SARDA HITL #6 Simulation: System Performance Analysis

NASA Ames Research Center/ American Airlines
January 20-21, Fort Worth, TX

SARDA Concept

- Goal: A collaborative decision support tool for airlines and tower controllers to enhance the efficiency of surface traffic.
  - Airline Operator Advisory
    - Provide gate push-back times and MC use to the ramp controllers (CLT)
  - Ground Controller Advisory
    - Provide spot/ramp release schedule to reduce taxi delay while maintaining runway throughput
  - Local Controller Advisory
    - Provide take-off and crossing sequence for efficient and safe runway usage

HITL #6 Simulation Objectives

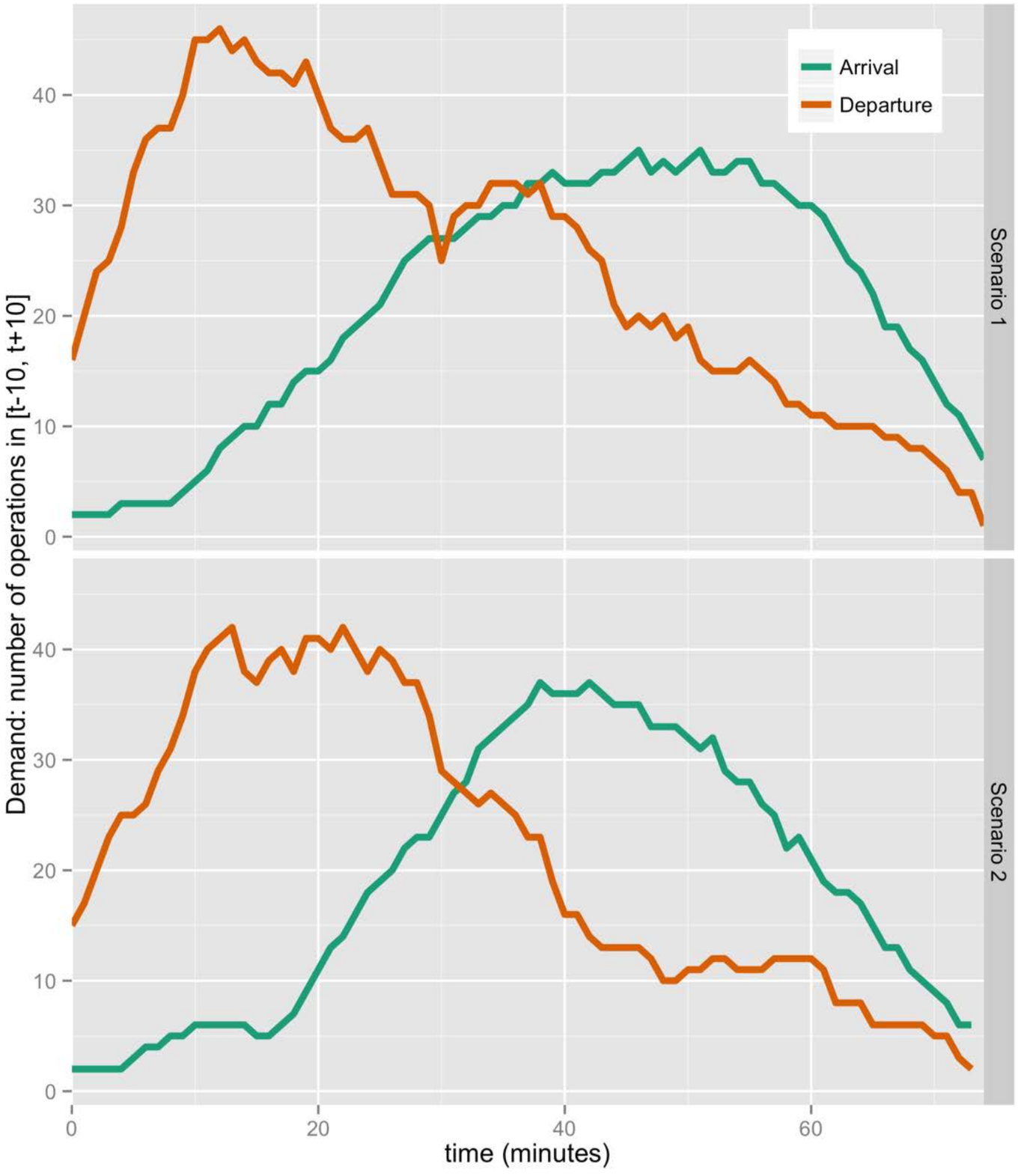
- Evaluate effects of the SARDA ramp controllers tool by comparing the two types of runs:
  - Baseline runs as current day operations (e.g., <15 in queue)
  - Advisory runs with SARDA scheduler
- SARDA advisories
  - Pushback advisories provide hold time
  - MC advisories provide advisory to indicate the flights that should be given the MC bypass option

Simulation Details [1]

- Two scenarios based on actual traffic data (5/16/2013)
- 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 15 nm, EDCT) in effect

Traffic Scenarios

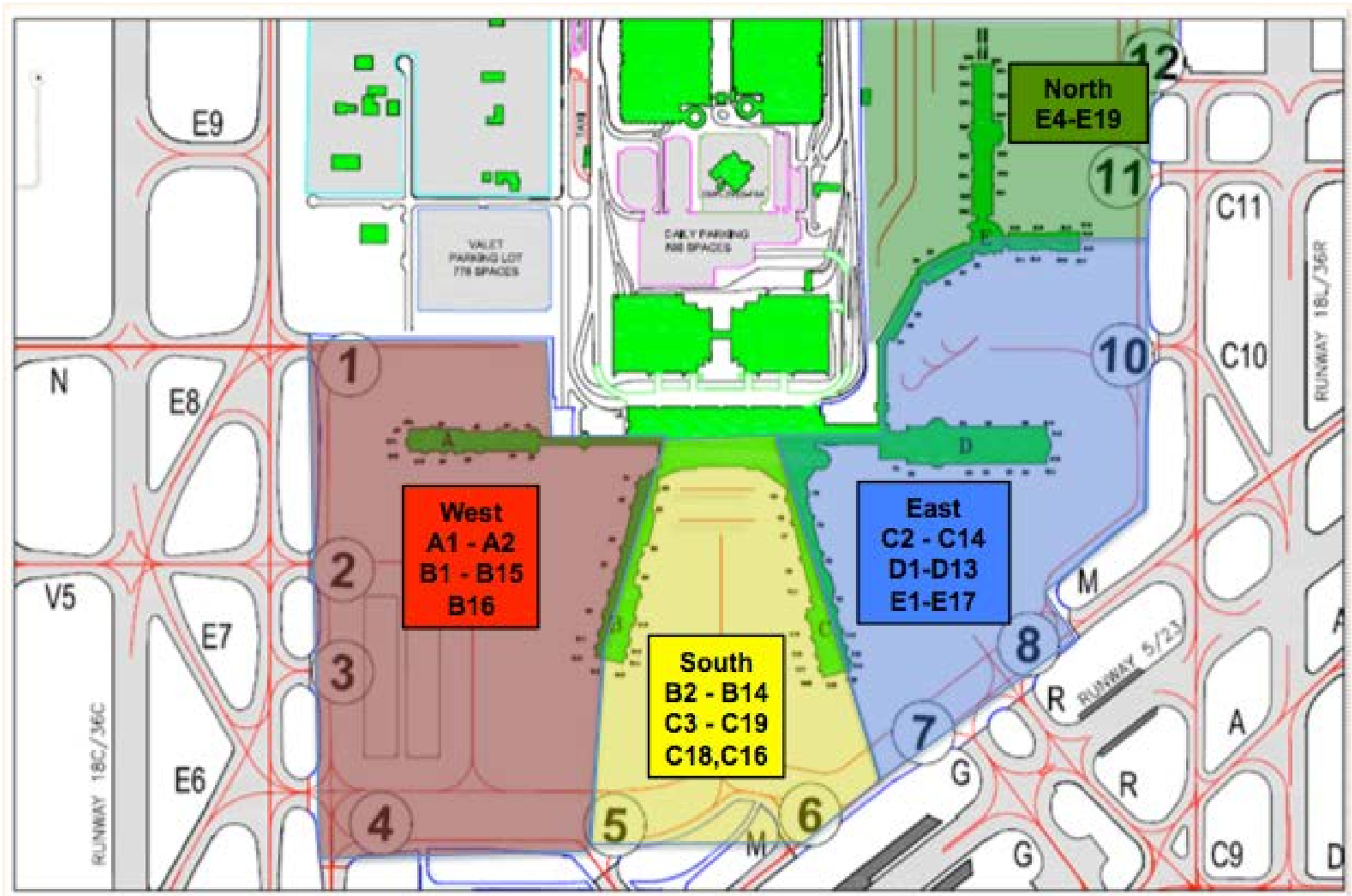
- Two one-hour long scenarios
  - based on actual recorded traffic data from CLT (May 16, 2013)
  - compressed slightly in time
- Departure push followed by arrival push
- Scenario 1:
  - 96 departures & 80 arrivals
- Scenario 2:
  - 84 departures & 72 arrivals



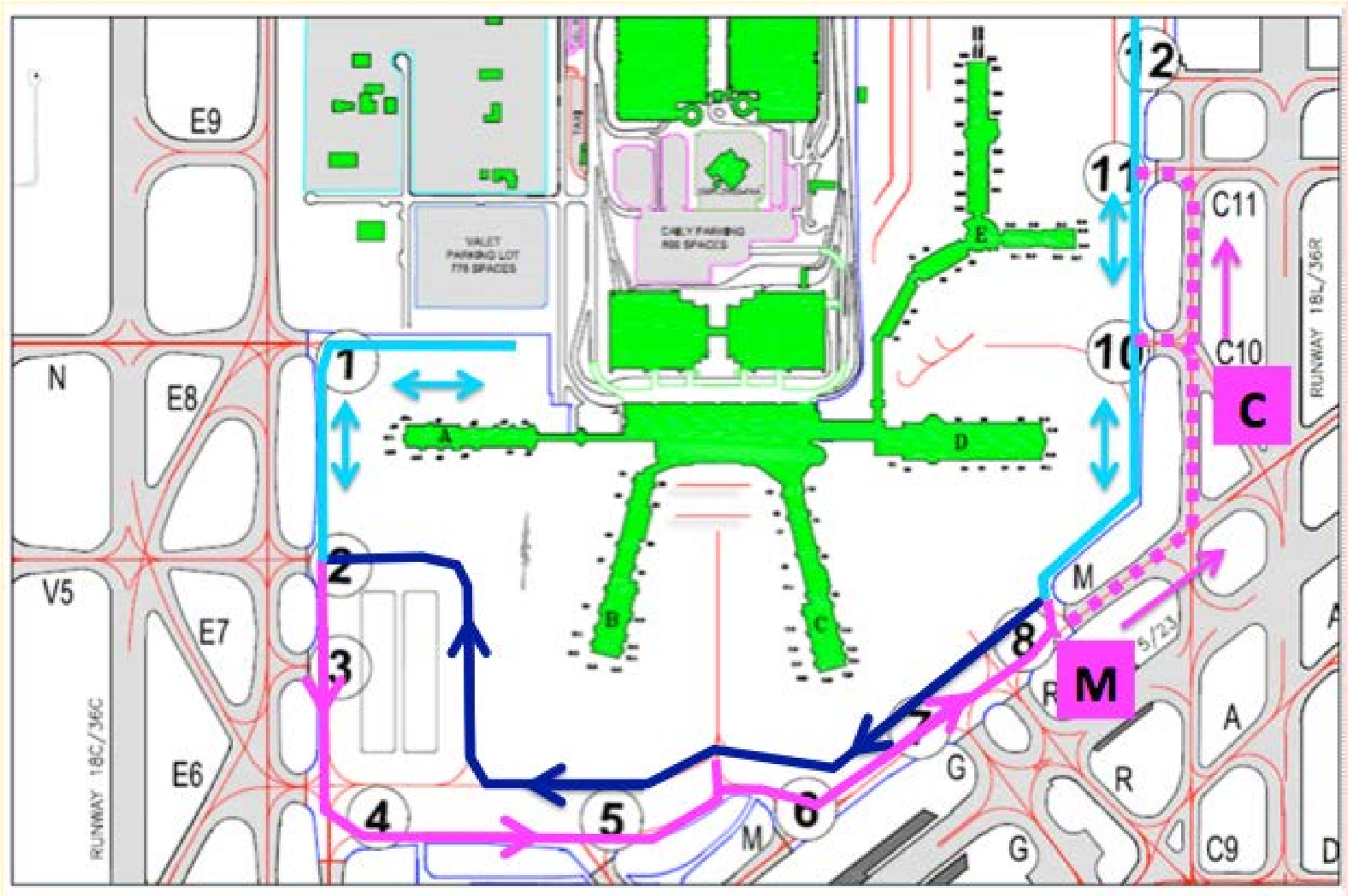
Simulation Details [2]

- 3 weeks – total of 48 scenario runs
- 4-sector configuration for ramp area
- 4 ramp controllers (2 from CLT)
- 1 ramp traffic manager by a NASA researcher
- 3 ATC controllers (2 Local and 1 Ground)
- 9 pseudo-pilots

4-Sector Ramp Configuration



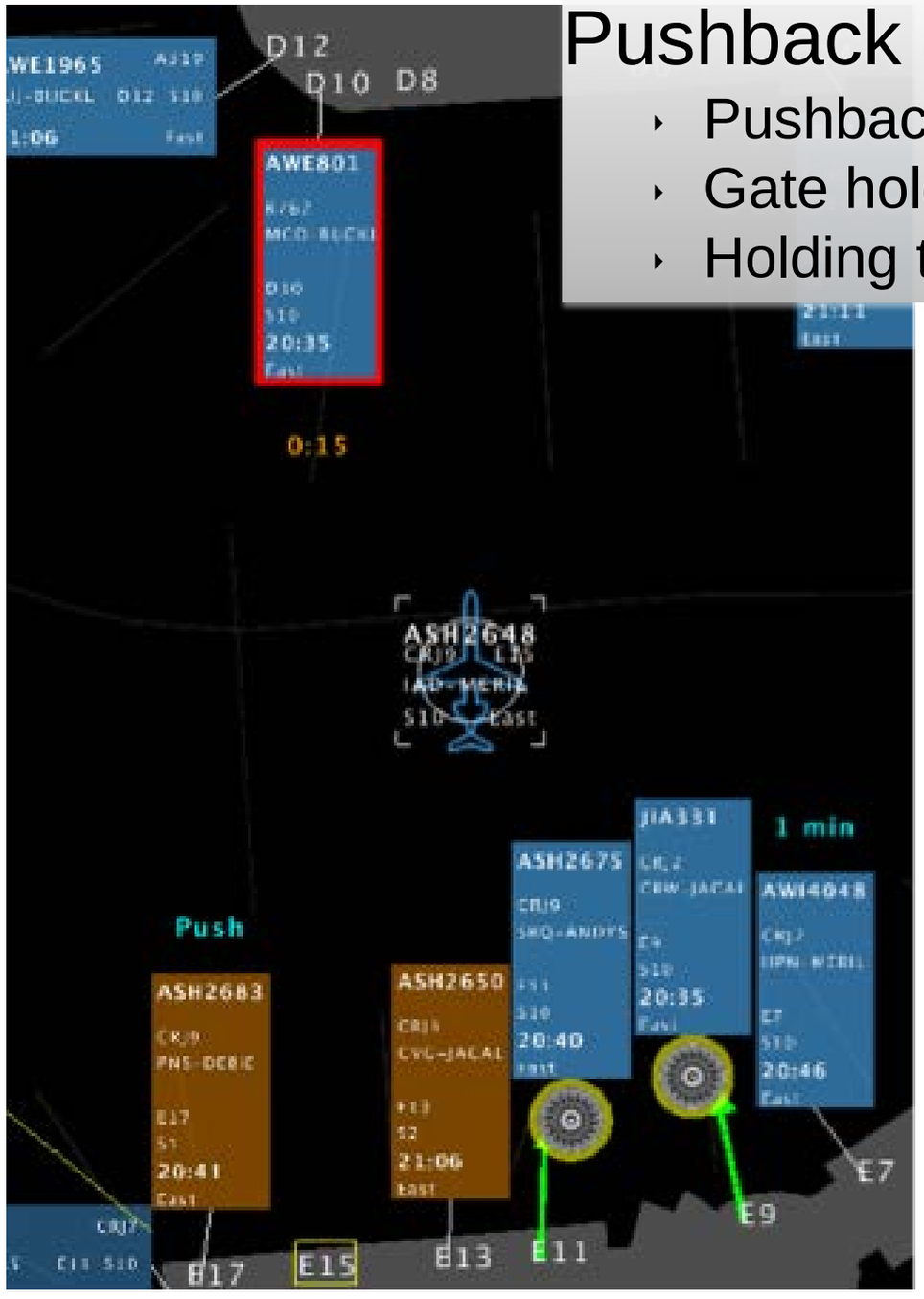
MC Bypass Taxiway



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

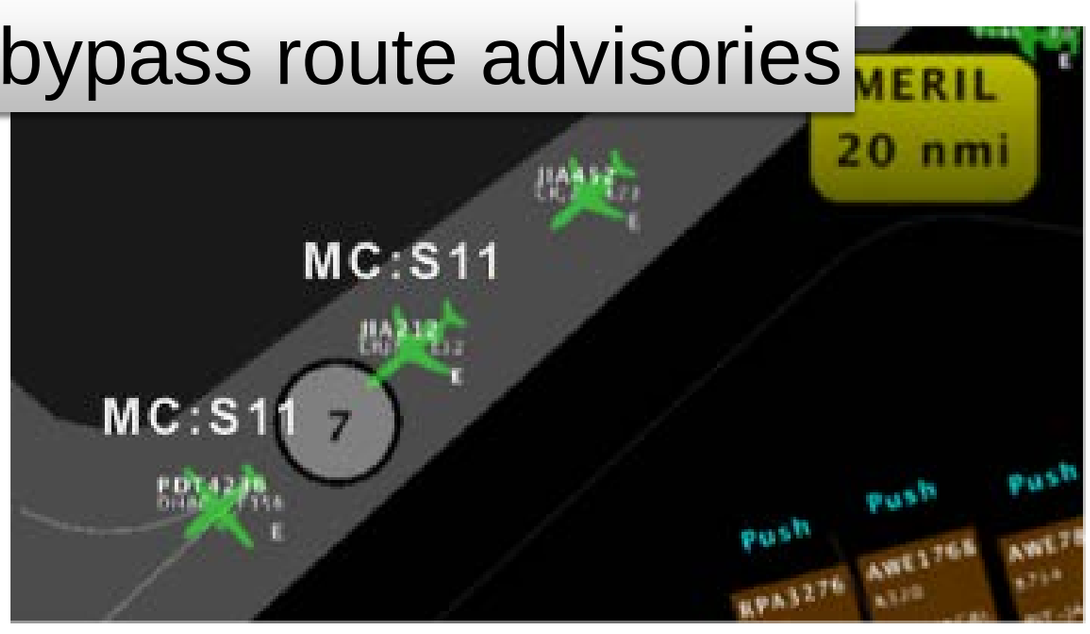
Ramp Traffic Console (RTC)



Pushback advisories

- Pushback
- Gate hold
- Holding time

MC bypass route advisories



Data Collected

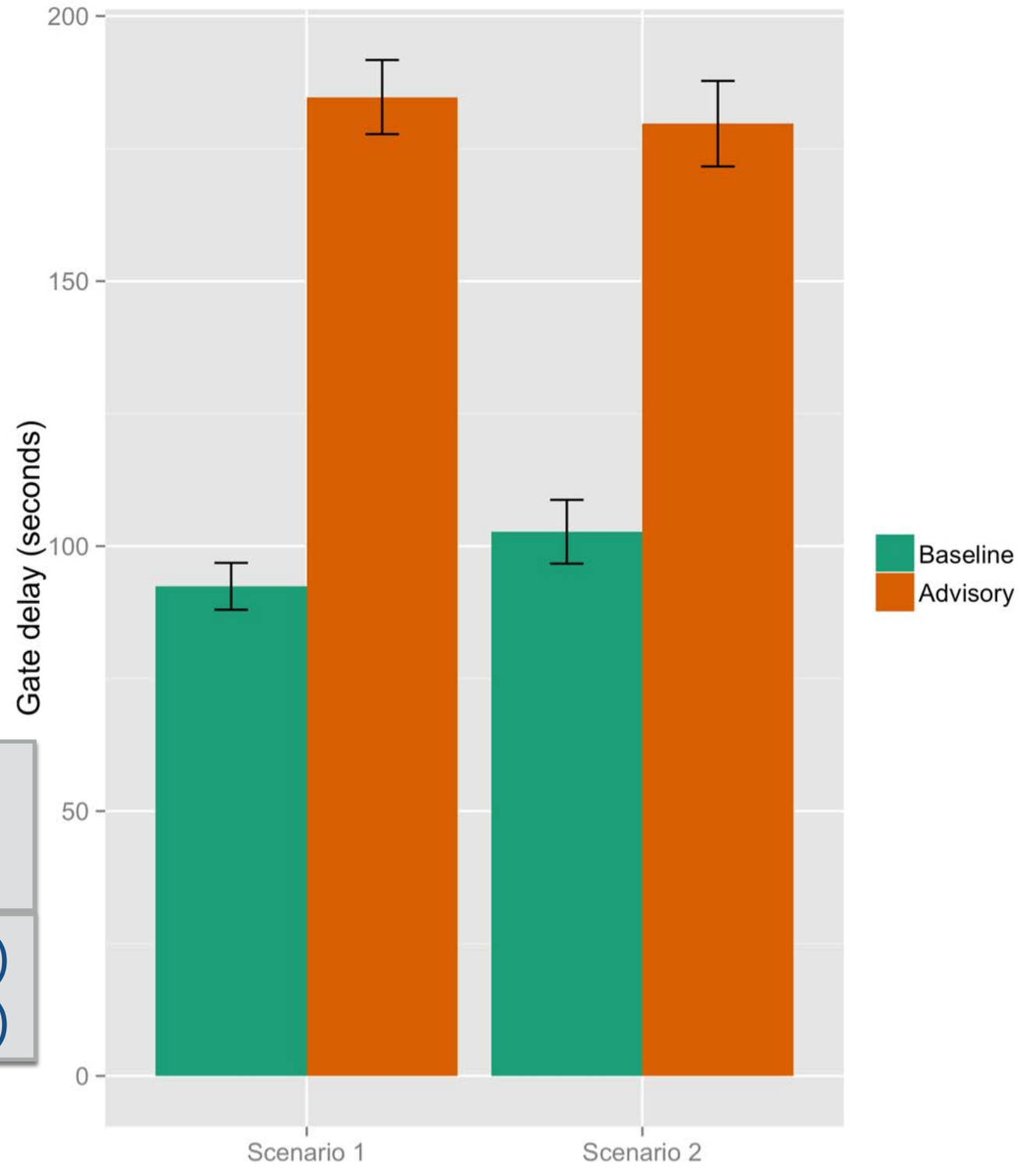
- Aircraft tracks
- Scheduler inputs and outputs
- ATC controller inputs
- Ramp controllers inputs
- Voice/video recordings
- Workload measurements
- Post run & post study surveys

Simulation Observations

- Did SARDA hold back aircraft at the gate?
- Was there any loss in runway usage due to holding?
- What are the observed benefits?
  - Reduced congestion on ramp and taxiways
  - Taxi times
  - Fuel and emission
  - TMI Conformance

Gate Hold

gate_delay = actual_out_time -
scheduled_pushback_time

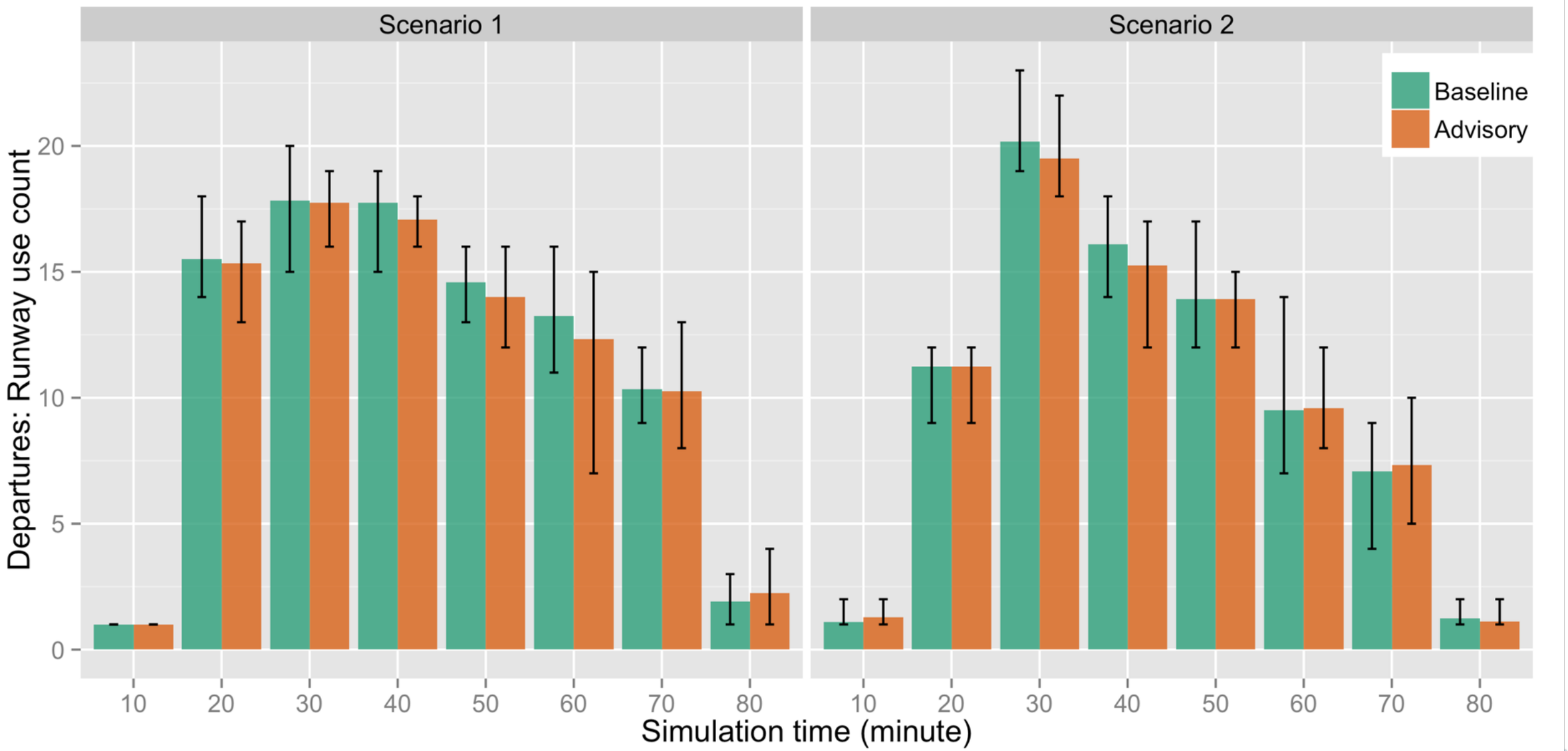


Departures are held at gates longer in Advisory runs

1.53 min increase in Scenario 1 (99.7%)
1.29 min increase in Scenario 2 (75.4%)

Runway Usage

No observable reduction in runway usage with advisory



Simulation Observations

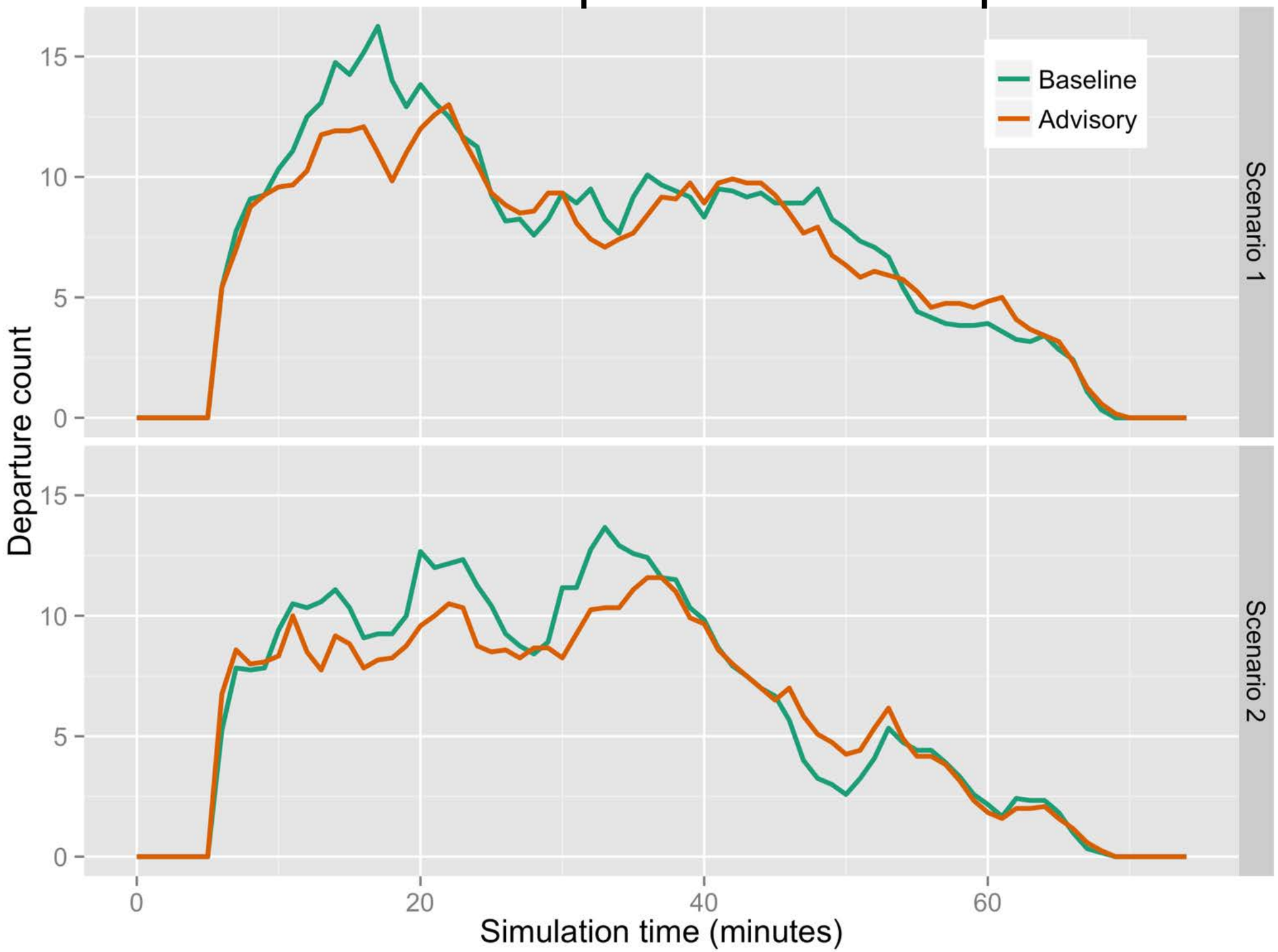
✓ Did SARDA hold back aircraft at the gate?

✓ Was there any loss in runway usage due to holding?

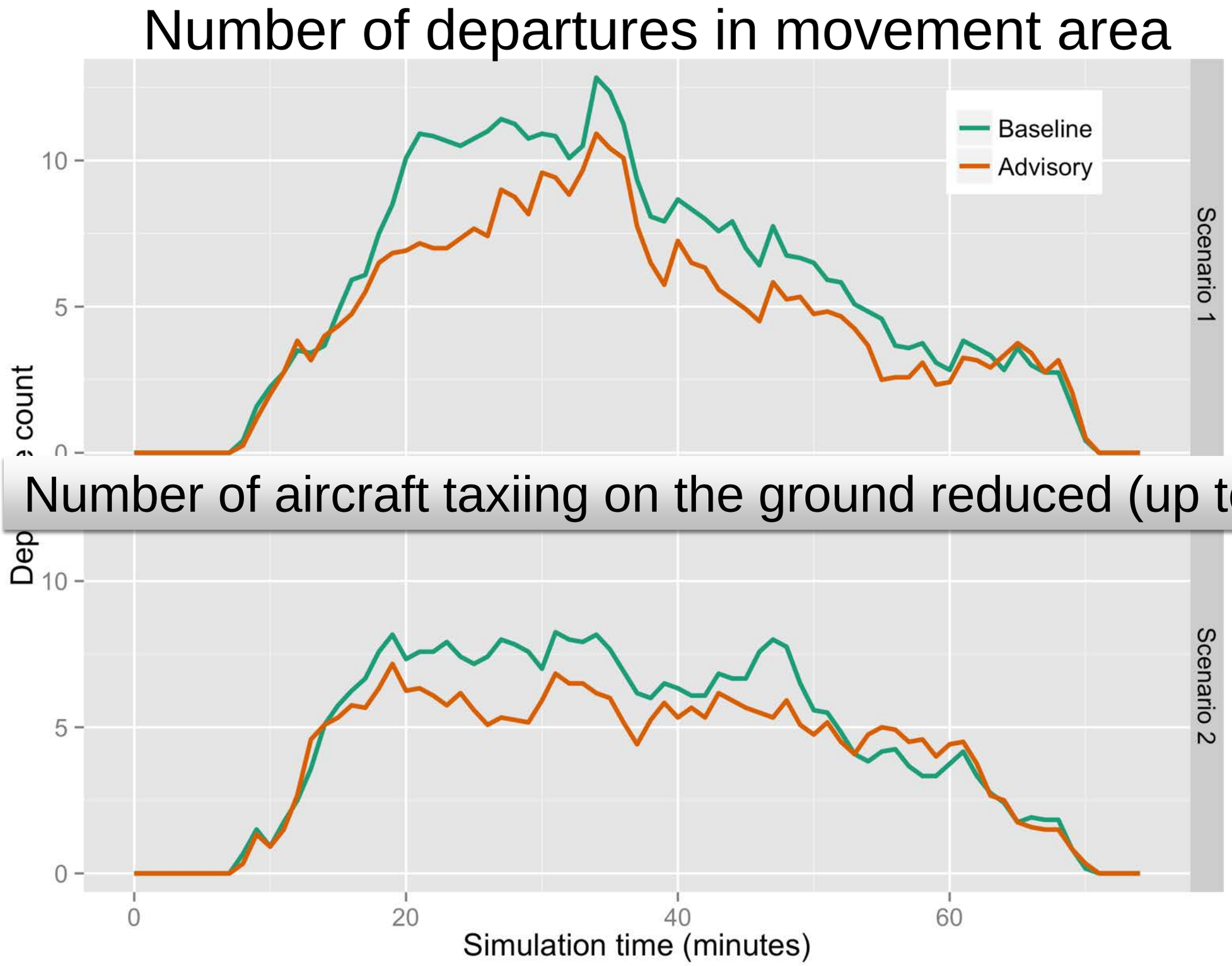
- What are the observed benefits?
  - Reduced congestion on ramp and taxiways
  - Taxi times
  - Fuel and emission
  - TMI Conformance

Surface Congestion

Number of departures in ramp area



Surface Congestion



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

Taxi Times

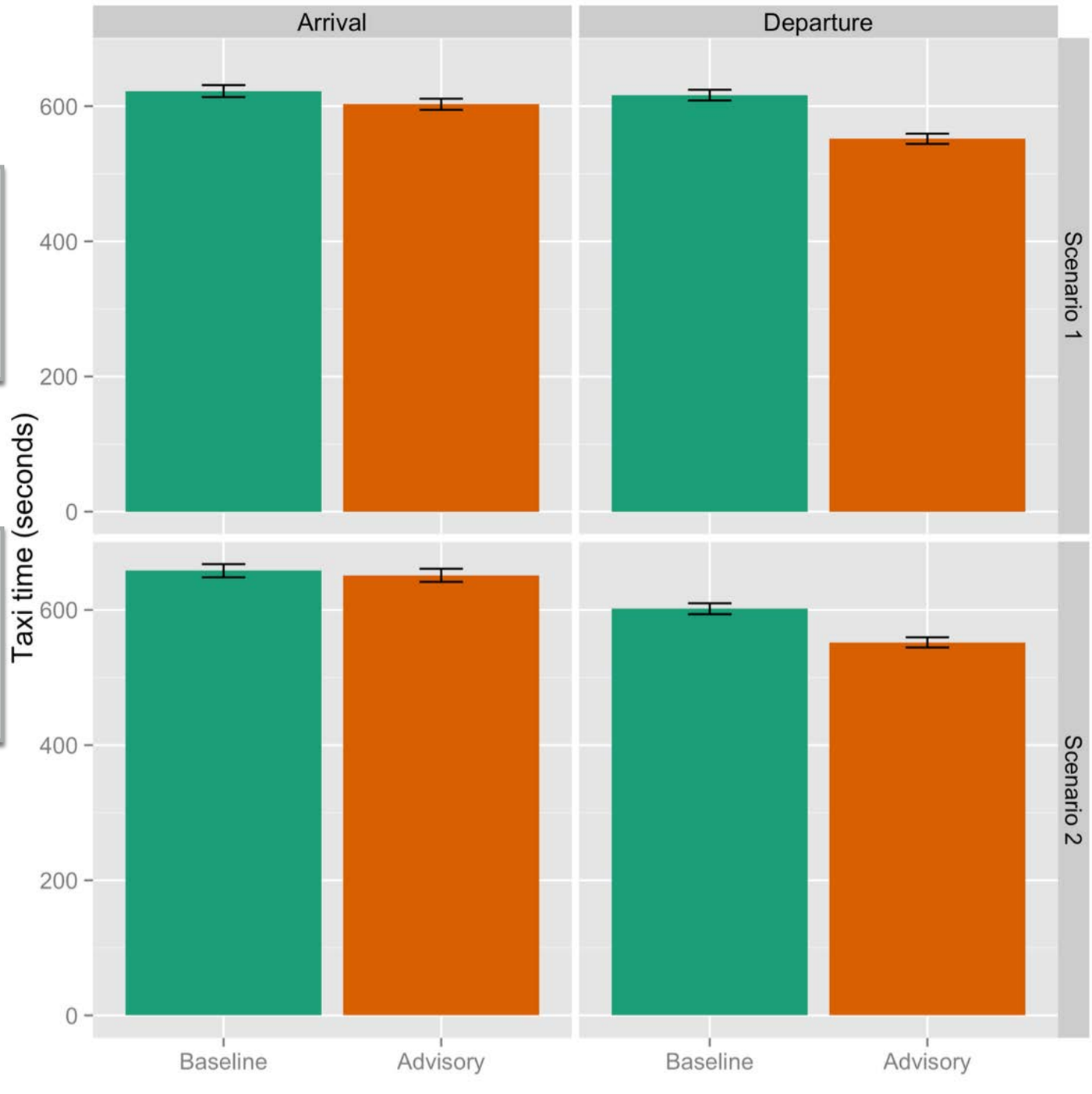
taxi-out_time = actual_off_time - actual_out_time
taxi-in_time = actual_in_time - actual_on_time

Arrivals

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

Departures

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



Fuel & Emissions Calculation

- Engines are off if aircraft is held at the gate
- Engine thrust level: 7% during all the taxi phases
- Two engines are running while taxiing

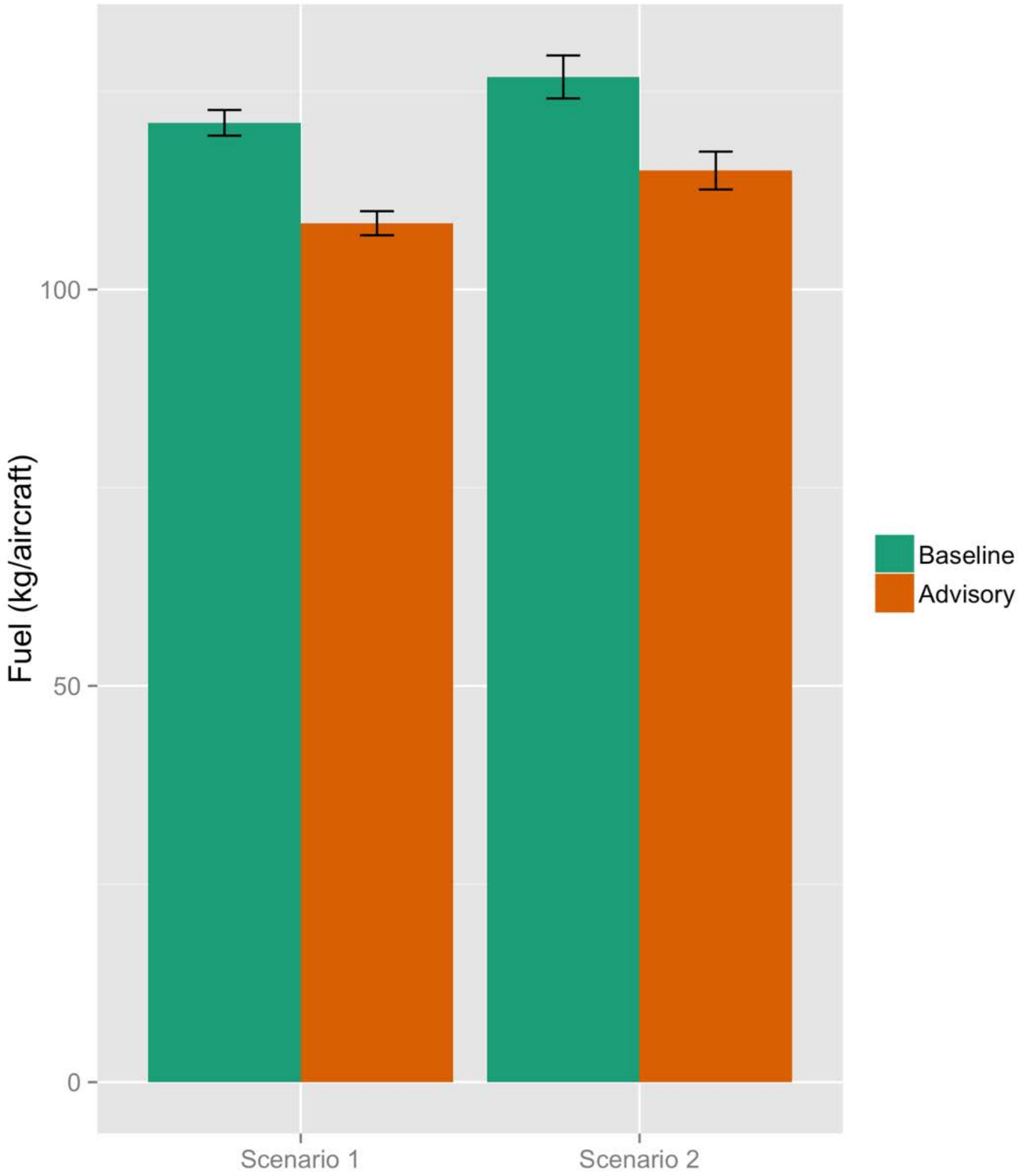
AC Type	Assumed AC Model	Assumed Engine Type	EI HC (g/kg)	EI CO (g/kg)	EI NOx (g/kg)	Fuel Flow (kg/sec)
Heavy	B772	Trent 892	1.59	29.62	8.88	0.57
B757	B752	RB211-535E4	0.56	19.40	7.33	0.34
Large	A319	CFM56-5A5	3.47	41.92	7.15	0.19

Fuel Savings

Departures

12.7 kg/flight saved in Scenario 1 (10.5%)
11.8 kg/flight saved in Scenario 2 (9.3%)

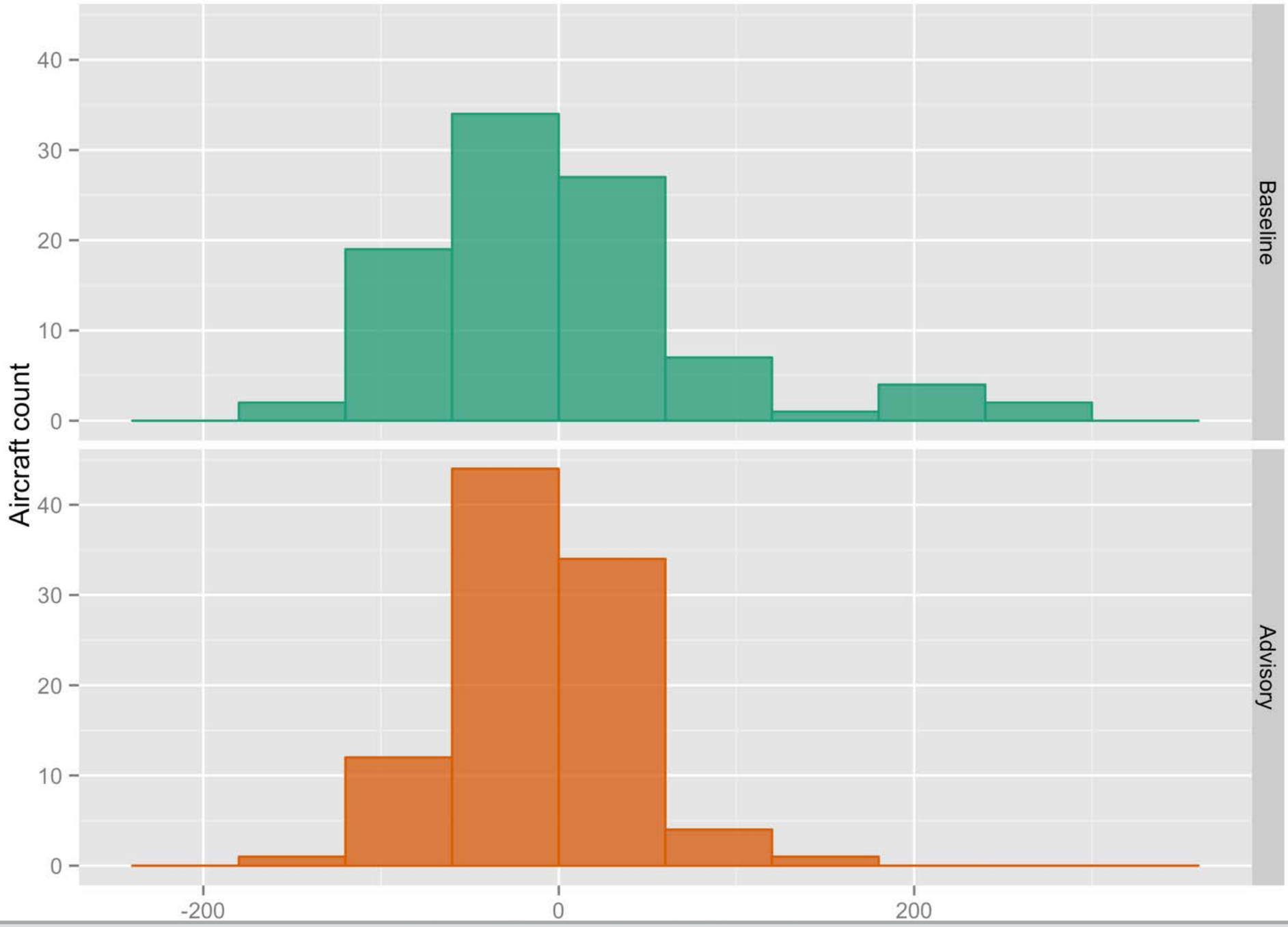
1.3 tonnes saved in Scenario 1 (12%)
1.1 tonnes saved in Scenario 2 (10.4%)



TMI Conformance

- Each scenario included five departures that had an assigned TMI
- Tower controllers were asked to release TMI departures within 1-minute window
- The observed take-off time was compared to the assigned TMI

TMI Conformance



Advisory runs resulted in smaller variances in the TMI deviations than Baseline runs

HITL #6 - Summary

- Aircraft were held at the gate longer with advisories.
- No significant differences in runway usage.
- Number of aircraft taxiing on the ground reduced (up to 4)
- Taxi-out times were reduced (8-10%)
- Fuel savings for departures:
  - 1.3 tonnes in Scenario 1,
  - 1.1 tonnes in Scenario 2
- Better TMI conformance.

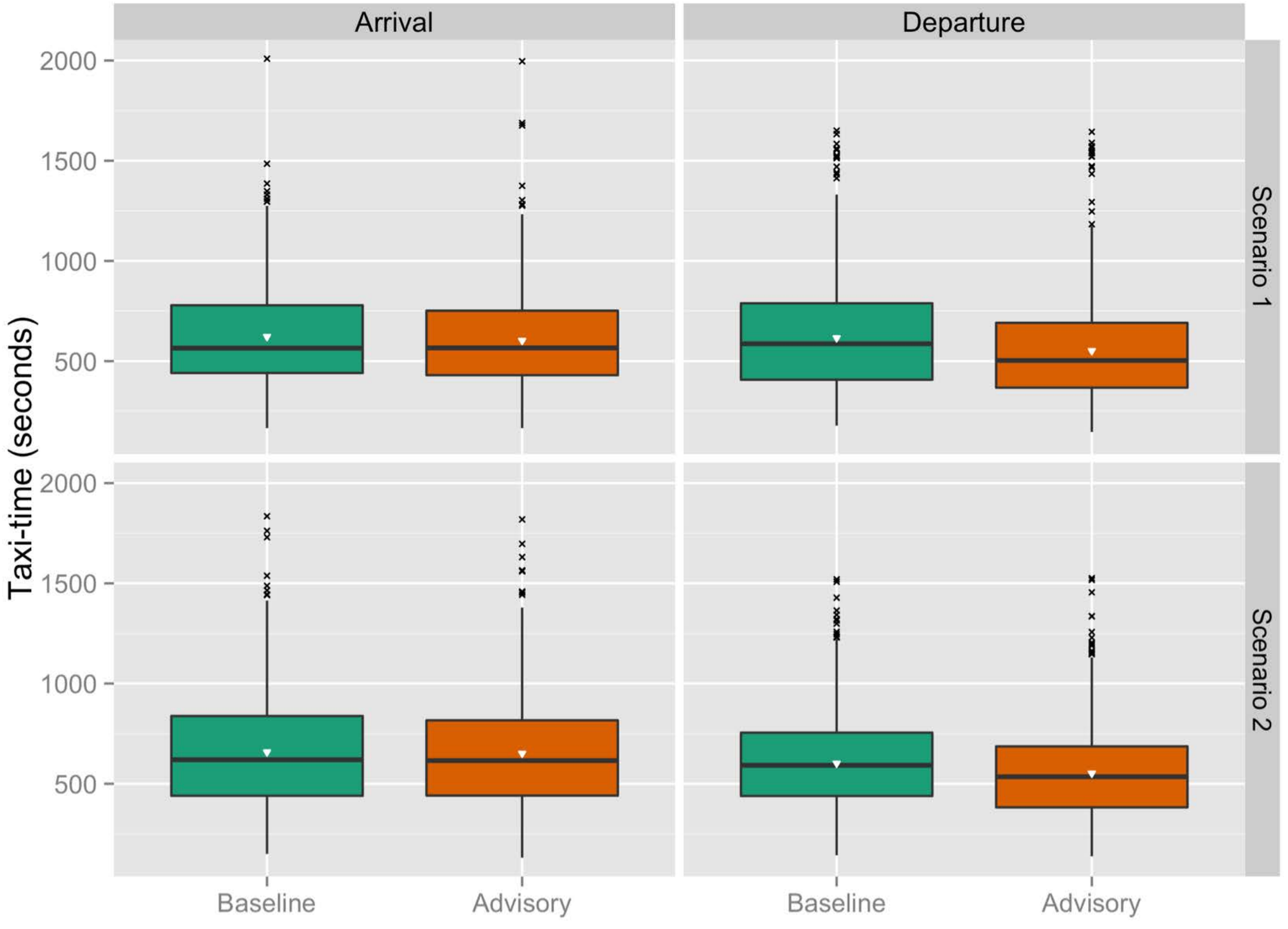
Other Performance Metrics

More performance metrics will be available later:

- Pushback advisory compliance
- MC route advisory compliance
- Takeoff sequence advisory compliance
- Stop-and-go frequency
- Emissions

Backup Slides

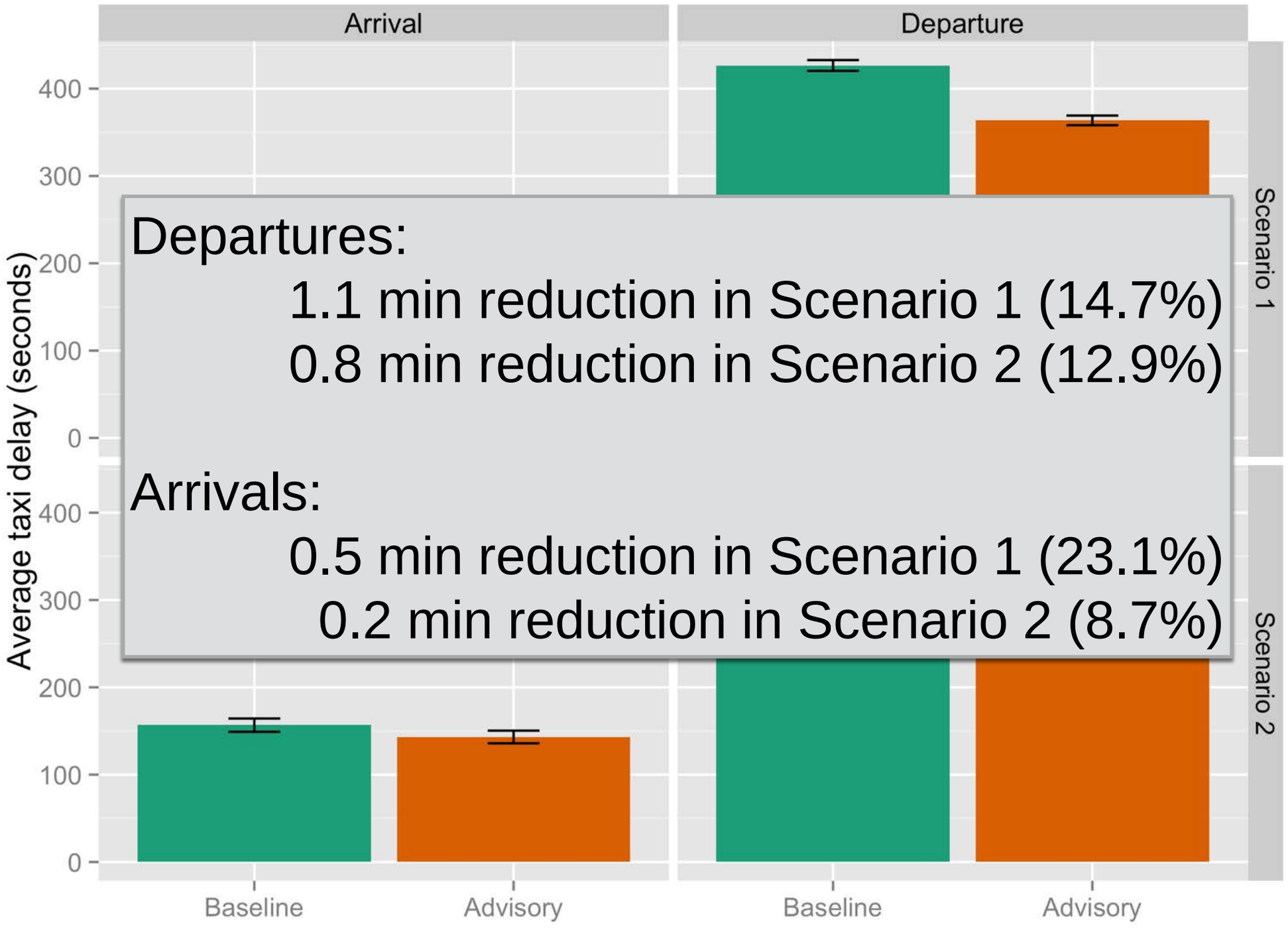
Taxi Times Distribution



Taxi Delay

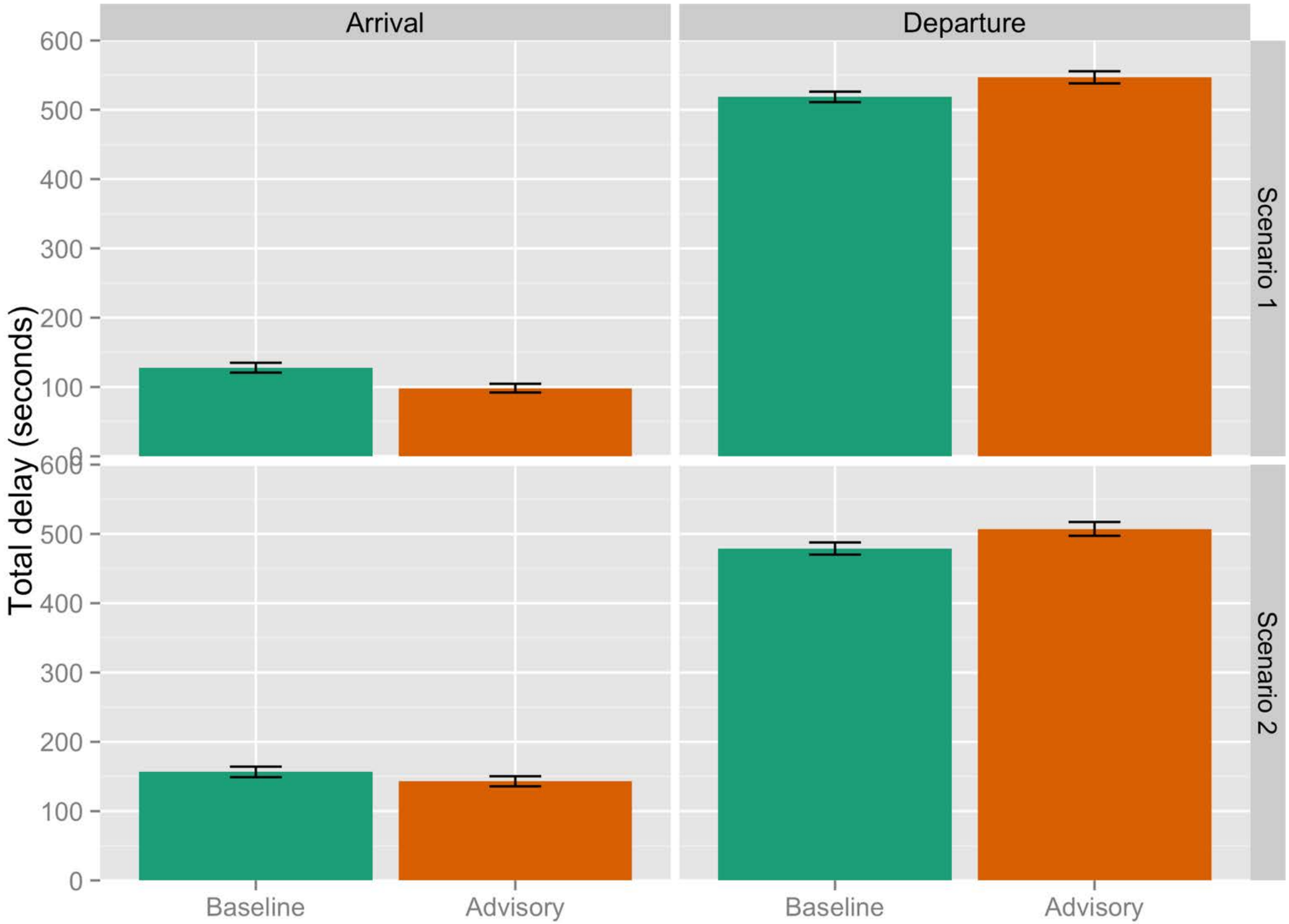
- Taxi-Delay = Actual_Taxi_Time – Unimpeded_Taxi_Time
- Unimpeded taxi time: time to travel on that route (gate-spot-runway combination) at 17 knots (8.75 m/s) without stops

Taxi Delay


Arrival
Departure
Scenario 1
Scenario 2
Average taxi delay (seconds)
400
300
200
100
0
Baseline
Advisory
Baseline
Advisory
Departures:
1.1 min reduction in Scenario 1 (14.7%)
0.8 min reduction in Scenario 2 (12.9%)
Arrivals:
0.5 min reduction in Scenario 1 (23.1%)
0.2 min reduction in Scenario 2 (8.7%)

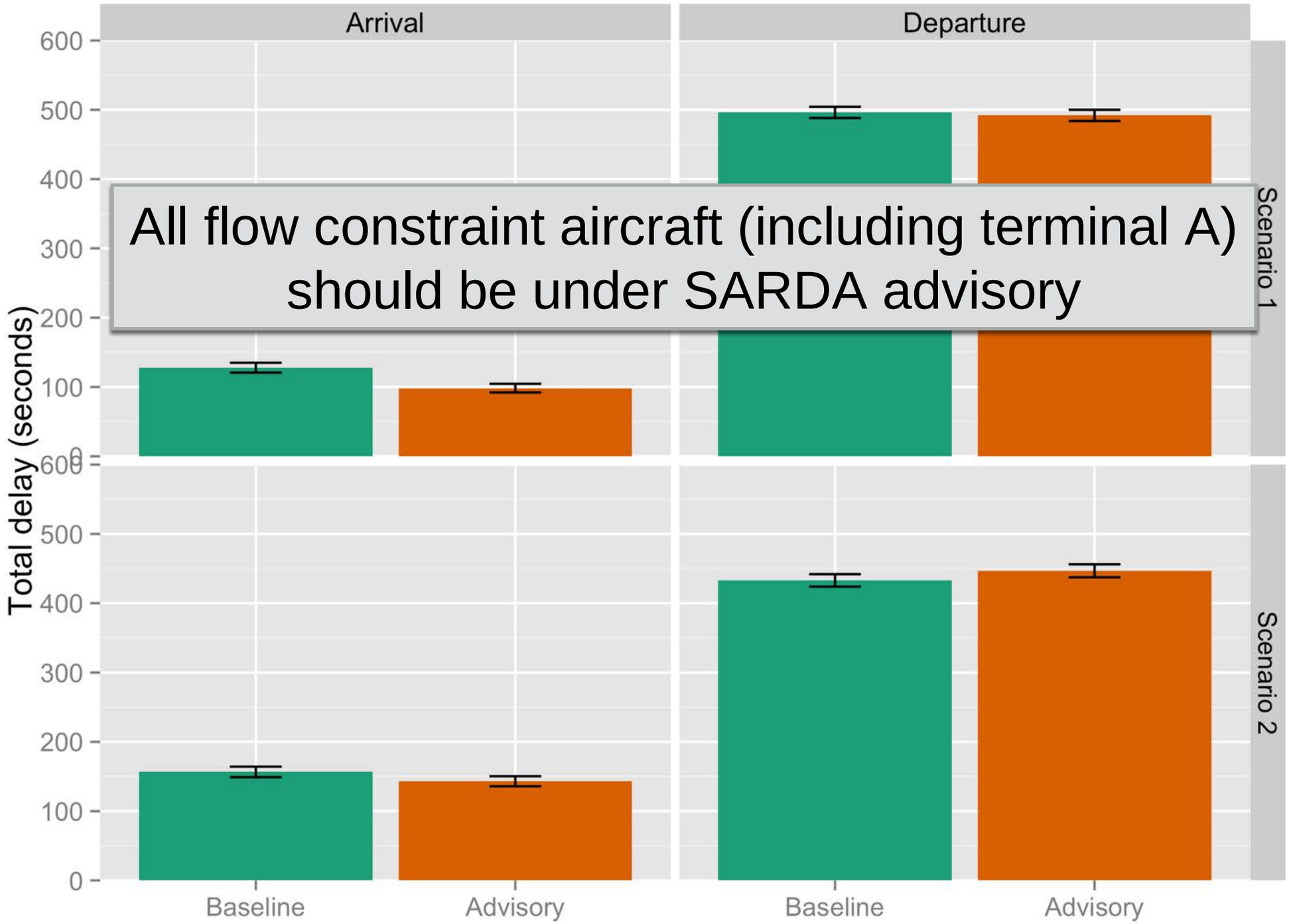
Total Delay

total_delay = taxi_delay + gate_delay



Total Delay (no MIT)

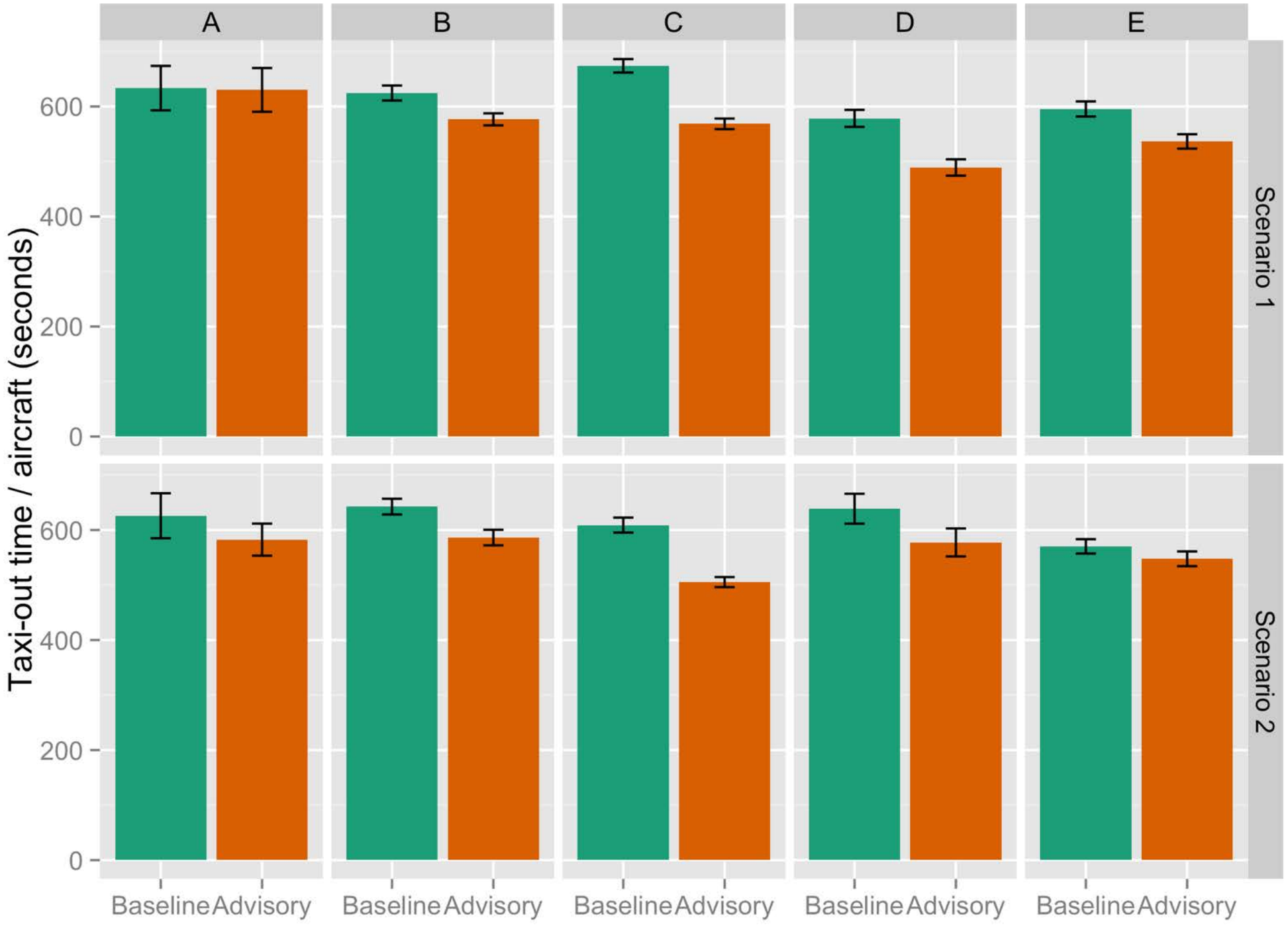
total_delay = taxi_delay + gate_delay



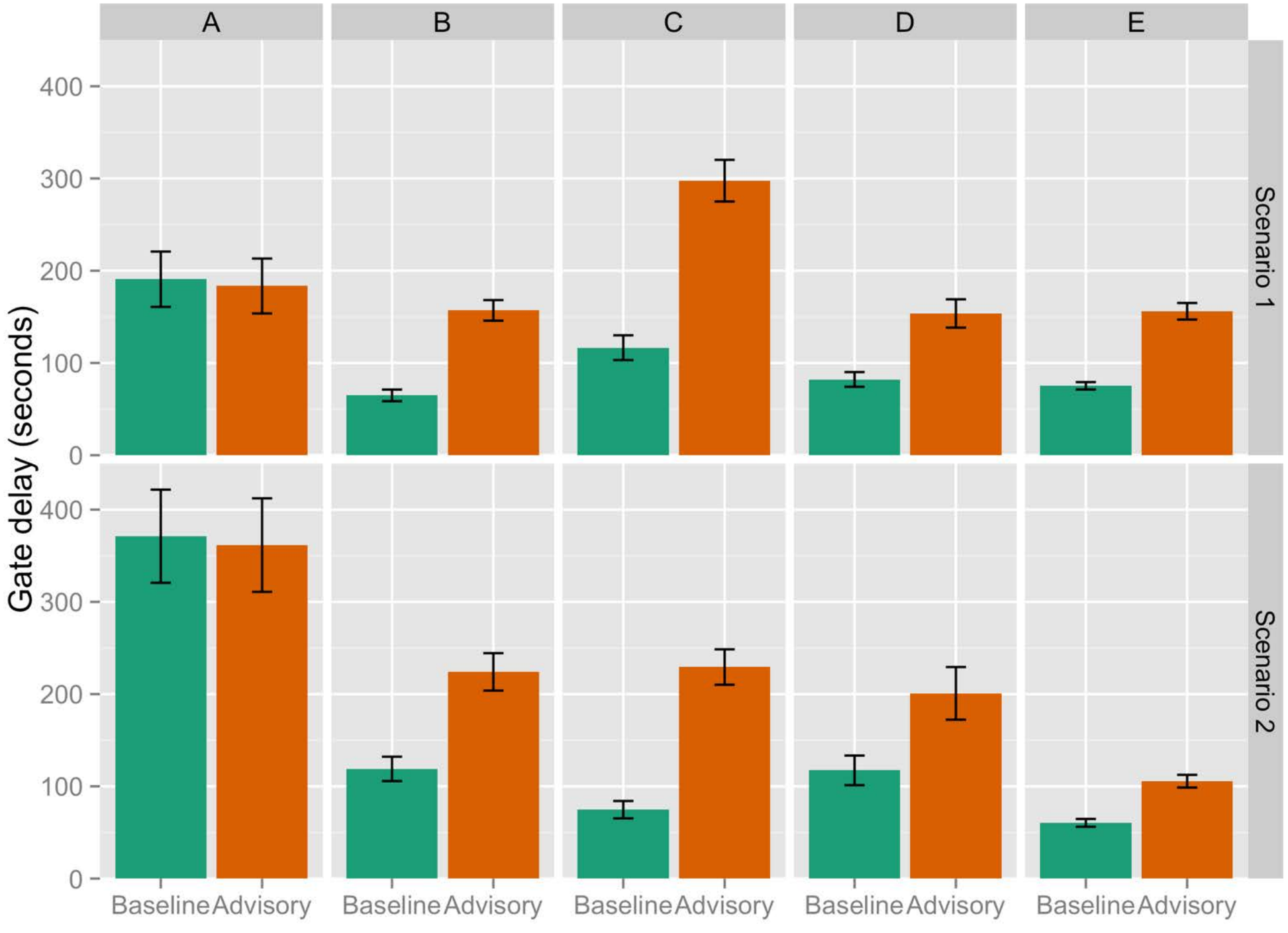
All flow constraint aircraft (including terminal A) should be under SARDA advisory

Analysis - by terminals

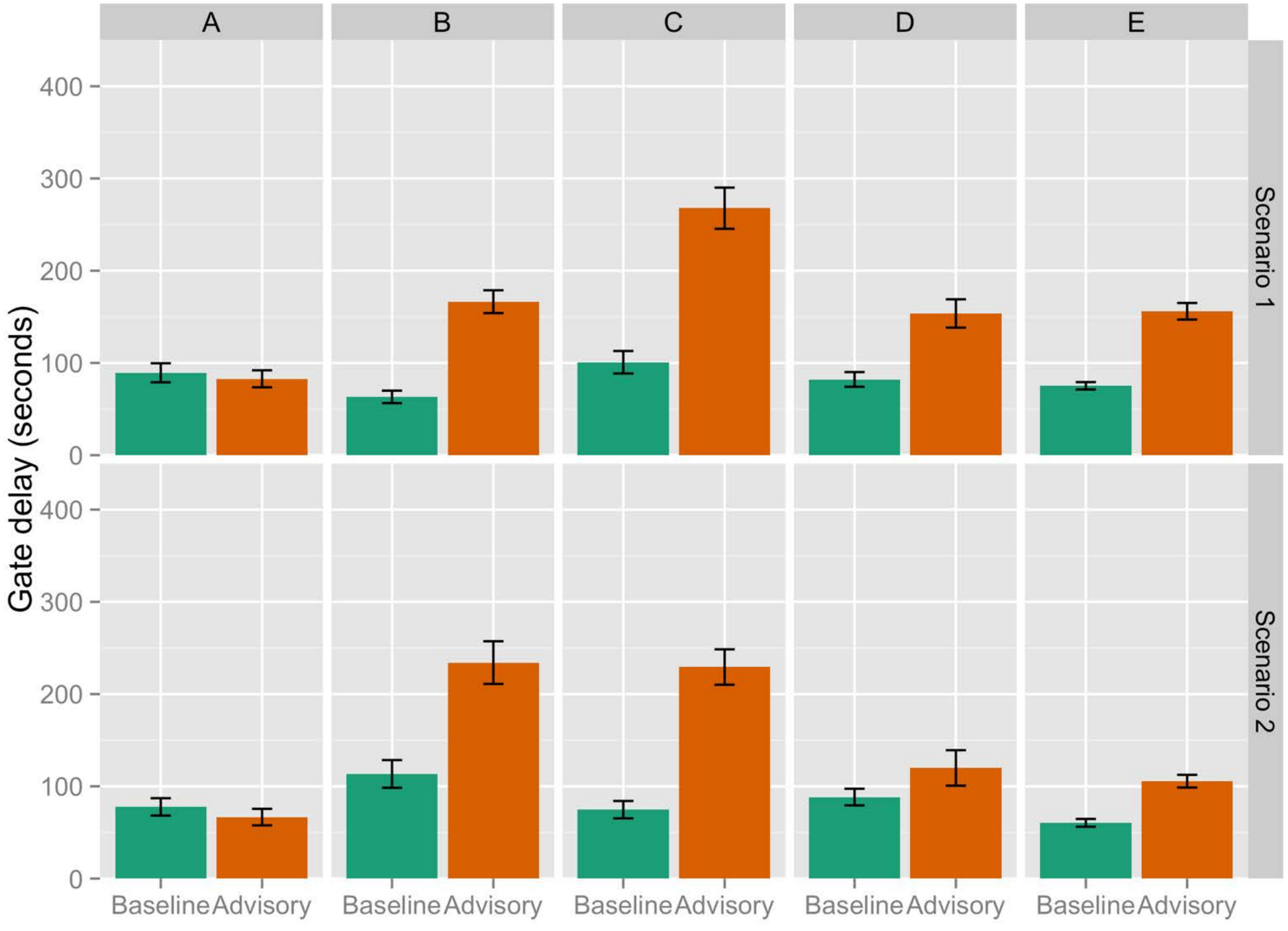
Taxi times


A
B
C
D
E
Scenario 1
Scenario 2
Taxi-out time / aircraft (seconds)
0
200
400
600
Baseline
Advisory

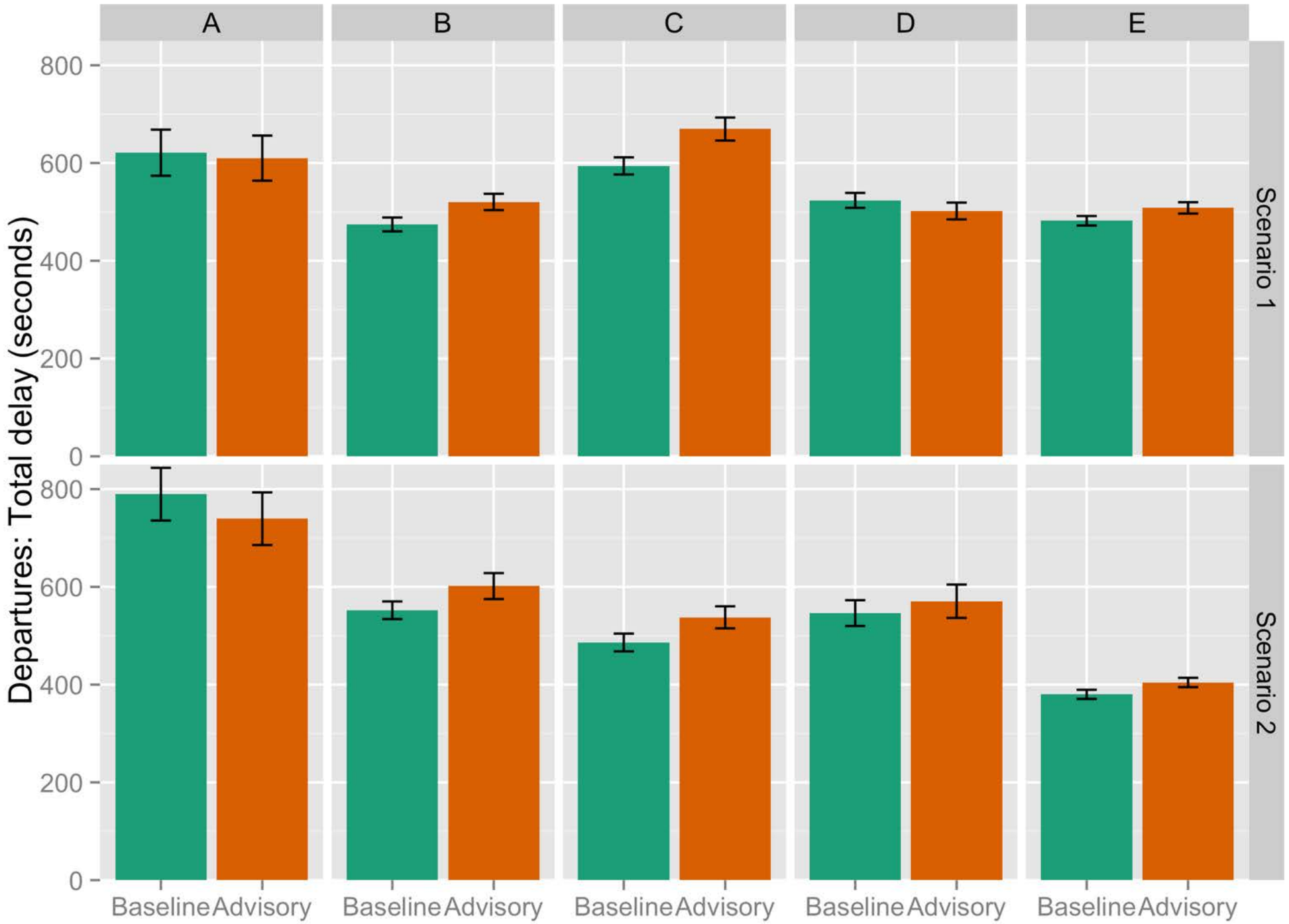
Gate Delay


A
B
C
D
E
Scenario 1
Scenario 2
Gate delay (seconds)
0
100
200
300
400
Baseline
Advisory

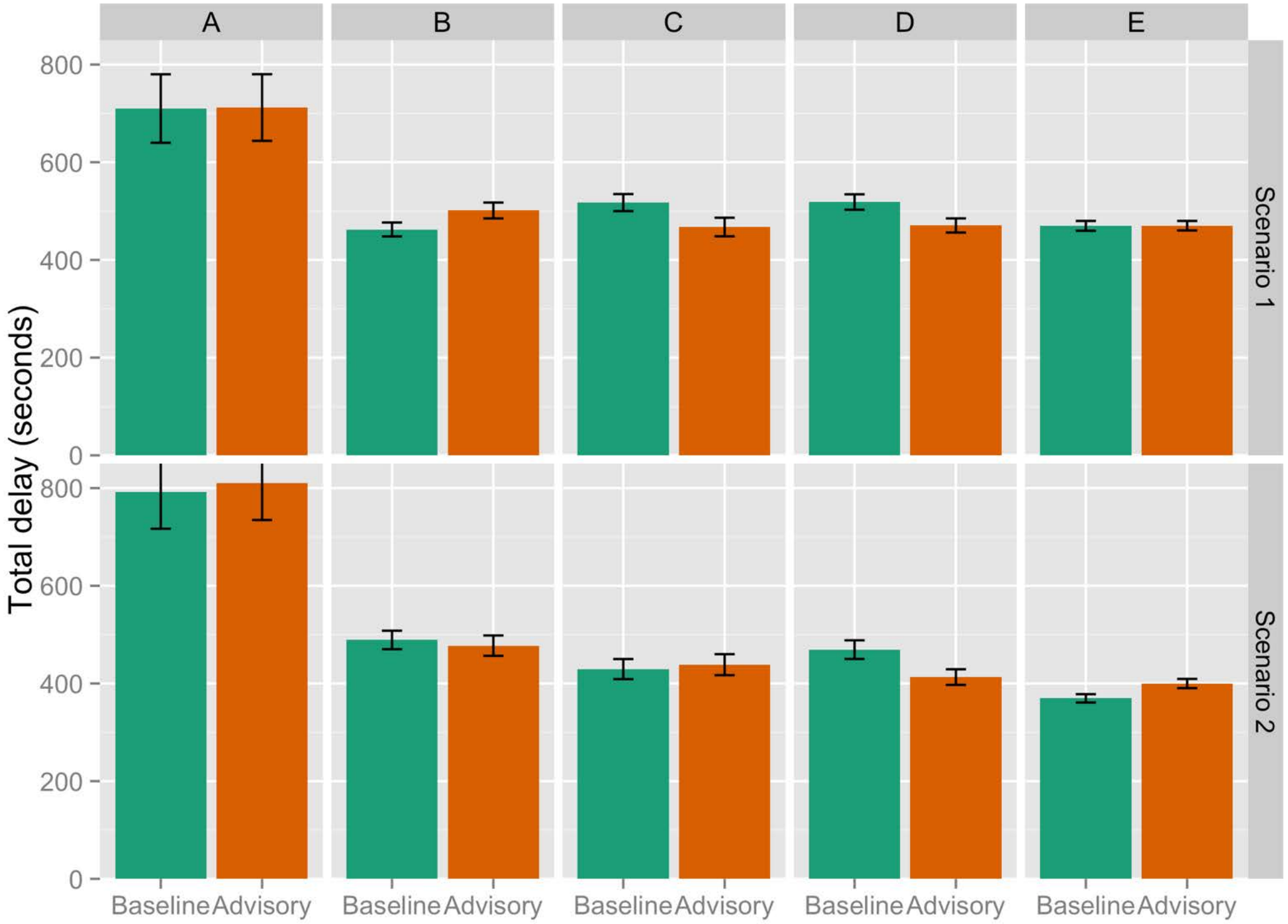
Gate Delay (no TMI)



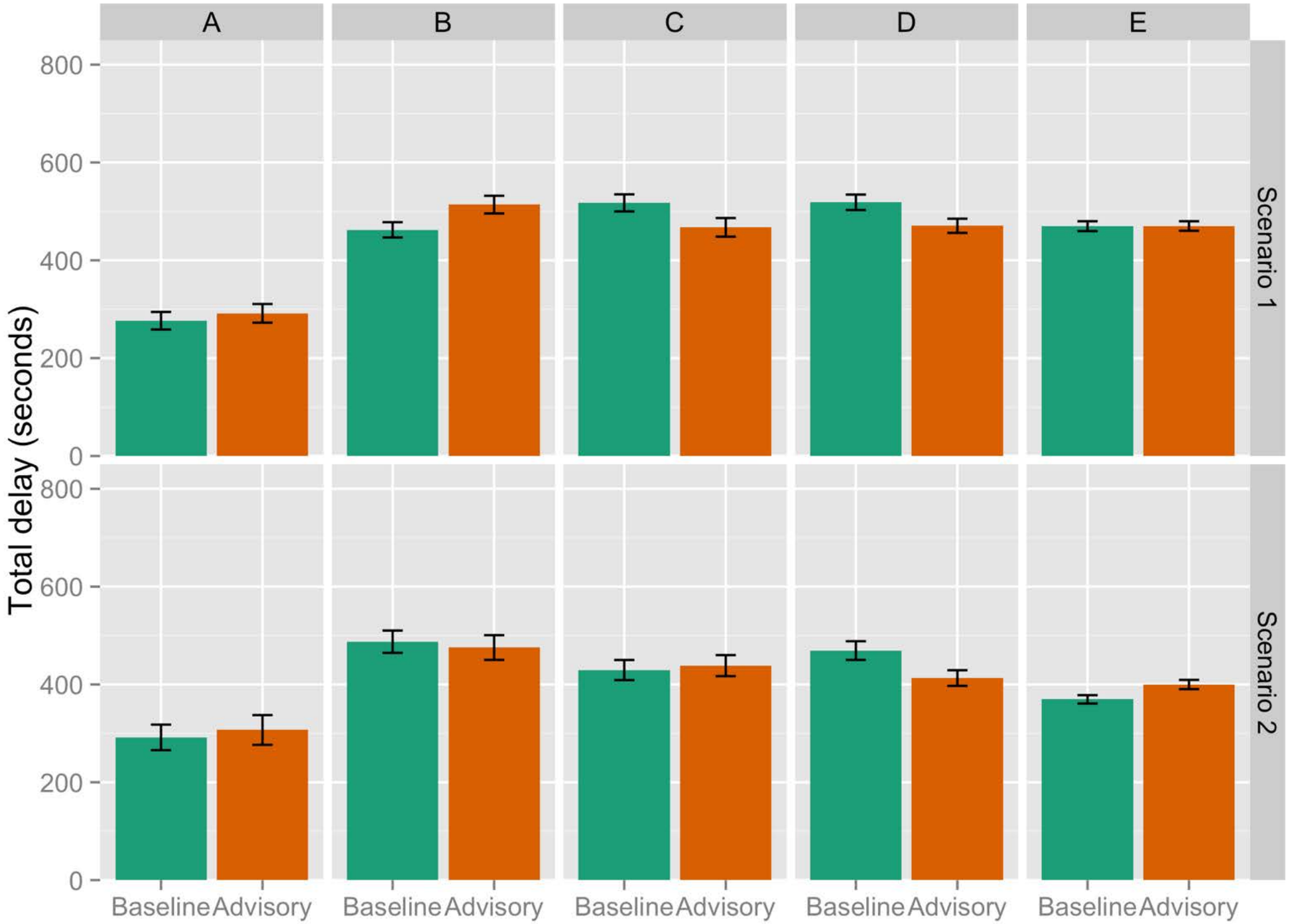
Total Delay


A
B
C
D
E
Departures: Total delay (seconds)
800
600
400
200
0
Scenario 1
Scenario 2
Baseline
Advisory

Total Delay (no MIT)

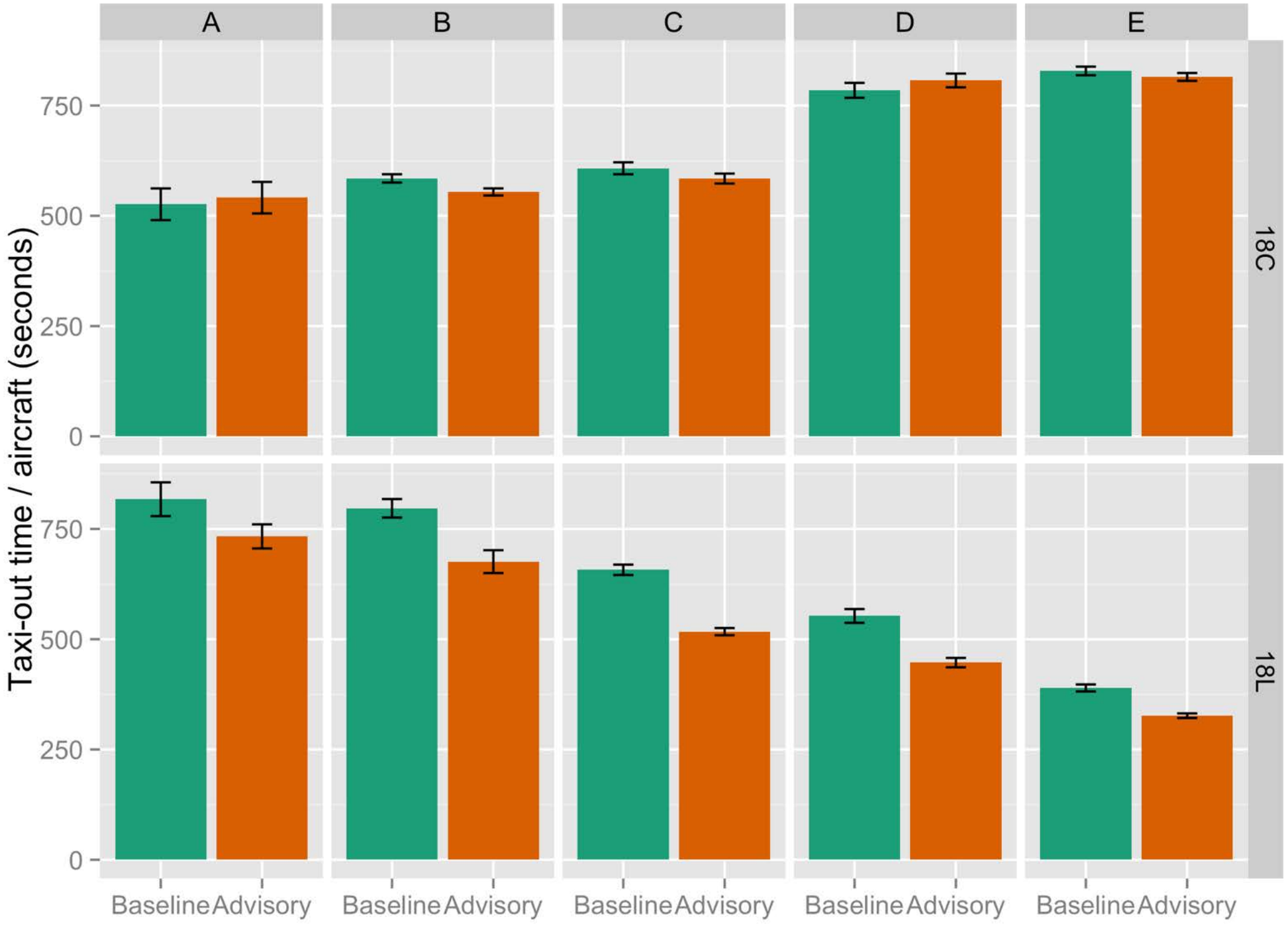


Total Delay (no MIT/TMI)

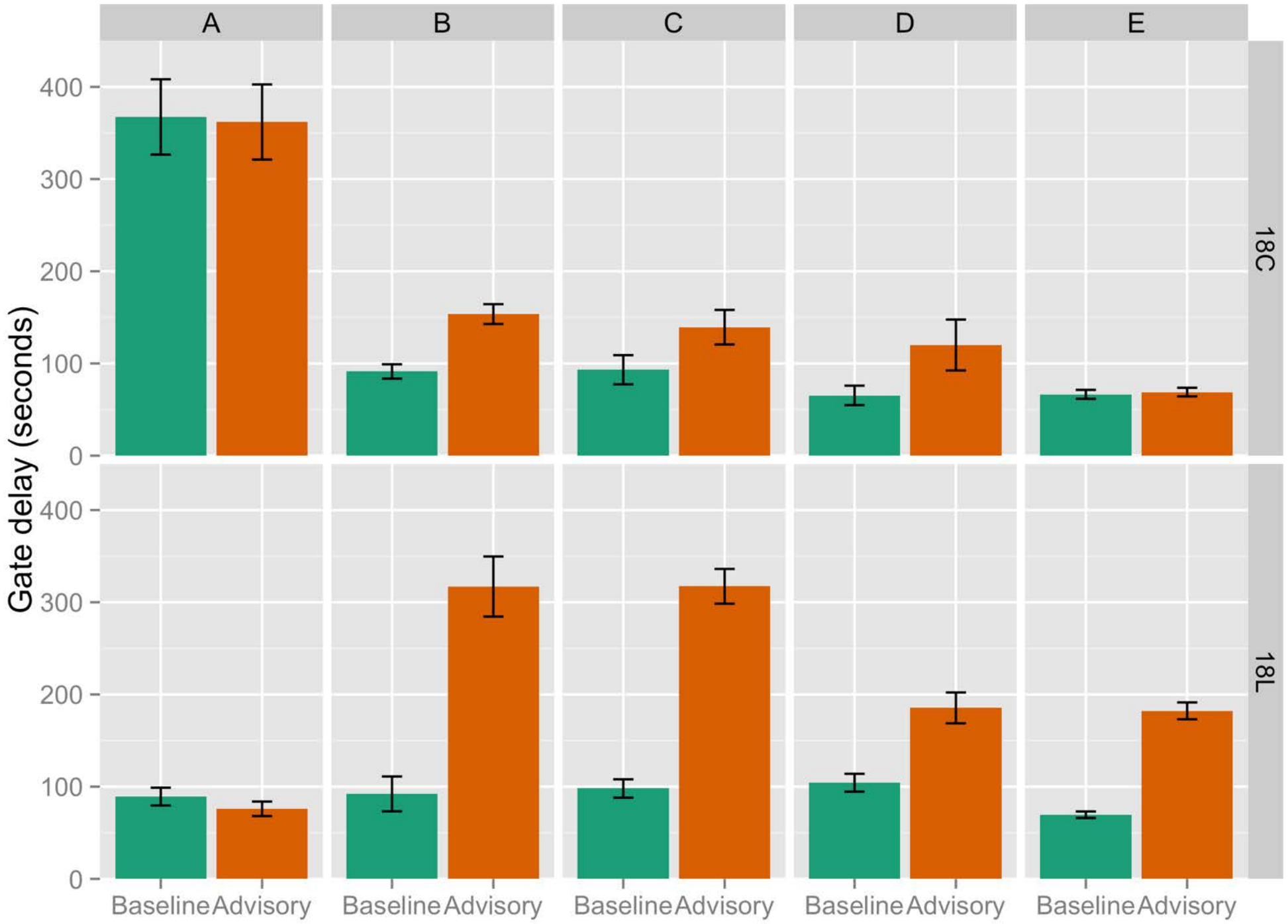


Analysis - by terminals and runways

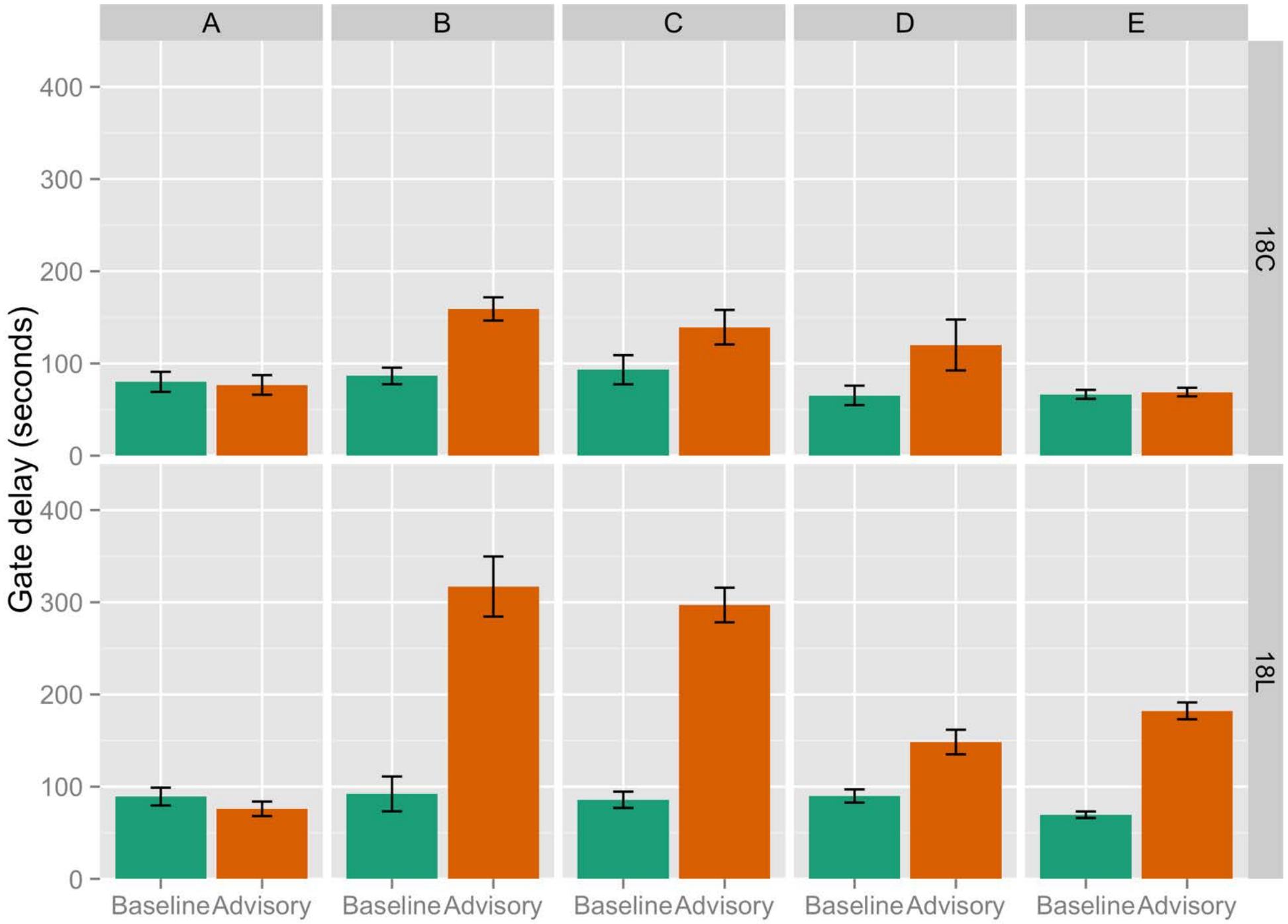
Taxi Times


A
B
C
D
E
18C
18L
Taxi-out time / aircraft (seconds)
0
250
500
750
Baseline
Advisory

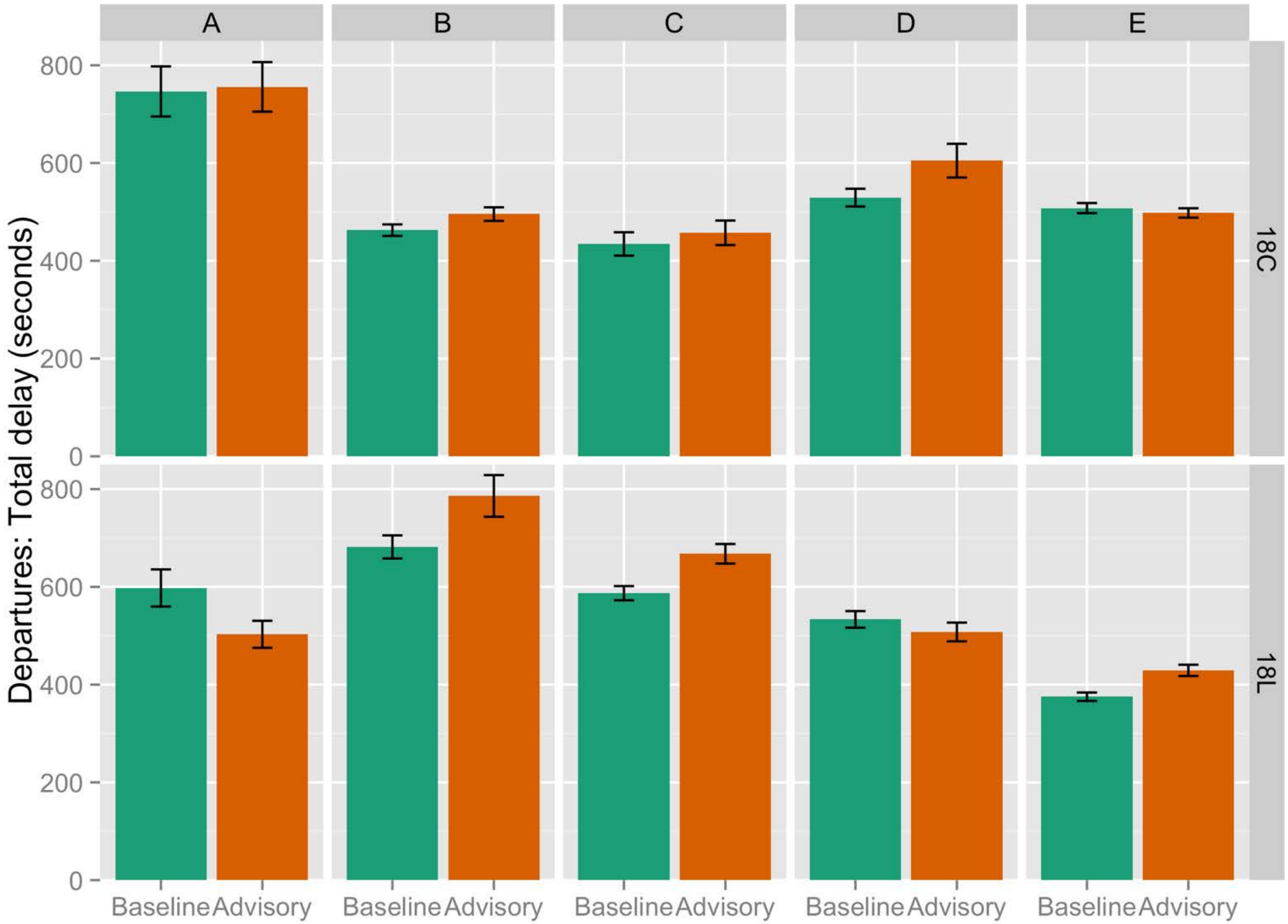
Gate Delay


A
B
C
D
E
18C
18L
Gate delay (seconds)
400
300
200
100
0
Baseline
Advisory

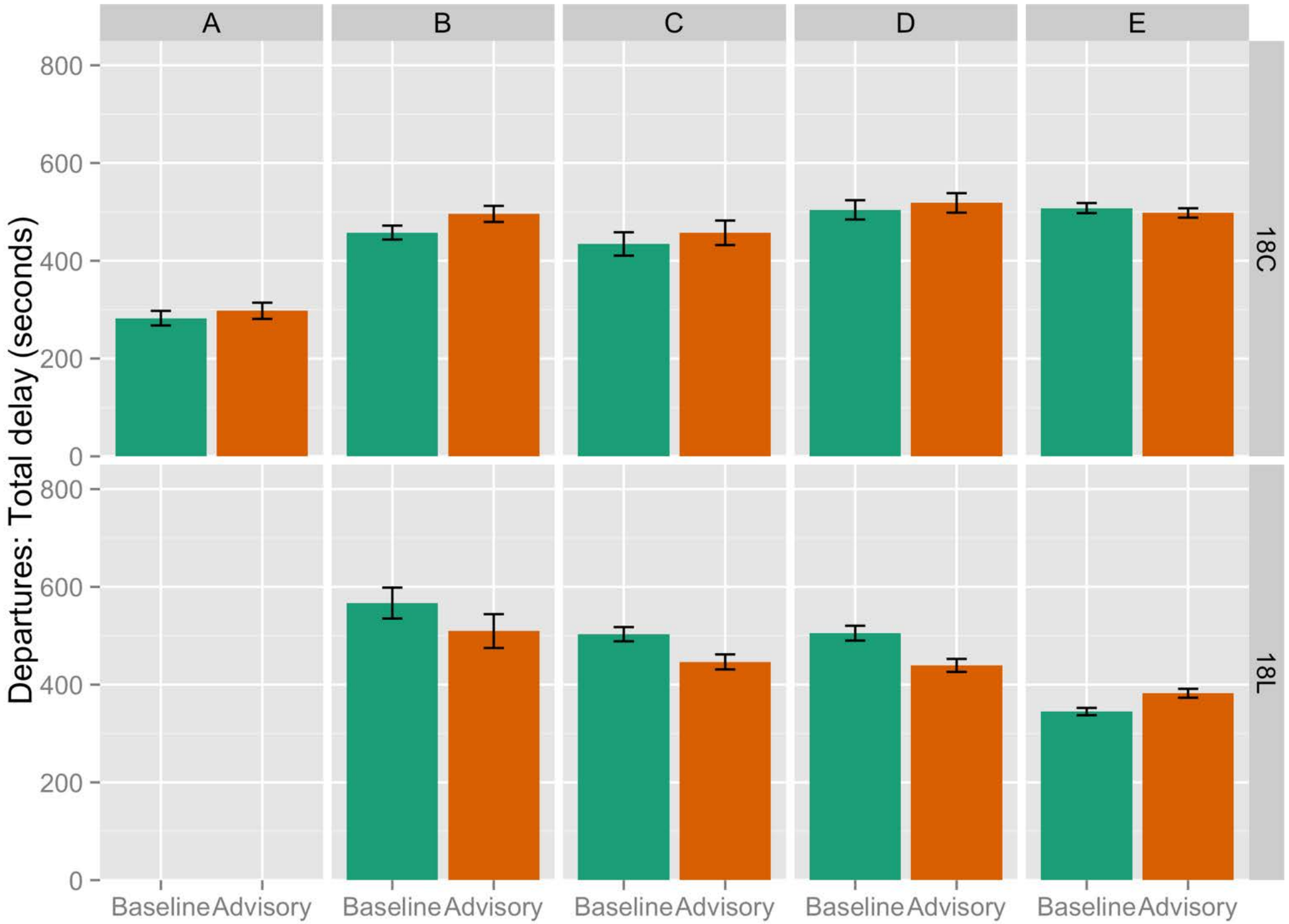
Gate Delay (no TMI)



Total Delay


A
B
C
D
E
18C
18L
Departures: Total delay (seconds)
800
600
400
200
0
Baseline
Advisory

Total Delay (no TMI/MIT)



Data Analysis HITL6 and HITL5

NASA Ames Research Center/ American Airlines

Fort Worth, TX

January 20-21, 2015

HITL6:
Human Factors Analysis of Results

Research Question

How does management of ramp traffic affect user workload and usability ratings under the following conditions-

- SARDA advisories (pushback & MC advisories)
- NO SARDA advisories (Baseline condition)

Method

- Post Run and Post Study questionnaire data were gathered to assess controller workload and usability ratings
- Post Study Questionnaire asked a series of specific questions regarding use of Pushback and MC Advisories

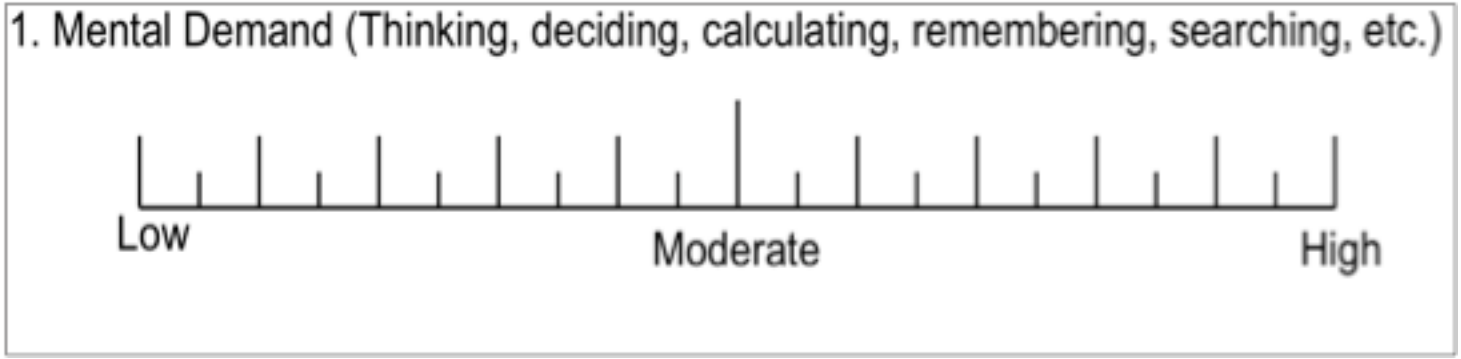
Workload

- Workload for HITL6 was defined by four components similar to NASA-TLX (Task Load Index):
  - Mental Demand (Thinking, deciding, calculating, searching, etc.)
  - Temporal Demand (Time pressure)
  - Frustration (Stress, annoyance, irritation)
  - Communication Demand (exchanging information, discussion, negotiation, etc.)

Workload Questions

- Controllers were asked to rate each of the four components of their workload after every run on a scale of 1-10

- For example, see the “mental demand” question response format below:

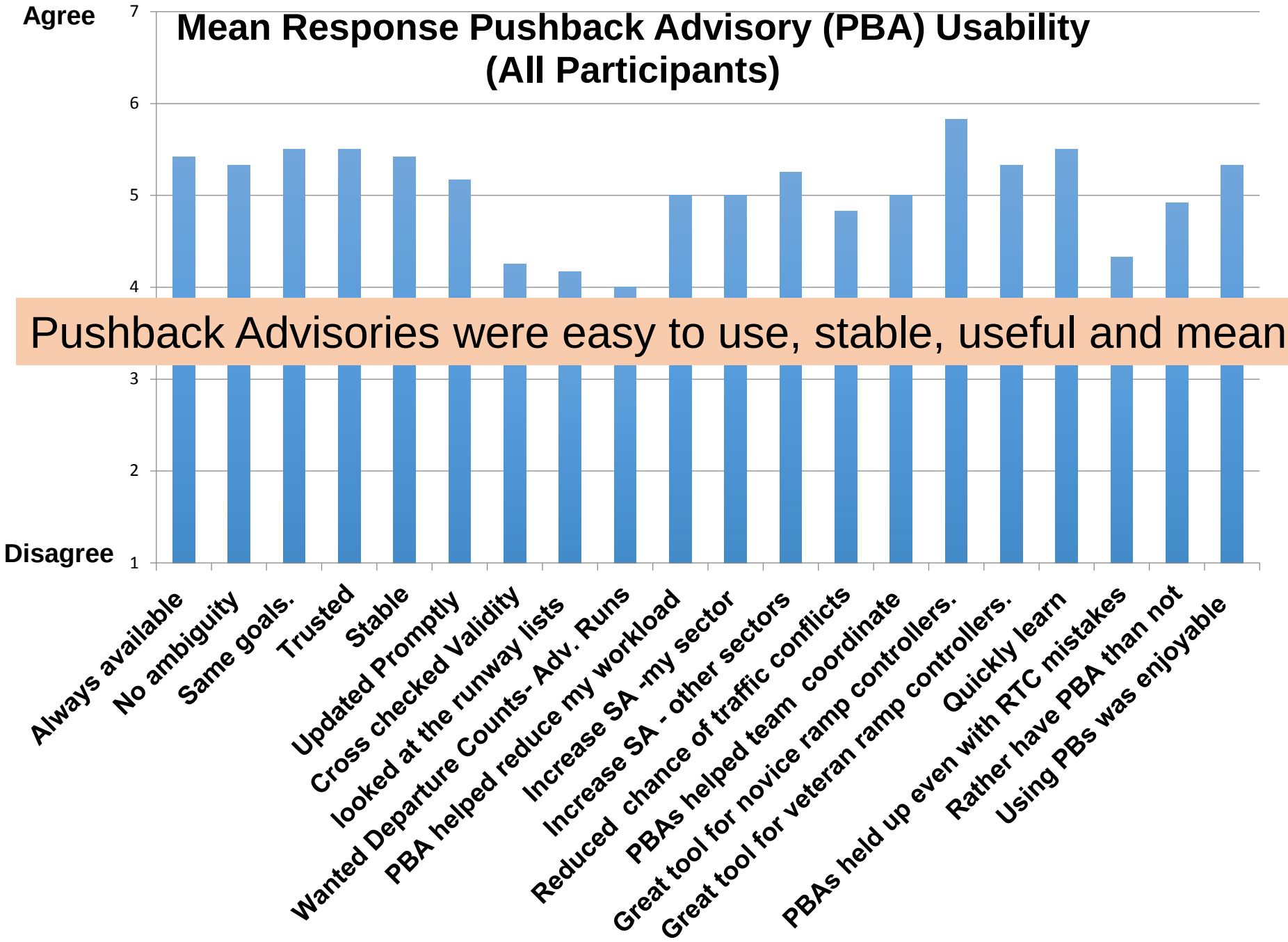


HITL6 Workload Summary

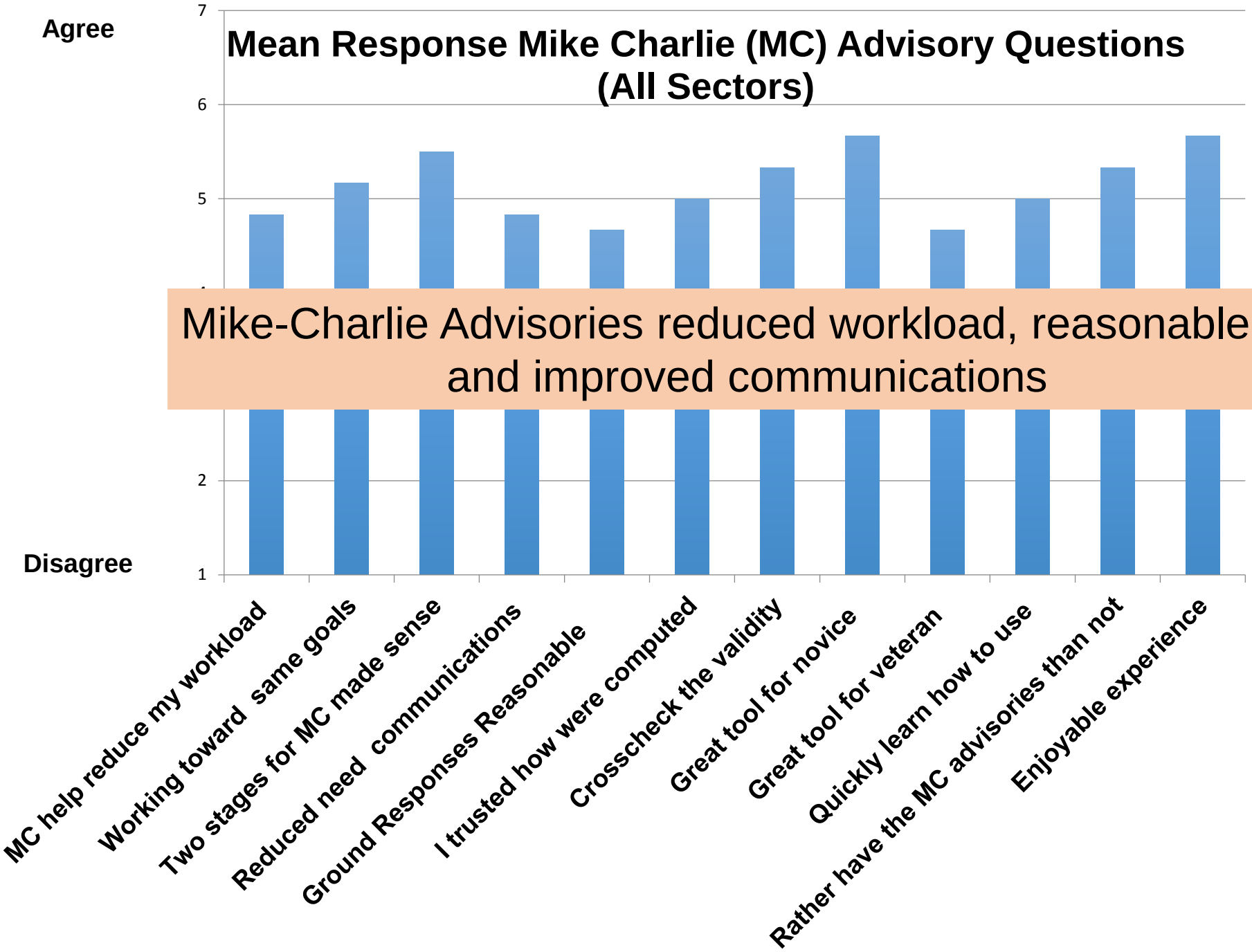
Workload Responses, Weeks 1-3, All Sectors
Means (SE)

Week	Mental Demand		Temporal Demand		Frustration		Communication	
	Advisory	Baseline	Advisory	Baseline	Advisory	Baseline	Advisory	Baseline
One	4.37(1.87)	4.43 (1.92)	2.53 (.64)	2.99 (.89)	1.2 (.32)	1.17 (.33)	2.71 (.71)	3.18 (.95)
Two	3.78 (2.05)	3.78 (2.06)	2.00 (.74)	2.12 (.86)	1.13 (.50)	1.06 (.43)	2.09 (.90)	1.94 (.86)
Three	4.24 (2.19)	4.56 (2.07)	2.28 (1.04)	2.45 (1.04)	0.75 (.46)	0.72 (.39)	2.99 (1.66)	2.70 (1.50)

No significant differences between the advisory and baseline conditions.
Differences between weeks shows individual differences



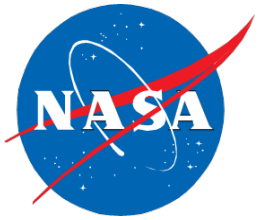
Pushback Advisories were easy to use, stable, useful and meaningful



Mike-Charlie Advisories reduced workload, reasonable, and improved communications

HITL6 Summary

- Similar workload was reported for the Advisory and Baseline Conditions
- Further statistical analysis showed that
  - In the Advisory condition, the South sector controller Frustration ratings were significantly lower
  - In the Advisory condition, the non CLT Coordination ratings were significantly lower
- Pushback: CLT controllers felt that the gate-hold times or pushback advisories were in a reasonable range more frequently towards the end of each week suggesting a learning effect
- M-C Advisory: The CLT controllers felt the MC advisories were stable more frequently towards the end of the week again suggesting a learning effect



HITL5

RTC vs. Paper Strips

HITL5:
Human Factors Analysis of Results

Research Question

How does the management of ramp traffic affect user workload and usability ratings under the following conditions:

- Paper Strips
- Ramp Traffic Console (RTC)

Method

- Post Run questionnaire data were gathered to assess controller workload and usability ratings
- Post Study Questionnaire asked a series of specific questions regarding preference for RTC versus Paper on a number of different parameters

Workload

- Workload for HITL5 is defined by four components of the NASA-TLX (Task Load Index):
  - Mental Demand (Thinking, deciding, calculating, searching, etc.)
  - Physical Demand (Hands and arm movement, force)
  - Temporal Demand (Time pressure)
  - Frustration (Stress, annoyance, irritation)

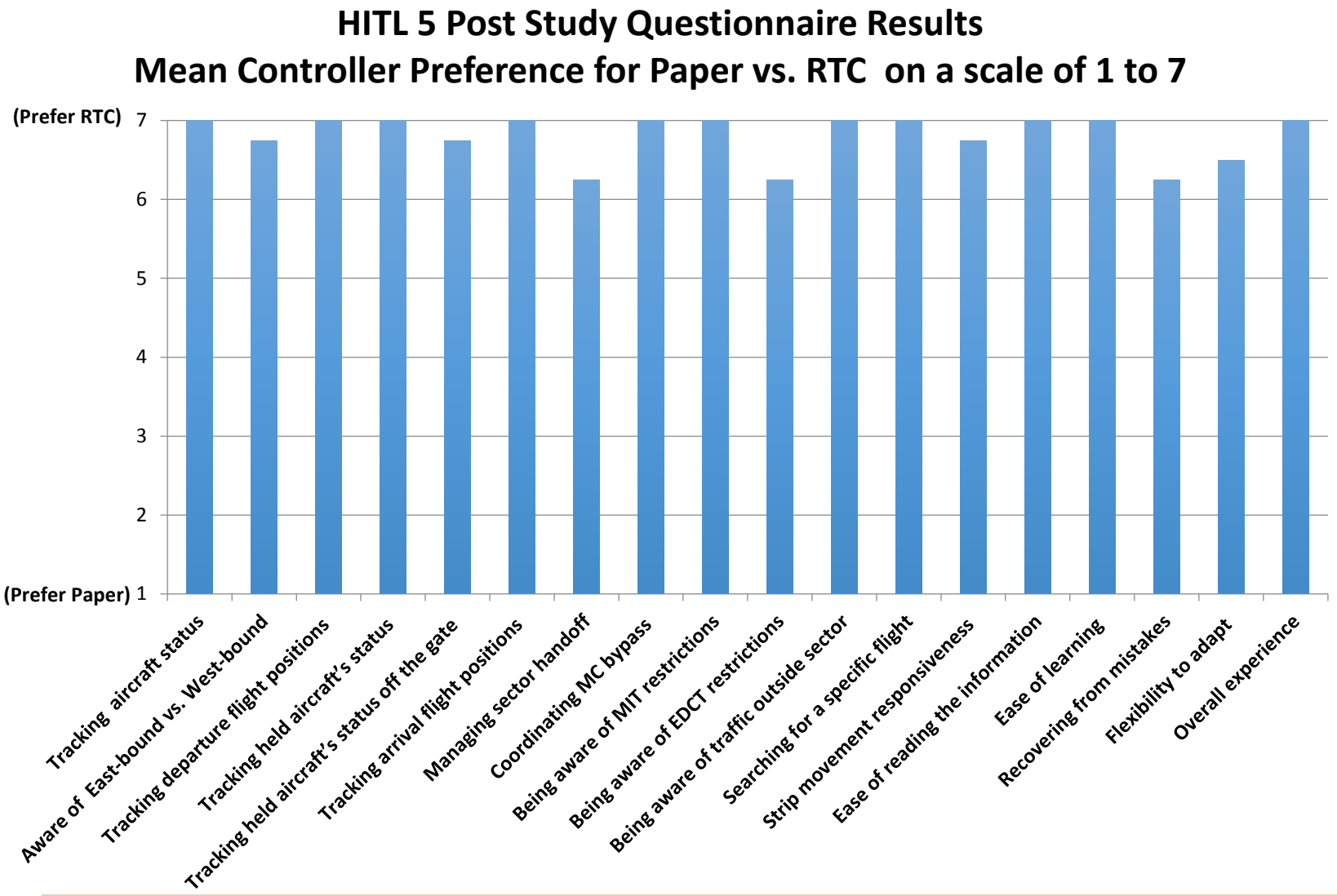
HITL5 Workload Results Summary

Mean Response (SE)
All Sectors

	Condition	
	Paper	RTC
Mental Demand	5.68(.82)	3.94(1.92)
*Time Pressure	4.87(.57)	2.41(.50)
Physical Demand	4.58(1.32)	2.78(1.43)
*Frustration	3.63(.31)	1.28 (.34)

* Significant results

Higher Workload experienced with paper strips versus RTC



Ramp Traffic Console was preferred over the paper strips

HITL5 Summary

- Trend shows that workload ratings were lower in the RTC condition for all four aspects of workload,
  - Significantly lower results for Temporal Demand and Frustration aspects of workload
- Post Study question responses showed preference for RTC over paper strips

In Summary

- Post Run questionnaire Results
  - indicate lower workload ratings for RTC condition
  - Usability ratings for Traffic management performance questions are lower in the RTC condition than in the paper condition showing a preference for RTC over Paper
  - Usability ratings for Resources and efficiency questions show mixed results

- Post study Questions show preference for RTC over paper strips