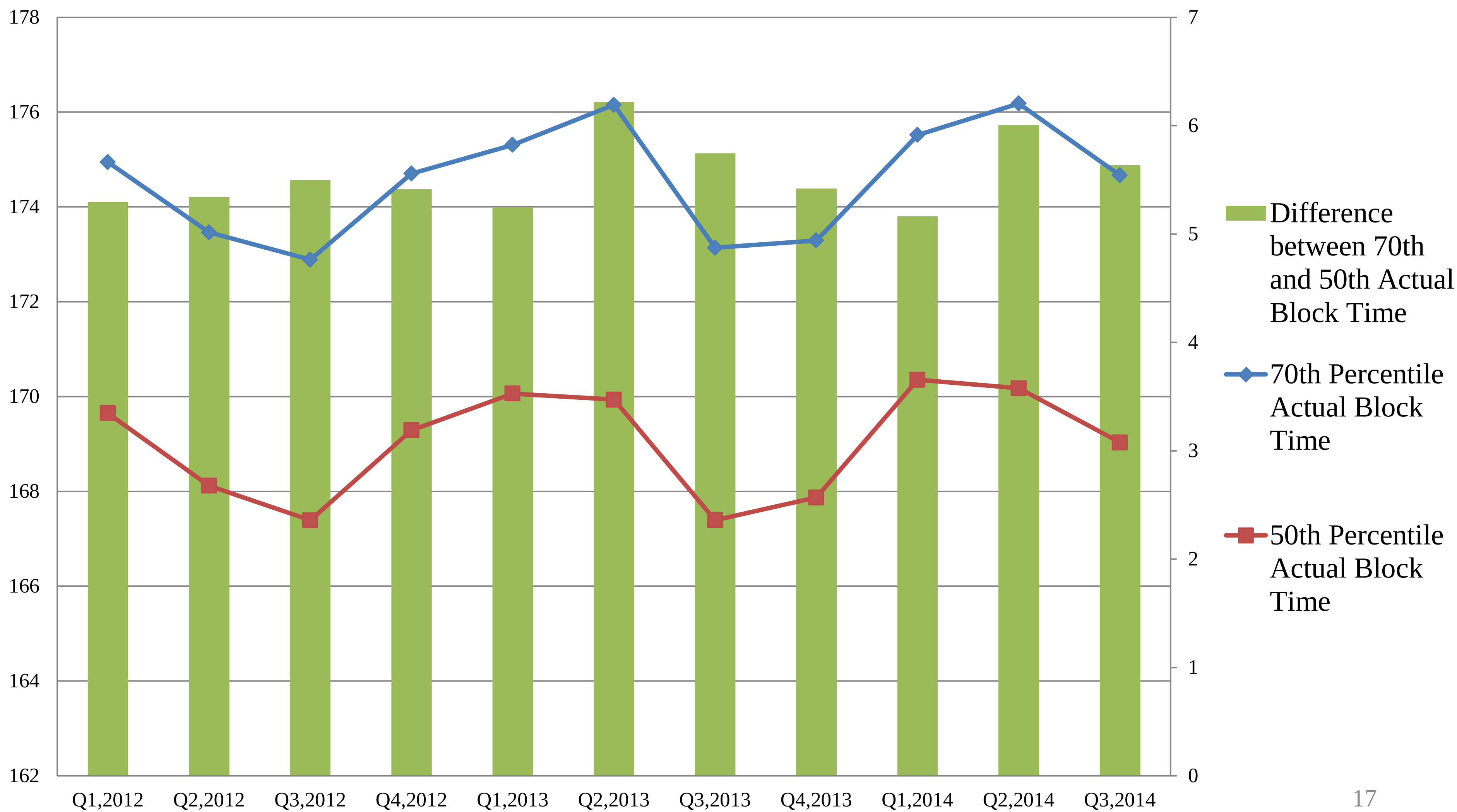
- We try to only include the 34 airports and 17 airlines suggested by the FAA internal data spreadsheet, and we end up with 1732 matched combinations {Dep, Arr, Airline, AC type, hour window} for 34 airports and 11 airlines
- After we filter out those combinations with number of flights smaller than 10, we end up with 586 matched combinations for 33 airports and 11 airlines



Trends of On-time Performance (A14) for Major Airports and Airlines



Trends of 50th and 70th Percentile Actual Block Time for Major Airports and Airlines



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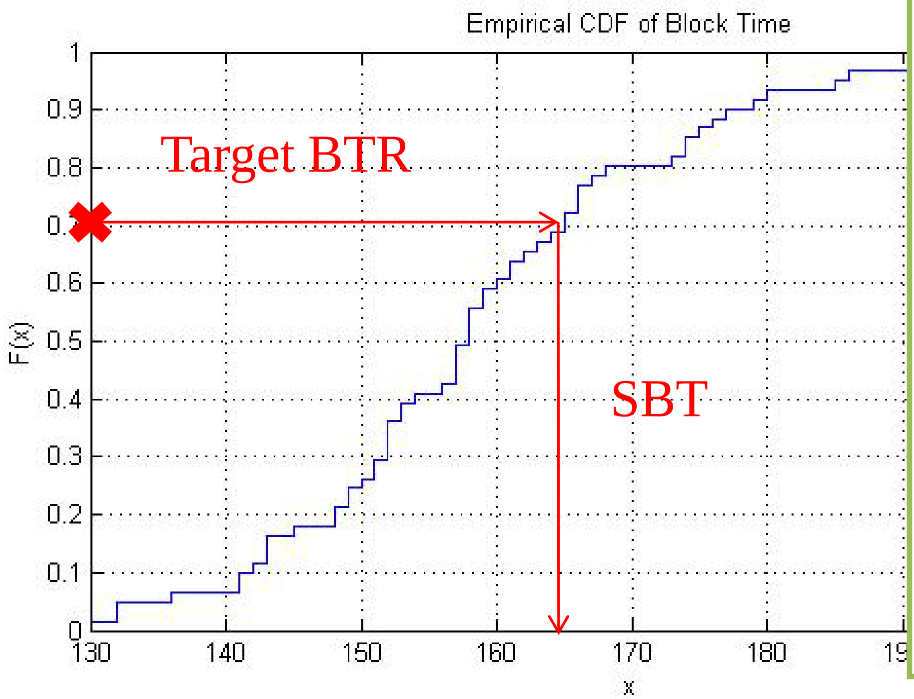
Scheduled Block Time (SBT) Model

- Modeling the impact of flight predictability on airline SBT setting
- Capturing predictability
  - Past experience: standard deviation
    - Largely driven by extremely long flight times
    - Cannot accurately reflect the airline's trade-off : keeping SBT short vs. achieving high on-time performance
  - Learn from industry practice
    - What matters: not the extreme value, but to capture the distribution of block time
    - More weight on certain regions of the distribution, less weight on the rest

Industry Practice on SBT

- Interview with Delta Air Lines personnel
- Block time setting group creates annual SBT file
- Based on historical block time data: BTR→SBT
- Proportion of flights: realized block time ≤ SBT



- Flights are grouped to generate the distribution
  - OD pair, aircraft type, departure time of the day, airline, quarter
- How long do they look back?
  - Airborne time: past 5 years
  - Taxi-out time: more recent dataset
- Predicting the future
  - Simulated data for expected changes

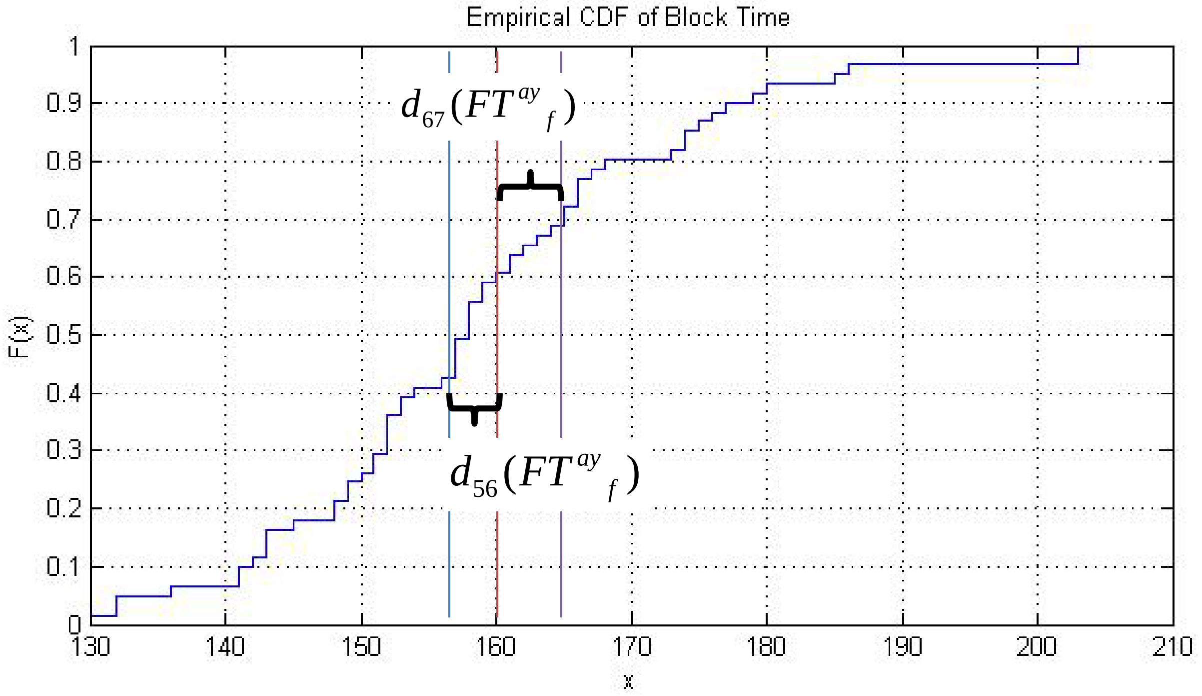
Scheduled Block Time (SBT) Model

- Modeling the impact of flight predictability on airline SBT setting
- 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

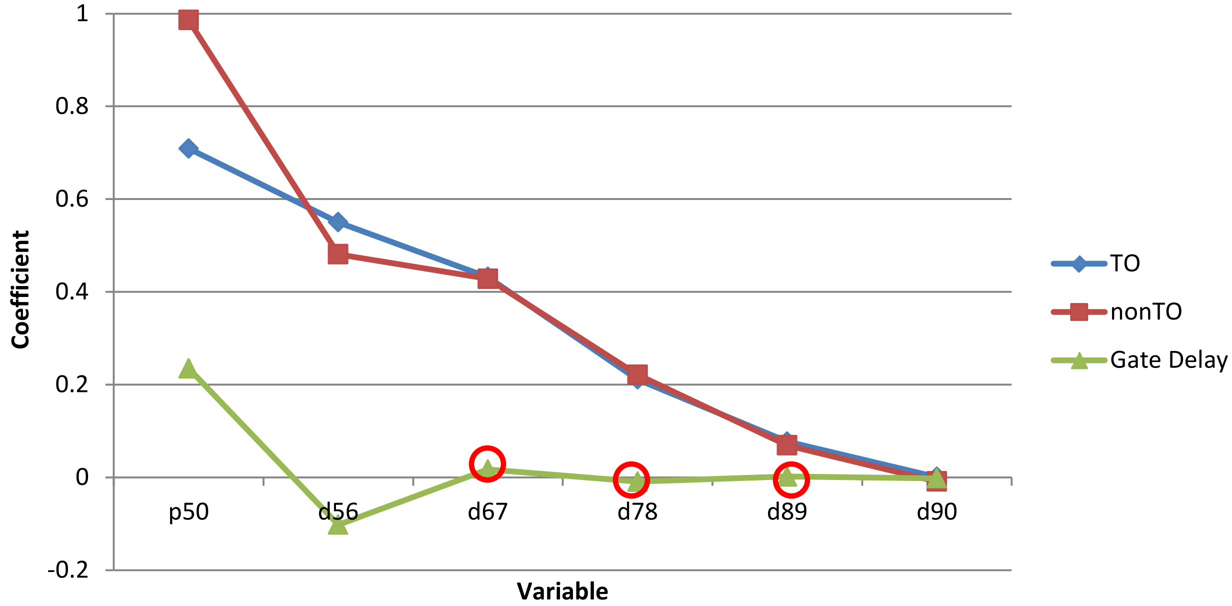
Percentile Model

- Capture the distribution with piece-wise approximation
- 50th to 100th percentile of BT distribution
- Median and the difference every 10th percentiles:

$$d_{56}(FT^{ay}{}_{f}) = p_{60}(FT^{ay}{}_{f}) - p_{50}(FT^{ay}{}_{f})$$



Estimation Results – Updated Model



- Where should we focus to reduce SBTs setting through predictability (adjusting historical BT distribution)?
- Effect of historical BT:
  - Median and inner right tail yield the most impact on SBT
  - Far right tail (extreme values) doesn't matter too much
- Effect of gate delay:
  - Currently negligible, insignificant
  - Future: should it be given more consideration?

Cost of Scheduled Block Time

- Statistical cost estimation: cost=g(output,factor prices, time variables)
- Time variables
  - Schedule□Actual
  - Fractions in
    - S∩A
    - ~S∩A
    - S∩~A
    - Etc
- Results
  - Cost penalty for ~S∩A
  - Little or no cost saving for S∩~A

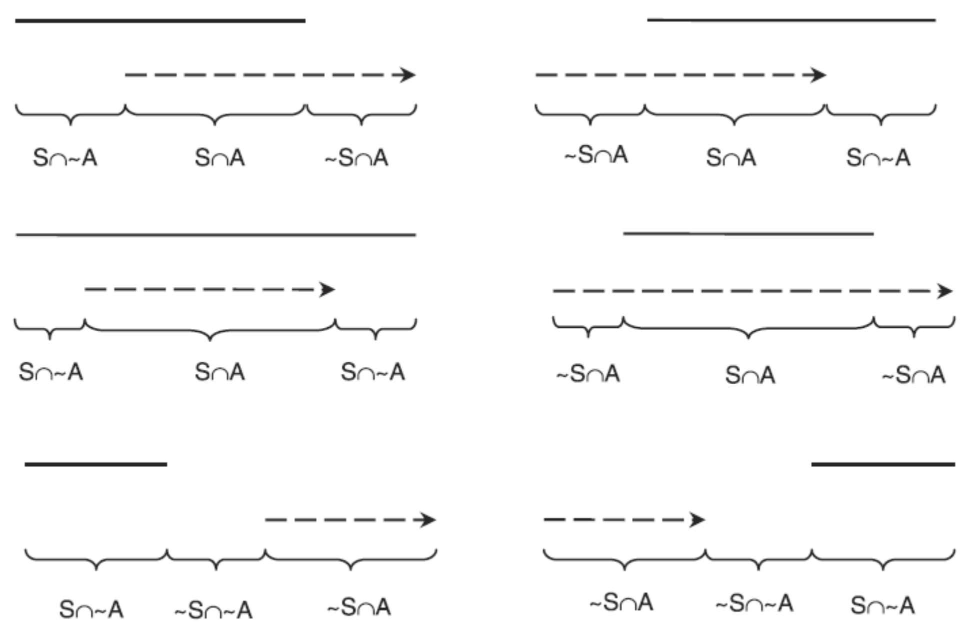


Fig. 4. Identification of time components in six possible situations.

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Quantifying Uncertainty Reflected in Fuel Loading

- In the flight planning process, airline dispatchers load discretionary (i.e., non-mission fuel) fuel for a number of reasons, one of which is to hedge against *uncertainty*
  - Airport outages
  - Weather events
  - Possible re-routes

- While some of this discretionary fuel is federally mandated (i.e. reserve), some of it is not

- What is the cost of carrying discretionary fuel?

Who Makes Fuel Decisions?

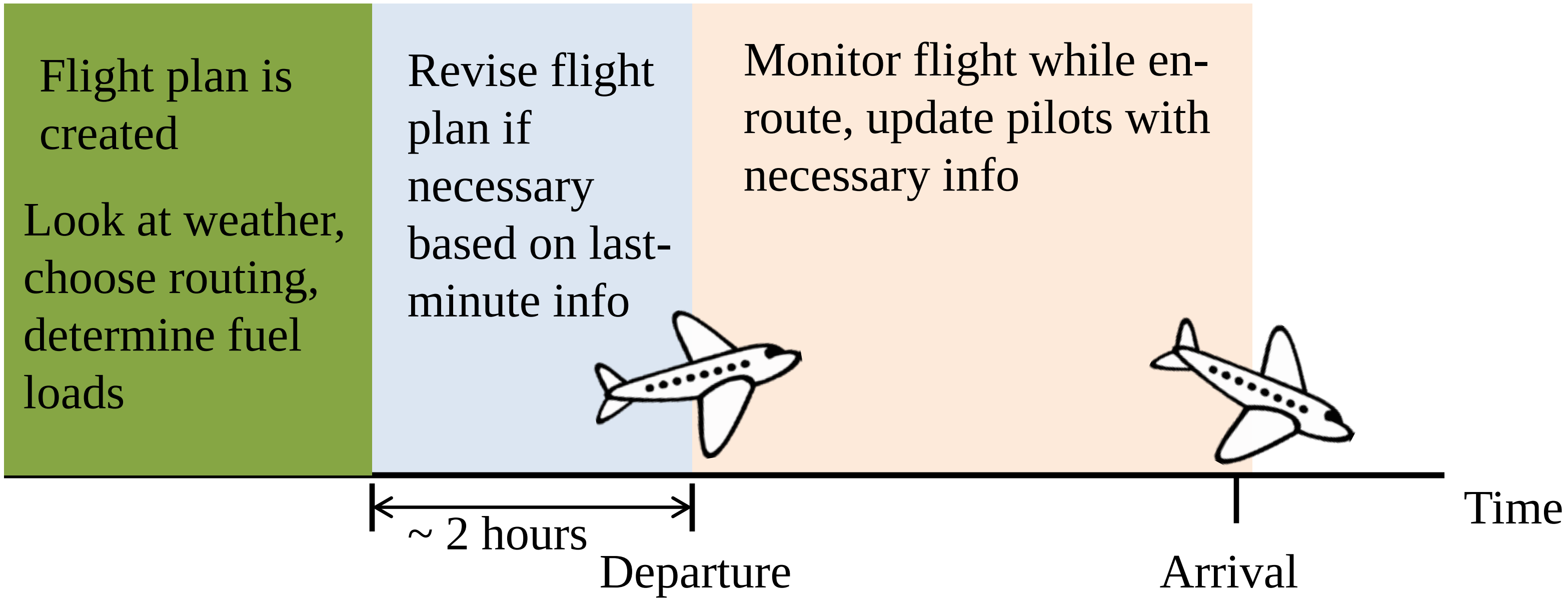
- Flight dispatchers
  - Airline employees, responsible for planning and monitoring all flights for an airline
  - Act as point of contact for pilots during flight
  - Determine characteristics of flight plan
    - Actual routing from origin to destination
    - How much fuel to load, including extra fuel for contingencies

Operational Control Center (OCC)

~200 people, working in a single room at a company's headquarters

Flight Planning Basics

- Timeline of dispatcher duties for a single flight



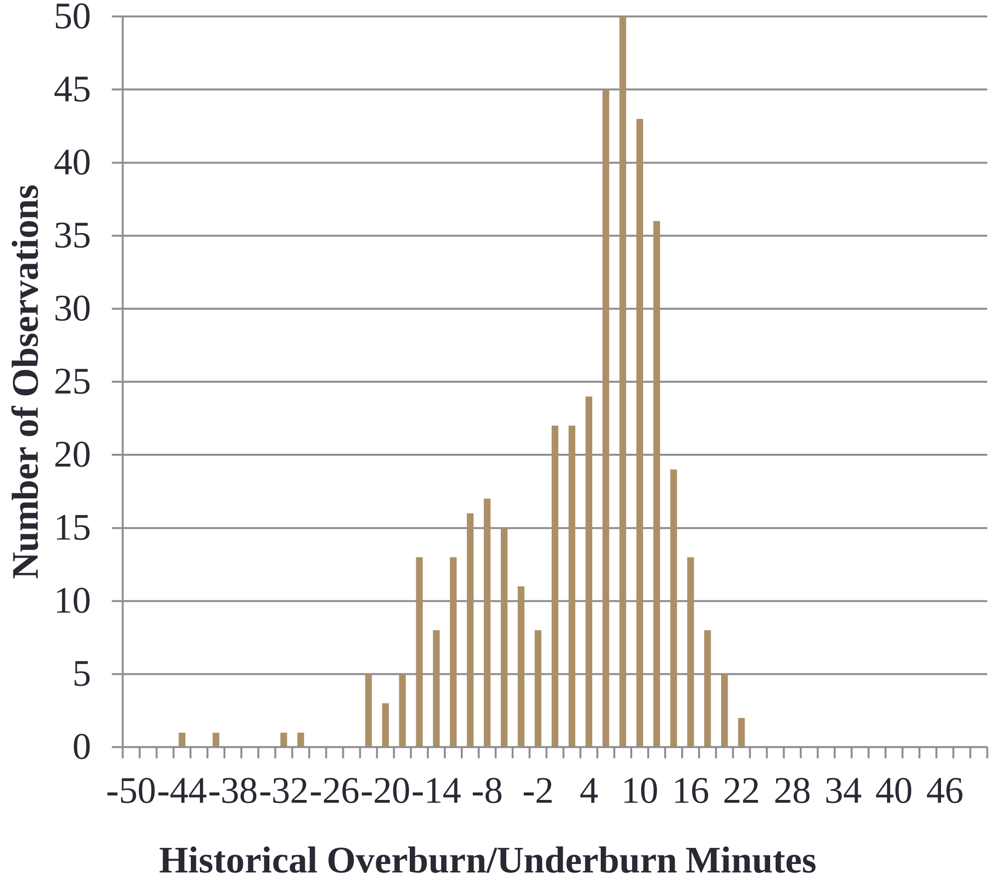
- Domestic dispatchers plan and monitor up to 40 flights in one ~9hr shift

Fuel Loading Distribution

Flight Plan Fuel (B757)			
	REQUIRED	DISCRETIONARY	Description
TAXI		:19/538	Suggestion based on historical data
TRIP MSP/KMSP-LAS/KLAS	2:50/20714		Flight Planning System
ALTN:PHX/KPHX FL260	:46/5313		Dispatchers' judgment
ALTN:**ONT/KONT FL240		:40/4726	Dispatchers' judgment
RESERVE FUEL	:45/4500		FAR requirement
CONTINGENCY FUEL	:06/575	:34/3259	Suggestion based on historical data
MIN FUEL FOR T/O	31103		
BLOCK FUEL		34900	
ON FUEL 13648	TAXI IN :05/142		
TARGET GATE ARRIVAL FUEL	13506		

Uncertainty and Flight Planning Basics

- Mission and reserve fuel is mostly calculated by the FPS
- The dispatcher has control over the contingency fuel
- How much contingency fuel should be added?
- Tool called Statistical contingency fuel (SCF)
  - Overburn/underburn fuel for historical similar flights are plotted on a histogram
  - The 95th and 99th percentile of overburn are shown to dispatchers: SCF95 & SCF99
  - The quantity represents the following: 99% of historical flights needed at the maximum SCF99 minutes of fuel beyond those planned to complete their mission



Overburn or Underburn is planned vs. actual burn

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

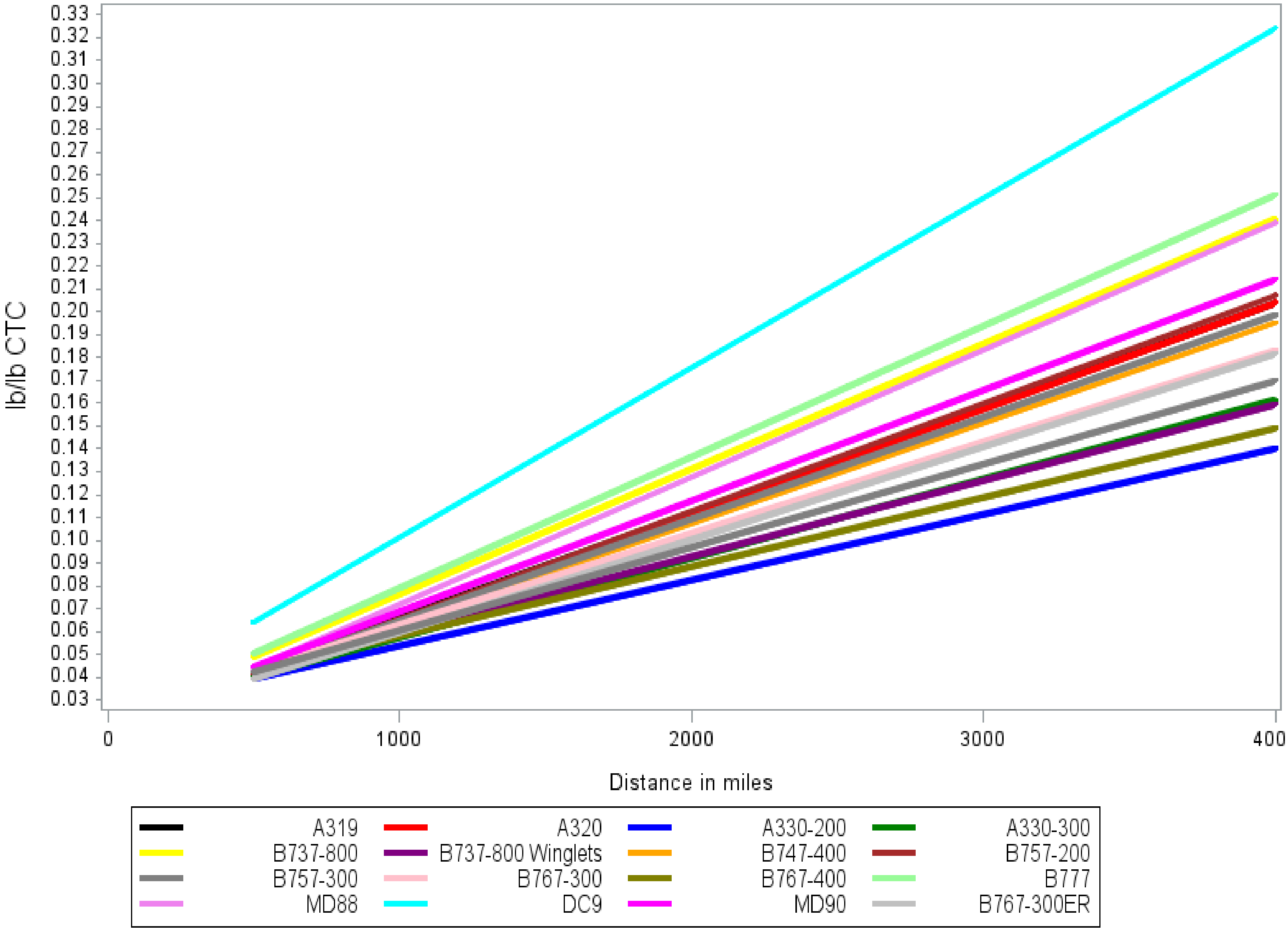
Dataset for Analysis

- All domestic flights for a year (June 2012 to May 2013) operated by Delta Airlines (we also have international flights, but this analysis is only for domestic)
- Flight statistics
- Fueling information (mission fuel, reserve fuel, tankering fuel, contingency fuel, suggested contingency fuel (SCF95/SCF99), alternate fuel – but not if an alternate is required, just if it's present)
- Actual fuel burn (fuel out and fuel in)
- Actual weather at the time of schedule arrival from NOAA

Estimate Cost to Carry Factors

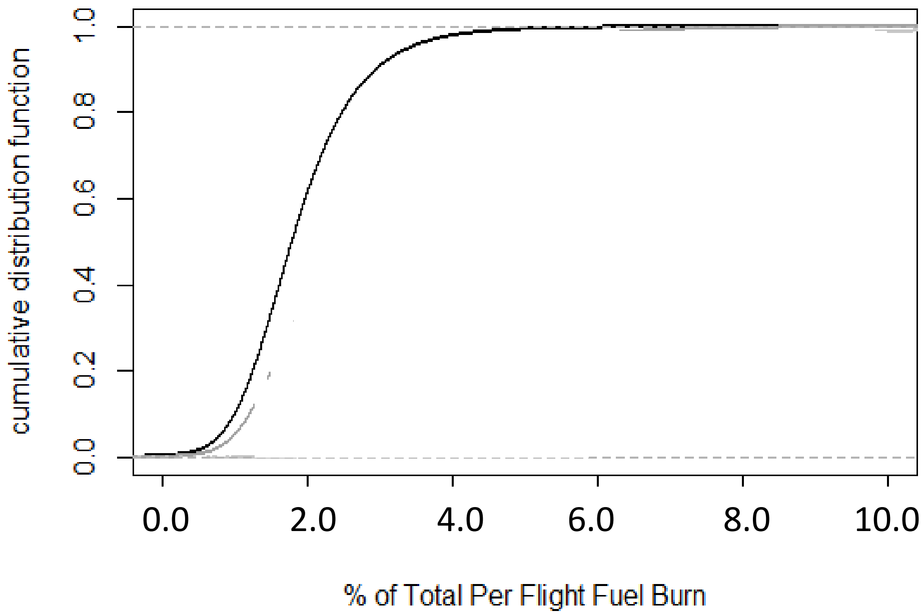
- Estimating the quantity of additional fuel loaded for both definitions of additional fuel is just calculation – but this additional fuel loaded needs to be converted into fuel burned
- There is a cost to carry this additional fuel in terms of additional fuel burned
- We calculated our own "cost to carry" factors which capture the fuel burned per pound of fuel carried per mile
- Special recognition for: icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION
- Delta has their own numbers, but these are less useful in a research context

Cost-to-Carry Factor Estimates in lb/lb

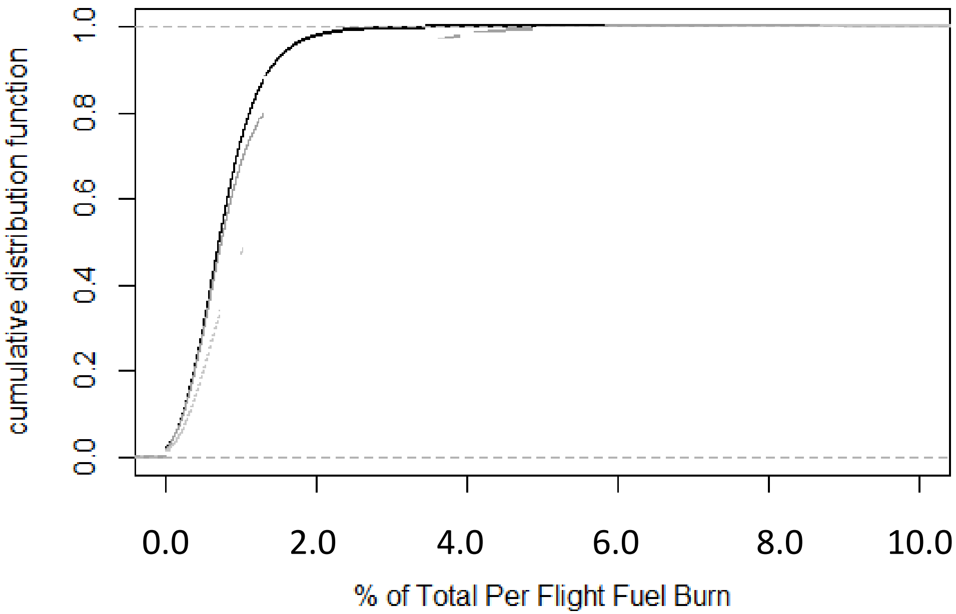


Distribution of the Percent of Fuel Consumed Attributed to Carrying Additional Fuel

Fuel on Arrival



Contingency 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

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)

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Stated Preference Analysis

- Airline ATC Coordinators asked to choose between a set of hypothetical GDPS
- Attributes of GDPs chosen to reveal utility functions
- Unpredictability premium for delay is about 15%

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 ○

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	

Thank You. Questions?