SARDA HITL #6 Simulation: System Performance Analysis (Initial Results)

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SARDA Concept

• Provide advisories to controllers incorporating future traffic
  – Pushback and MC bypass taxiway use
  – Runway sequence
  – Spot release

• Increased efficiency and predictability in surface operations

• Reduced fuel consumption and emissions

• No concession in runway throughput
HITL #6 Simulation Objectives

• Evaluate effects of the SARDA ramp controllers tool by comparing the two types of runs:
  – **Baseline runs** as current day operations (e.g., <15 in queue)
  – **Advisory runs** with SARDA scheduler

• SARDA advisories
  – **Pushback advisories** provide hold time
  – **MC advisories** provide advisory to indicate the flights that should be given the MC bypass option
Simulation Details (1)

• 2 scenarios created based on actual traffic data (5/16/2013), compressed in time

• Departure push with the first part of the next arrival push overlapping

• Each scenario is about 1 hour long

• South-flow configuration (Departing: 18L, 18C; arriving: 23, 18R) with the Arrival-Departure Window (ADW) rule enforced

• Clear weather - VFR

• TMI (MIT @ MERIL 20 nm, EDCT) in effect

• Four-sector configuration for ramp area
Simulation Details (2)

- 3 weeks – total of 48 scenario runs (counterbalanced between scenarios and between subjects)
- 4 ramp controllers (2 from CLT US Airways ramp tower)
- 1 ramp traffic manager by a NASA researcher
- 3 ATC controllers (2 Local and 1 Ground)
- 9 pseudo-pilots
Simulation Details (3)

• Ramp controllers were asked to follow pushback advisory as much as possible
• Ramp controllers were asked to consider to follow MC advisory through coordination with ramp traffic manager
4 Ramp Sector Configuration

North
E4-E19

East
C2 - C14
D1-D13
E1-E17

South
B2 - B14
C3 - C19
C18,C16

West
A1 - A2
B1 - B15
B16
MC Bypass Taxiway
Ramp Traffic Console (RTC)

- Pushback advisories
  - Pushback
  - Gate hold
  - Holding time

- MC bypass route advisories
Traffic Pattern

- Two one-hour long scenarios based on actual recorded traffic data from CLT (May 16, 2013) and compressed slightly in time
  - Departure push followed by arrival push
- Scenario 1: 96 departures & 80 arrivals
- Scenario 2: 84 departures & 72 arrivals
Data Collected

• Surface Management System (SMS) logs
  – Aircraft tracks
  – Scheduler inputs and outputs
  – ATC controller inputs
• RTC logs – ramp controllers inputs
• Voice/video recordings
• Workload measurements
• Post run & post study surveys
Performance Metrics

• Gate-hold time
• Taxi-out and taxi-in time
• Taxi delay
• Runway usage
• Wheels-off time predictability
• TMI compliance
• Fuel consumption
• Emissions
• Compliance to advisories
Average Gate-hold Time

- \((\text{Gate-hold Time}) = (\text{Actual Out Time}) - (\text{Scheduled Pushback Time})\)
- As expected, departures are held at gates longer in Advisory runs
  - Increased gate-hold time (79-100%) with Advisory

\[\begin{array}{c|c|c|c|c}
\text{Scenario 1} & \text{Baseline} & \text{Advisory} & \text{Baseline} & \text{Advisory} \\
\hline
\text{Hold time (sec/aircraft)} & 100 & 200 & -100 & 250 \\
\end{array}\]

1.54 min increase in Scenario 1 (100.2%)
1.35 min increase in Scenario 2 (78.7%)
Average Taxi-out Time

- \((\text{Taxi-out Time}) = (\text{Actual Takeoff Time}) - (\text{Actual Pushback Time})\)
- Taxi time reduction (8-11%) for departures with Advisory

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Taxi time (sec/aircraft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>600</td>
</tr>
<tr>
<td>Advisory</td>
<td>500</td>
</tr>
<tr>
<td>Baseline</td>
<td>600</td>
</tr>
<tr>
<td>Advisory</td>
<td>500</td>
</tr>
</tbody>
</table>

1.1 min reduction in Scenario 1 (10.5%)
0.8 min reduction in Scenario 2 (8.3%)
Average Taxi-out Time by Area

- Ramp: Gate to Spot
- Airport Movement Area (AMA): Spot to Runway
- Departures spend more time in ramp area while taxiing
- With Advisory, more taxi time reduction in AMA
Taxi-out Time by Runway

- Runway 18L for Eastbound flights and Runway 18C for Westbound flights
- Longer taxi distance from gates to Runway 18C, leading to longer taxi time
- Most taxi-out time reduction by Advisory comes from the departures for Runway 18L
Average Taxi-out Delay

- \( \text{(Taxi-out Delay)} = (\text{Actual Taxi-out Time}) - (\text{Unimpeded Taxi-out Time}) \)
- Unimpeded taxi time: time to travel on that route (gate-spot-queue combination) at 15 knots (8m/s) without stops
- Taxi delay reduction (13-15%) for departures with Advisory

1.1 min reduction in Scenario 1 (15.4%)
0.8 min reduction in Scenario 2 (13.6%)
Taxi-out Delay Distribution

- Larger variation in delay in Baseline
Total Delay for Departures

- \((\text{Total Delay}) = (\text{Gate-hold Time}) + (\text{Taxi-out Delay})\)
- With Advisory, small increase in total delay (6-7%) due to longer gate-holding was observed

**0.5 min** increase in Scenario 1 (5.9%)
**0.5 min** increase in Scenario 2 (7.1%)
Total Delay Discussion

• Possible reasons for higher total delay with Advisory
  – Not too much congested traffic in scenarios to get more taxi delay reduction with Advisory
  – Scheduler may be overly conservative, resulting in longer gate-holding
    • Scheduler’s updates may add additional gate-holding times
  – Ramp controllers have some delays to follow the pushback advisories due to communication delay, busy with other traffic, safety issue, etc.
  – Single lane in ramp area can make it difficult for flights to meet the predicted takeoff times by Scheduler as desired
Total Delay for Departures & Arrivals

- \((\text{Total Delay}) = (\text{Sum of Delays}) / (\text{Number of departures and arrivals})\)
  - Delays include taxi-out delay and gate delay for departures and taxi-in delay for arrivals
- Total average delay is nearly the same for Baseline and Advisory

**0.01 min** increase in Scenario 1 (0.3%)
**0.16 min** increase in Scenario 2 (3.3%)
Average Taxi-in Time

• (Taxi-in Time) = (Actual Gate-in Time) – (Actual Landing Time)
• No adverse effect on arrivals with Advisory

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
</tr>
<tr>
<td>Advisory</td>
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</tr>
<tr>
<td>Scenario 1</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td></td>
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<tr>
<td>Advisory</td>
<td></td>
</tr>
<tr>
<td>Scenario 2</td>
<td></td>
</tr>
</tbody>
</table>

0.3 min reduction in Scenario 1 (3.1%)
0.1 min reduction in Scenario 2 (1.0%)
Average Taxi-in Time by Area

- **Ramp**: Spot to Gate
- **Airport Movement Area (AMA)**: Runway to Spot
- Arrivals spend more time in ramp area while taxiing
- No significant taxi-in time changes in both areas with Advisory
Taxi-in Time by Runway

- Longer taxi distance from Runway 18R to gates, leading to longer taxi time
- Similar taxi-in time between Baseline and Advisory for both runways

![Taxi-in Time (by Runway)](chart.png)
Average Taxi-in Delay

- \((\text{Taxi-in Delay}) = (\text{Actual Taxi-in Time}) - (\text{Unimpeded Taxi-in Time})\)
- Unimpeded taxi time: time to travel on that route (runway exit-spot-gate combination) at 15 knots (8 m/s) without stops
- Taxi delay reduction (13-37%) for arrivals with Advisory

**Taxiing delay for arrivals**

- **0.5 min** reduction in Scenario 1 (37.4%)
- **0.2 min** reduction in Scenario 2 (13.0%)
Taxi-in Delay Distribution

• Similar distribution between Baseline and Advisory
Departure Runway Usage

Runway Usage - Scenario 1, Rwy 18L

- Baseline
- Advisory

Runway Usage - Scenario 1, Rwy 18C

- Baseline
- Advisory

Runway Usage - Scenario 2, Rwy 18L

- Baseline
- Advisory

Runway Usage - Scenario 2, Rwy 18C

- Baseline
- Advisory
Wheels-off Time Predictability

- Compared actual takeoff times with the predicted takeoff times obtained from Scheduler when the departures start pushing back
- Smaller variations in the time difference with Advisory

Takeoff time difference distribution - Scenario 1

- Baseline
- Advisory

Takeoff time difference distribution - Scenario 2

- Baseline
- Advisory

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Mean (Actual Off Time - Predicted Off Time)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>11.2 seconds</td>
<td>123.6 seconds</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>41.0 seconds</td>
<td>150.8 seconds</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>-31.6 seconds</td>
<td>133.0 seconds</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>-20.5 seconds</td>
<td>151.8 seconds</td>
</tr>
</tbody>
</table>
Wheels-off Time Predictability

- Compared actual takeoff times with the predicted takeoff times obtained from Scheduler when the departures are at the assigned spots
- Smaller variations in the time difference with Advisory

**Takeoff time difference distribution - Scenario 1**

- Mean: 41.8
- Std. Dev.: 107.5

**Takeoff time difference distribution - Scenario 2**

- Mean: 20.4
- Std. Dev.: 99.8

**Takeoff time difference distribution - Scenario 1**

- Mean: 60.5
- Std. Dev.: 130.0

**Takeoff time difference distribution - Scenario 2**

- Mean: 30.6
- Std. Dev.: 127.4
Number of Taxiing Aircraft

- Number of aircraft taxiing on the ground reduced (up to 4) with Advisory

Number of aircraft taxiing - Scenario 1

Number of aircraft taxiing - Scenario 2
Number of Taxiing Aircraft by Area

Number of aircraft taxiing - Scenario 1

Number of aircraft taxiing - Scenario 2

Ramp Area

AMA

Simulation time (minutes)
Other Performance Metrics

• More performance metrics will be evaluated later, including:
  – Traffic Management Initiatives (TMI) compliance
  – Pushback advisory compliance
  – MC route advisory compliance
  – Takeoff sequence advisory compliance
  – Stop-and-go frequency
  – Fuel consumption
  – Emissions
Backup
Gate-hold Time by Week

- Gate-hold times have variations week by week depending on controllers.
Traffic Pattern & Gate-hold Time

• Long gate-hold times observed frequently when traffic demand is high
Taxi-out Time by Week

- Taxi-out times have variations week by week depending on controllers
- Taxi time reduction: 10-12% for Scenario 1 and 5-10% for Scenario 2
Taxi-out Time by Week & Area

- Taxi-out times have variations week by week depending on controllers.
Taxi-in Time by Week

- Taxi-in times have variations week by week depending on controllers
- With Advisory, taxi-in times sometimes increase by holding arrivals at hardstands longer, but the benefit for departures is greater than the cost to arrivals
Taxi-in Time by Week & Area

- Taxi-in times have variations week by week depending on controllers.
- When the total taxi-in time increases with Advisory (Week 2 for Scenario 1 and Week 1 for Scenario 2), the increase comes from ramp area, which means longer holding at Hardstands.

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**Taxi-in Time (Scenario 1, by Week & Area)**

- Baseline
- Advisory
- Week 1
- Week 2
- Week 3

**Taxi-in Time (Scenario 2, by Week & Area)**

- Baseline
- Advisory
- Week 1
- Week 2
- Week 3
Cumulative Runway Usage

Cumulative Runway Usage - Scenario 1, Rwy 18L

Cumulative Runway Usage - Scenario 1, Rwy 18C

Cumulative Runway Usage - Scenario 2, Rwy 18L

Cumulative Runway Usage - Scenario 2, Rwy 18C
Departure Throughput (Week 1)

Runway Throughput for Rwy 18L (Scenario 1, Week 1)

Runway Throughput for Rwy 18C (Scenario 1, Week 1)

Runway Throughput for Rwy 18L (Scenario 2, Week 1)

Runway Throughput for Rwy 18C (Scenario 2, Week 1)
Simple Sum of Taxi Delays

- \((\text{Taxi-out Delay per departure}) + (\text{Gate Delay per departure}) + (\text{Taxi-in Delay per arrival})\)

0.02 min decrease in Scenario 1 (-0.2%)

0.30 min increase in Scenario 2 (3.2%)