Demonstration of Reduced Taxi Congestion at BOS through Airport Surface Movement Optimization Strategies

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Introduction

- Airport surface congestion leads to increased taxi times, fuel burn and emissions
  - Nationally (2007 ASPM)
    - 150 million minutes taxi-out, 63 million minutes taxi-in
    - 6 million tons CO₂, 45,000 tons CO
    - 8,000 tons NOₓ
    - 4,000 tons hydrocarbons
  - BOS (2008 ASPM)
    - 3.2 million minutes taxi-out, 1.2 million mins taxi-in
    - 151,000 tons CO₂, 1,100 tons CO
    - 201 tons NOₓ
    - 104 tons hydrocarbons
Motivation for control strategy: Departure throughput saturation

Curves can be defined for different configurations and IMC/VMC
Simple control strategy: “N-Control”

- Departure runway throughput “saturated” when number of aircraft pushed back (denoted N) is greater than N*
- Try to keep N during congested periods close to some value (N_{ctrl}), where N_{ctrl} > N*

![Graph showing takeoff rate vs. number of departing aircraft on the ground with saturation regime and range of N_{ctrl}}
Demo of N-Control concept at Boston Logan airport

- 16 demo periods between Aug 23 and Sept 24
- Focus on 4PM-8PM departure push
Objectives of demo

- Demonstrate potential benefits (in terms of taxi-out time and fuel consumption) of N-control concept

- Incorporate simple N-Control concepts into current operational procedures with minimal controller workload and procedural modifications
  - Risk mitigation: begin with large values of $N_{ctrl}$ and decrease gradually
  - Monitor carefully for off-nominal events, gate-use conflicts, traffic flow management restrictions, etc.
  - First-Come First-Served
  - Rate-based control (i.e., suggest rate of aircraft pushbacks)
Schematic of approach: *Suggested rate* determination

- Config
- IMC/VMC
- Demand

Prior analysis

- Departure rate
- No. of departures on ground
- Desired $N_{\text{ctrl}}$

- Recommended ground controller pushback rate in next time period

- Predicted departure rate in next time period

- Current $N$

No. of departures on ground throughout next time period

(influences next time period)
Schematic of approach: *Suggested rate* determination

Current time 1558hrs

- **4L,4R|4L,4R,9**
- **VMC**
- **12 arrivals 1600-1615hrs (from ETMS)**

**Suggested rate** determination

- Departure rate
- Desired $N_{ctrl}$
- Recommended ground controller pushback rate in next time period

**Predicted departure rate in next time period**

**Current N remaining on surface throughout next time period**

**Current N**

*(influences next time period)*
Recommended ground controller pushback rate in next time period

Desired $N_{ctrl} = 20$ (> $N^* = 17$)

Current $N$ remaining on surface throughout next time period

Suggested rate determination

Current time 1558hrs

4L, 4R, 4L, 4R, 9

VMC

12 arrivals 1600-1615hrs (from ETMS)

Predicted departure rate 1600-1615hrs = 11

12 arrivals 1600-1615hrs (from ETMS)

Current $N$ remaining on surface throughout next time period (influences next time period)

Takeoff rate (ac/15 min)

Desired $N_{ctrl} = 20$ (> $N^* = 17$)

Recommended ground controller pushback rate in next time period

Schematic of approach: Suggested rate determination

Current time 1558hrs

4L, 4R, 4L, 4R, 9

VMC

12 arrivals 1600-1615hrs (from ETMS)

Predicted departure rate 1600-1615hrs = 11

12 arrivals 1600-1615hrs (from ETMS)

Current $N$ remaining on surface throughout next time period (influences next time period)
Current time 1558hrs

- **Current N = 26** (from ASDE-X & counting)
- **Recommended ground controller pushback rate in next time period**
- **Desired $N_{ctrl} = 20 (> N^* = 17)$**
- **Predicted departure rate 1600-1615hrs = 11**
- **Current $N$ remaining on surface throughout next time period = 15**

**Schematic of approach: Suggested rate determination**

- **4L,4R|4L,4R,9**
- **VMC**
- **12 arrivals 1600-1615hrs (from ETMS)**
- **BOS throughput in segment (VMC : 4L, 4R | 4L, 4R, 9)**
- **4L,4R|4L,4R,9**
- **Suggested rate determination**

(influences next time period)
Recommended ground controller pushback rate = 5 a/c over 15 mins or 1 per 3 mins

Current N remaining on surface throughout next time period = 15

Suggested rate determination

Current time 1558hrs

Predicted departure rate 1600-1615hrs = 11

Current N = 26 (from ASDE-X & counting)

VMC

4L, 4R | 4L, 4R, 9

12 arrivals 1600-1615hrs (from ETMS)

Desired N_{ctrl} = 20 (> N^{*}=17)
Pilot typically told by GC to push at discretion and contact GC again when ready to taxi. If airport is very congested, pilot asked to hold at gate.

Pilot contacts CD when ready to push. CD issues “route of flight” clearance and pilot told to monitor GC. CD passes flight strip and control to GC.
Demo setup

Location of card containing suggested pushback rate

Red = demo modification to current procedures
Communicating suggested push rate

- Suggest pushback rates using color-coded cards
- No verbal communications with tactical air traffic controllers
Gate-holds from a sample demo period

- Maintained runway utilization during metering: 3 min of “dry runway” in > 35 hours of active rate control of pushbacks
Playback of surface surveillance data
Visualization of ASDE-X data

Before

During metering
Average taxi-out times with metering

- Average taxi-out times on the evening of Sept 2, 2010
- Gate-holds in effect between 1815 and 1930

![Bar chart showing taxi-out times](chart.png)
Average taxi-out times without metering

- Average taxi-out times on the evening of August 17, 2010
- Evening with similar demand as Sept 2, but no metering
## Preliminary results of BOS field tests

<table>
<thead>
<tr>
<th>Date</th>
<th>Time Period</th>
<th>Configuration</th>
<th>Number of Gate-holds</th>
<th>Avg. gate-hold (min)</th>
<th>Total gate-hold (taxi time savings, min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 8/26</td>
<td>4.45-8PM</td>
<td>27, 22L</td>
<td>22R</td>
<td>62</td>
<td>4.06</td>
</tr>
<tr>
<td>2. 8/29</td>
<td>4.45-8PM</td>
<td>27, 32L</td>
<td>33L</td>
<td>35</td>
<td>3.24</td>
</tr>
<tr>
<td>3. 8/30</td>
<td>5-8PM</td>
<td>27, 32L</td>
<td>33L</td>
<td>8</td>
<td>4.75</td>
</tr>
<tr>
<td>4. 9/2</td>
<td>4.45-8PM</td>
<td>27, 22L</td>
<td>22R</td>
<td>45</td>
<td>8.33</td>
</tr>
<tr>
<td>5. 9/3</td>
<td>4-7.45PM</td>
<td>4R</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6. 9/6</td>
<td>5-8PM</td>
<td>27, 22L</td>
<td>22R</td>
<td>18</td>
<td>2.21</td>
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<tr>
<td>7. 9/7</td>
<td>5-7.45PM</td>
<td>27, 22L</td>
<td>22R</td>
<td>11</td>
<td>2.09</td>
</tr>
<tr>
<td>8. 9/9</td>
<td>5-8PM</td>
<td>27, 32L</td>
<td>33L</td>
<td>11</td>
<td>2.18</td>
</tr>
<tr>
<td>9. 9/10</td>
<td>5-8PM</td>
<td>27, 32L</td>
<td>33L</td>
<td>56</td>
<td>3.70</td>
</tr>
<tr>
<td>10. 9/12</td>
<td>4.45-7.30PM</td>
<td>4L, 4R</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11. 9/17</td>
<td>4.45-7.30PM</td>
<td>4L, 4R</td>
<td>9</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>37 hrs</strong></td>
<td></td>
<td></td>
<td><strong>247</strong></td>
<td><strong>4.3 min</strong></td>
</tr>
</tbody>
</table>

No metering during test periods on 8/23, 9/16, 9/19, 9/24

≈ 12,000-5,000 kg of fuel saved
(holds with engines off; APU on or off)
Number of gateholds commensurate with traffic

Comparison of Total Traffic Share and Gate Hold Share

- Percentage of Aircraft Held
- Percentage of Total Departures during Demo Periods
Fuel burn reduction depends on aircraft fleet mix
Some early observations

- N-Control requires congestion to work (as expected)
  - Very little metering in most efficient configuration (4L,4R |9)
- Can handle target departure times (e.g., EDCTs)
  - Preferable to get EDCTs while still at gate
- Many factors drive throughput, but approach can adapt to variability
  - Heavy landings on departure runway, arrivals, controller crossing strategies, birds on runway,…
- Controllers have different strategies to implement suggested rate
- Need to consider ground crew constraints, gate-use conflicts, different taxi procedures for international flights, etc.
- Significant benefits seen even from preliminary analysis
  - 4.3 min decrease in taxi-out times
  - 50-60 kg decrease in fuel burn per gate-held flight
  - In the most congested periods, up to 44% of flights experienced gate-holds
Summary

- Demo of incorporating N-Control techniques into current operational procedures with minimal controller/pilot workload and procedural modifications
  - Use of rate cards for conveying pushback rates to controllers
  - Risk-mitigation:
    - Conservative values of $N_{ctrl}$
    - Carefully identify, monitor and address off-nominal events/other issues
  - Intensive demo of concept over 16 periods of 3-4 hours each
  - Targeted 4PM-8PM time frame (Aug 23–Sept 23, 2010)

- Identified and monitored implementation issues
  - Daily debrief telecon with airline reps, BOS tower, FAA, Massport
  - Approaches to accommodate EDCTs, gate-use conflicts, track gate-holds, etc.

- Next steps:
  - Evaluate general applicability of N-Control concept
  - Detailed evaluation of benefits (in terms of taxi-out time, fuel burn and emissions reduction) of N-control concept