Assessing Tactical Scheduler Options for Time-Based Surface Metering

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Time-Based Surface Metering

**Tactical Scheduler**

- earliest pushback times
- target pushback times
- hold advisories
- ready for pushback
- pushback clearance

- Improve efficiency
- Improve predictability

**UNCERTAINTY**

- Pilot ready for pushback
- Taxi and departure clearances

- Airline Ops
- ATCT Control
- Ramp Control
ATD-2 Parallel Efforts

- Field Demonstration
  - Demonstrate viability of ATD-2 tools in the real operating environment

- Human-In-The-Loop simulation
  - Develop/test human factors interfaces and procedures

- Fast-time simulation
  - Extrapolate field results
  - Refine scheduler for future phases of field demonstration
  - Easily adapt concepts to other airports
Objective

- Benchmark evaluation of the ATD-2 tactical scheduler in fast-time simulation
- Parametric analysis of taxi time delay buffer mitigation of surface congestion uncertainty
Outline

Tactical Scheduler

Fast-Time Simulation

Evaluation Results
Tactical Scheduler

- Trajectory Prediction
  - Earliest Pushback Time
  - Earliest Runway Time

- Runway Scheduling
  - Target Runway Time
  - Target Pushback Time

- Advisory Generation
  - Taxi Time
  - Delay Buffers

- Flight state and intent
- Separation constraints

- Surface congestion
Advisory Generation

Target Pushback Time = Target Runway Time - \(\text{Unimpeded Transit Time}\) - \(\text{Surface Congestion}\)

- **A** accounts for congestion along route
- **B** accounts for congestion at runway

Taxi Time Delay Buffers
Outline

Tactical Scheduler

Fast-Time Simulation

Evaluation Results
Fast-Time Simulation

Surface Operations Scheduler & Simulator (SOSS)

Charlotte Douglas International (CLT)

South flow configuration
Traffic Scenario

4 hours from 3/11/2016, high demand, low weather impact

ops per 15-min

18L dep
18C dep

simulation time (min)
Traffic Scenario

4 hours from 3/11/2016, high demand, low weather impact

ops per 15-min

simulation time (min)

18C arr
18C dep
18L arr
18L dep
Traffic Scenario

4 hours from 3/11/2016, high demand, low weather impact

ops per 15-min

simulation time (min)

18L dep
18C dep
18R arr
23 arr
Simulation Parameters and Variables

**SOSS**
- 0.5 sec time step
- Surface congestion uncertainty modelled

**Tactical Scheduler**
- called every 10 sec
- Delay Buffers
  - $A = 1.05$
  - $B = \{0, 1, 2, \ldots\}$ min

**Evaluation Metrics**
- Departure Delay
- Runway Time Prediction
- Throughput Prediction
- Departure Queue
Departure Delay Results

Best job moving delay to gate without increasing total much

<table>
<thead>
<tr>
<th>Taxi Time Buffer B (min)</th>
<th>AMA</th>
<th>Ramp</th>
<th>Gate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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Runway Time Prediction Results

Departures are late on average

Predictability (stdev) worsens quickly as taxi time buffer is increased

Runway Time Prediction Error (min)

Late

Early

taxi time buffer B (min)

<table>
<thead>
<tr>
<th>taxi time buffer B (min)</th>
<th>Runway Time Prediction Error (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Late avg: 1.5, stdev: 1.0</td>
</tr>
<tr>
<td>1</td>
<td>Late avg: 2.0, stdev: 1.2</td>
</tr>
<tr>
<td>2</td>
<td>Late avg: 2.5, stdev: 1.5</td>
</tr>
<tr>
<td>3</td>
<td>Late avg: 3.0, stdev: 2.0</td>
</tr>
<tr>
<td>4</td>
<td>Late avg: 3.5, stdev: 2.5</td>
</tr>
<tr>
<td>5</td>
<td>Late avg: 4.0, stdev: 3.0</td>
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<td>Late avg: 5.5, stdev: 4.5</td>
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</tr>
<tr>
<td>10</td>
<td>Late avg: 6.5, stdev: 5.5</td>
</tr>
</tbody>
</table>
Throughput Prediction Results

Predictability (stdev) independent of buffer

Better to under predict throughput slightly to keep pressure on the runways
### Departure Queue

<table>
<thead>
<tr>
<th>Departure queues</th>
<th>Number of departures:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ramp</strong></td>
<td>In ramp</td>
</tr>
<tr>
<td><strong>AMA</strong></td>
<td>In Active Movement Area (AMA)</td>
</tr>
<tr>
<td><strong>Taxi = Ramp + AMA</strong></td>
<td>In ramp and AMA</td>
</tr>
<tr>
<td><strong>Queue</strong></td>
<td>in line from runway within 200m of each other</td>
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</tbody>
</table>
Departure Queue Results

Maximum queue lengths for 18L (0-120 min)

- Taxi, AMA, and Queue increase with buffer
- Taxi begins to saturate
- Queue > AMA when line extends into the ramp
- Ramp saturates quickly and does not increase with taxi delay buffer
Maximum Queue Length Example

Runway 18L
$B = 10 \text{ min}$
$q_{AMA} = 11$
$q_{line} = 12$
Departure Queue Results

Maximum queue lengths for 18L (0-120 min)

- Taxi
- Queue
- AMA
- Desired Taxi

max # of dep

taxi time buffer B (min)
### Summary and Conclusion

<table>
<thead>
<tr>
<th></th>
<th>Move as much delay to gate without increasing total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runway Time</td>
<td>Keep buffers small for better predictability</td>
</tr>
<tr>
<td>Prediction</td>
<td>Under-predict slightly to maintain pressure on runways</td>
</tr>
<tr>
<td>Throughput</td>
<td></td>
</tr>
<tr>
<td>Prediction</td>
<td>Avoid saturating the Taxi and AMA queues</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Buffer B</th>
<th>0</th>
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**Recommend buffers between 2 and 5 minutes for future simulations**
Future Work

- Add other uncertainties
- Add traffic management initiatives
- Add airline priority
Questions

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