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

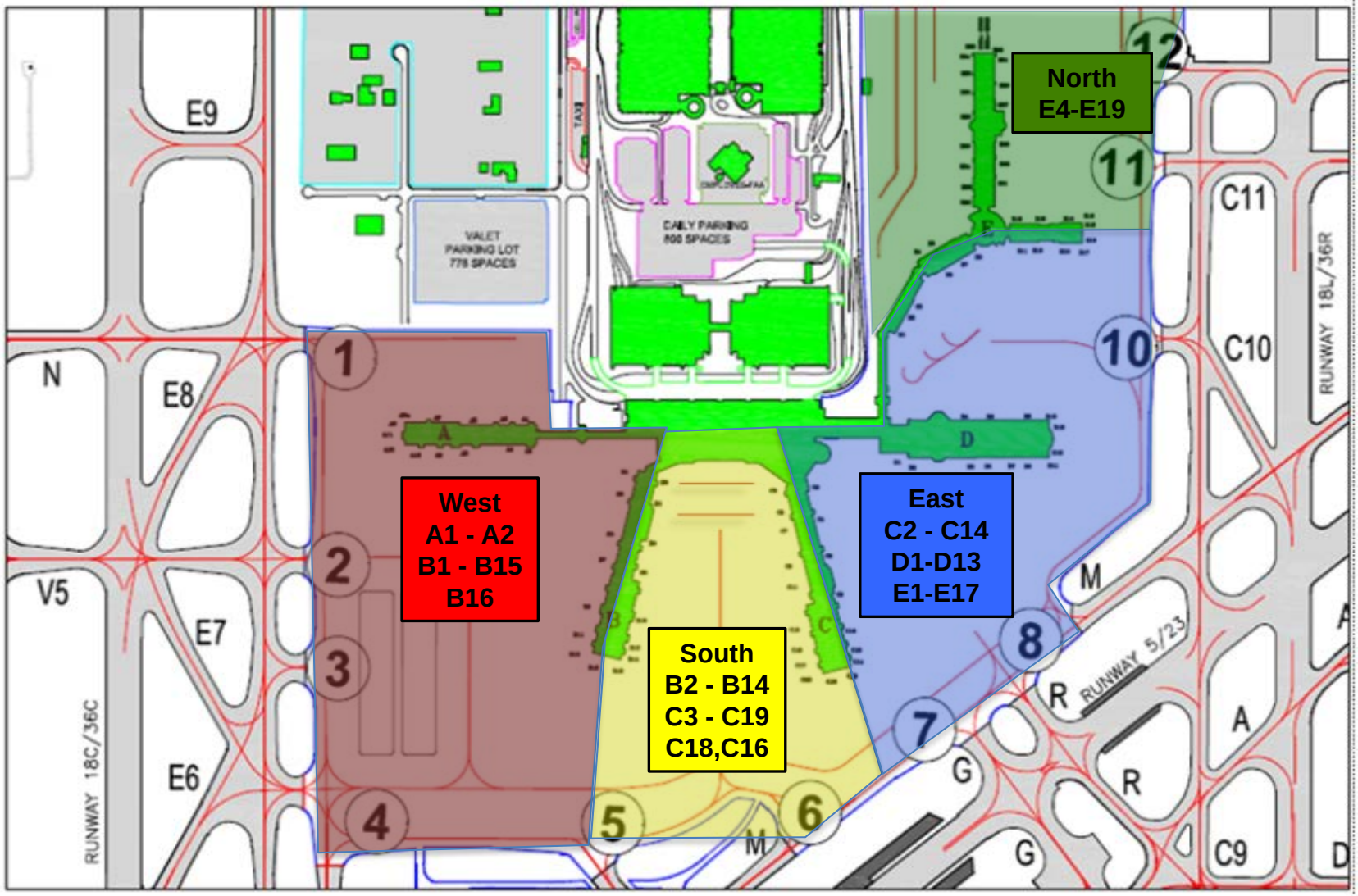
Simulation Details (2)

- 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

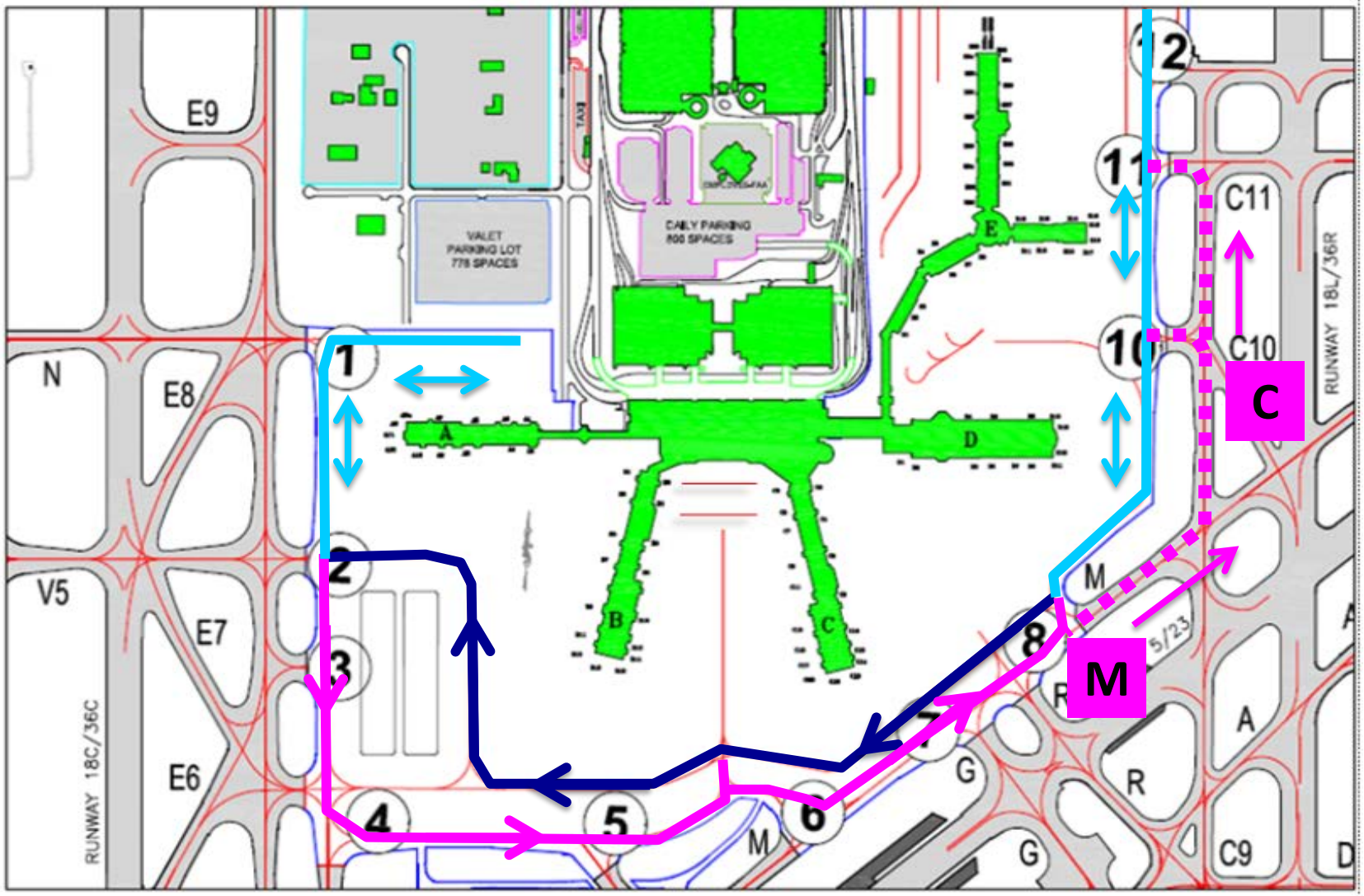
Simulation Details (3)

- 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

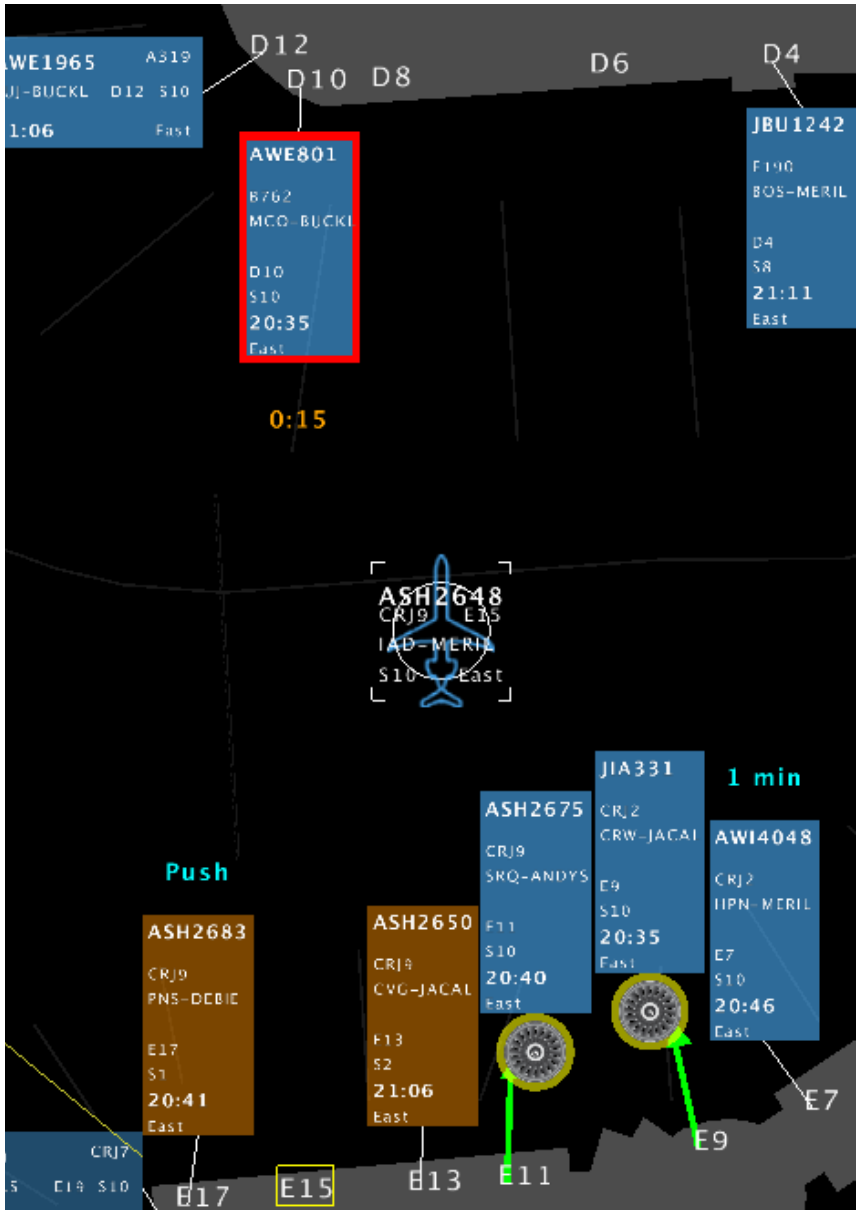
4 Ramp Sector Configuration



MC Bypass Taxiway

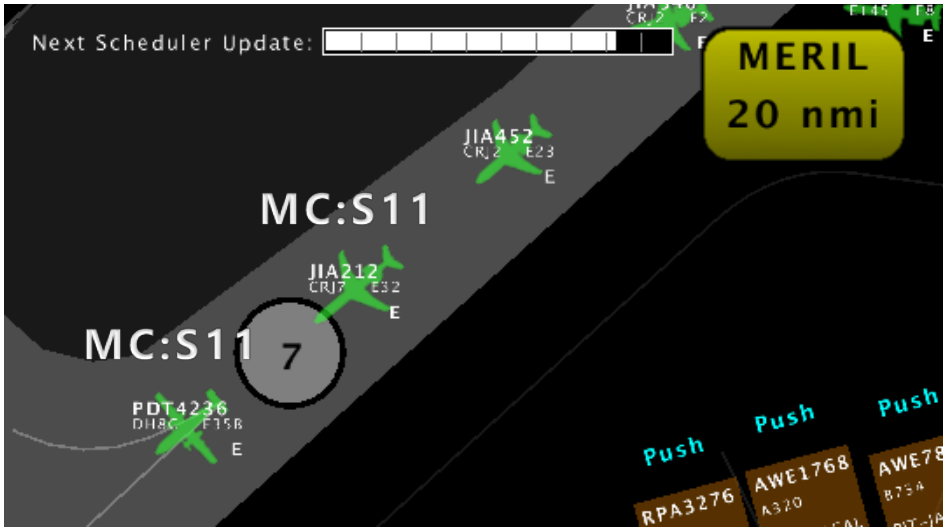


Ramp Traffic Console (RTC)



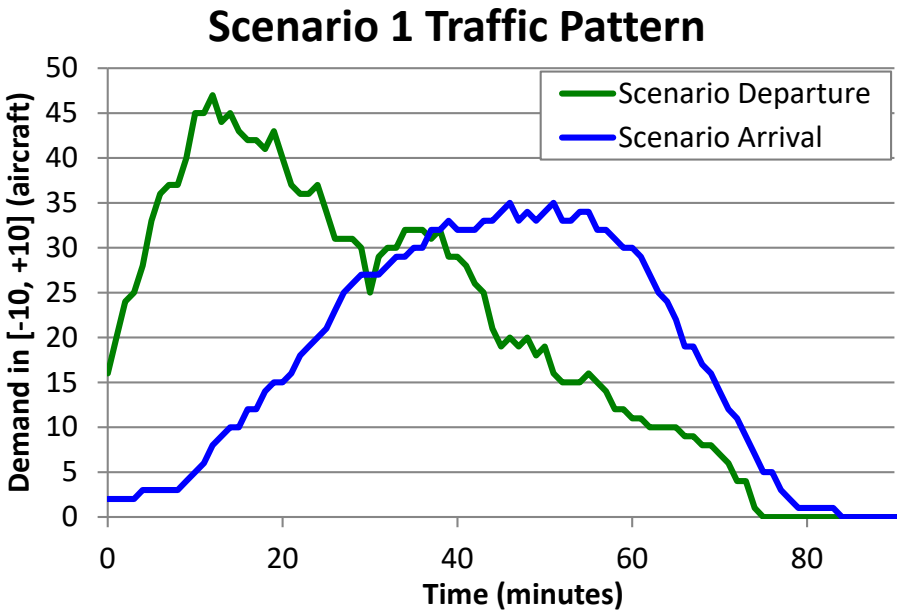
- **Pushback advisories**
  - Pushback
  - Gate hold
  - Holding time

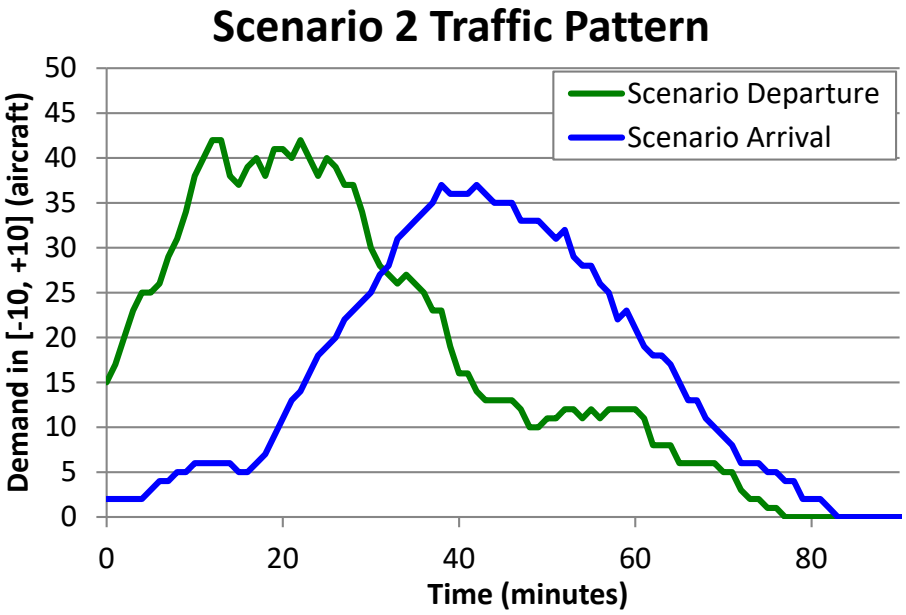
- **MC bypass route advisories**



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

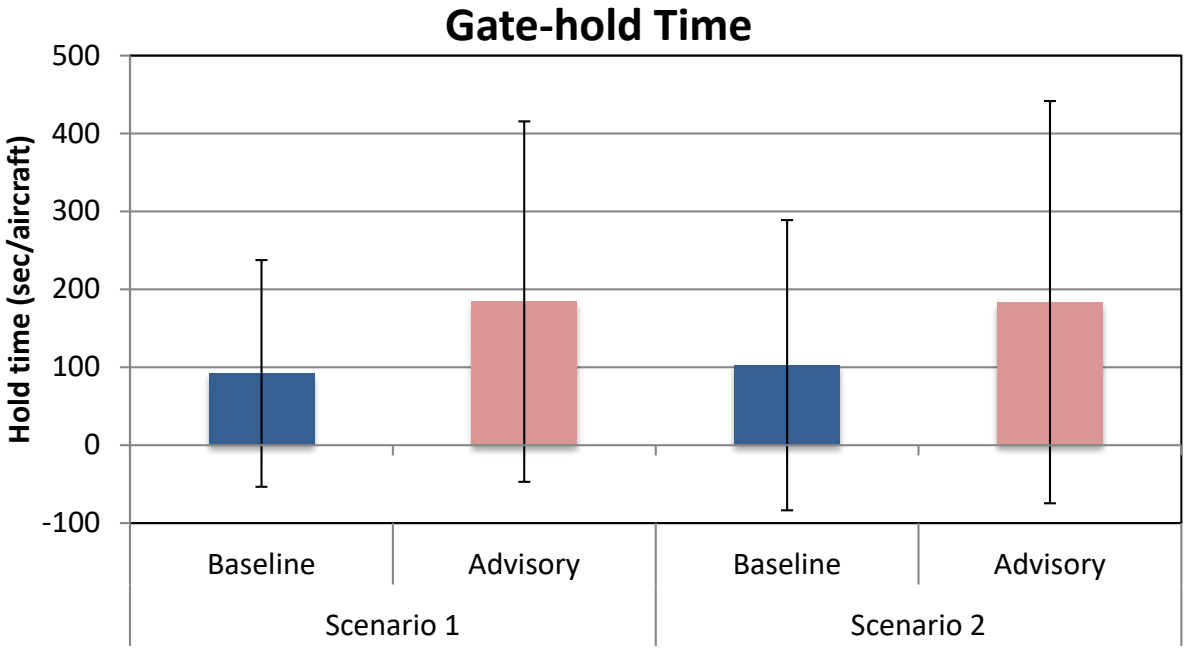
- Surface Management System (SMS) logs
  - Aircraft tracks
  - Scheduler inputs and outputs
  - ATC controller inputs
- RTC logs – ramp controllers inputs
- Voice/video recordings
- Workload measurements
- Post run & post study surveys

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

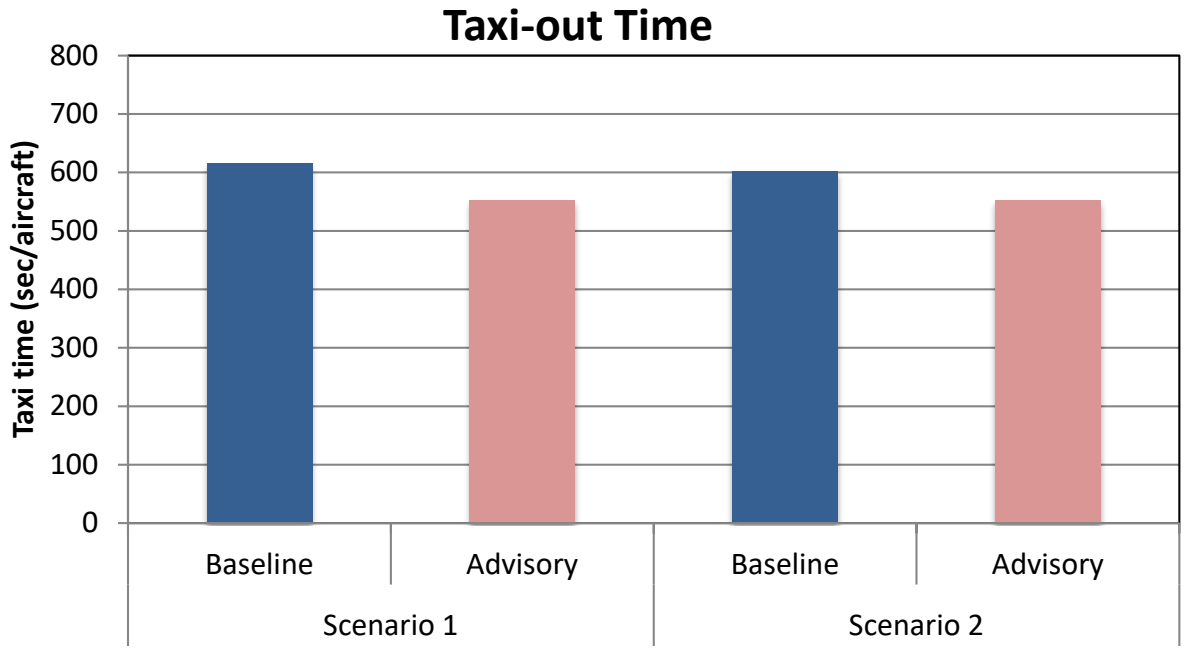
- (Gate-hold Time) = (Actual Out Time) – (Scheduled Pushback Time)
- As expected, departures are held at gates longer in Advisory runs
  - Increased gate-hold time (79-100%) with Advisory



1.54 min increase in Scenario 1 (100.2%)
1.35 min increase in Scenario 2 (78.7%)

Average Taxi-out Time

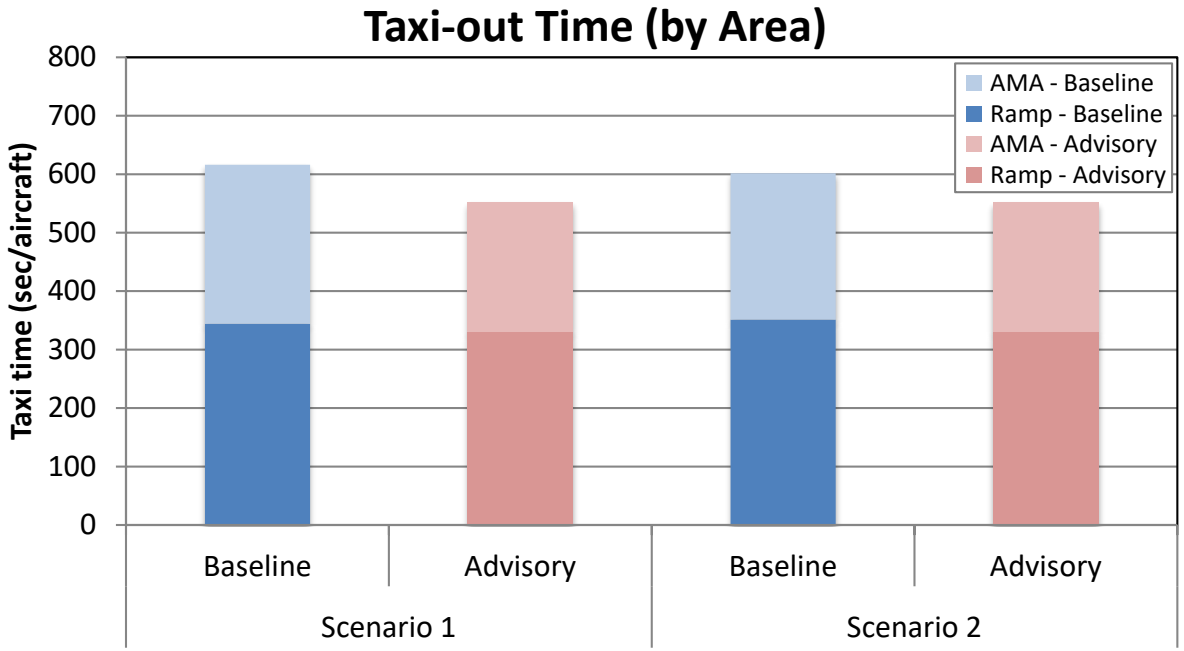
- (Taxi-out Time) = (Actual Takeoff Time) – (Actual Pushback Time)
- Taxi time reduction (8-11%) for departures with Advisory



1.1 min reduction in Scenario 1 (10.5%)
0.8 min reduction in Scenario 2 (8.3%)

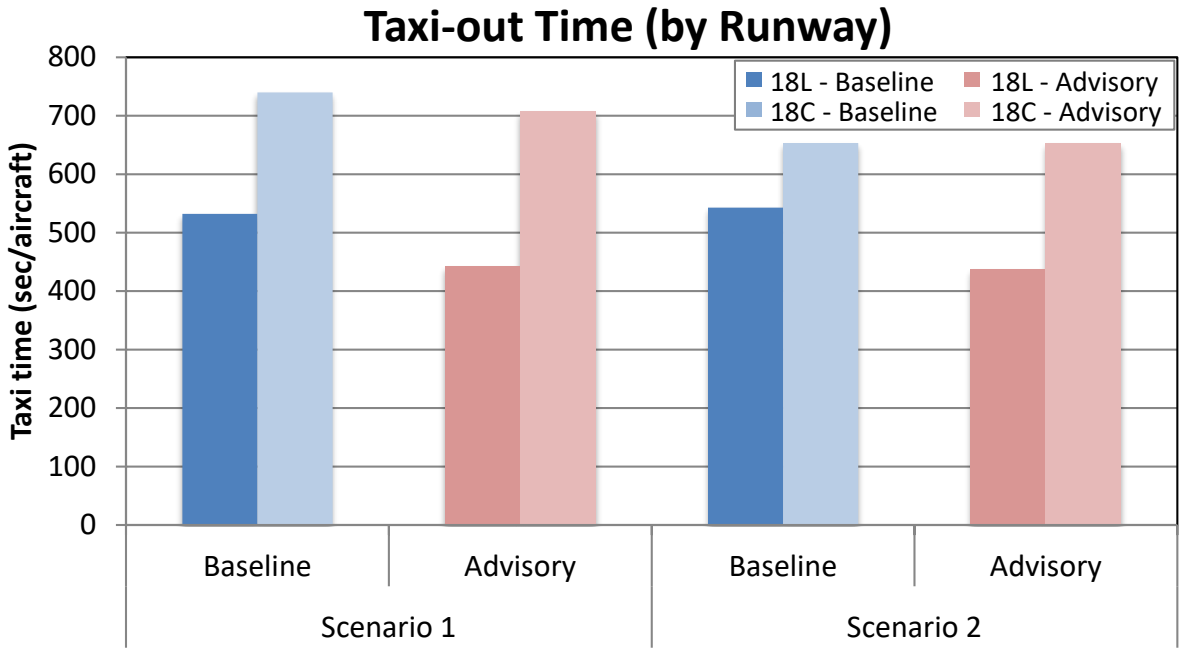
Average Taxi-out Time by Area

- 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



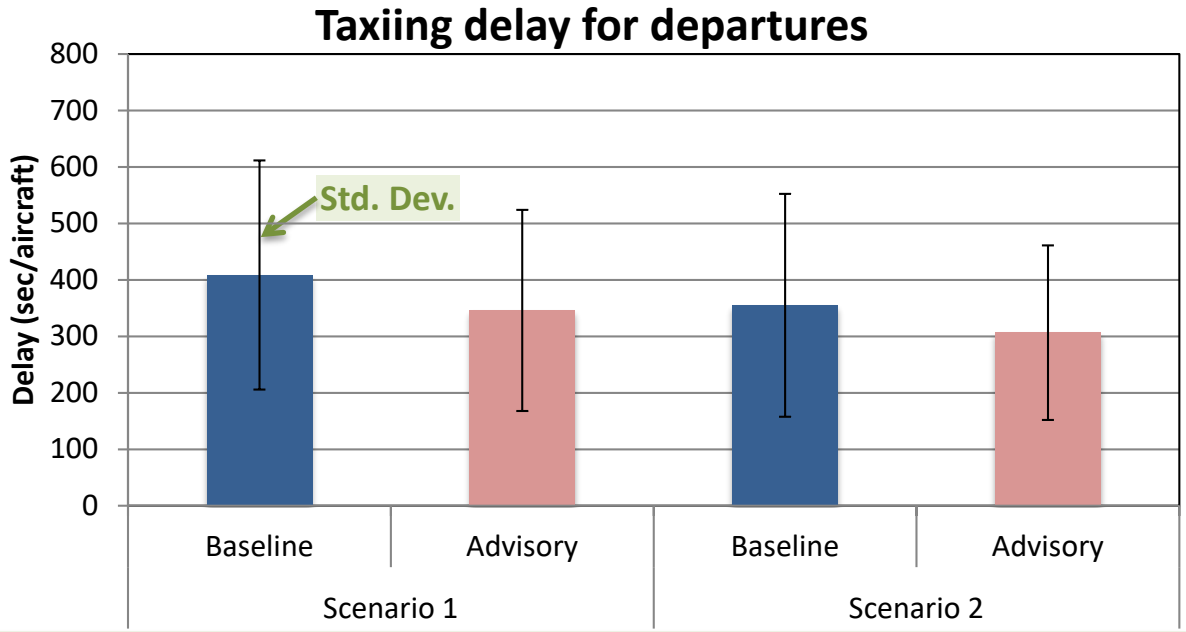
Taxi-out Time by Runway

- 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

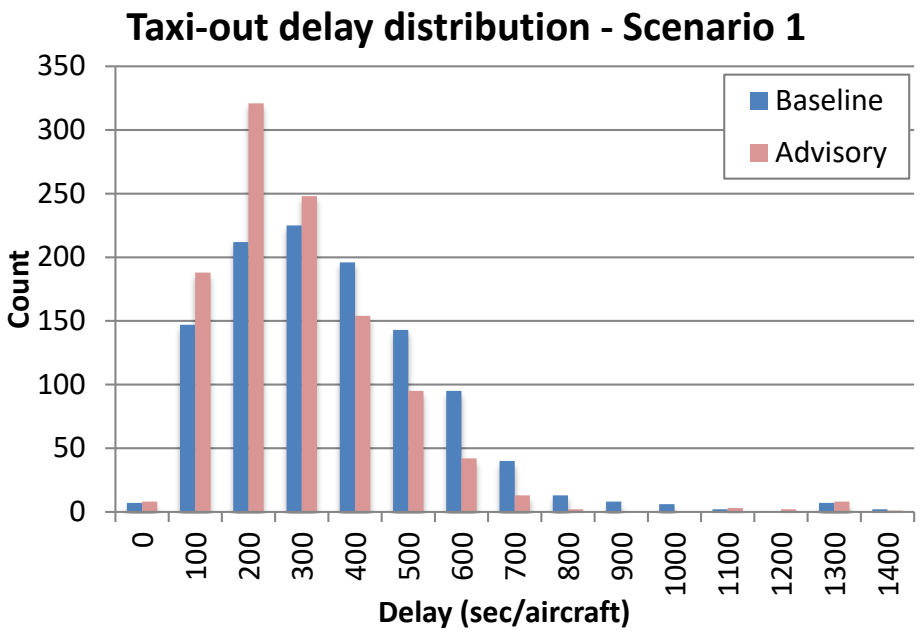
- (Taxi-out Delay) = (Actual Taxi-out Time) – (Unimpeded Taxi-out Time)
- Unimpeded taxi time: time to travel on that route (gate-spot-queue combination) at 15 knots (8m/s) without stops
- Taxi delay reduction (13-15%) for departures with Advisory

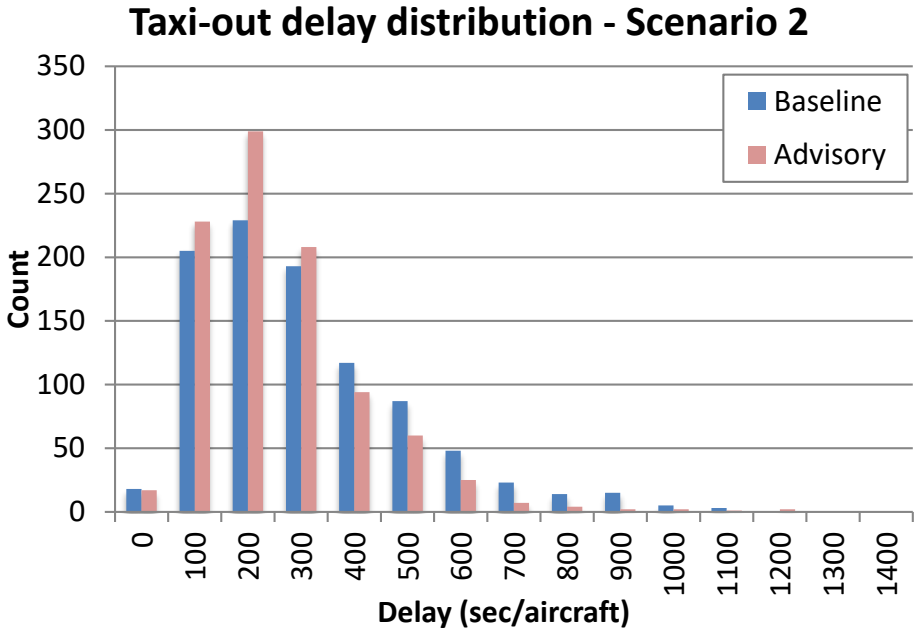


1.1 min reduction in Scenario 1 (15.4%)
0.8 min reduction in Scenario 2 (13.6%)

Taxi-out Delay Distribution

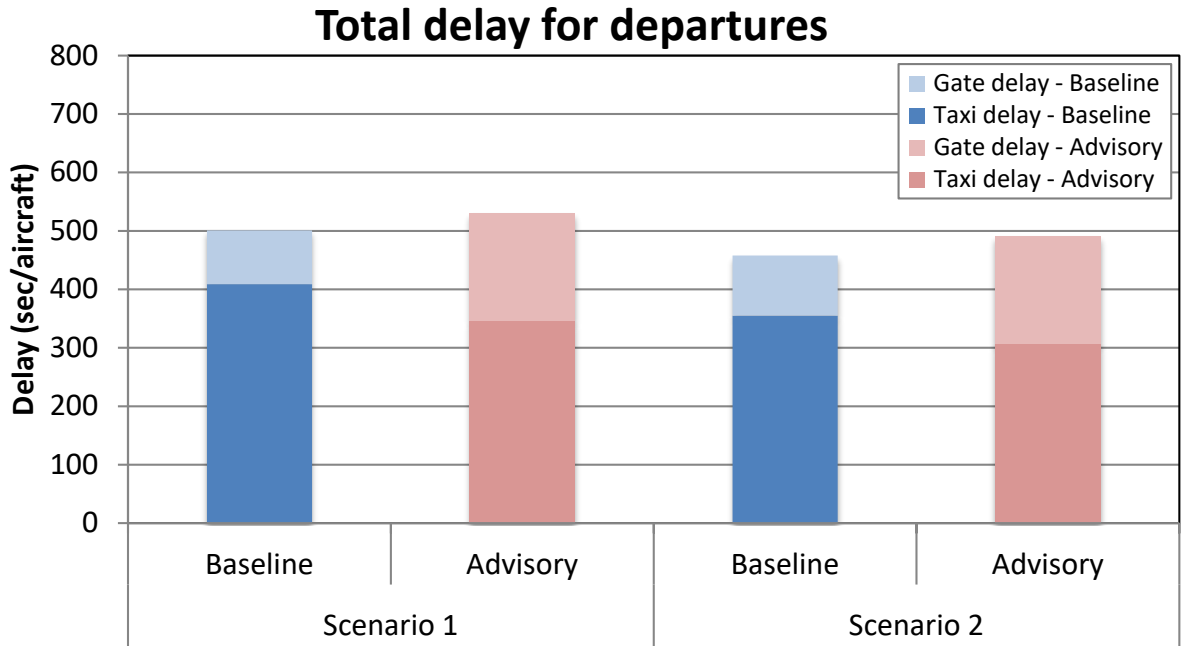
- Larger variation in delay in Baseline





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



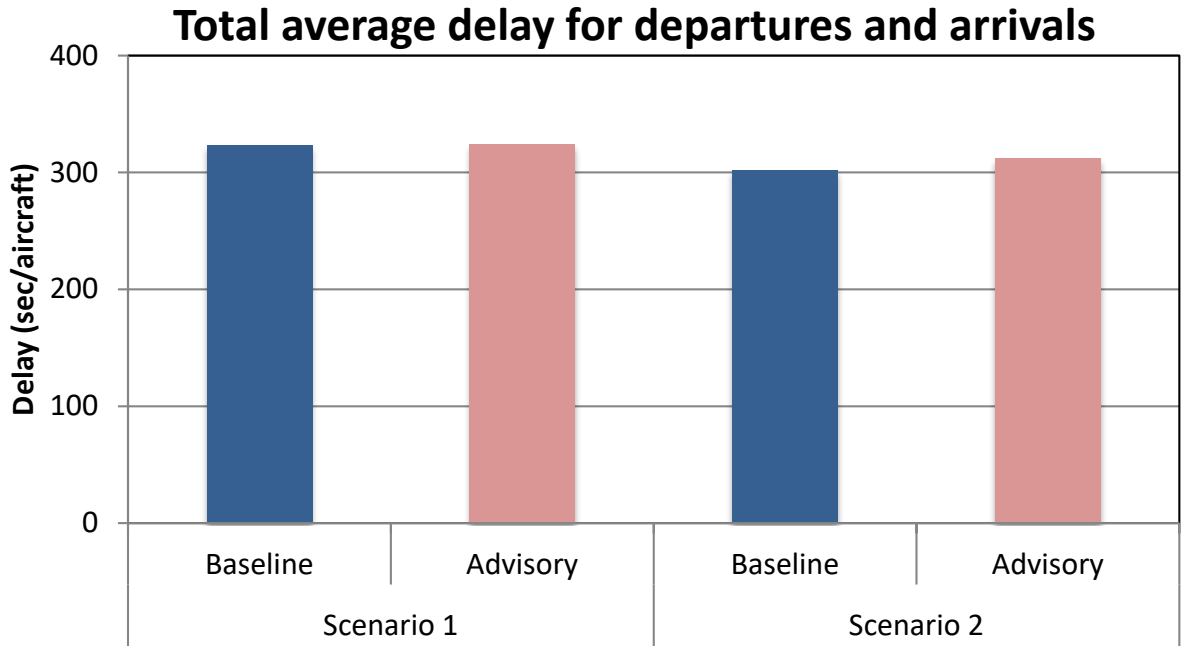
0.5 min increase in Scenario 1 (5.9%)
0.5 min increase in Scenario 2 (7.1%)

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

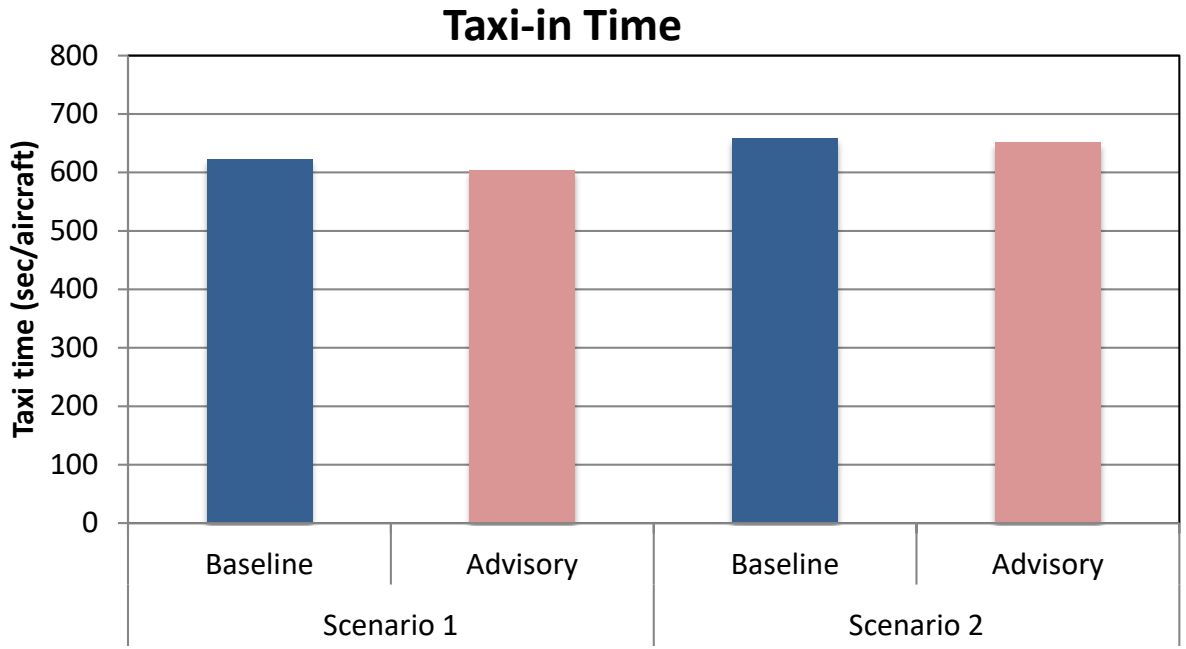
- (Total Delay) = (Sum of Delays) / (Number of departures and arrivals)
  - Delays include taxi-out delay and gate delay for departures and taxi-in delay for arrivals
- Total average delay is nearly the same for Baseline and Advisory



0.01 min increase in Scenario 1 (0.3%)
0.16 min increase in Scenario 2 (3.3%)

Average Taxi-in Time

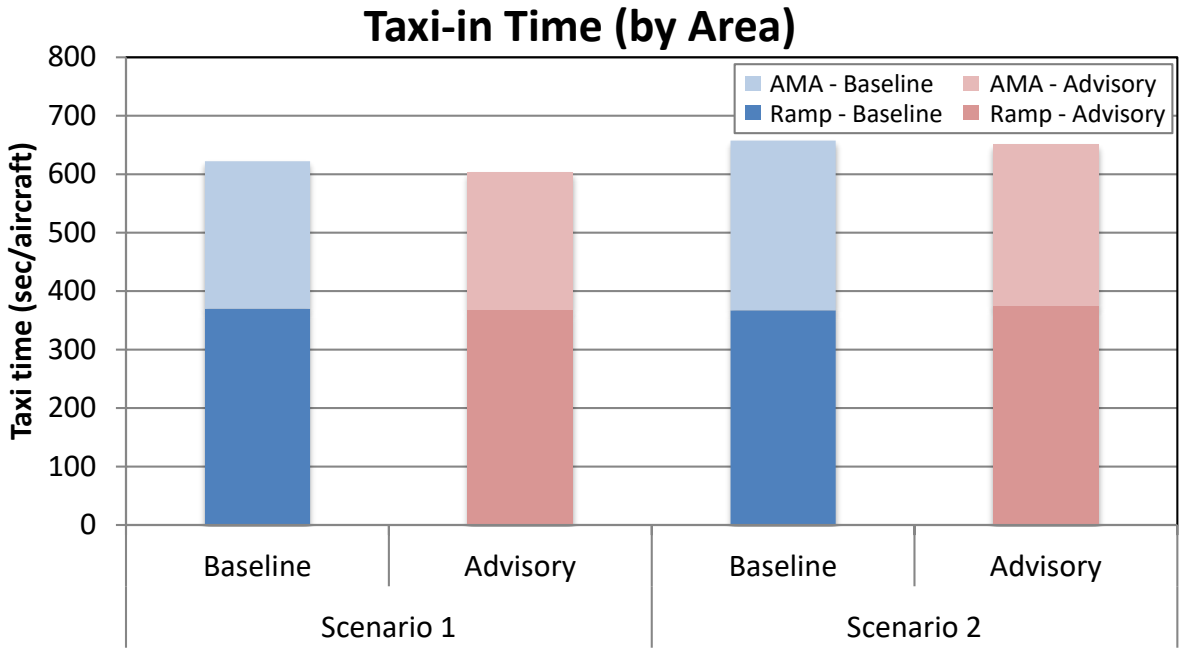
- (Taxi-in Time) = (Actual Gate-in Time) – (Actual Landing Time)
- No adverse effect on arrivals with Advisory



0.3 min reduction in Scenario 1 (3.1%)
0.1 min reduction in Scenario 2 (1.0%)

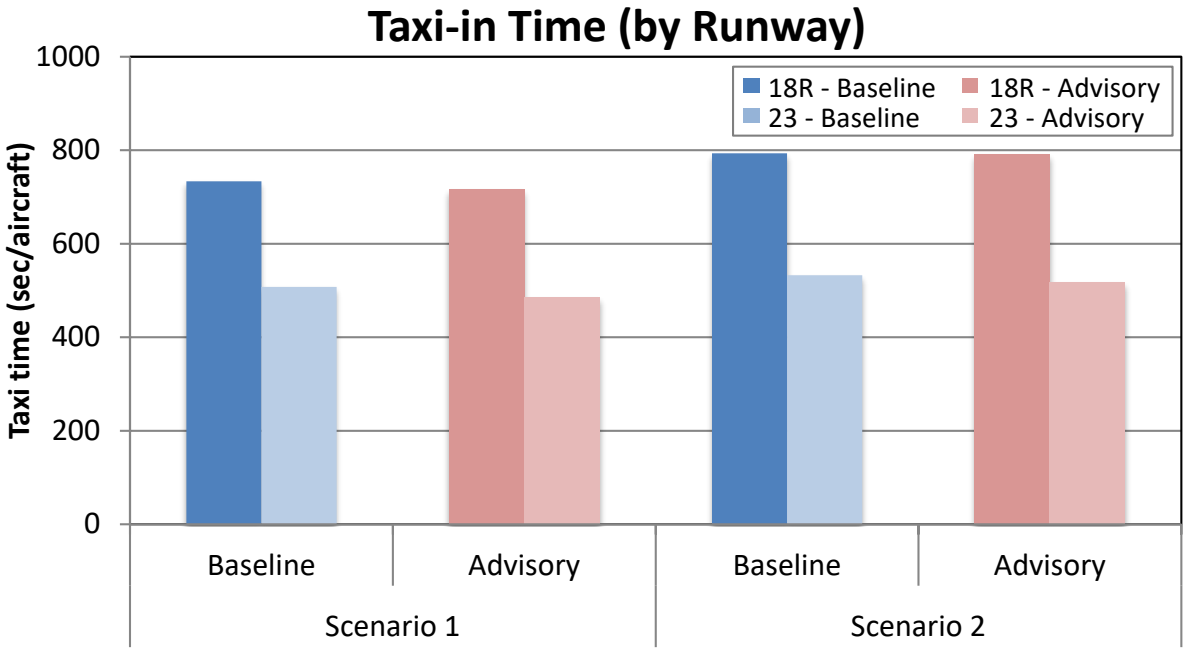
Average Taxi-in Time by Area

- 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



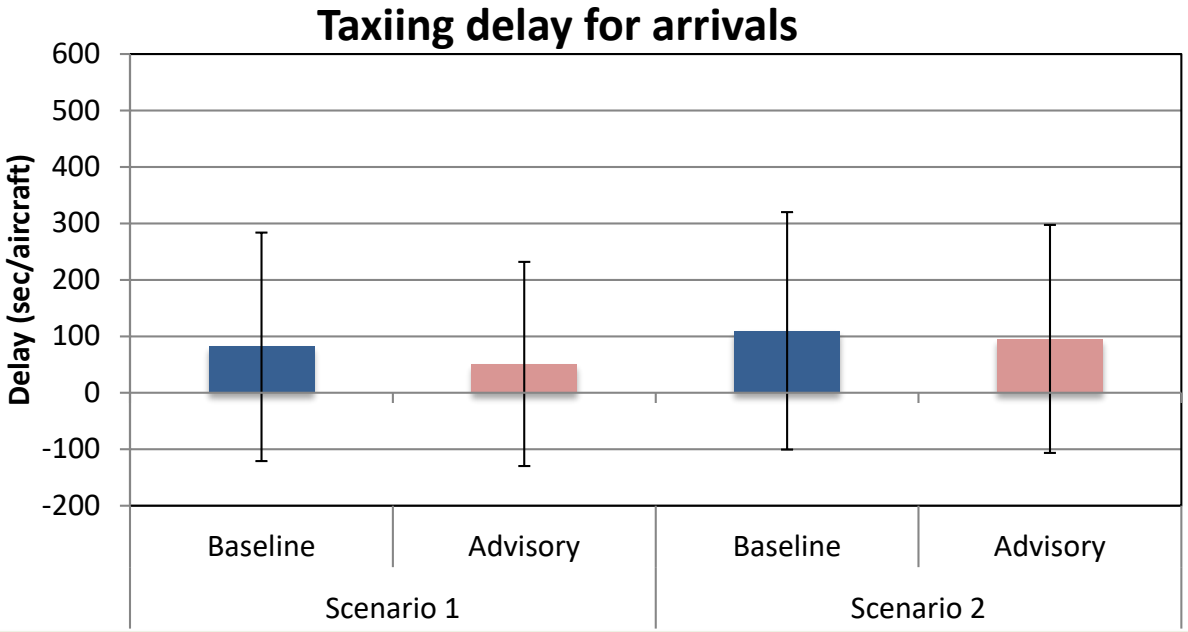
Taxi-in Time by Runway

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



Average Taxi-in Delay

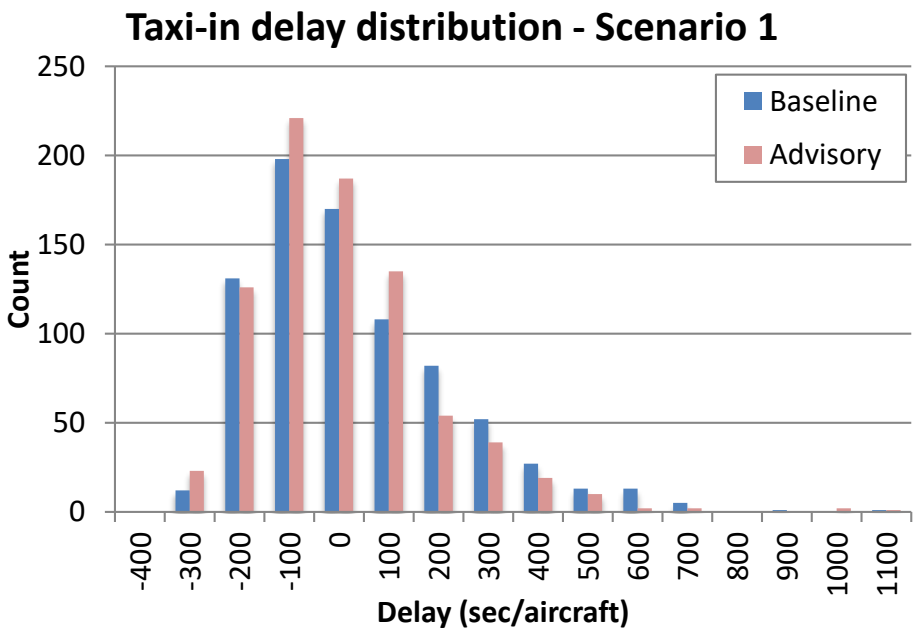
- (Taxi-in Delay) = (Actual Taxi-in Time) – (Unimpeded Taxi-in Time)
- Unimpeded taxi time: time to travel on that route (runway exit-spot-gate combination) at 15 knots (8m/s) without stops
- Taxi delay reduction (13-37%) for arrivals with Advisory

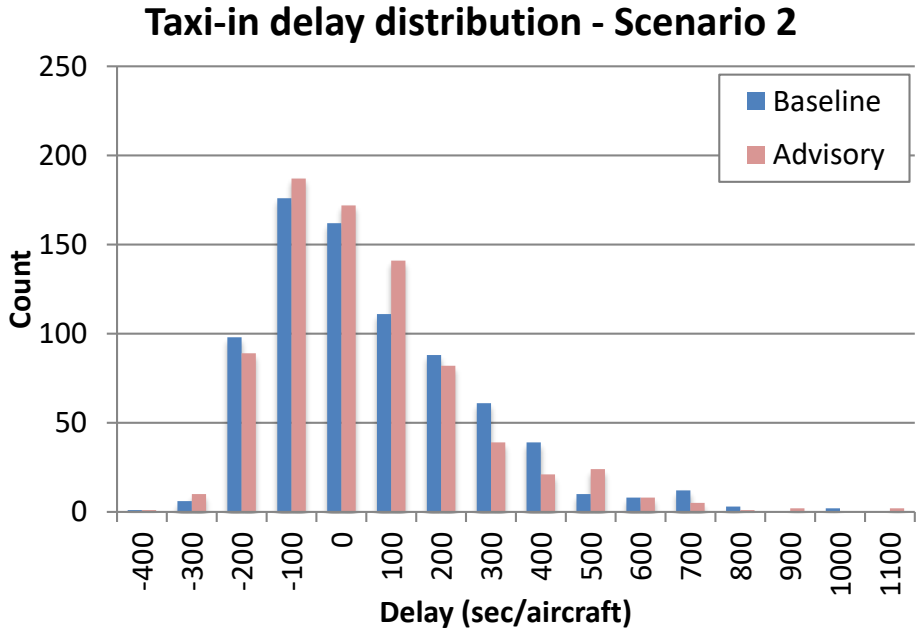


0.5 min reduction in Scenario 1 (37.4%)
0.2 min reduction in Scenario 2 (13.0%)

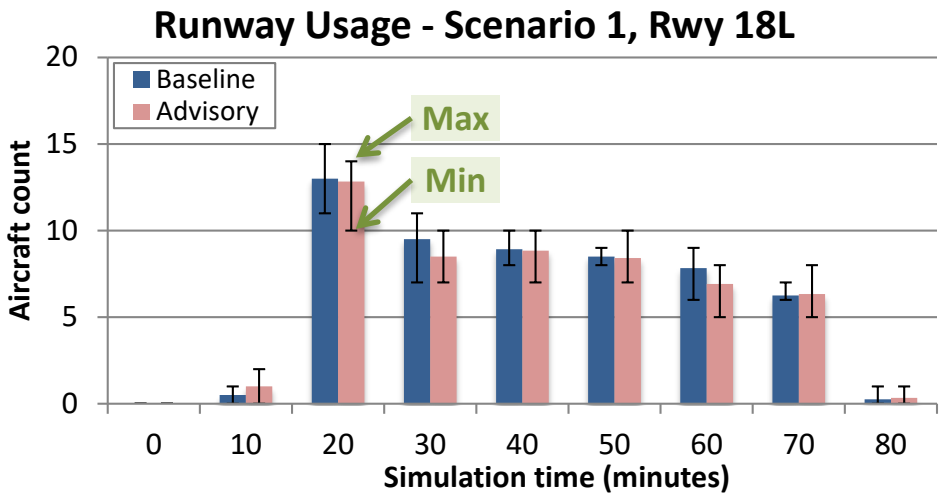
Taxi-in Delay Distribution

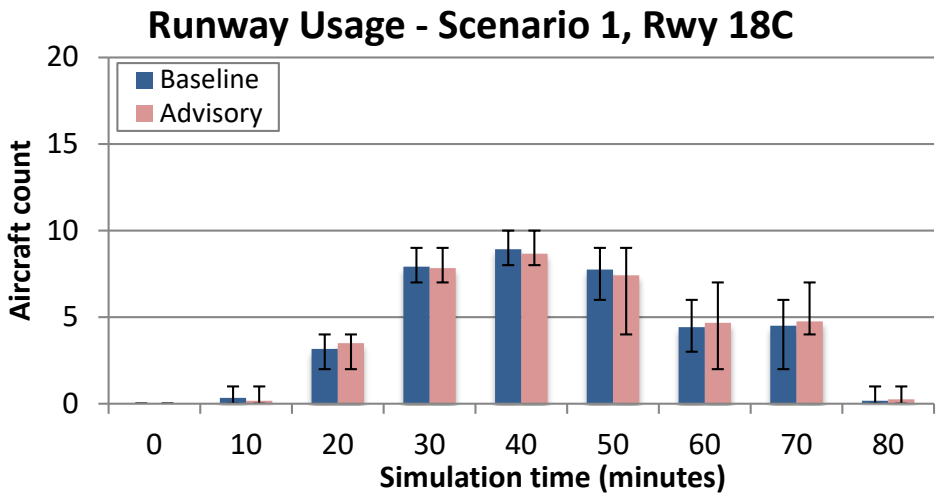
- Similar distribution between Baseline and Advisory

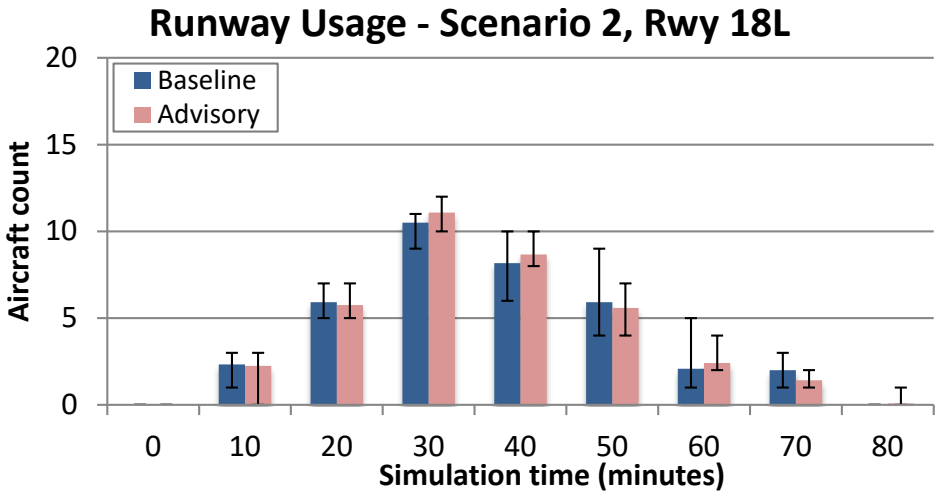


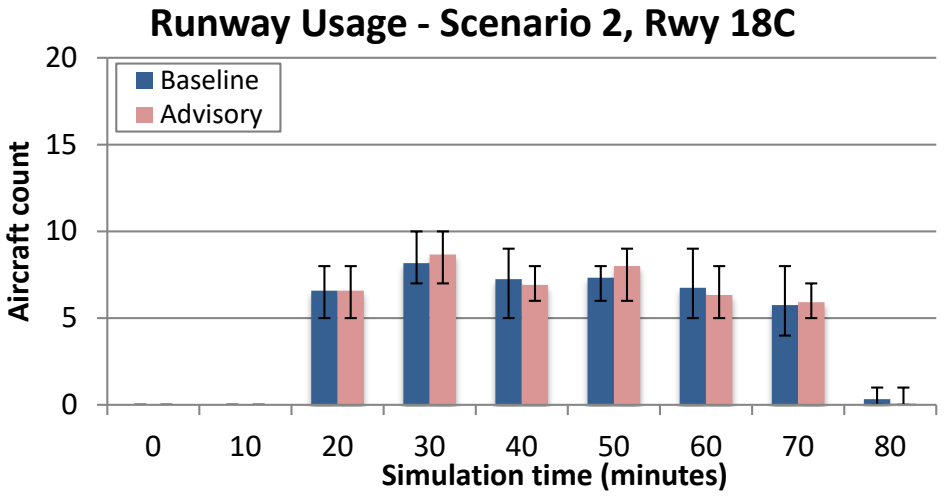


Departure Runway Usage



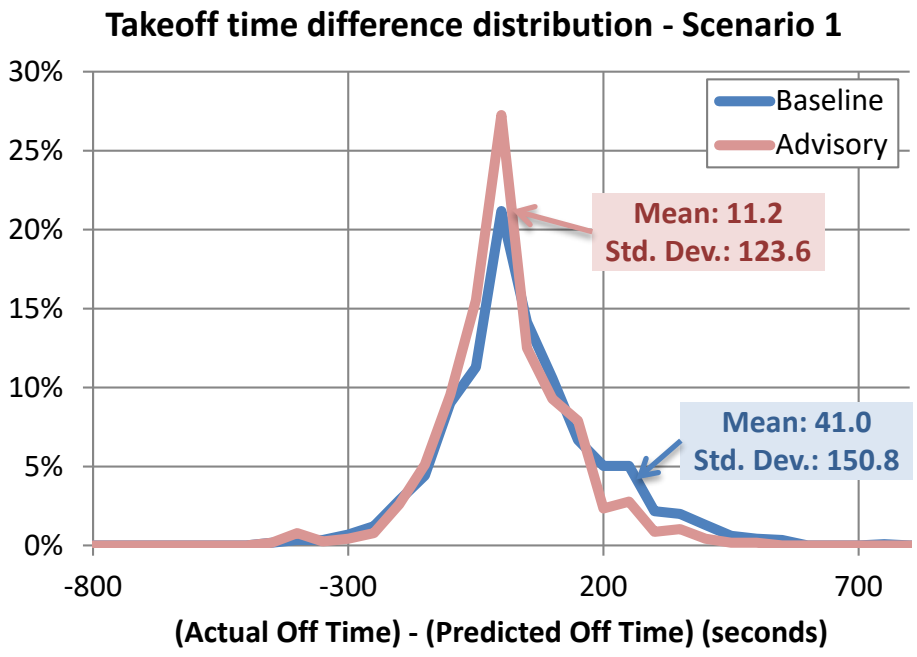


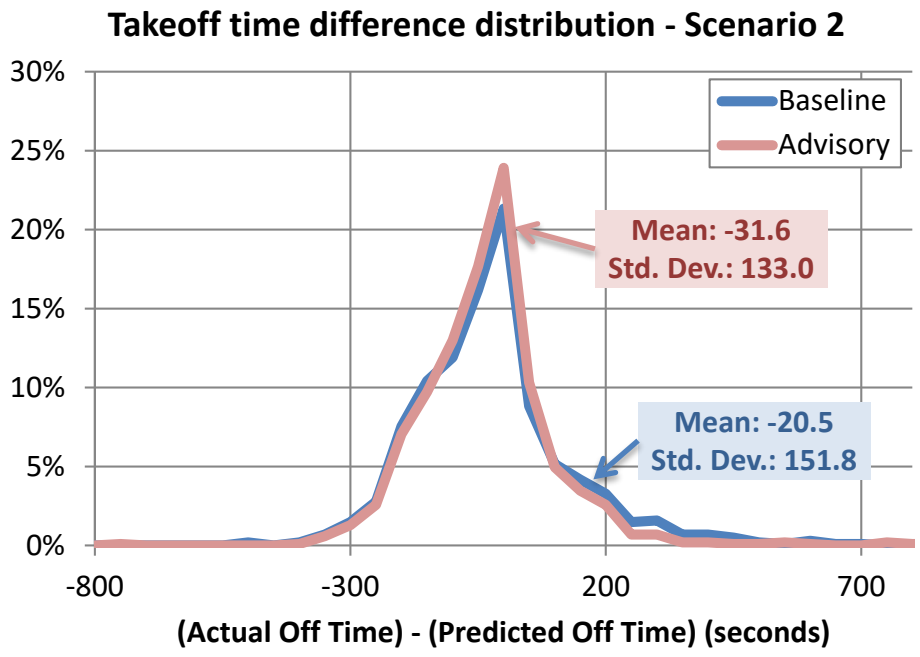




Wheels-off Time Predictability

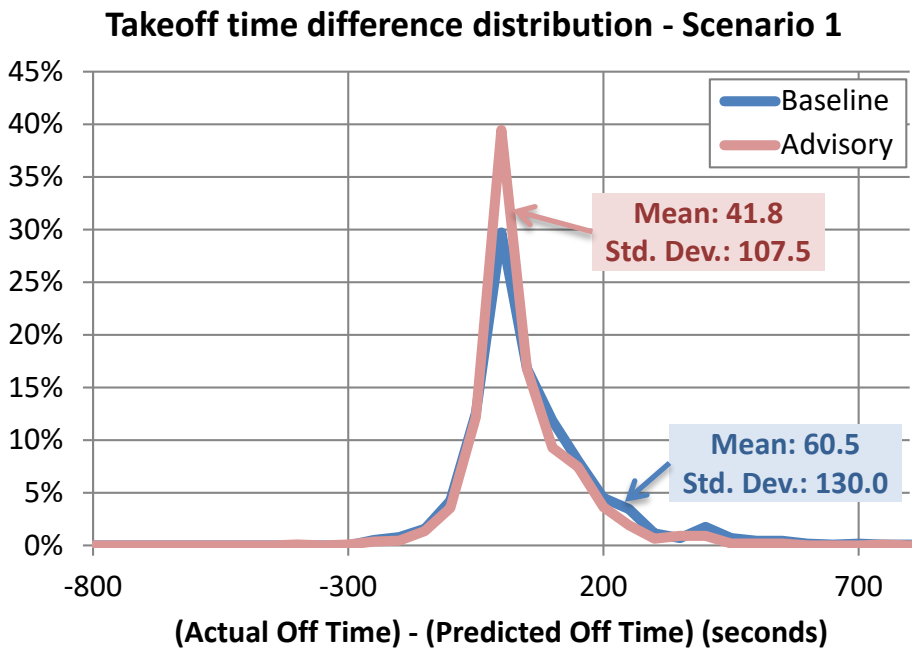
- Compared actual takeoff times with the predicted takeoff times obtained from Scheduler <u>when the departures start pushing back</u>
- Smaller variations in the time difference with Advisory

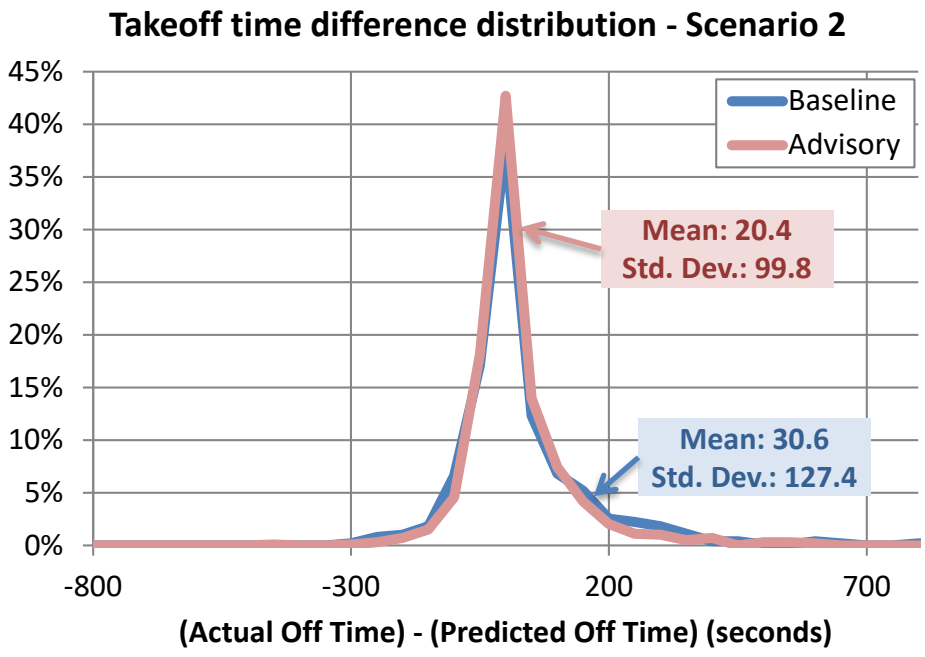




Wheels-off Time Predictability

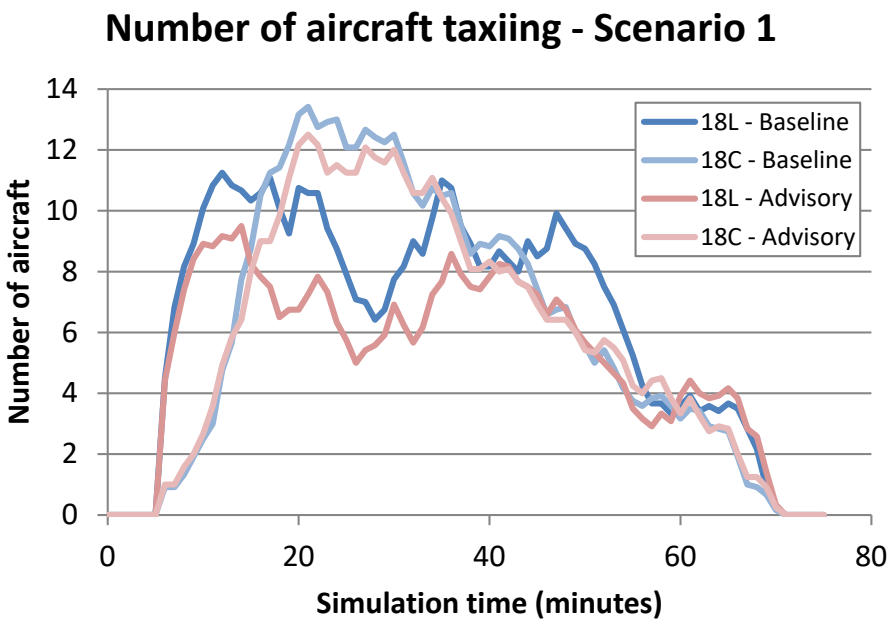
- Compared actual takeoff times with the predicted takeoff times obtained from Scheduler <u>when the departures are at the assigned spots</u>
- Smaller variations in the time difference with Advisory

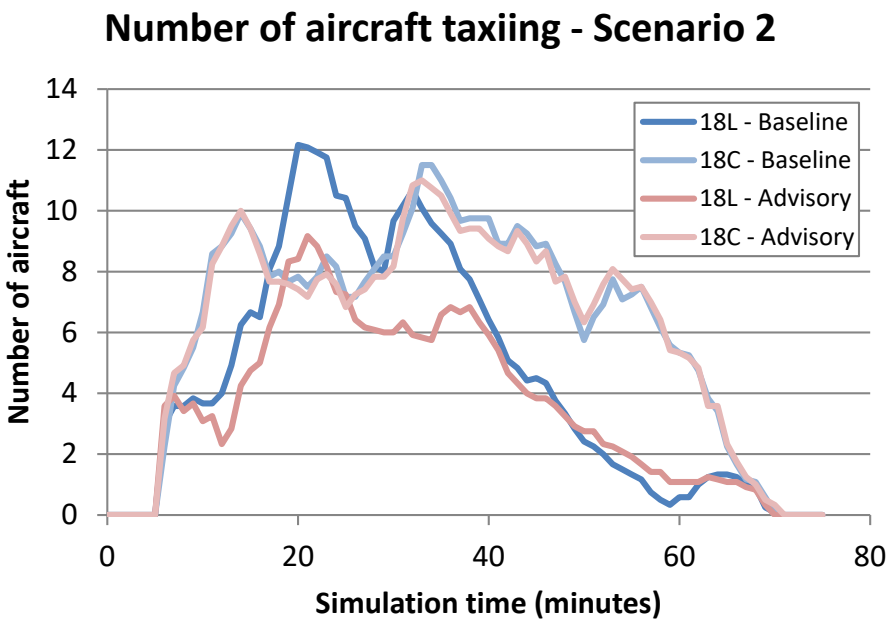




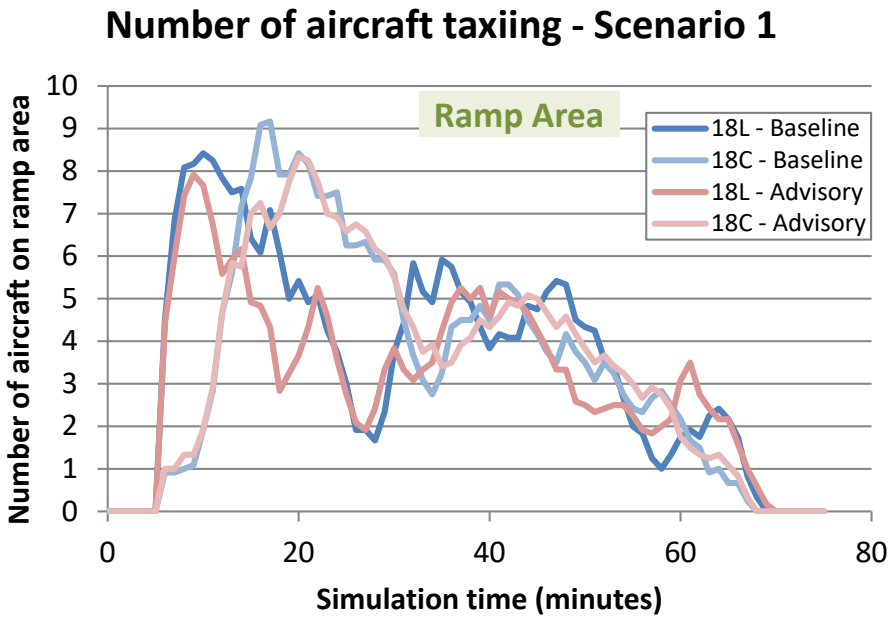
Number of Taxiing Aircraft

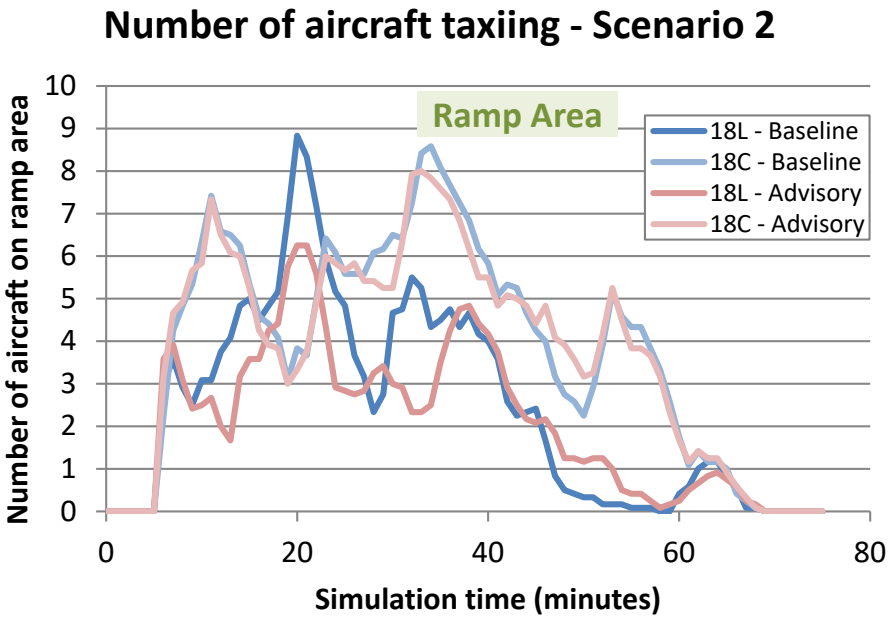
- Number of aircraft taxiing on the ground reduced (up to 4) with Advisory

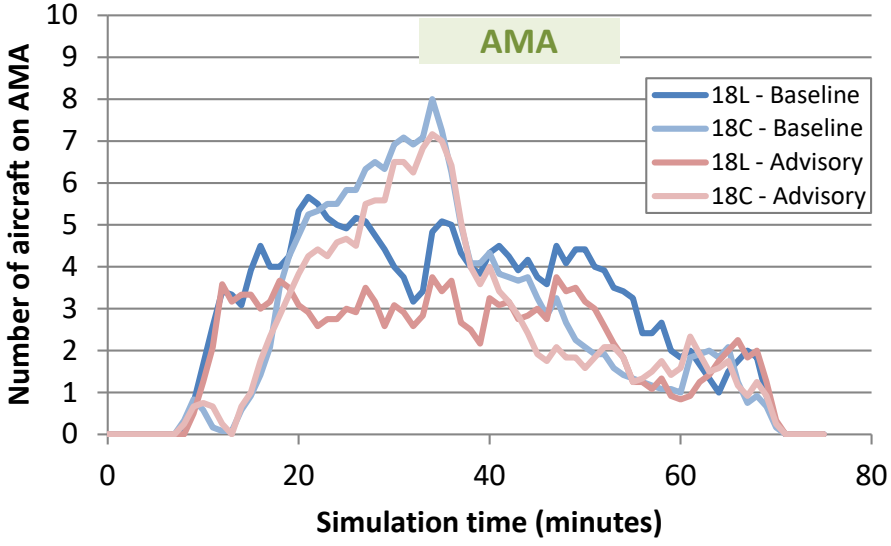


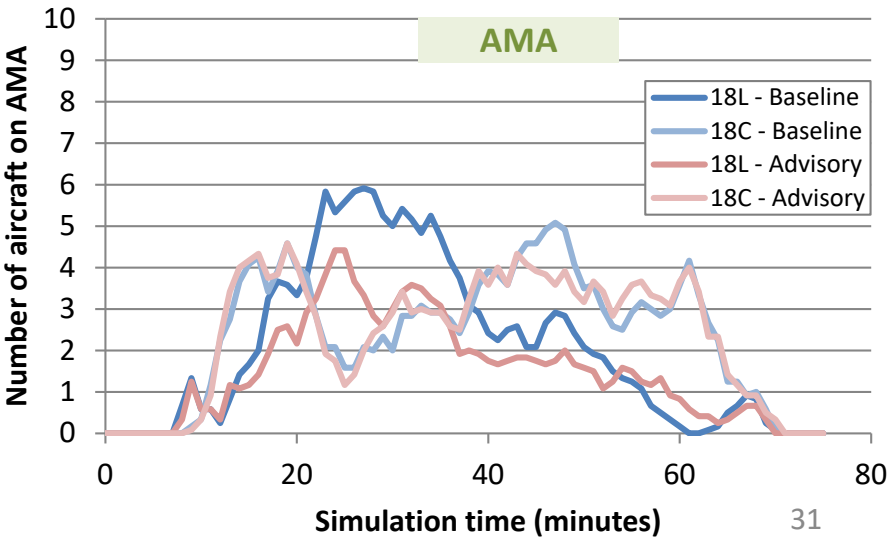


Number of Taxiing Aircraft by Area









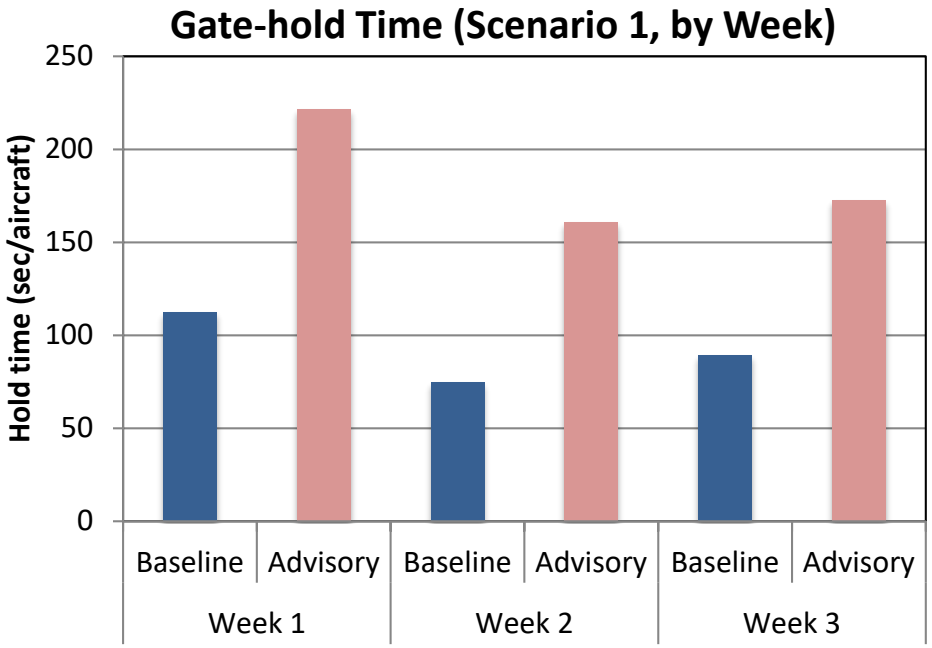
Other Performance Metrics

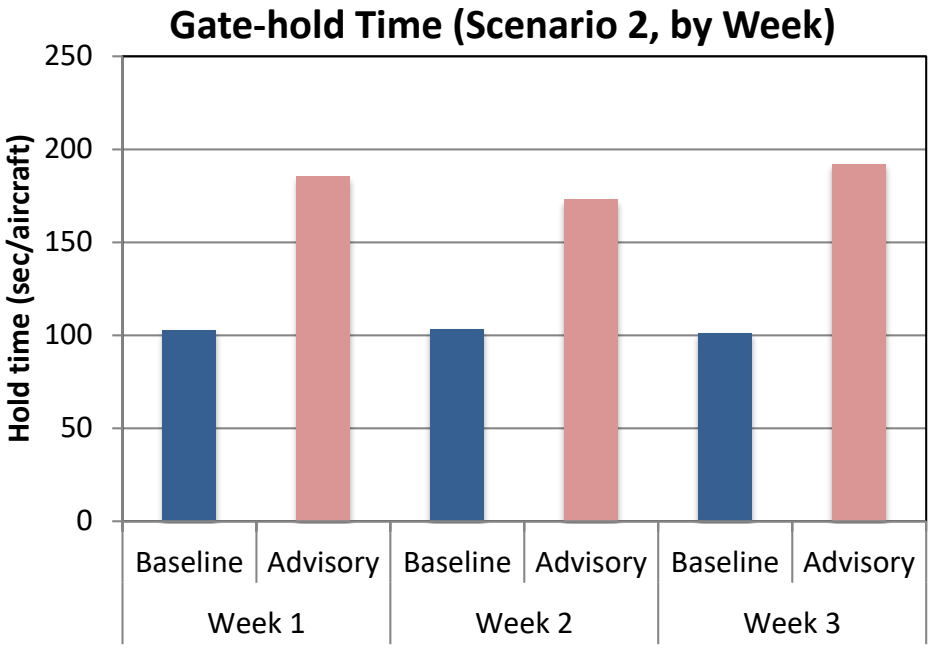
- More performance metrics will be evaluated later, including:
  - Traffic Management Initiatives (TMI) compliance
  - Pushback advisory compliance
  - MC route advisory compliance
  - Takeoff sequence advisory compliance
  - Stop-and-go frequency
  - Fuel consumption
  - Emissions

Backup

Gate-hold Time by Week

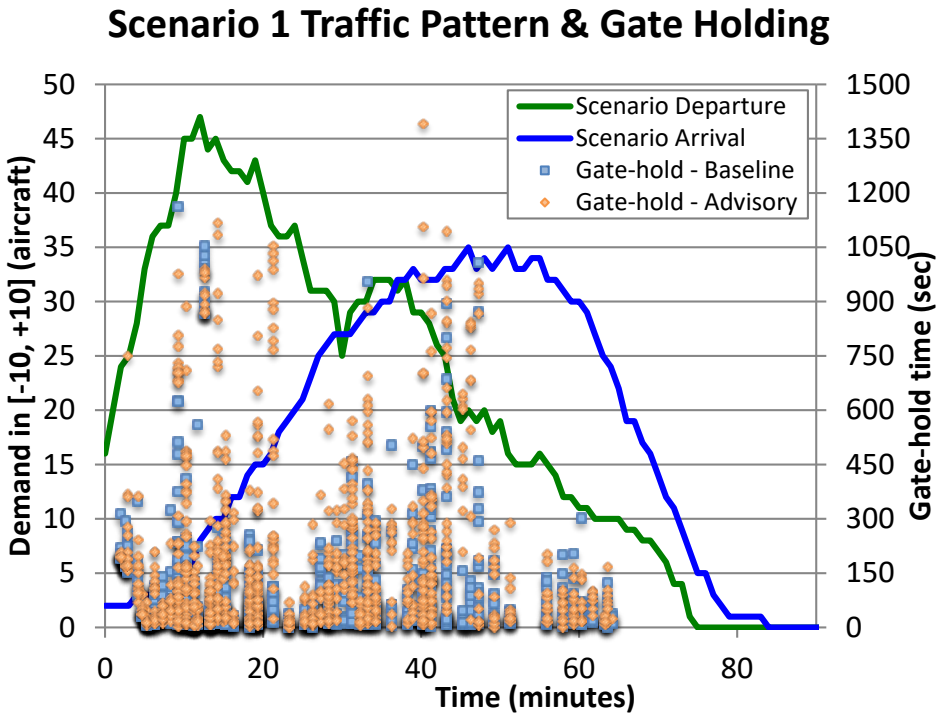
- Gate-hold times have variations week by week depending on controllers

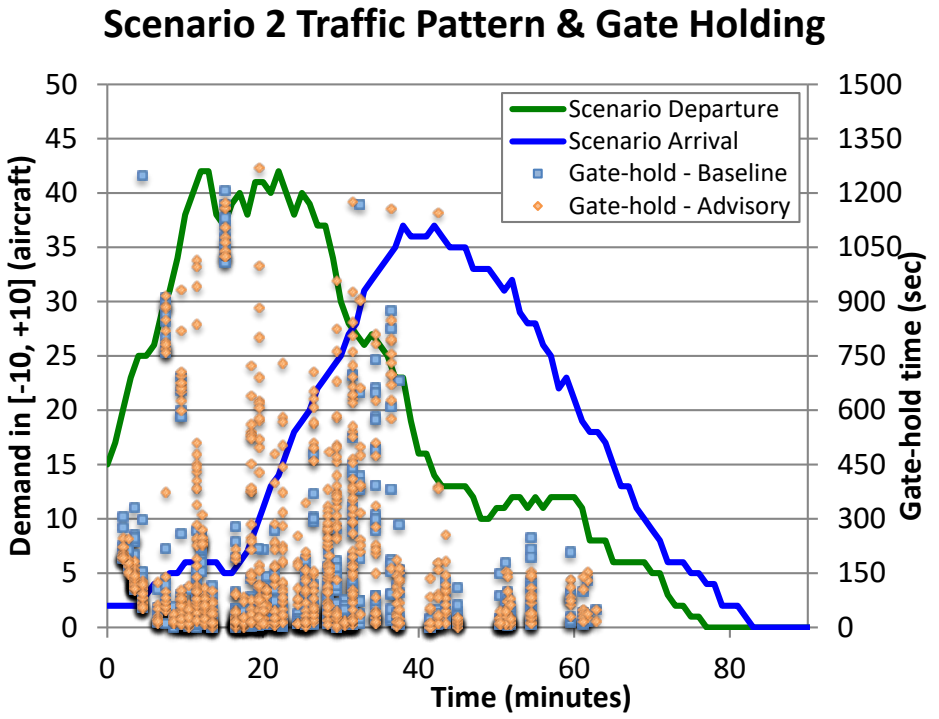




Traffic Pattern & Gate-hold Time

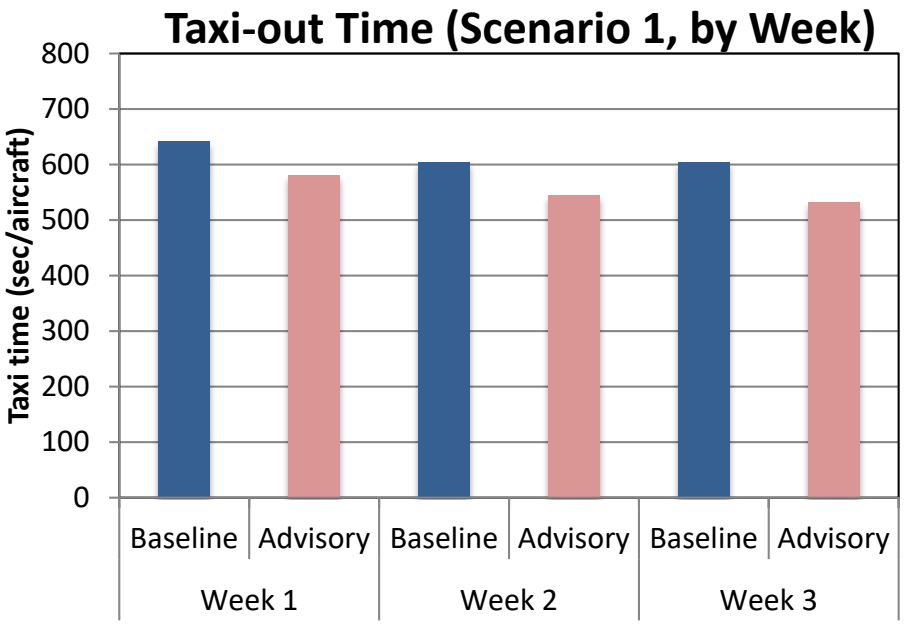
- Long gate-hold times observed frequently when traffic demand is high

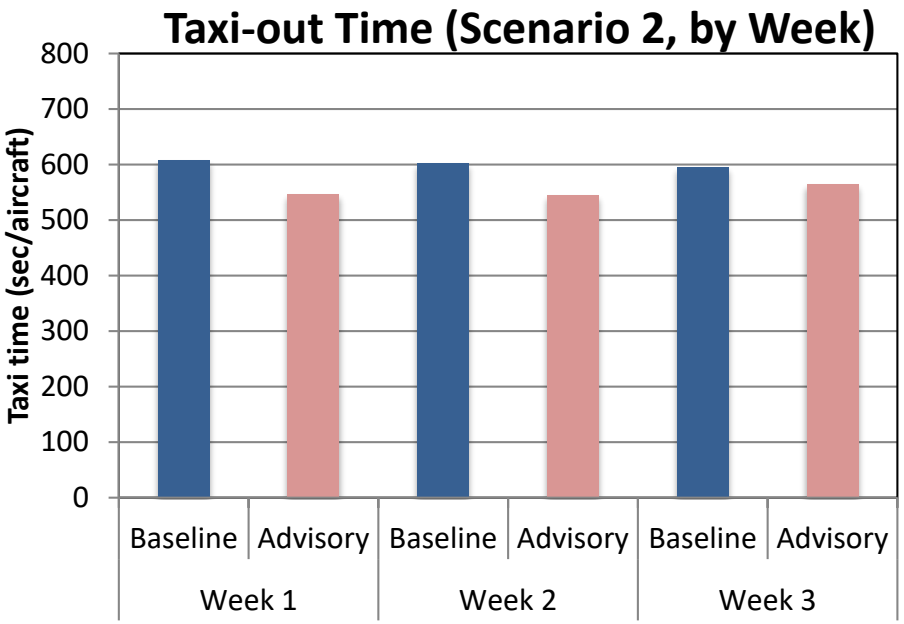




Taxi-out Time by Week

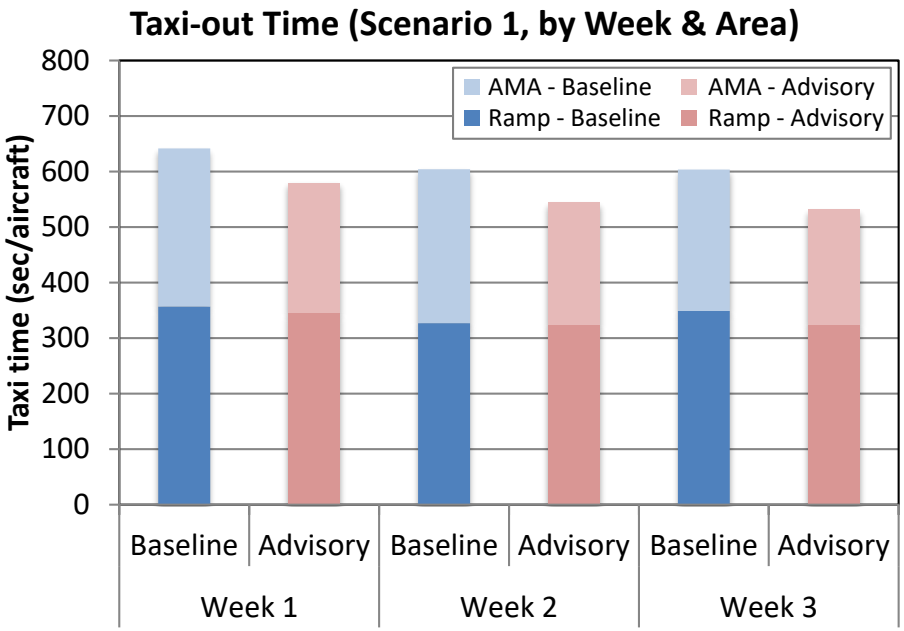
- Taxi-out times have variations week by week depending on controllers
- Taxi time reduction: 10-12% for Scenario 1 and 5-10% for Scenario 2

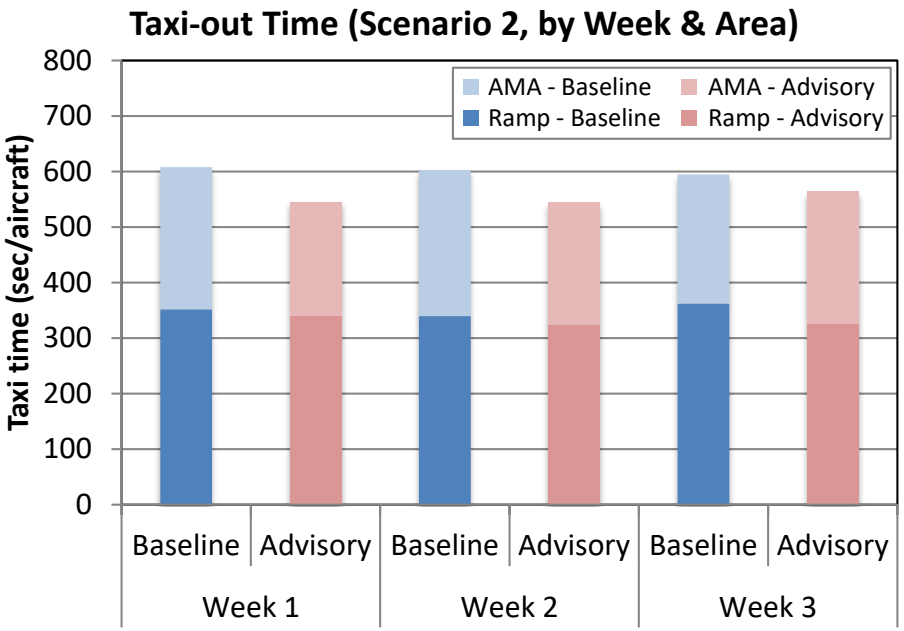




Taxi-out Time by Week & Area

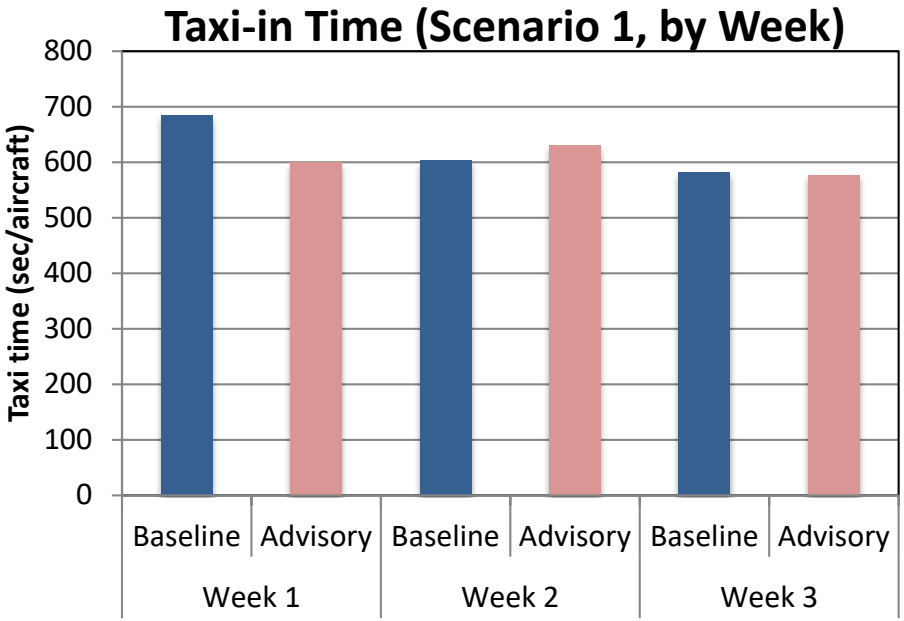
- Taxi-out times have variations week by week depending on controllers

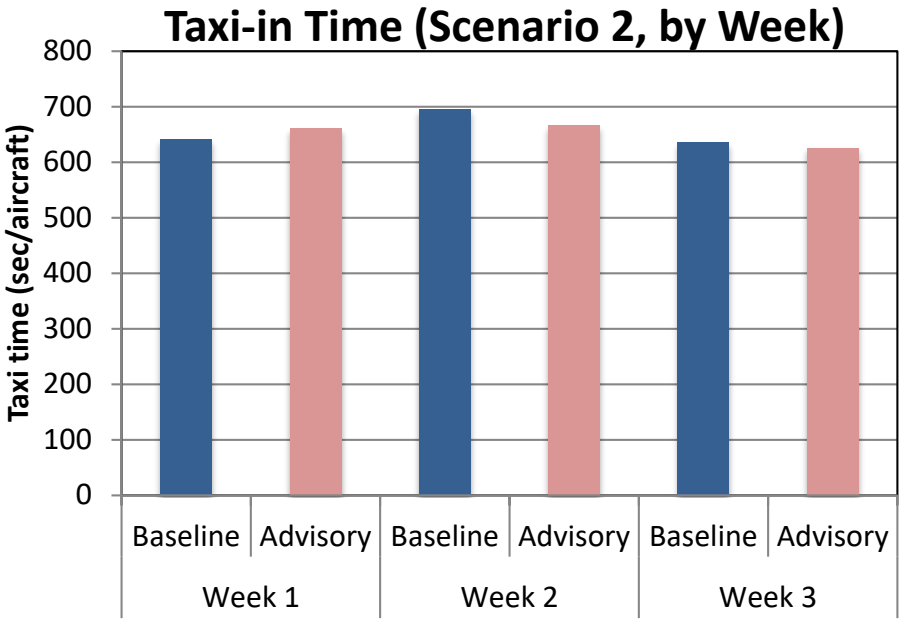




Taxi-in Time by Week

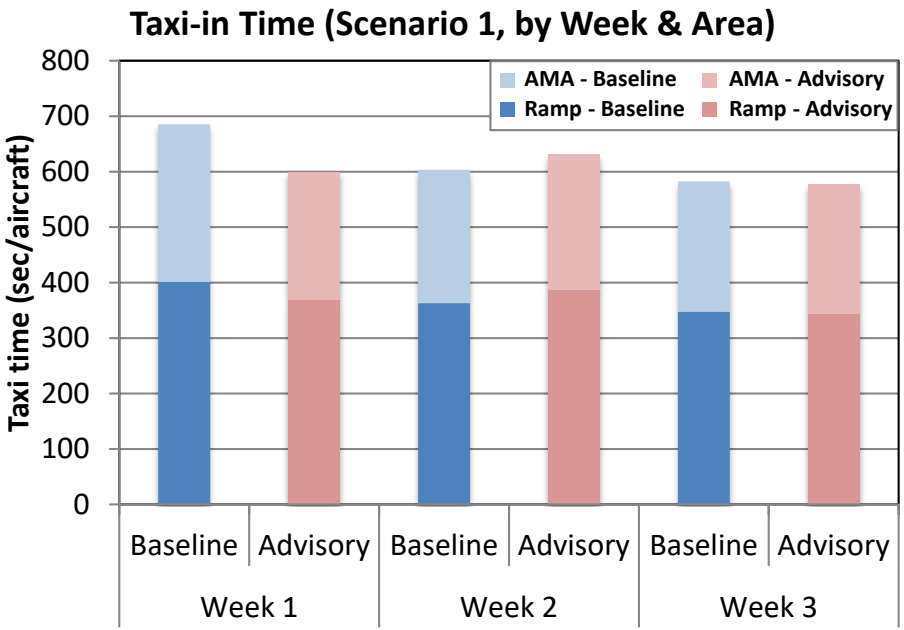
- Taxi-in times have variations week by week depending on controllers
- With Advisory, taxi-in times sometimes increase by holding arrivals at hardstands longer, but the benefit for departures is greater than the cost to arrivals

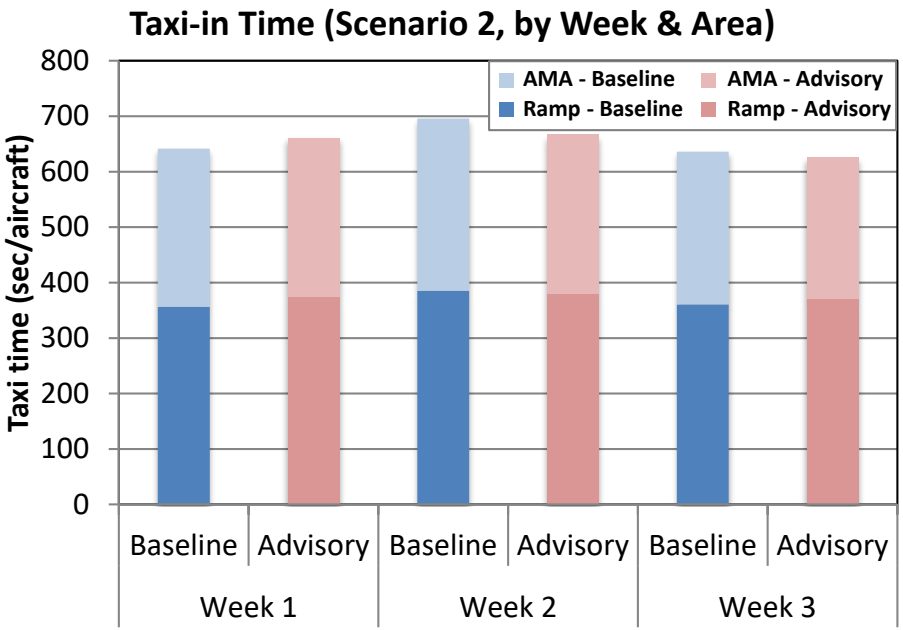




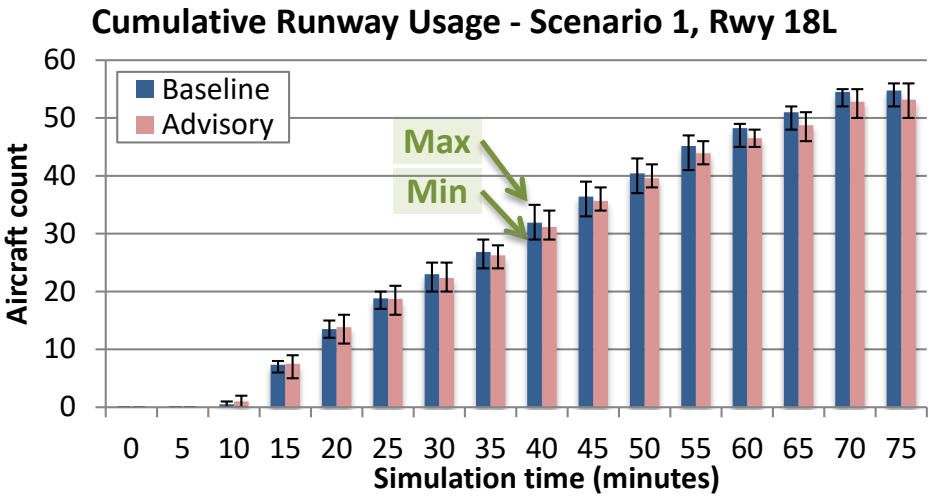
Taxi-in Time by Week & Area

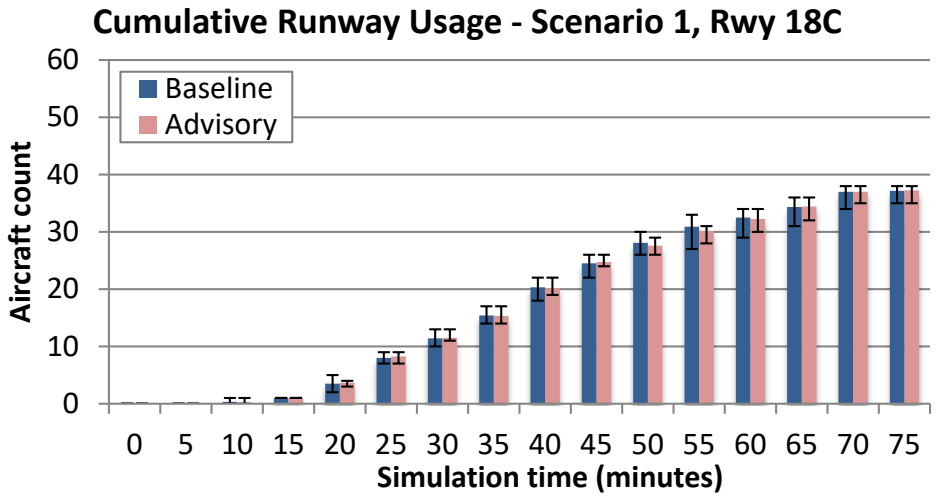
- Taxi-in times have variations week by week depending on controllers
- When the total taxi-in time increases with Advisory (Week 2 for Scenario 1 and Week 1 for Scenario 2), the increase comes from ramp area, which means longer holding at Hardstands

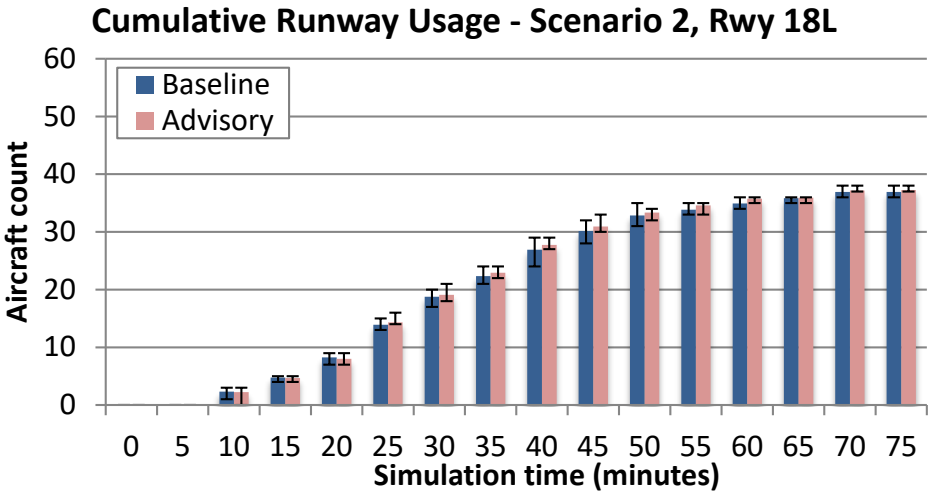


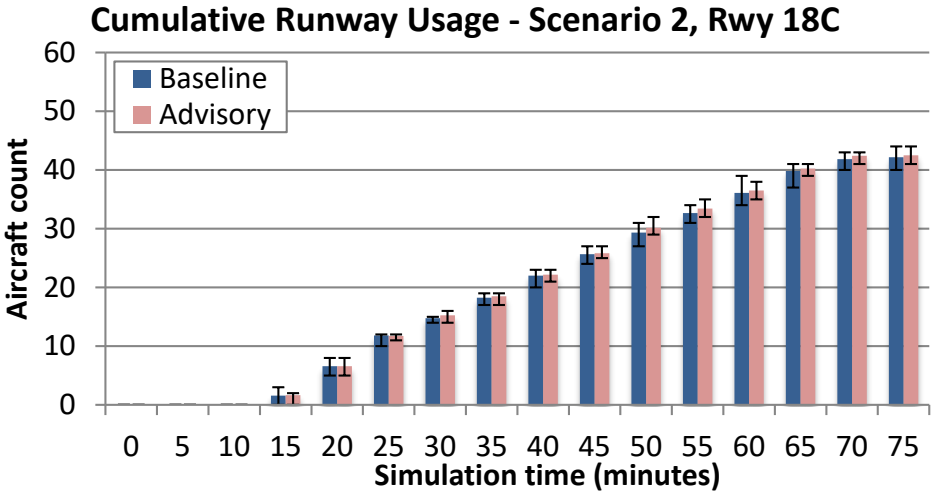


Cumulative Runway Usage

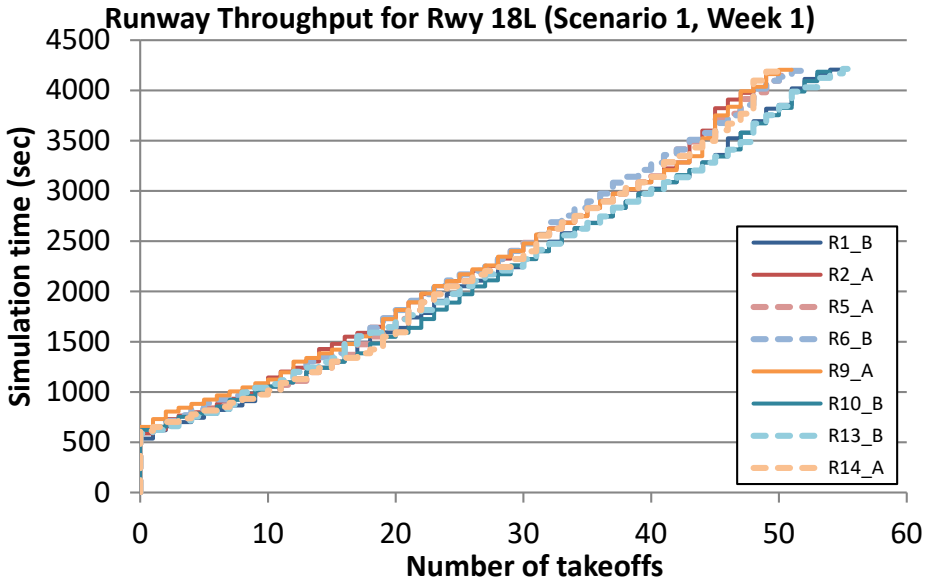


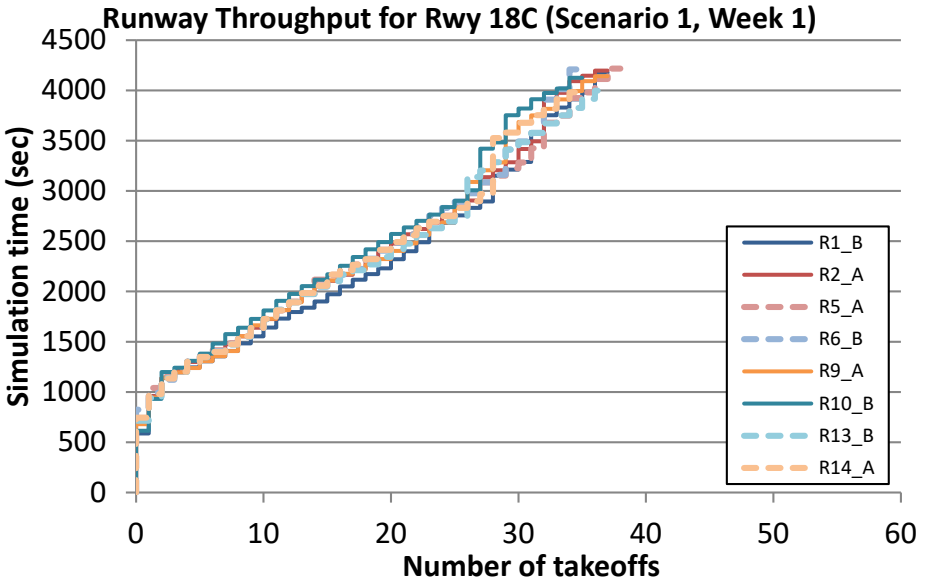


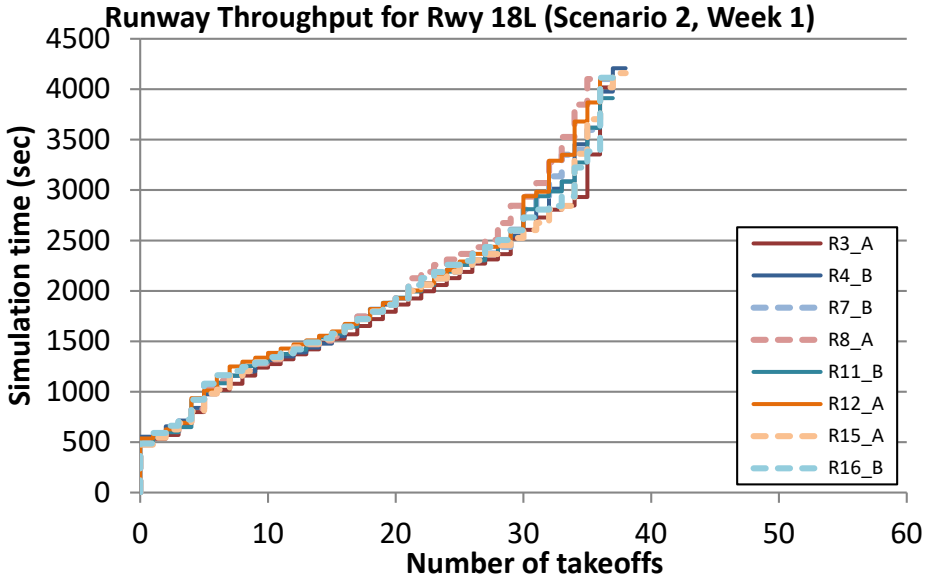


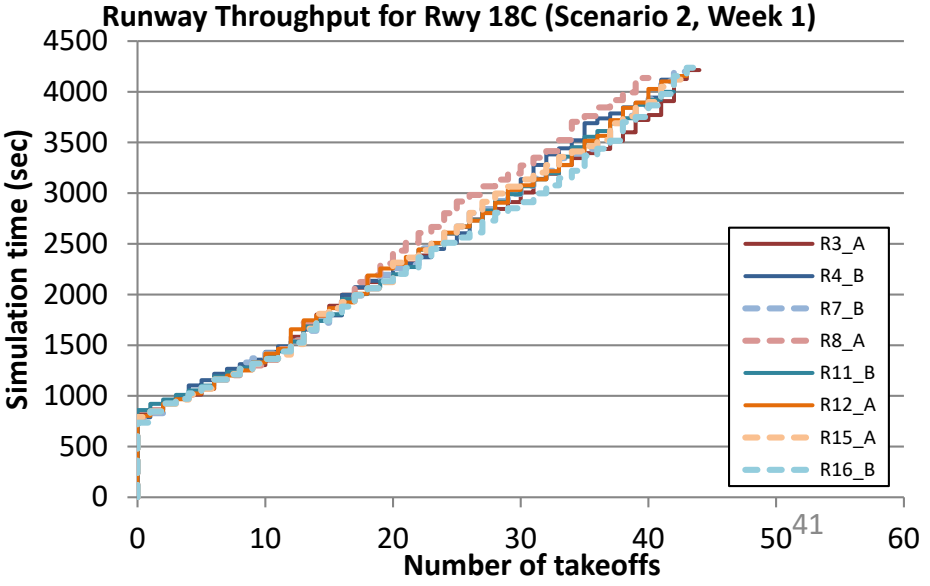


Departure Throughput (Week 1)



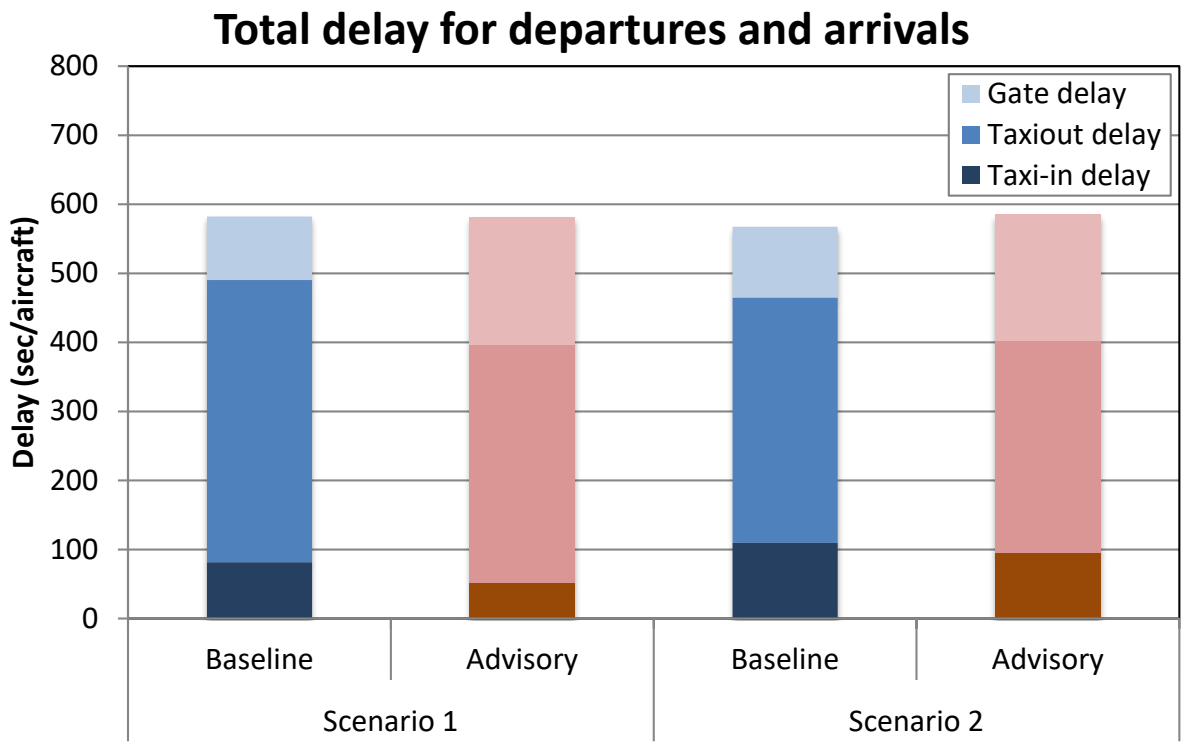






Simple Sum of Taxi Delays

- **(Taxi-out Delay per departure) + (Gate Delay per departure) + (Taxi-in Delay per arrival)**



<u>0.02 min</u> decrease in Scenario 1 (-0.2%)
<u>0.30 min</u> increase in Scenario 2 (3.2%)