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?
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)

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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.

<table>
<thead>
<tr>
<th>ID</th>
<th>Departure</th>
<th>Arrival</th>
<th>Airline</th>
<th>Aircraft type</th>
<th>Hour window (from 0 to 24)</th>
<th>Q1, 2013</th>
<th>Q2, 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Number of flights</td>
<td>Mean SBT (in minutes)</td>
</tr>
<tr>
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<td>DAL</td>
<td>MD88</td>
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<td>104</td>
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<td>AAL</td>
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<td>5</td>
<td>ABQ</td>
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<td>SWA</td>
<td>B733</td>
<td>2</td>
<td>24</td>
<td>96</td>
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</table>
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

<table>
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<td>2</td>
<td>24</td>
<td>96</td>
</tr>
</tbody>
</table>
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

<table>
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<td>24</td>
<td>96</td>
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Average quarterly SBT

<table>
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<th>Q2, 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>108</td>
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</table>
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

Weighted average on time flights percentage

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

- **70th Percentile Actual Block Time**
- **50th Percentile Actual Block Time**
- **Difference between 70th and 50th Actual Block Time**
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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
- 50\textsuperscript{th} to 100\textsuperscript{th} percentile of BT distribution
- Median and the difference every 10\textsuperscript{th} percentiles:

\[ d_{56}(FT^{ay}_f) = p_{60}(FT^{ay}_f) - p_{50}(FT^{ay}_f) \]
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 $\cap$ Actual
  - Fractions in
    - $S \cap A$
    - $\sim S \cap A$
    - $S \cap \sim A$
    - Etc

- Results
  - Cost penalty for $\sim S \cap A$
  - Little or no cost saving for $S \cap \sim A$

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

- Flight plan is created
  - Look at weather, choose routing, determine fuel loads

- Revise flight plan if necessary based on last-minute info

- Monitor flight while en-route, update pilots with necessary info

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

<table>
<thead>
<tr>
<th>Flight Plan Fuel (B757)</th>
<th>REQUIRED</th>
<th>DISCRETIONARY</th>
<th>Description</th>
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<td>TAXI</td>
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<td>:19/538</td>
<td>Suggestion based on historical data</td>
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<td>TRIP MSP/KMSP-LAS/KLAS</td>
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<td>Flight Planning System</td>
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<td>ALTN:PHX/KPHX FL260</td>
<td>:46/5313</td>
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<td>Dispatchers’ judgment</td>
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<tr>
<td>ALTN:**ONT/KONT FL240</td>
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<td>:40/4726</td>
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<td>RESERVE FUEL</td>
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<td>FAR requirement</td>
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<td>CONTINGENCY FUEL</td>
<td>:06/575</td>
<td>:34/3259</td>
<td>Suggestion based on historical data</td>
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</table>
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
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:

• Delta has their own numbers, but these are less useful in a research context
Cost-to-Carry Factor Estimates in lb/lb

![Graph showing cost-to-carry factor estimates in lb/lb for different aircraft models at various distances in miles.](image)
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 1\textsuperscript{st} Alternate Fuel Removed

**Contingency fuel definition:** “Additional” Contingency Fuel (fuel above SCF 99) plus 2\textsuperscript{nd} Alternate Fuel
Annual Cost to Carry Across our Study Airline for All Domestic Flights

<table>
<thead>
<tr>
<th></th>
<th>Cost to Carry (lbs)</th>
<th>Cost to Carry @ $2/gallon ($)</th>
<th>Cost to Carry @ $3/gallon ($)</th>
<th>Cost to Carry @ $4/gallon ($)</th>
<th>CO₂ (lbs)</th>
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<td>5.56*10^7</td>
<td>8.35*10^7</td>
<td>1.11*10^8</td>
<td>5.81*10^8</td>
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<td>Contingency Fuel</td>
<td>9.46*10^7</td>
<td>2.83*10^7</td>
<td>4.24*10^7</td>
<td>5.65*10^7</td>
<td>2.95*10^8</td>
</tr>
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</table>

- 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%

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<tr>
<th>Attributes</th>
<th>GDP A</th>
<th>GDP B</th>
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<tbody>
<tr>
<td>Average Delay per Flight (minutes)</td>
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<td>35</td>
</tr>
<tr>
<td>Maximum Flight Delay (minutes)</td>
<td>250</td>
<td>270</td>
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<tr>
<td>Unrecoverable Delay per Flight (minutes)</td>
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<tr>
<td>Change in Delay per flight after Initial Plan (minutes)</td>
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<td>-20</td>
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<td>Lead Time (minutes)</td>
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<td>Number of Revisions</td>
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<td>Average delay per flight(^a)</td>
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<td>-10.5</td>
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<td>Maximum flight delay(^a)</td>
<td>0.002</td>
<td>0.64</td>
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<tr>
<td>Negative change in delay per flight(^a,c)</td>
<td>-0.011***</td>
<td>-3.11</td>
</tr>
<tr>
<td>Positive change in delay per flight(^a,c)</td>
<td>-0.012***</td>
<td>-2.82</td>
</tr>
<tr>
<td>Lead time(^a)</td>
<td>0.0001</td>
<td>0.05</td>
</tr>
<tr>
<td>Number of revisions(^a)</td>
<td>-0.136</td>
<td>-0.58</td>
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<tr>
<td>Threshold 1</td>
<td>-1.472***</td>
<td>-5.03</td>
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<tr>
<td>Threshold 2</td>
<td>-0.259</td>
<td>-0.89</td>
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<td>Threshold 3</td>
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<td>Threshold 4</td>
<td>1.293***</td>
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<td>Number of obs.</td>
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Thank You. Questions?