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

Hanbong Lee
Waqar Malik
Yoon Jung
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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

South
B2 - B14
C3 - C19
C18,C16

East
C2 - C14
D1-D13
E1-E17

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

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

**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

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)](chart.png)

Scenario 1
- Baseline
- Advisory

Scenario 2
- Baseline
- Advisory
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

**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

![Total average delay for departures and arrivals](image)

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

- \[(\text{Taxi-in Time}) = (\text{Actual Gate-in Time}) - (\text{Actual Landing Time})\]
- 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)](image.png)
Average Taxi-in Delay

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

**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

Takeoff time difference distribution - Scenario 2

Mean: 11.2
Std. Dev.: 123.6

Mean: -31.6
Std. Dev.: 133.0

Mean: 41.0
Std. Dev.: 150.8

Mean: -20.5
Std. Dev.: 151.8
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 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
Simple Sum of Taxi Delays

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

\[
\begin{align*}
\text{Scenario 1} & : 0.02 \text{ min (\(-0.2\%\))} \\
\text{Scenario 2} & : 0.30 \text{ min (\(3.2\%\))}
\end{align*}
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