Impact of EOBT Uncertainty on Airport Surface Congestion Management

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Motivation

- Airport surface congestion leads to increased taxi time, fuel burn & environmental impacts.

- Advanced automation systems are under development to reduce surface congestion:
  - FAA Terminal Flight Data Manager (TFDM)
  - NASA Airspace Technology Demonstrator-2 (ATD-2)

- Effectiveness of systems depend on algorithm design and accuracy of key input data, e.g., Earliest Off-Block Time (EOBT).

Need for analysis to understand relationship between automation system benefits and EOBT accuracy to inform future algorithm design and airline investments.
**Motivation**

Default procedures: aircraft push when ready

Large queue

**Congestion management procedure: aircraft publish EOBTs**

- EOBT: 1205Z
- EOBT: 1210Z
- EOBT: 1215Z
- EOBT: 1203Z
- EOBT: 1220Z
- EOBT: 1210Z

- Earliest Off Block Time (EOBT)
- Runway Configuration
- Taxi-out Time Prediction
- Airport
- Congestion management algorithm

Target Off Block Time (TOBT)
**Motivation**

Default procedures: aircraft push when ready

Large queue

Congestion management procedure: aircraft publish EOBTs

Smaller queue

EOBT: 1215Z

EOBT: 1220Z

Earliest Off Block Time (EOBT)

Target Off Block Time (TOBT)
Motivation

Default procedures: aircraft push when ready

Aircraft in large queue with engines on

Congestion management procedure: aircraft publish EOBTs

Aircraft held at gate with engines off

Smaller queue
Outline

Need for analysis to understand relationship between automation system benefits and EOBT accuracy to inform future algorithm design and airline investments

• Development and validation of queuing network models for surface operations at Charlotte (CLT)

• Evaluation of a candidate congestion management algorithm using queuing model (NASA’s ATD-2) at CLT

• Estimation of levels of EOBT uncertainty in currently reported data at Charlotte (CLT), Dallas (DFW) & Newark (EWR)

• Assessment of the impact of EOBT uncertainty on the performance of congestion management algorithm
Queuing Network Model of CLT

• Need queuing model to allow with/without surface congestion management comparisons

Charlotte airport layout

Queuing network representation
Model Validation: Typical Day

- Comparison between the model and data for a typical day (06/25/16)
Model Validation: Typical Day

• Comparison between the model and data for a typical day (06/25/16)
Model Validation: Aggregate Statistics

- Error statistics on an independent test set: 7,484 departures, May/June 2016, CLT northflow

<table>
<thead>
<tr>
<th>Statistics (min)</th>
<th>Gate to spot</th>
<th>Spot to runway</th>
<th>Taxi-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean values</td>
<td>9.68</td>
<td>10.40</td>
<td>20.09</td>
</tr>
<tr>
<td>Mean error</td>
<td>-0.87</td>
<td>-0.58</td>
<td>-1.45</td>
</tr>
<tr>
<td>Mean</td>
<td>error</td>
<td></td>
<td>3.08</td>
</tr>
<tr>
<td>% flights with</td>
<td>error</td>
<td>&lt; 5 mins</td>
<td>82%</td>
</tr>
</tbody>
</table>

- Queuing network model can be adapted to other airports
  - Extended to DFW and EWR for this phase of the analysis
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Congestion Management Algorithm: Ideal Case

(a) Default scenario (no congestion management)

Push ready time

Taxi-out time

Unimpeded time

Wait time

Take-off time

Take-off time

Push ready time
Congestion Management Algorithm: Ideal Case

(a) Default scenario (no congestion management)
- Take-off time
- Taxi-out time
- Unimpeded time
- Wait time

(b) Congestion management (ideal case)
- Push ready time
- Gate hold time = predicted wait time
- Taxi-out time = unimpeded time

TOBT = Target Off Block Time
• Buffer parameter accounts for errors in taxi-out time prediction, EOBT and other sources, in order to avoid losing runway utilization

• ATD-2 logic: TOBT = EOBT + max(0, Predicted wait time – Buffer)
Congestion Management Algorithm: ATD-2 logic

(a) Default scenario (no congestion management)

Push ready time

Taxi-out time

Take-off time

(b) Congestion management (ATD-2 algorithm logic)

Gate hold time = predicted wait time - buffer

TOBT (new gate release time)

• Buffer parameter accounts for errors in taxi-out time prediction, EOBT and other sources, in order to avoid losing runway utilization

• ATD-2 logic: TOBT = EOBT + max(0, Predicted wait time – Buffer)
• Departure metering logic tested using stochastic simulations
  – 6,447 departures over 15 day period at CLT

• Taxi-out time reduction depends on the choice of excess queue buffer (larger the buffer, lower the benefits)

• Optimal buffer is lowest value that ensures no loss in runway utilization

• Results with a planning horizon of 20 min
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- Assessment of the impact of EOBT uncertainty on the performance of congestion management algorithm
• Many airlines publish EOBT data through TFMS feed
  – EOBT messages from a major airline shown here

• EOBT error(t) = EOBT(t) – AOBT

• EOBT error varies for different lookahead times
Evaluation of Empirical EOBT Uncertainty

- Many airlines publish EOBT data through TFMS feed
  - EOBT messages from a major airline shown here

- EOBT error(t) = EOBT(t) – AOBT

- EOBT error varies for different look-ahead times
Evaluation of EOBT Uncertainty Summary Results

- CLT: 12/13/2017 – 02/12/2018
- DFW: 05/01/2018 – 07/31/2018
- EWR: 01/01/2018 – 11/11/2018
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Congestion Management in the Presence of EOBT Uncertainty

- EOBT uncertainty impacts congestion management because of:
  - Reduced prediction accuracy of taxi-out times
  - Non-conformance to the target pushback time

- Need to increase excess queue buffer parameter to account for uncertainties and to maintain runway utilization
Congestion Management in the Presence of EOBT Uncertainty

Taxi-out time & fuel benefits decrease as EOBT error increases
• Surface congestion management automation systems will enable fuel and emissions reductions

• Analysis presented to understand relationship between automation system benefits and input data (esp. EOBT) accuracy

• Informs future algorithm design and airline investment decisions

• Recommended next steps
  – Extend analysis to broader range of airports and operating conditions
  – Analyze incentives for airlines to improve the accuracy of EOBT data
  – Develop and evaluate surface congestion algorithms that can
    • Explicitly handle uncertainties
    • Account for uncertainties in arrival times, in addition to EOBT uncertainties
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