How Airlines Set Scheduled Block Time

Lu Hao, Mark Hansen
University of California, Berkeley
ATM R&D 2013
06/10/2013
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

Effective flight time (EFT)

Gate delay

Departure delay

Taxi-out

Air time

Arrival delay

Taxi-in

CRS departure time

Actual departure time

Wheels off

Actual block time (FT)

CRS arrival time

Wheels on

Scheduled block time (SBT)

Effective flight time (EFT)

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
- Block time setting group creates annual SBT file
- Based on historical block time data: BTR → SBT
  - Proportion of flights: realized block time ≤ SBT

- 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%
- 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
- Block time setting group, annual SBT file
- Based on historical block time data: BTR $\rightarrow$ SBT
  - Proportion of flights: realized block time $\leq$ 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: $d_{56}^{f,q,y} = Q_{0.6}^{f,q,y} - Q_{0.5}^{f,q,y}$
Variables – Flight Level

• 50th to 100th percentile of block time distribution
  – Captures the distribution piece-wise
  – 50th percentile (median BT): $Q_{0.5}^{f,q,y}$
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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 $\rightarrow$ 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

\[ SBT_{a,y+1}^{f} = \alpha_1 \times D_{f}^{qv} + \alpha_2 \times \text{dist}_{od} + \beta_1 \times Q_{0.5}^{f,q,y} + \sum_{i=5}^{9} \beta_{i-3} \times d_{i,i+1}^{f,q,y} + \alpha_3 \times HHI_{od} + \]

\[ \sum_{q=2}^{4} \gamma_q \times Q_{q}^{y} + \gamma_5 \times OEP_{o} + \gamma_6 \times OEP_{d} + \text{const} \]
# Estimation Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>SE</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.011</td>
<td>0.214</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>$D_{ay}^f$</td>
<td>0.039</td>
<td>0.0044</td>
<td>&lt;.0001</td>
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<tr>
<td>$Dist_{od}$</td>
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<tr>
<td>$Q_{0.5}^{f,q,y}$</td>
<td>0.936</td>
<td>0.0033</td>
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<tr>
<td>$d_{56}^{f,q,y}$</td>
<td>0.463</td>
<td>0.0309</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>$d_{67}^{f,q,y}$</td>
<td>0.236</td>
<td>0.0256</td>
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<tr>
<td>$d_{78}^{f,q,y}$</td>
<td>0.075</td>
<td>0.0194</td>
<td>0.0001</td>
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<tr>
<td>$d_{89}^{f,q,y}$</td>
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<td>0.0110</td>
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<tr>
<td>$d_{90}^{f,q,y}$</td>
<td>0.0084</td>
<td>0.0016</td>
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<tr>
<td>$Q_2^y$</td>
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<td>0.11</td>
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<td>$Q_3^y$</td>
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<td>$Q_4^y$</td>
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<td>$OEP_D$</td>
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<tr>
<td>R-square</td>
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</table>

- **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 $\rightarrow$ increase SBT
Comparison to Hypothetical Models

• **Model 1**: $SBT = \text{mean}(FT)$
  – Recall: $\text{mean} = \text{area above CDF}$
  – Calculate the area with difference in percentiles

$$SBT \approx 0.75 \times p_{50} + 0.45 \times d_{56} + 0.35 \times d_{67} + 0.25 \times d_{78} + 0.15 \times d_{89} + 0.05 \times d_{90}$$

• **Model 2**: $SBT = FTq$
  – According to airline, $q = 0.65 - 0.75$
  – For example, assuming $q = 0.7$:

$$SBT = 1 \times p_{50} + 1 \times d_{56} + 1 \times d_{67} + 0 \times d_{78} + 0 \times d_{89} + 0 \times d_{90}$$
## Comparison to Hypothetical Models

<table>
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<tr>
<th>Variable</th>
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<tr>
<td>$D_{day_f}$</td>
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<td>0</td>
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<td>$d_{f,q,y}^{90}$</td>
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<td>0.05</td>
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- Hypothetical model 1
  - 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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<td></td>
<td>0</td>
</tr>
</tbody>
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- 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 80\(^{th}\) percentile
- United–only up to 60\(^{th}\) percentile: aggressively set SBT

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>LCC</th>
<th>AA</th>
<th>DL</th>
<th>UA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercep</td>
<td>1.909(3.75)</td>
<td>2.304(2.35)</td>
<td>1.773(1.10)</td>
<td>5.632(8.66)</td>
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<tr>
<td>Dist_{od}</td>
<td>0.0046(4.61)</td>
<td>0.0027(2.41)</td>
<td>0.00496(2.59)</td>
<td>0.006(7.47)</td>
</tr>
<tr>
<td>HHI_{od}</td>
<td>0.9595(2.18)</td>
<td>-2.187(-3.97)</td>
<td>2.481(1.80)</td>
<td>-0.491(-0.88)</td>
</tr>
<tr>
<td>OEP_{O}</td>
<td>0.316(1.42)</td>
<td>0.365(0.6)</td>
<td>-0.222(-0.27)</td>
<td>0.387(0.99)</td>
</tr>
<tr>
<td>OEP_{D}</td>
<td>-0.935(-4.34)</td>
<td>-0.459(-1.16)</td>
<td>1.191(1.32)</td>
<td>1.068(2.75)</td>
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<tr>
<td>Hub_origin</td>
<td>-1.398(-4.2)</td>
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<td>-0.321(-1.03)</td>
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<td>Hub_des</td>
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<td>-1.882(-3.23)</td>
<td>-0.799(-2.59)</td>
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<tr>
<td>R-square</td>
<td>0.9967</td>
<td>0.9955</td>
<td>0.9962</td>
<td>0.9976</td>
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<tr>
<td>Observatio n No.</td>
<td>2363</td>
<td>1825</td>
<td>586</td>
<td>1978</td>
</tr>
</tbody>
</table>

### Market Variables

- **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

SBT reduction: 1 min per flight
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
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SBT increase: 0.6 min per flight
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

<table>
<thead>
<tr>
<th>Per Flight Improvement</th>
<th>Original</th>
<th>Scenario1</th>
<th>Scenario2</th>
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</thead>
<tbody>
<tr>
<td>SBT</td>
<td>146.564</td>
<td>145.618</td>
<td>147.154</td>
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<tr>
<td>Reduction</td>
<td>0.946</td>
<td>-0.59</td>
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<tr>
<td>Delay</td>
<td>-2.034</td>
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<td>Reduction</td>
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<tr>
<td>Positive Delay</td>
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<td>3.505</td>
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<td>Reduction</td>
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<td>0.714</td>
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<tr>
<td>Negative Delay</td>
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<td>on-time performance</td>
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