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

- **West**
  - A1 - A2
  - B1 - B15
  - B16

- **East**
  - C2 - C14
  - D1-D13
  - E1-E17

- **South**
  - B2 - B14
  - C3 - C19
  - C18, C16

- **North**
  - E4-E19
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

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

**Gate-hold Time**

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

- (Taxi-out Time) = (Actual Takeoff Time) – (Actual Pushback Time)
- Taxi time reduction (8-11%) for departures with Advisory

![Taxi-out Time Chart]

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 Area)](image_url)
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

- (Taxi-out Delay) = (Actual Taxi-out Time) – (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

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

**Total delay for departures**

- **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

- \((\text{Total Delay}) = \frac{(\text{Sum of Delays})}{(\text{Number of departures and arrivals})}\)
  - 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 \text{ min} \quad \text{increase in Scenario 1 (0.3%)}
0.16 \text{ min} \quad \text{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

*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 (8m/s) without stops
- Taxi delay reduction (13-37%) for arrivals with Advisory

\[\text{Delay (sec/aircraft)}\]

- **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

Runway Usage - Scenario 1, Rwy 18C

Runway Usage - Scenario 2, Rwy 18L

Runway Usage - Scenario 2, Rwy 18C
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

Takeoff time difference distribution - Scenario 2
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

- Baseline: Mean: 41.8, Std. Dev.: 107.5
- Advisory: Mean: 60.5, Std. Dev.: 130.0

Takeoff time difference distribution - Scenario 2

- Baseline: Mean: 20.4, Std. Dev.: 99.8
- Advisory: 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 Taxiing Aircraft by Area

Number of aircraft taxiing - Scenario 1

Number of aircraft taxiing - Scenario 2
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.
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)

- R1_B
- R2_A
- R5_A
- R6_B
- R9_A
- R10_B
- R13_B
- R14_A

Simulation time (sec)

Number of takeoffs

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

- R1_B
- R2_A
- R5_A
- R6_B
- R9_A
- R10_B
- R13_B
- R14_A

Simulation time (sec)

Number of takeoffs

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

- R3_A
- R4_B
- R7_B
- R8_A
- R11_B
- R12_A
- R15_A
- R16_B

Simulation time (sec)

Number of takeoffs

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

- R3_A
- R4_B
- R7_B
- R8_A
- R11_B
- R12_A
- R15_A
- R16_B

Simulation time (sec)

Number of takeoffs
Simple Sum of Taxi Delays

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

\[0.02 \text{ min decrease in Scenario 1 (-0.2%)}\]
\[0.30 \text{ min increase in Scenario 2 (3.2%)}\]