How Airlines Set Scheduled Block Time

Lu Hao, Mark Hansen
University of California, Berkeley

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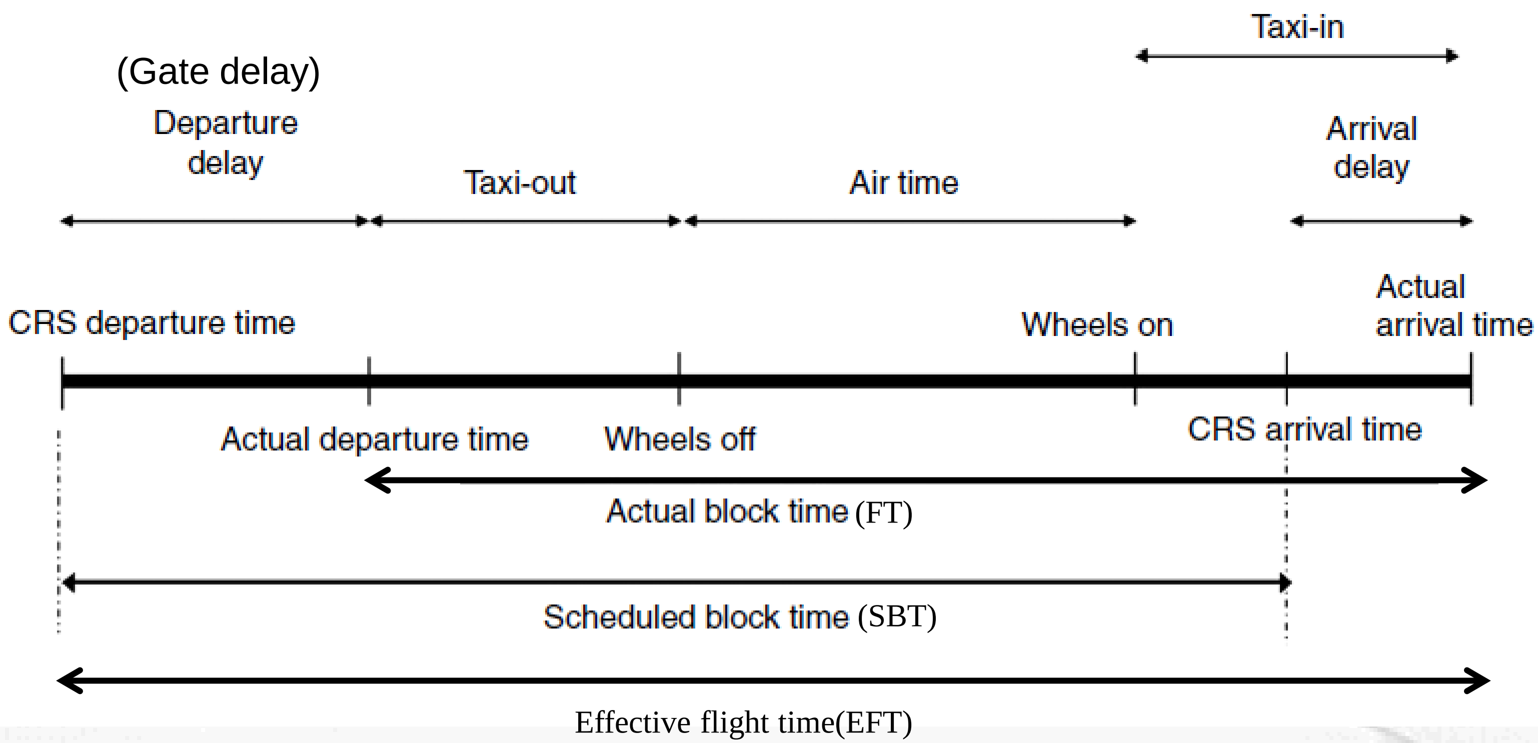
Outline

- Background and objectives
- Industry practice
- Empirical behavioral study
  - Data and modeling
  - Population model
  - Airline analysis
- Ongoing work

SBT in the Context of Flight Time Decomposition



Picture Source: Deshpande, V. and M. Arikan. The Impact of Airline Flight Schedules on Flight Delays. *Manufacturing & Service Operations Management*, Articles in Advance, pp. 1-18.

Background

- SBT is crucial in airline scheduling
- Airlines' trade-off in setting SBT
  - Shorter SBT
    - SBTs are expensive: crew cost, fuel cost
    - Aircraft utilization
    - More competitive in the market
  - Longer SBT
    - Better on-time performance
    - Less propagated delay

Background and Objectives

- SBT is set ahead of time based on historical performance
  - Related to actual block time performance
  - Variability as well as mean
  - Capture the impact of block time distribution
- Opportunities for reduced cost and improved reliability
- Consider heterogeneity across airlines

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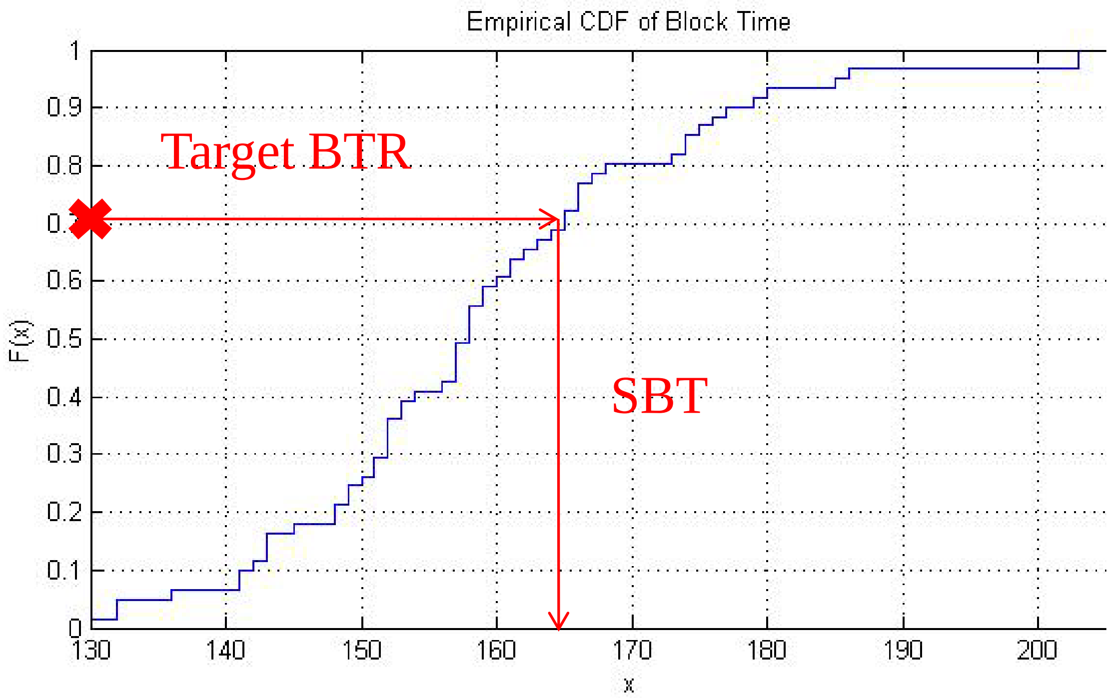
Industry Practice on SBT

- 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



- BTR: 65% to 75%
- Longer flights: set lower BTR to avoid early arrivals
- Hub airports (ATL): lower BTR to avoid early arrivals
- Internal feedback: shorter SBT for more turn time

Industry Practice on SBT

- Interview with Delta Airlines personnel
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- Early arrivals:
  - No gate available, ramp congestion; passenger don't like waiting
  - Crew cost won't be reduced
  - On-time performance only counts late arrivals; no credit for early arrivals

- BTR: 65% to 75%
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Industry Practice on SBT

- Interview with Delta Airlines personnel
- Block time setting group, annual SBT file
- Based on historical block time data: BTR→SBT
  - Proportion of flights: realized block time ≤ SBT
- Adjustment to SBT file
  - Comparison with other airlines
  - Simulation for new facility improvement
  - Sometimes adjusted to improve on-time performance

- ❑ Gate delay not explicitly considered
- ❑ Potential improvements for SBT through reducing flight time variability

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Data for Models

- Scheduled block-time (SBT)
  - Uniform for each individual flight over a quarter
  - Median SBT
- Data from two consecutive years
  - SBT: year 2010
  - Historical flight data: year 2009
- Individual flight defined by airline flight number, and OD, e.g., AA 112 from ORD-LGA
  - Flight by flight, Quarter-to-quarter match
  - Flights flown more than 50 times on weekdays in both quarters in the two years
  - 17,733 observations

Variables – Flight Level

- 50^{th} to 100^{th} percentile of block time distribution
  - Captures the distribution piece-wise
  - 50^{th} percentile (median BT): $Q_{0.5}^{f,q,y}$
  - The difference every 10^{th} percentiles: $d_{56}^{f,q,y} = Q_{0.6}^{f,q,y} - Q_{0.5}^{f,q,y}$

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- Average gate delay

Variables – OD level

- Flight distance
- Competitiveness of the OD pair
  - Herfindahl index (HHI): $HHI_{od} = \sum_{i=1}^{N} \left(\frac{s_i}{s_{od}} \right)^2$
  - Increases in HHI → Decrease in competition, more concentrated market
- Airport characteristic
  - OEP 35 airports
  - Dummy variables for origin and destination airports

Model Specification

- Assumption: scheduled block-time is affected by the actual flight data in the same quarter of the previous year

$$SBT^{a,y+1}{}_{f} = \alpha_1 \times \overline{D^{qy}{}_{f}} + \alpha_2 \times dist_{od} + \beta_1 \times Q_{0.5}^{f,q,y} + \sum_{i=5}^{9} \beta_{i-3} \times d_{i,i+1}^{f,q,y} + \alpha_3 \times HHI_{od} +$$

$$\sum_{q=2}^{4} \gamma_q \times Q^{y}{}_{q} + \gamma_5 \times OEP_O + \gamma_6 \times OEP_D + const$$

Estimation Results

Variable	Estimate	SE	p-Value
Intercept	2.011	0.214	<.0001
$\overline{Day}_f$	0.039	0.0044	<.0001
$Dist_{od}$	0.009	0.00038	<.0001
$Q_{0.5}^{f,q,y}$	0.936	0.0033	<.0001
$d_{56}^{f,q,y}$	0.463	0.0309	<.0001
$d_{67}^{f,q,y}$	0.236	0.0256	<.0001
$d_{78}^{f,q,y}$	0.075	0.0194	0.0001
$d_{89}^{f,q,y}$	0.066	0.0110	<.0001
$d_{90}^{f,q,y}$	0.0084	0.0016	<.0001
Q_2^y	0.131	0.11	0.2337
Q_3^y	0.053	0.1091	0.6249
Q_4^y	0.126	0.1092	0.2480
HHI_{od}	-2.254	0.1587	<.0001
OEP_O	1.037	0.1028	<.0001
OEP_D	0.521	0.1	<.0001
R-square	0.9962		

- Effect of historical BT:
  - Median(left tail): strong
  - The "inner right tail": moderate — airline's BTR target
  - Additional flight time above the 70th percentile: not strong
- Competition (HHI): more competitive OD→ increase SBT

Comparison to Hypothetical Models

- Model1: SBT=mean(FT)
  - Recall: mean=area above CDF
  - Calculate the area with difference in percentiles

$$SBT \approx 0.75 \times p50 + 0.45 \times d56 + 0.35 \times d67 + 0.25 \times d78 + 0.15 \times d89 + 0.05 \times d90$$

- Model2: SBT=FTq
  - According to airline, q=0.65-0.75
  - For example, assuming q=0.7:

$$SBT = 1 \times p50 + 1 \times d56 + 1 \times d67 + 0 \times d78 + 0 \times d89 + 0 \times d90$$

Comparison to Hypothetical Models

	Percentile model			Hypothetical model 1	Hypothetical model 2
Variable	Estimate	SE	p-Value	Coefficient	Coefficient
Intercept	2.011	0.214	<.0001	0	0
$\overline{D^{ay}}_f$	0.039	0.0044	<.0001	-	-
$Q_{0.5}^{f,q,y}$	0.936	0.0033	<.0001	0.75	1
$d_{56}^{f,q,y}$	0.463	0.0309	<.0001	0.45	1
$d_{67}^{f,q,y}$	0.236	0.0256	<.0001	0.3	1
$d_{78}^{f,q,y}$	0.075	0.0194	0.0001	0.25	0
$d_{89}^{f,q,y}$	0.066	0.0110	<.0001	0.15	0
$d_{90}^{f,q,y}$	0.0084	0.0016	<.0001	0.05	0

- Hypothetical model1
  - Median: more weight on median (left side of distribution)
  - Percentile differences: down-weight the right side of the distribution
  - Airlines tend to be “optimistic” when setting scheduled block-time

Comparison to Hypothetical Models

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$d_{90}^{f,q,y}$	0.0084	0.0016	<.0001	0.05	0

- Hypothetical model 2
  - Median: all flights consider the median value
  - Inner right tail weights shifted to the outer tail
  - Composite behavior, vary between flights, airlines
  - Some consideration given to far right tail

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Airline Analysis

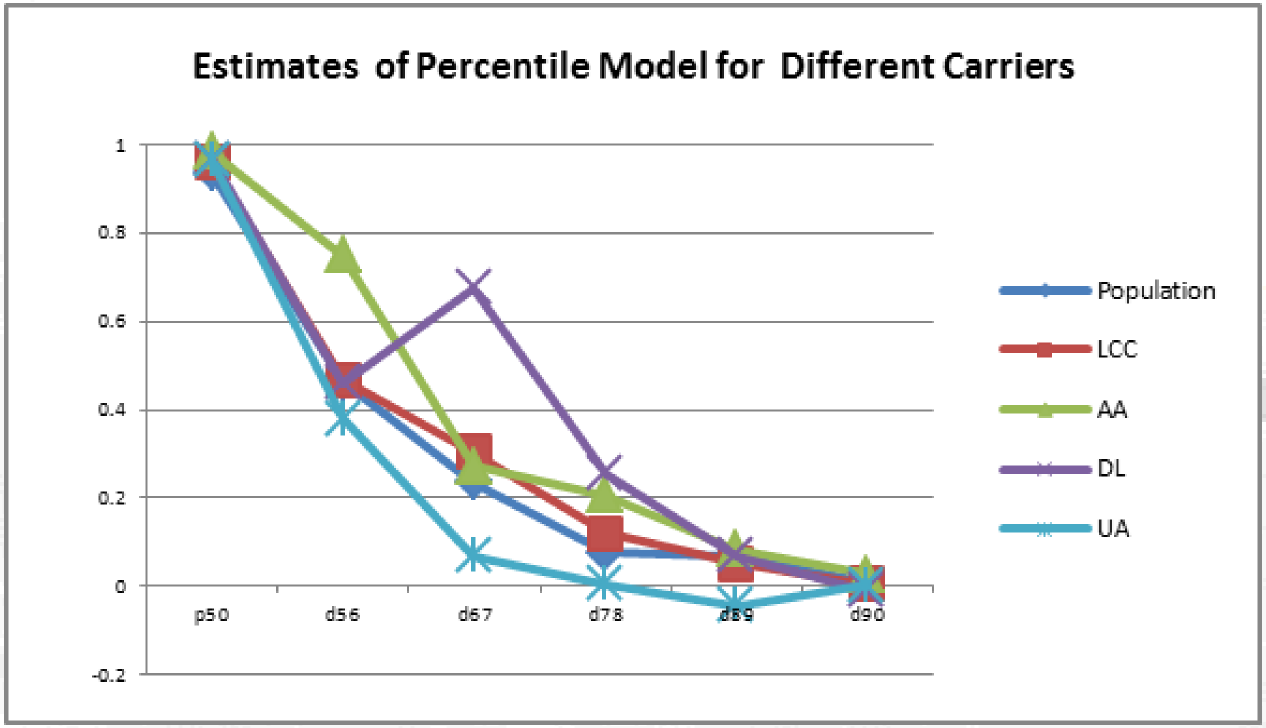
- Investigate heterogeneity in SBT setting behavior across airlines
  - Legacy v.s. low cost carriers: cost, market, competition
  - Difference across different legacy carriers
- Six airlines picked for study
  - United, American, Delta
  - JetBlue, Southwest, AirTran

New Variable for Legacy Carrier

- Legacy carriers have large hubs, own a majority of gates
- SBTs set shorter for hubs to avoid early arrivals
- Additional dummy variables for airline-specific hub airports: *hub_origin*, *hub_des*

Impact of BT Distribution

- Median value is a major predictor
- Delta–strong effect up to 80th percentile
- United–only up to 60th percentile: aggressively set SBT



- Delta and AA: conservative SBT setting
- United: more aggressive approach
- LCC: most comparable to population model

Market Variables

	Percentile Model			
Variable	LCC	AA	DL	UA
Intercept	1.909 (3.75)	2.304 (2.35)	1.773 (1.10)	5.632 (8.66)
$Dist_{od}$	0.0046 (4.61)	0.0027 (2.41)	0.00496 (2.59)	0.006 (7.47)
HHI_{od}	0.9595 (2.18)	-2.187 (-3.97)	2.481 (1.80)	-0.491 (-0.88)
OEP_O	0.316 (1.42)	0.365 (0.6)	-0.222 (-0.27)	0.387 (0.99)
OEP_D	-0.935 (-4.34)	-0.459 (-1.16)	1.191 (1.32)	1.068 (2.75)
Hub_origin	-	-1.398 (-4.2)	-2.308 (-3.66)	-0.321 (-1.03)
Hub_des	-	-1.459 (-3.73)	-1.882 (-3.23)	-0.799 (-2.59)
R-square	0.9967	0.9955	0.9962	0.9976
Observation No.	2363	1825	586	1978

- Large airport (OEP)
  - Not significant except LCC
  - LCC set shorter SBT when flying into large airport
- Competition (HHI)
  - Delta, LCC: shorten SBT with high competition
  - AA: conservative
- Hub airports (legacy)
  - Shorter SBT for hub airports
  - Avoid early arrivals

Conclusion

- SBT setting is based on BTR (percentile) target
- Aggregate level
  - BTR targets range between 50% to 70%
  - Far right tail only has minor impact
  - Willing to experience delay in trade for shorter SBT
- Heterogeneity across airlines
  - UA: most aggressive
  - AA: least aggressive
  - High competition: Delta and LCC shorten SBT, AA prolongs SBT
- Gate delay is rarely considered

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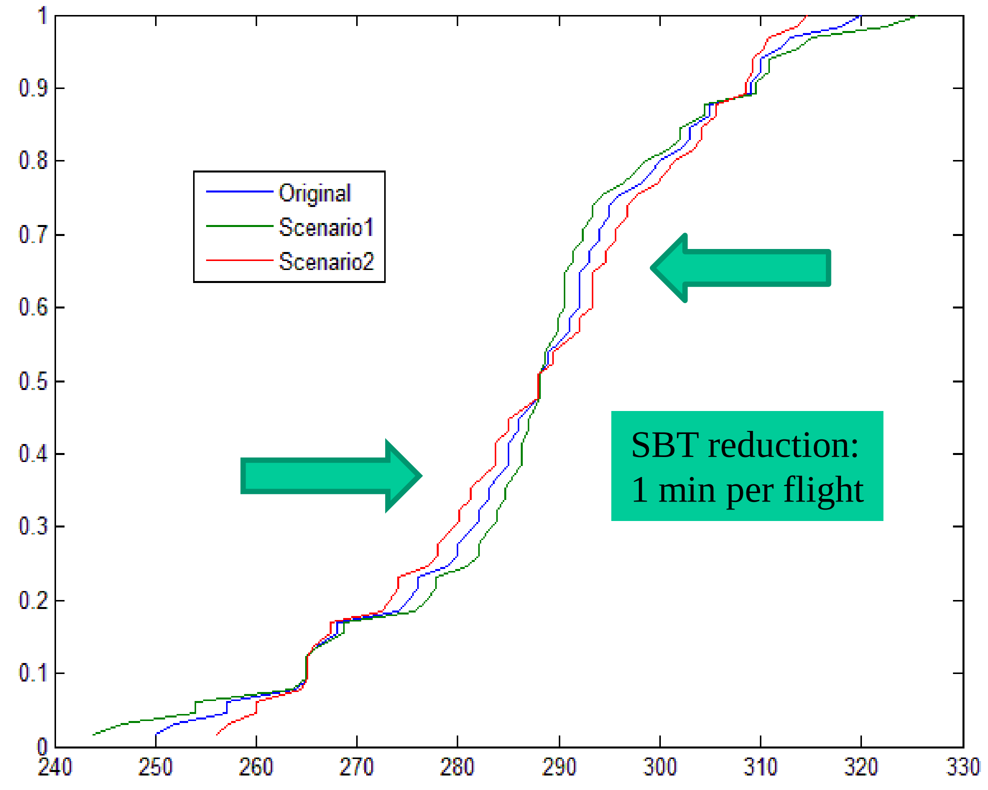
Ongoing Work

- Impact of change in historical BT
  - Different scenarios of changed BT distribution (average BT remains the same)
  - Consequent change in SBT, delay, on-time performance
  - Focusing on inner tails brings the best improvement



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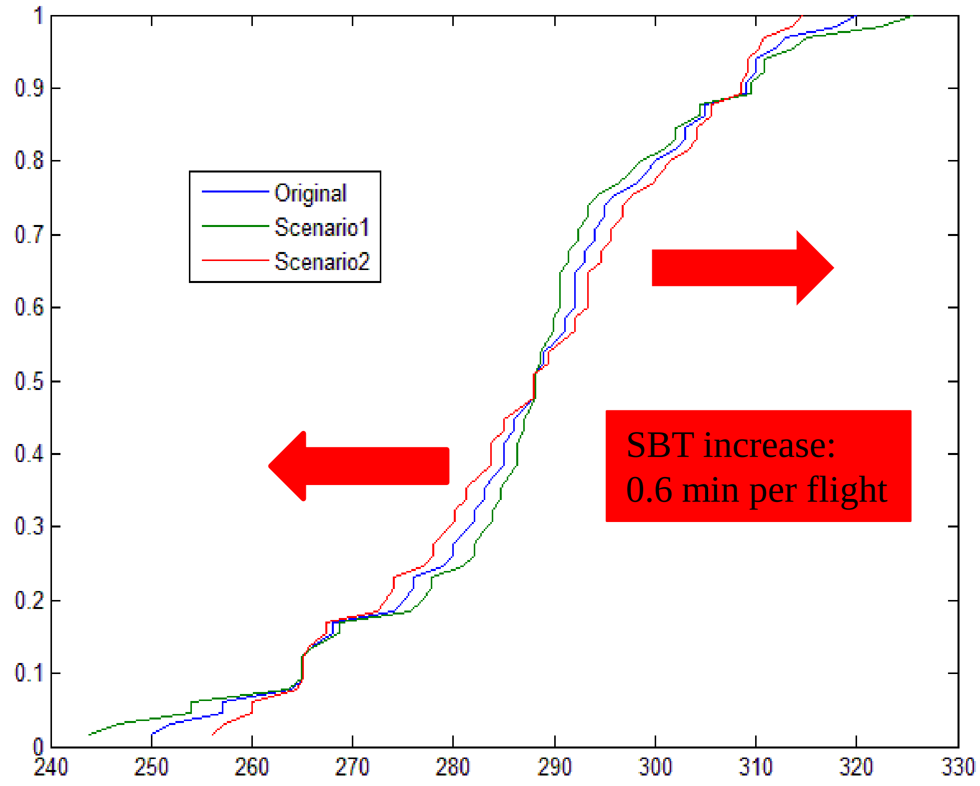

Ongoing work

- Hypothetical scenarios confirm the effect of inner right tail on SBT
- Air Traffic Management procedures to realize the adjustment to BT distribution
  - Re-sequencing the departure queue
  - Priority to flights predicted to be in the higher percentile of its historical BT distribution
  - Push the distribution towards the center
- Explore incorporating historical gate delay into SBT

Thank you!

Ongoing Work

- Impact of change in historical BT
  - Different scenarios of changed BT distribution (average BT remains the same)
  - Consequent change in SBT, delay, on-time performance
  - Focusing on inner tails (Scenario 1) brings the best improvement

Per Flight Improvement			
	Original	Scenario1	Scenario2
SBT	146.564	145.618	147.154
Reduction		0.946	-0.59
Delay	-2.034	-1.088	-2.623
Reduction		0.946	-0.589
Positive Delay	4.219	4.129	3.505
Reduction		0.09	0.714
Negative Delay	6.253	5.217	6.128
Reduction		1.036	0.125
on-time performance	0.7999	0.8061	0.8177
Improvement		0.0062	0.0178
A0 on-time performance	0.5698	0.6021	0.582
Improvement		0.0323	0.0122