Assessing Tactical Scheduler Options for Time-Based Surface Metering

Shannon Zelinski
Robert Windhorst

NASA Ames Research Center
Time-Based Surface Metering

**Tactical Scheduler**
- Earliest pushback times
- Target pushback times
- Hold advisories

**UNCERTAINTY**
- Improve efficiency
- Improve predictability

**Airline Ops**
- Taxi and departure clearances

**ATCT Control**
- Ready for pushback

**Ramp Control**
- Pushback clearance

**Pilot**
- Pilot ready for pushback clearance

**Integrated Arrival/Departure/Surface**
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
- Advisory Generation
  - Target Pushback Time
  - Taxi Time
  - Delay Buffers

- Separation Constraints
- Flight State and Intent

- Surface Congestion
Advisory Generation

\[ \text{Target Pushback Time} = \text{Target Runway Time} - \left( \text{Unimpeded Transit Time} - \text{Surf} \text{ice Congestion} \right) - \text{B} \]

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

**Advisory Generation**

- **Unimpeded Transit Time**
- **Surface Congestion**
Outline

Tactical Scheduler

Fast-Time Simulation

Evaluation Results
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

simulation time (min)
Traffic Scenario

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

4 hours from 3/11/2016, high demand, low weather impact
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
Runway Time Prediction Results

Departures are late on average

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

<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</td>
</tr>
<tr>
<td>1</td>
<td>Early</td>
</tr>
<tr>
<td>2</td>
<td>avg</td>
</tr>
<tr>
<td>3</td>
<td>stddev</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
Throughput Prediction Results

Throughput Prediction Error (dep per 15-min)

Under-predicted

Over-predicted

Predictability (stdev) independent of buffer

Better to underpredict 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>Ramp</td>
<td>In ramp</td>
</tr>
<tr>
<td>AMA</td>
<td>In Active Movement Area (AMA)</td>
</tr>
<tr>
<td>Taxi = Ramp + AMA</td>
<td>In ramp and AMA</td>
</tr>
<tr>
<td>Queue</td>
<td>in line from runway within 200m of each other</td>
</tr>
</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

\[ B = 10 \text{ min} \]

\[ q_{\text{AMA}} = 11 \]

\[ q_{\text{line}} = 12 \]
Departure Queue Results

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

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

Buffer B

0 1 2 3 4 5 6 7 8 9 10

Recommend buffers between 2 and 5 minutes for future simulations
Future Work

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

Shannon.j.zelinski@nasa.gov