Use of Airport Surface Simulations for ATD-2 Benefits Assessment

Presentation at the NASA ATD-2 Industry Workshop

Aditya Saraf
Director of Research Programs, ATAC Corporation
09/05/2019
Outline

- Objectives
- Benefits analysis methodology
- Simulation platform
- Results
- Conclusions and Simulation-related lessons learned
Objectives

- Estimate benefits provided by NASA’s ATD-2 system
  - At three major U.S. airports (CLT, DFW, EWR)
  - Via high-fidelity simulations using NASA’s SOSS (Surface Operations Simulator and Scheduler) simulation platform

- Extrapolate to nationwide benefits

- Compare ATD-2 costs with benefits on a nationwide scale
Methodology

- Identify **operational shortfalls** that ATD-2 can address and associated ATD-2 **benefit mechanisms** and **benefit metrics**

- Develop a **combined airspace-surface simulation platform** that can simulate key operational shortfalls and benefit mechanisms

- Conduct **high-fidelity surface-airspace simulations** for simulating current-day and future ATD-2 operations at **three airport sites** and **carefully selected simulation days**

- Extrapolate results to FAA Core 30 airports using **medium-fidelity queuing simulation models** and FAA **TFDM benefits analysis results**

- Extrapolate to **annualized** benefits

- Follow **FAA-recommended processes** for cost analysis

- Compute **advantages to the FAA’s TFDM program**
COMBINED SURFACE-AIRSPACE SIMULATION PLATFORM
Combined Airspace-Surface Simulation Platform Architecture

**AOSS: ATD-2 Tactical Surface Scheduler**
- Surface traffic state
- Taxi routes

**AOSS*: Airspace Sim**
- Sector-based Airspace Model
- Takeoff $\rightarrow$ Departure Fix Xing $\rightarrow$ Sector 1 $\rightarrow$ Sector 2 $\rightarrow$ ... $\rightarrow$ TBFM Metering Arc
- Enroute and Departure fix merge models
- Queuing at nodes estimates in air delays

**SOSS**
- Added models
  - Push readiness
  - EOBT uncertainty
  - Taxi rerouting

**AOSS: Center TFM**
- Existing processes for fitting departures into overhead enroute traffic stream slots
- Focus airport flights merging with overhead traffic at TBFM meter arcs

**AOSS: Surface TFM**
- Existing processes for handling APREQ, EDCT constraints
- Sequence changes for miles-in-trail impacted departure fixes

**Simulated Airspace Trajectory**
- Simulated Surface Trajectory
- Simulated Airspace Trajectory

**Gate delays for APREQ/EDCT flights**
- Surface delays for MIT flights

**ATOTs**
- ETOTs
- Airspace routes

**APREQ takeoff time window constraints**

*AOSS: Airspace Operations Simulator & Scheduler*
CLT Combined Surface-Airspace Model

**Surface Model Features:**
- Controller surface conflict resolution model
- Model of coordination with receiving center: APREQ and EDCT implementation model incl. uncertainties
- Runway separations, sequencing for miles-in-trail restriction adherence
- ATD-2 departure metering emulation

**Airspace Model Features:**
- Departure fix and enroute merging model
- Model of coordination with surface departure traffic mgmt: timeline-based electronic APREQ requests (TBFM IDAC integration)
- Sector transit time uncertainty models
- Model of airborne delays for center miles-in-trails

---

ATAC AOSS Models
Airspace Transit From Runway Takeoff to TBFM Meter Arc Crossing

Simulation Injection Arcs for Non-CLT Flights

NASA SOSS Models Surface Trajectories
Benefit Mechanisms Modeled

- **Data Exchange**
  - EOBTs provided to the ATD-2 Tactical Scheduler
  - Leads to accurate OFF time estimates
  - ATD-2 Scheduler communicates gate release times to the airline

- **Tactical Surface Scheduling**
  - High-fidelity emulation of Tactical Surface Scheduling algorithm enables sequencing and gate holds

- **Integrated Airspace Scheduling**
  - APREQ release times negotiated based on accurate OFF time estimates with receiving Center
  - APREQ delays absorbed at the gate
## Experiment Design: Simulation Days Selection

<table>
<thead>
<tr>
<th>Condition</th>
<th>TMI/ APREQ Indices</th>
<th>Weather</th>
<th>Recom. Date</th>
<th># Days</th>
<th>% Occur.</th>
<th>Total Daily Precip (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CONUS</td>
<td>Apt</td>
<td>Demand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6/15/2016</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5/17/2016</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>6/1/2016</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>8/15/2016</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>5/6/2016</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>8/13/2016</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>5/31/2016</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4/12/2016</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>7/23/2016</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6/4/2016</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6/5/2016</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>6/21/2016</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6/17/2016</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7/4/2016</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5/1/2016</td>
<td>2</td>
</tr>
</tbody>
</table>

### Tercile Grouping Rules

<table>
<thead>
<tr>
<th>Condition</th>
<th>Good (0)</th>
<th>Fair (1)</th>
<th>Poor (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APREQ/MIT indices</td>
<td>Both &lt; 50%</td>
<td>One &gt; 50%</td>
<td>Both &gt; 50%</td>
</tr>
<tr>
<td>CONUS WITI</td>
<td>≤ 33⅓ %</td>
<td>&gt; 33⅓ % and ≤ 66⅔ %</td>
<td>&gt; 66⅔ %</td>
</tr>
<tr>
<td>Local WITI</td>
<td>≤ 33⅓ %</td>
<td>&gt; 33⅓ % and ≤ 66⅔ %</td>
<td>&gt; 66⅔ %</td>
</tr>
<tr>
<td>Departure index</td>
<td>≤ 33⅓ %</td>
<td>&gt; 33⅓ % and ≤ 66⅔ %</td>
<td>&gt; 66⅔ %</td>
</tr>
</tbody>
</table>

Σ % Occur. = 80%

Encompasses 80% of operational conditions for FY2015
Benefits Analysis & Extrapolation

**High Fidelity Sims**
- Baseline
  - CLT1
  - CLT2
  - CLT6
- ATD-2
  - CLT1
  - CLT2
  - CLT6

**Medium Fidelity Sims**
- DFW1
- DFW2
- DFW6
- EWR1
- EWR4

**Nationwide Extrapolation**
- CLT
  - Baseline ATD-2
- DFW
  - Baseline ATD-2
- EWR
  - Baseline ATD-2

**Performance Metrics from High-fidelity Sims at 3 Study Airports**

**Model Validation**

**Other Medium Fidelity Sims Models**
- PHL
- BOS
- JFK
- TFDM BCA Results

**Performance Metrics from Medium-fidelity Sims at 3 Study Airports over a Wider Set of Days**

**Annualization & Monetization**
- Scale individual airport benefits results to an annualized level
- Convert taxi time savings to $ savings using cost of fuel, airline direct operating cost and cost of passenger time
Mesoscopic Models of CLT

- Both baseline and ATD-2 metering models

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Departures (14,122 flights)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxi-out time</td>
<td>20.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Gate to spot</td>
<td>9.7</td>
<td>-0.3</td>
</tr>
<tr>
<td>Spot to runway</td>
<td>10.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Arrivals (16,383 flts)</td>
<td>10.2</td>
<td>0.5</td>
</tr>
</tbody>
</table>
RESULTS
Summary of Taxi-Out Time Saving Benefits

<table>
<thead>
<tr>
<th></th>
<th>CLTS</th>
<th>CLTN</th>
<th>DFWN</th>
<th>DFWS</th>
<th>EWRS</th>
<th>EWRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Per Departure Taxi-Out Time Saving (Min)</td>
<td>1.72</td>
<td>1.89</td>
<td>2.34</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Benefits Calculation

- Two primary benefits
  - Shifting delays from taxiways to the gates
    - Fuel Savings for reduced taxi time
  - Earlier off time
    - Airline Direct Operating Costs (ADOC)
    - Passenger Value of Time (PVT)

Annual Benefits =
\[ \sum \left[ \text{(Benefits on individual simulation day)} \times \text{Number of similar days in the year} \right] \]
Cost Analysis

- Examine major cost drivers within the TFDM program

- Apply risk reduction to parts of the TFDM program
  - Assume a small decrease in the point estimate due to NASA ATD-2 work

- Risk parameter adjustments
  - Mode decreased by 2.5%
Economic Analysis

- Apply changes to cost & benefits to the base TFDM Benefit-to-Cost ratio (B/C)

- Methodology
  - \((B/C)_{\text{TFDM}} = 1.03\), from earlier study
  - \(B_{\text{ATD2}} = 1.77 \times B_{\text{TFDM}}\); \(C_{\text{ATD2}} = 0.965 \times C_{\text{TFDM}}\)
  - \((B/C)_{\text{ATD2}} = 1.77/0.965 \times 1.03 = 1.89\)
CONCLUSIONS AND LESSONS LEARNED
Conclusions

- ATD-2 offers significant taxi-out time savings benefits at congested airports in the NAS, without having negative impact on taxi-in times, OFF time performance and airport throughput.

- Annual total of 3.5 million minutes of reduced taxi-time at CLT, EWR, and DFW.

- $2.6 Billion in monetary benefits nationwide due to significant reduction in taxi times as well as in surface delay.

- Incorporation of ATD-2 into the FAA’s TFDM system improves the B/C ratio of the TFDM program from 1.03 to 1.89.
Use of Simulations for Benefits Assessment: Lessons Learned

- Model validation is complex

- Careful selection of simulation timeframes is important

- High-fidelity of simulations can limit the number of scenarios we can simulate
Other Examples of Simulation Use

- **ATAC NRA – Benefits Assessment of Multi Flight Common Routes (MFCR)**
  - Applied FACET simulations to emulate rerouting situations on real historical days

**Diagram**

- **NASA Sherlock ASDI Data**
  - (April-October 2016)
- **NASA Sherlock CWAM Data**
  - (April-October 2016)
- **TFMDI Reroute Advisory Data**
- **NASA Sherlock End-to-End Merged Flight Trajectory Data**

**Replicate Reroute Situations on Historical Dates Using FACET Simulations**

- **Apply Emulation of NASA’s MFCR Group Route Allocation Algorithm**
  - Group NASCENT flights by common RCF
  - Determine common route

**ATAC Reroute Analysis Tool**

- Identify which flights are impacted by a FAA Playbook
- Identify which playbook-impacted flights have MFCR and NASCENT route advisories
- Compute MFCR and NASCENT flight distance savings
- Savings computed w.r.t. most recent flight plan as well as w.r.t. the actual flight track

**Reroute Analysis Database**

*ASDI – Aircraft Situation Display to the Industry*
*CWAM – Convective Weather Avoidance Model*
*TFMDI – TFM Data to the Industry*
Other Examples of Simulation Use

- ATAC Phase II SBIR – NAS Element Closure Planner
  - What-if analysis simulation for recommending optimum closure times and durations
QUESTIONS

Contact:
Aditya Saraf, ATAC Corporation
Email: aps@atac.com
Phone: 408-736-2822
BACKUP SLIDES
Efficiency: Taxi-Out Time Savings

Sim #1: 06/15/2016
South Flow
1000-1600 UTC

Sim #2: 05/06/2016
North Flow
1600-2100 UTC
Impact on Taxi-In Times

Sim #1: 06/15/2016
South Flow
1000-1600 UTC

Sim #2: 05/06/2016
North Flow
1600-2100 UTC
Impact on OFF-Time Performance

Simulated Takeoff Time Difference
ATD-2 Sim Flight – Baseline Sim Flight

Sim #1: 06/15/2016
South Flow
1000-1600 UTC
Impact on OFF-Time Performance

Simulated Takeoff Time as compared to SOBT + AAL Taxi Budget
Simulated Taxi Out Time as compared to AAL Budget
Impact on Airport Throughput

Cumulative Runway Takeoff Counts
Red – Baseline (current-day) operations
Blue – ATD-2 operations

Sim #1: 06/15/16
South Flow

Runway Throughput, 18C

Runway Throughput, 18L

CUMULATIVE THROUGHPUT
(# TAKEOFFS UNTIL TIME t)

MINUTES PAST MIDNIGHT ON 6/15/2016 (600 = 10:00 AM)
Benefit Mechanism: Demand Throttling

Sim #1: 06/15/16
South Flow
Benefit Mechanism: APREQ Coordination

BASELINE

All Departures
Mean = 22.65
STD = 8.71

APREQ Departures
Mean = 26.82
STD = 10.85

Non-APREQ Departures
Mean = 21.92
STD = 8.1

Taxi Out Times (min)

ATD-2

All Departures
Mean = 20.62
STD = 6.47

APREQ Departures
Mean = 22.37
STD = 6.39

Non-APREQ Departures
Mean = 20.31
STD = 6.45

Taxi Out Times (min)

Sim #2: 05/06/2016, North Flow, 1600-2100 UTC
**Benefit Mechanism: TMI Compliance**

**Sim #1: 06/15/16, South Flow**

### Simulated Takeoff Times As Compared to the APREQ Window

<table>
<thead>
<tr>
<th>Time Window</th>
<th>Baseline</th>
<th>ATD-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beyond -15 min</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Within -15 to -15 min</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Within -5 to -5 min</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Within -2/+1 min</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Within +1 to +5 min</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Beyond +5 to +15 min</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Beyond +15 min</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

---

*ATAC - Aviation Analysis Experts*