Assessment of Ramp Times (ART 2) Human-in-the-Loop (HITL) Simulation

Final Results

March 2019

Executive Summary

- Airspace Technology Demonstration 2 (ATD-2) sub-project conducted a human-in-the-loop (HITL) simulation to assess various strategies for Ramp controllers to deliver aircraft to the spot at a specified time.

- Results show that the rate of compliance with the spot time improved when Ramp controllers first complied with a gate hold advisory for pushing aircraft off the gates.

- Results also show that Ramp controller workload was lower when they only had to focus on complying with the gate hold advisories.

- Background

- Research Question

- HITL Conditions and Guidance

- HITL Parameters

- Research Metrics

- Results

- Appendix – Scenario metrics

Background

- Surface Collaborative Decision Making (CDM) Concept
  - During a Surface Metering Program (SMP), aircraft absorb surface delay in the ramp area ideally at the gate instead of at the runway departure queue
    - Saves fuel and carbon dioxide
    - Would improve schedule predictability elsewhere on surface
  - Aircraft must be delivered to the "spot" where Air Traffic Control (ATC) takes control of the aircraft within compliance of a specific time
- Airspace Technology Demonstration 2 (ATD-2) field demo at Charlotte Douglas International Airport (CLT) has shown that these savings occur when Ramp controllers release aircraft at a specific gate time
  - This time is determined by a surface scheduler during an SMP

CLT has limited Ramp real estate, resulting in single-lane taxi areas (orange arrows). This creates a challenge when trying to deliver aircraft to a spot at a specified time.

What strategy is best for use by Ramp Controllers to meet a time at the spot for airports with ramp constraints like CLT?
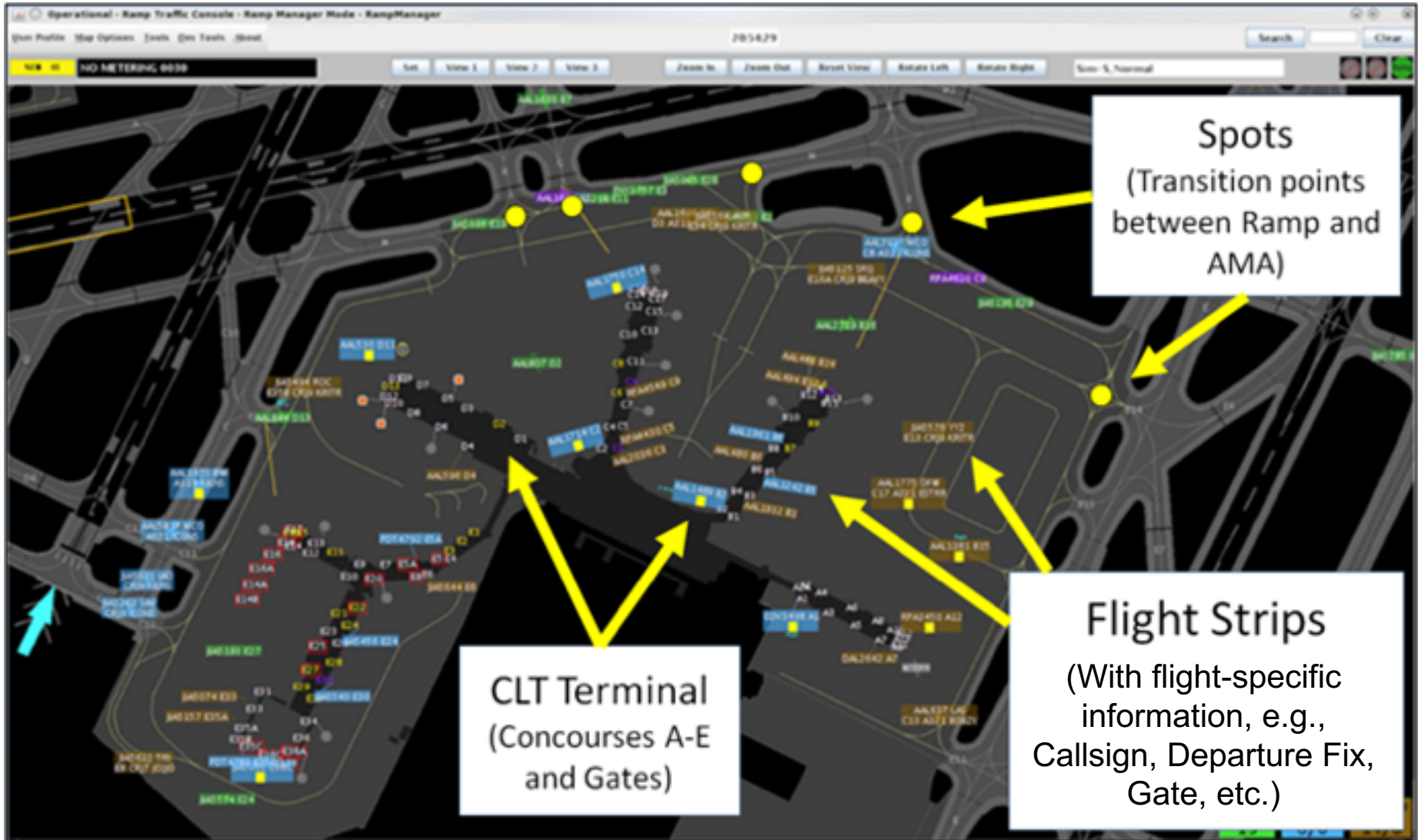
- **Baseline** Ramp Controllers instructed to operate as they would in normal, current-day operations

- **TOBT Compliance** During metering, Ramp Controllers instructed to focus on ensuring that flights push from the gate within ± 2 min. of the Target-Off-Block Time (TOBT) presented by the advisory

- **TOBT & TMAT Compliance** During metering, Ramp Controllers instructed to pushback flights in compliance with TOBT ± 2 min and to deliver flights to the spot at their Target Movement Area Times (TMAT) within ± 5 min

Additional Participant Guidance

- Use best judgement and company policy for determining hold procedures at a gate. E.g., if a departure flight with a TOBT gate hold advisory had a gate conflict with an arrival flight, a Ramp controller might push the departure off the gate early to free the gate for the arrival.

- Spot assignments could be changed for a flight

- In all conditions, ATC Tower Ground and Local Controllers instructed to operate as they would in normal, current-day operations

Spots
(Transition points between Ramp and AMA)

CLT Terminal
(Concourses A-E and Gates)

Flight Strips
(With flight-specific information, e.g., Callsign, Departure Fix, Gate, etc.)

RTC Flight Displays

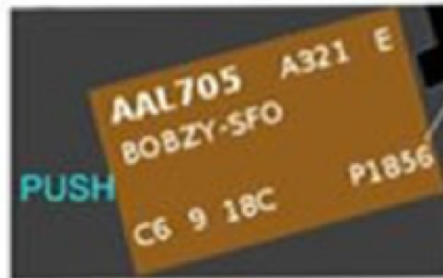- ## Baseline (no advisories)

At gate prior to pushback

After pushback while taxiing

- ## Both metering conditions

(Left) At gate showing gate hold advisory ("4 min"), which counts down to the TOBT. (Right) Displays "PUSH" when countdown ends.

After pushback, displays TMAT ("1941") for arriving at the spot.

Three 70 Minute Scenarios and Three Conditions were Balanced as to Order

Run #	Scenario	Condition	Start Time	End Time	Duration
1	B	TOBT	6/26 13:05	6/26 14:16	71min
2	A	TOBT & TMAT	6/26 14:51	6/26 16:02	71min
3	C	Baseline	6/27 08:34	6/27 09:44	70min
4	B	TOBT & TMAT	6/27 10:11	6/27 11:21	70min
5	A	Baseline	6/27 12:50	6/27 14:00	70min
6	C	TOBT	6/27 14:43	6/27 15:53	70min
7	C	TOBT & TMAT	6/28 08:34	6/28 09:44	70min
8	A	TOBT	6/28 10:11	6/28 11:22	71min
9	B	Baseline	6/28 12:48	6/28 13:58	70min

Scenarios B and C duplicated with variations from Scenario A which was based on live traffic recordings from CLT during Bank 2 (CLT's heaviest traffic bank); all scenarios had similar traffic loads

- 4 experienced Ramp Controllers (2 active and 2 retired)
  - Rotated in each run through the 4 CLT Ramp positions: North, East, South, and West Sectors
- 1 active Ramp Manager
- 4 retired ATC Tower controllers
- 1 active ATC Traffic Management Coordinator (TMC)
- 8 Pseudo-pilots
- 2 TRACON confederates

- AMA surface counts

- Runway throughput

- Scenario descriptives

- TOBT compliance

- TMAT compliance

Qualitative Metrics

- During each run
  - Workload Assessment Keypad (WAK) tablets collected workload ratings on a 1-5 scale every 5 minutes
- Post-run surveys
  - Workload ratings via 5 NASA Task Load Index (TLX) items
  - Situation Awareness (SA) ratings via adapted 3-D Situational Awareness Rating Technique (SART)
  - Acceptability ratings
- Post-study survey & debrief

HITL Variations Affecting Performance Metrics

- Departure pushback times (intended variation)
- Movement area entry times at spots
- Ramp controller-initiated spot changes
- Departure runway separation times
- Runway crossing times at Runway 36C
- Missing arrivals
- Arrival landing times
- Traffic Management Initiative (TMI) flights
  - APREQ and/or EDCT
- GA departures

Results

Questions

- **Compliance with pushback advisories (TOBTs) and spot times (TMATs)**
    - **Were the Ramp Controllers able to comply with the TOBTs?**
    - **Were the Ramp Controllers able to comply with the TMATs?**
- Ramp Controller workload and situation awareness
    - What were the impacts of the conditions on Ramp Controllers' workload and situation awareness?
- What were the processes Ramp Controllers used to meet TMATs?
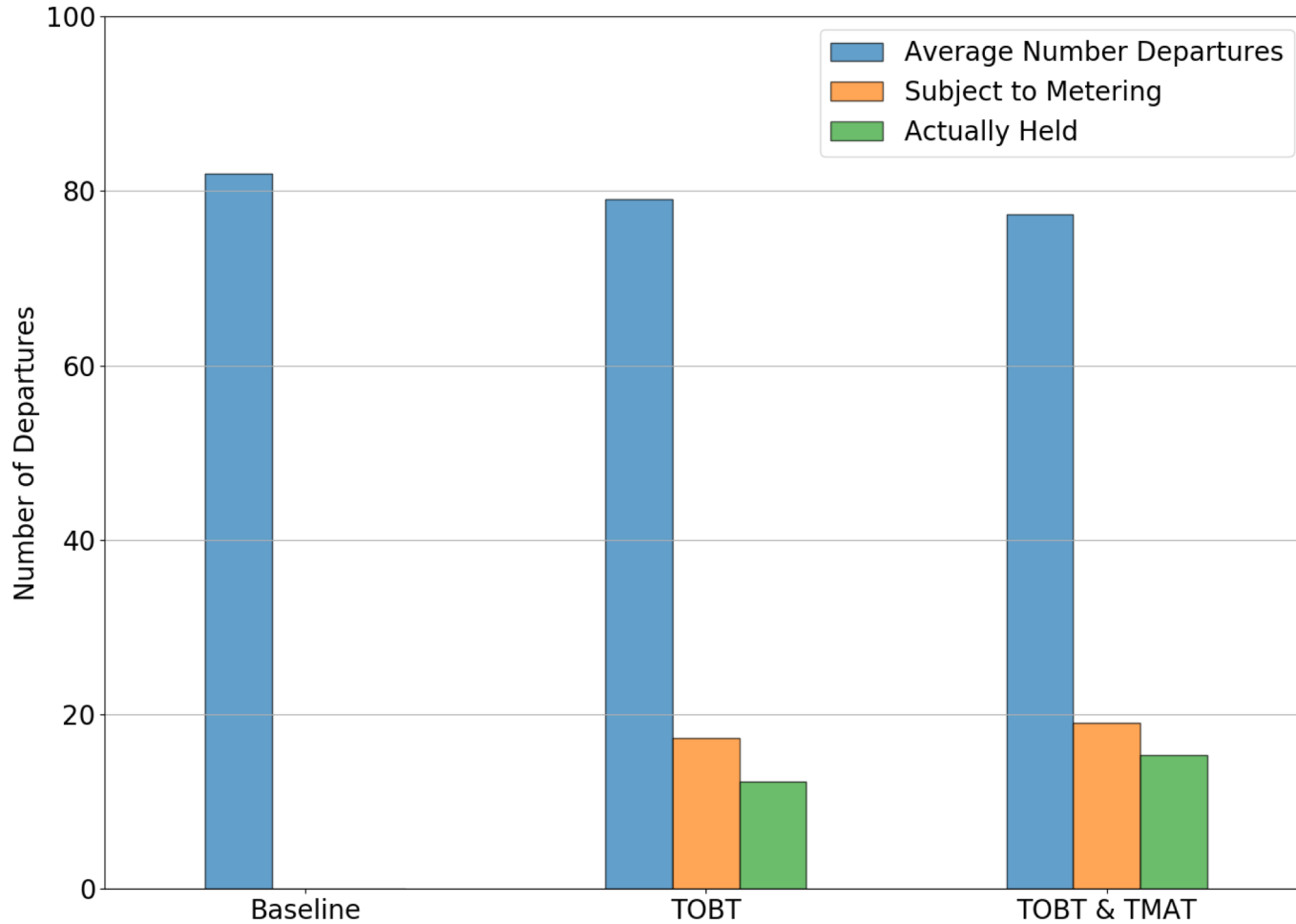
Orange aircraft subject to metering were assigned both TOBT and TMAT

TMAT Compliance Increases for Aircraft Compliant with TOBT

Compliance	TOBT Condition	TOBT & TMAT Condition	Sig. Level Chi Square
TOBT (±2 min)	61.7% (21/34)	57.1% (24/42)	p = .68, 0.2 (df 1)
TMAT (±5 min)	85.3% (29/34)	69.0% (29/42)	p = .10, 2.7 (df 1)
TMAT Given TOBT Compliance	95.2% (20/21)	75.0% (18/24)	p = .07, 3.3 (df 1)

- In both conditions the TMAT compliance increased when aircraft were first compliant with the TOBT advisory. This was also found in operational data [Coupe et al., 2019]

- TMAT compliance in the TOBT condition was higher than the TOBT & TMAT condition but the sample size is relatively small

Coupe, W. J., Lee, H., Jung, Y., Chen, L., & Robeson, I.: Scheduling Lessons Learned During Phase 1 Field Evaluation of the ATD-2 Integrated Arrival, Departure, Surface Concept. 13th USA/Europe Air Traffic Management Research and Development Seminar, In Press (2019)
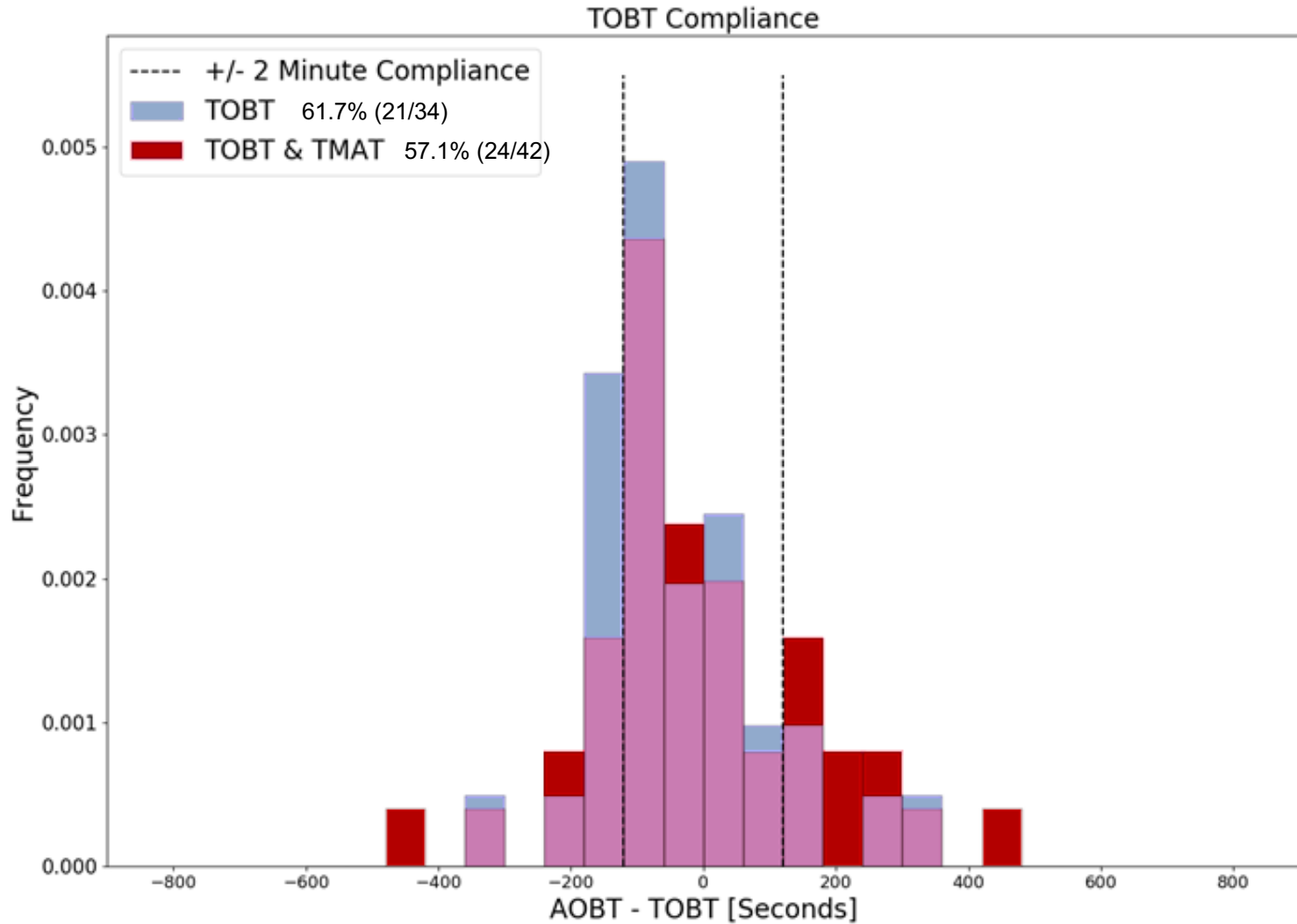
TOBT compliance was similar across the two conditions
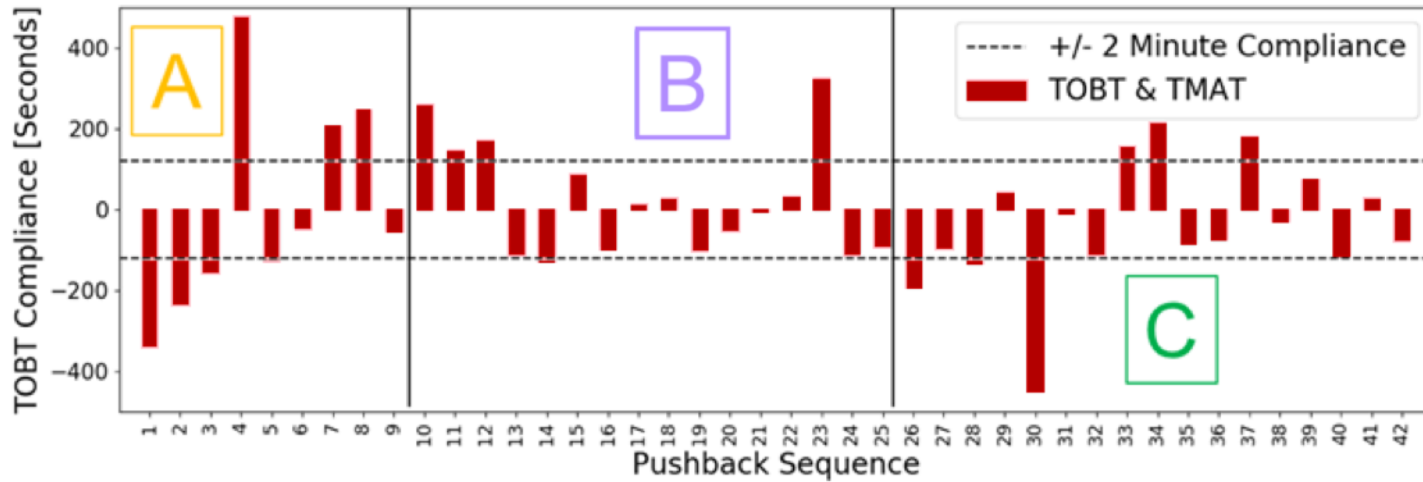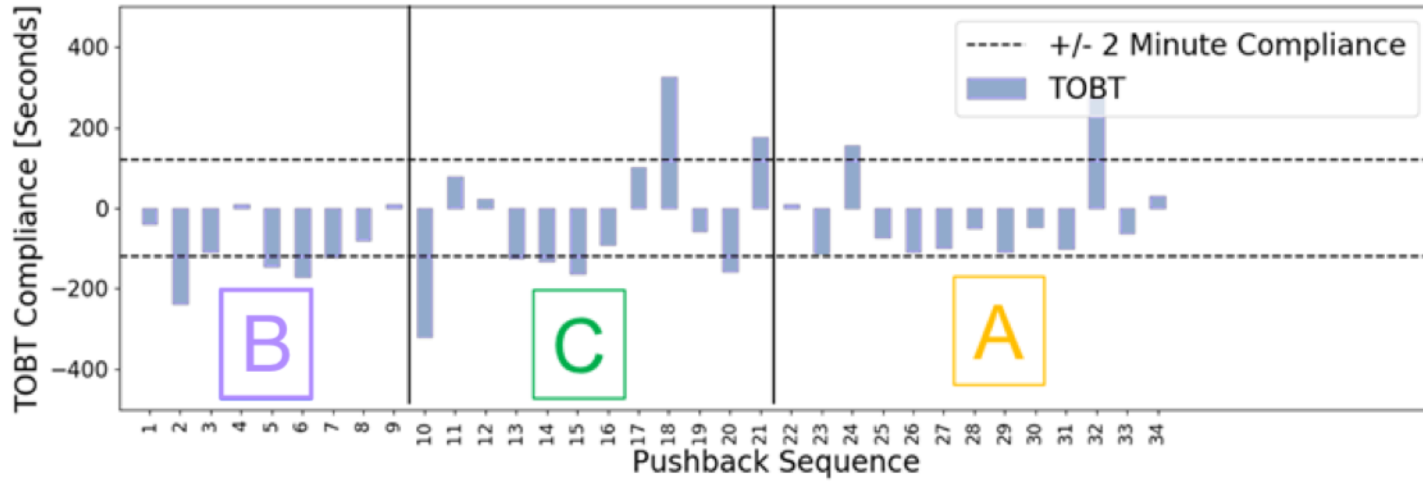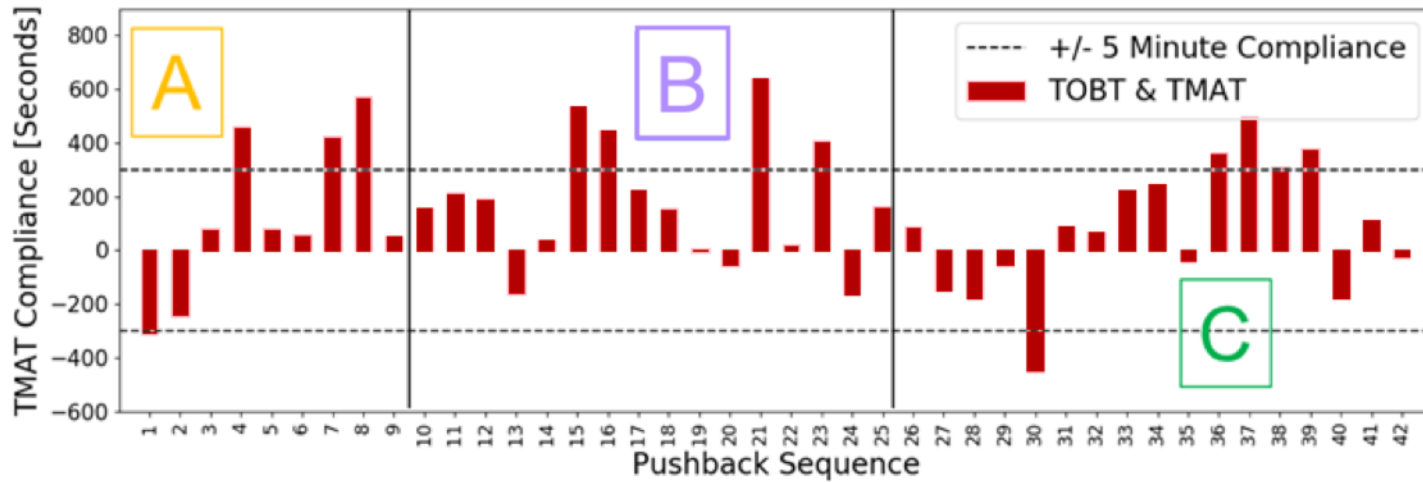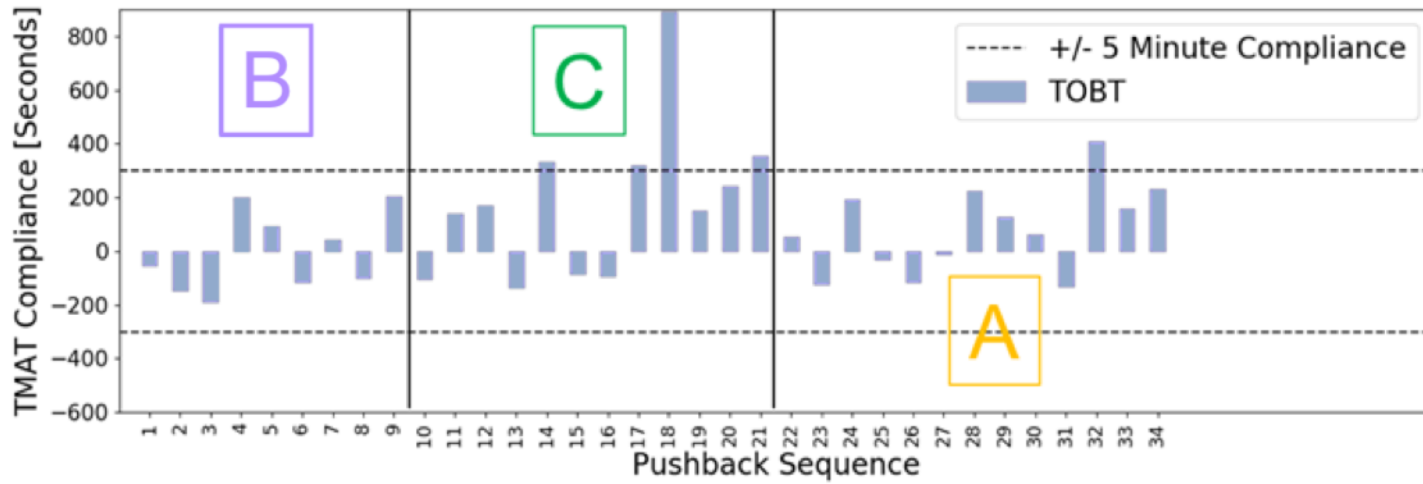
TOBT compliance as a function of pushback sequence in each of the three scenarios

AMA Target Time and
TMAT Compliance Histogram
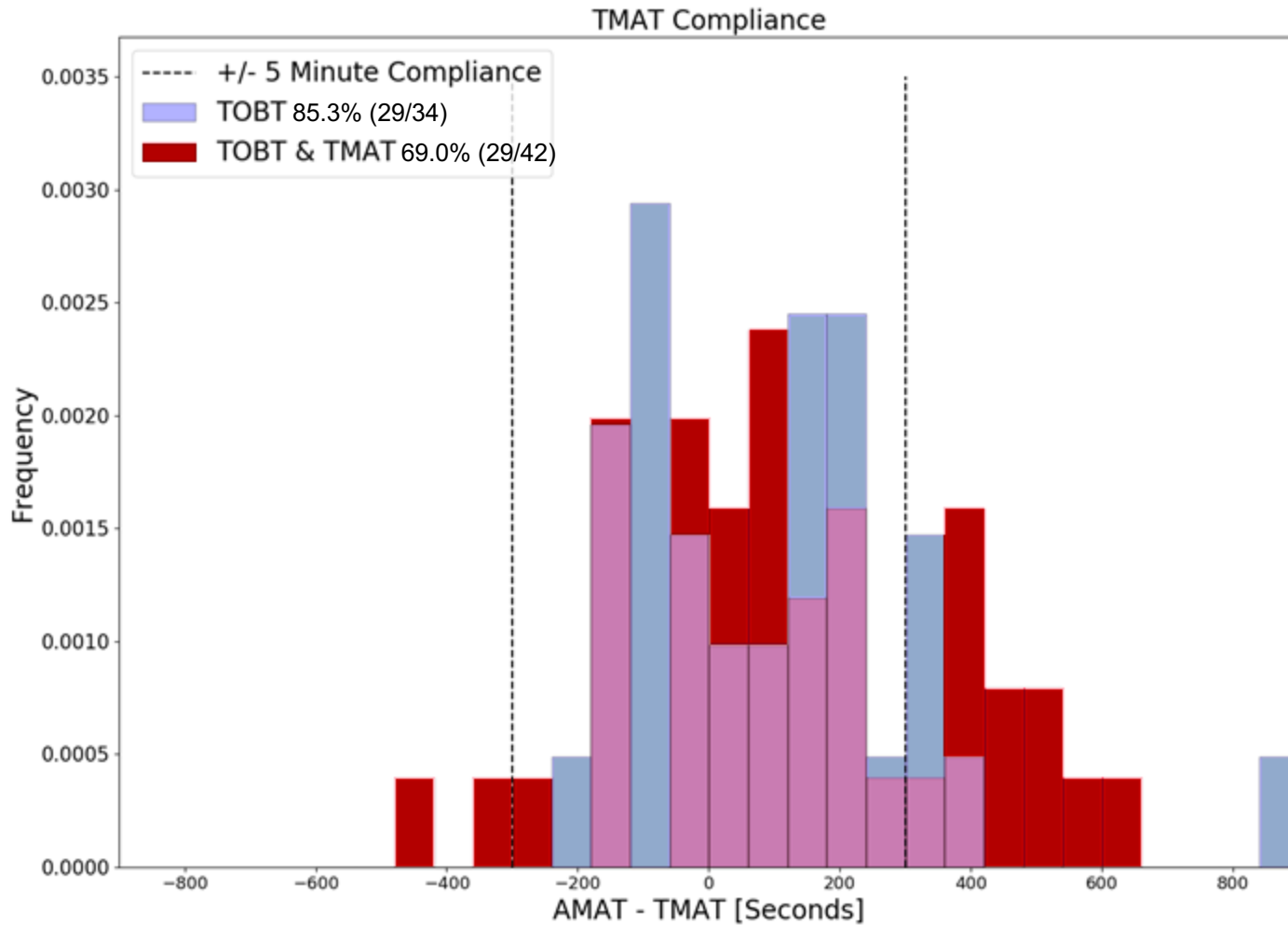
TMAT compliance was higher in the TOBT condition
compared to the TOBT & TMAT condition

Sequential TMAT Compliance and Scenarios

TMAT compliance as a function of pushback sequence in each of the three scenarios

Results Summary

Compliance with pushback advisories (TOBTs) and spot times (TMATs)

- Were the Ramp Controllers able to comply with the TOBTs?
  - TOBT compliance across the conditions was relatively similar with a compliance of 61.7% and 57.1% for the TOBT and TOBT & TMAT conditions, respectively

- Were the Ramp Controllers able to comply with the TMATs?
  - **Across both conditions the TMAT compliance increased when aircraft were first compliant with the TOBT advisory**
    - This relationship was also found in the operational field data [Coupe et al., 2019]
  - TMAT compliance was higher in the TOBT condition with 85.3% (29/34) compared to the TOBT & TMAT condition with 69.0% (29/42)
    - Sample size is relatively small
  - Increased controller workload could play a role and is explored in the following question

Questions

- Compliance with pushback advisories (TOBTs) and spot times (TMATs)
  - Were the Ramp Controllers able to comply with the TOBTs?
  - Were the Ramp Controllers able to comply with the TMATs?
- **Ramp Controller workload and situation awareness**
  - **What were the impacts of the conditions on Ramp Controllers' workload and situation awareness?**
- What were the processes Ramp Controllers used to meet TMATs?

Workload Assessment Keypad (WAK)

- WAK collected individual data points of workload during each run for the Ramp personnel once every 5 minutes

All workload data collection

- Ramp personnel asked to consider a workload rating of "3", or moderate, as comparable to nominal operations at CLT

Average Ramp Controller Workload During Runs
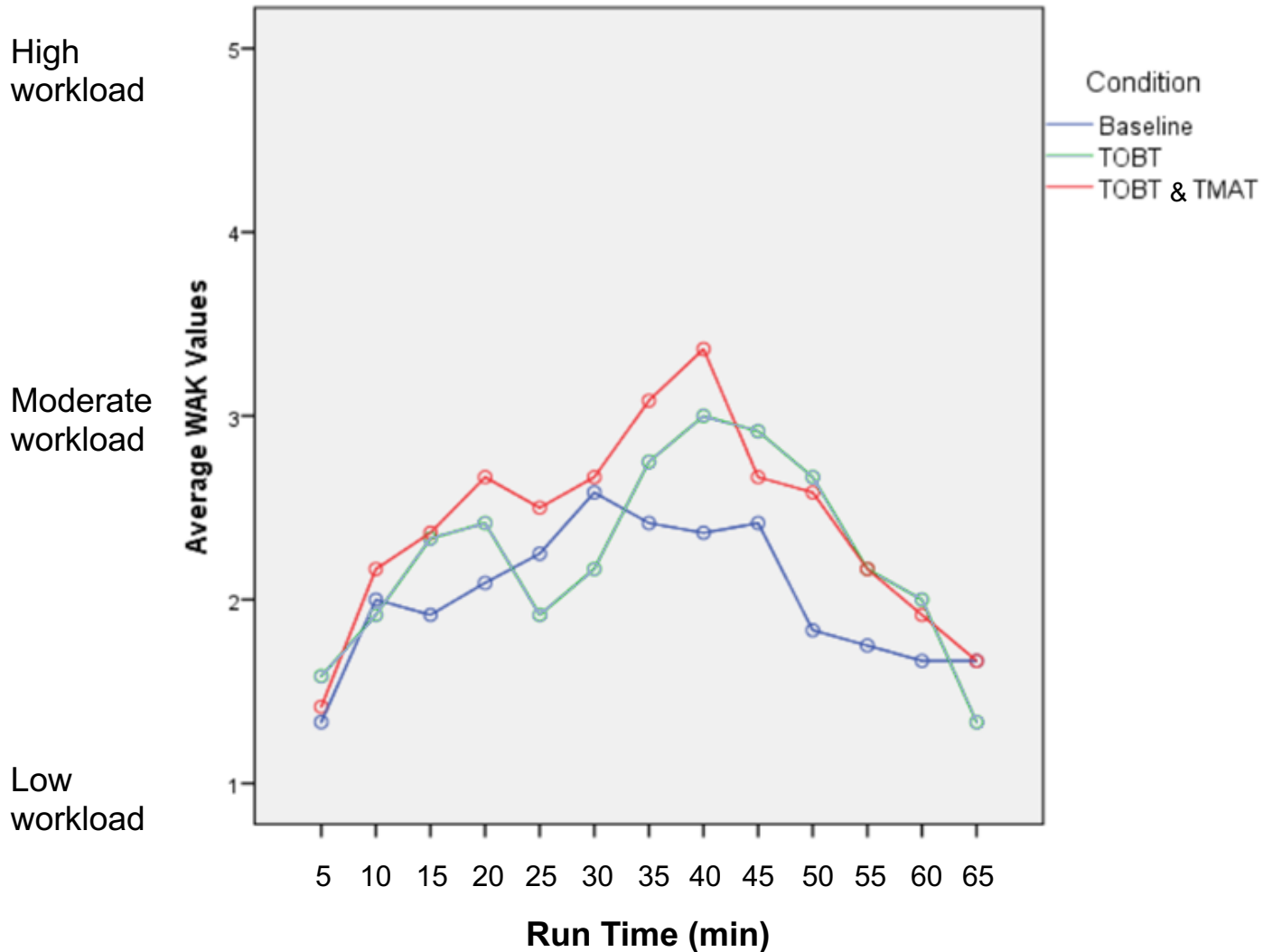
Ramp Controller workload highest in TOBT & TMAT condition

Average Ramp Manager Workload During Runs
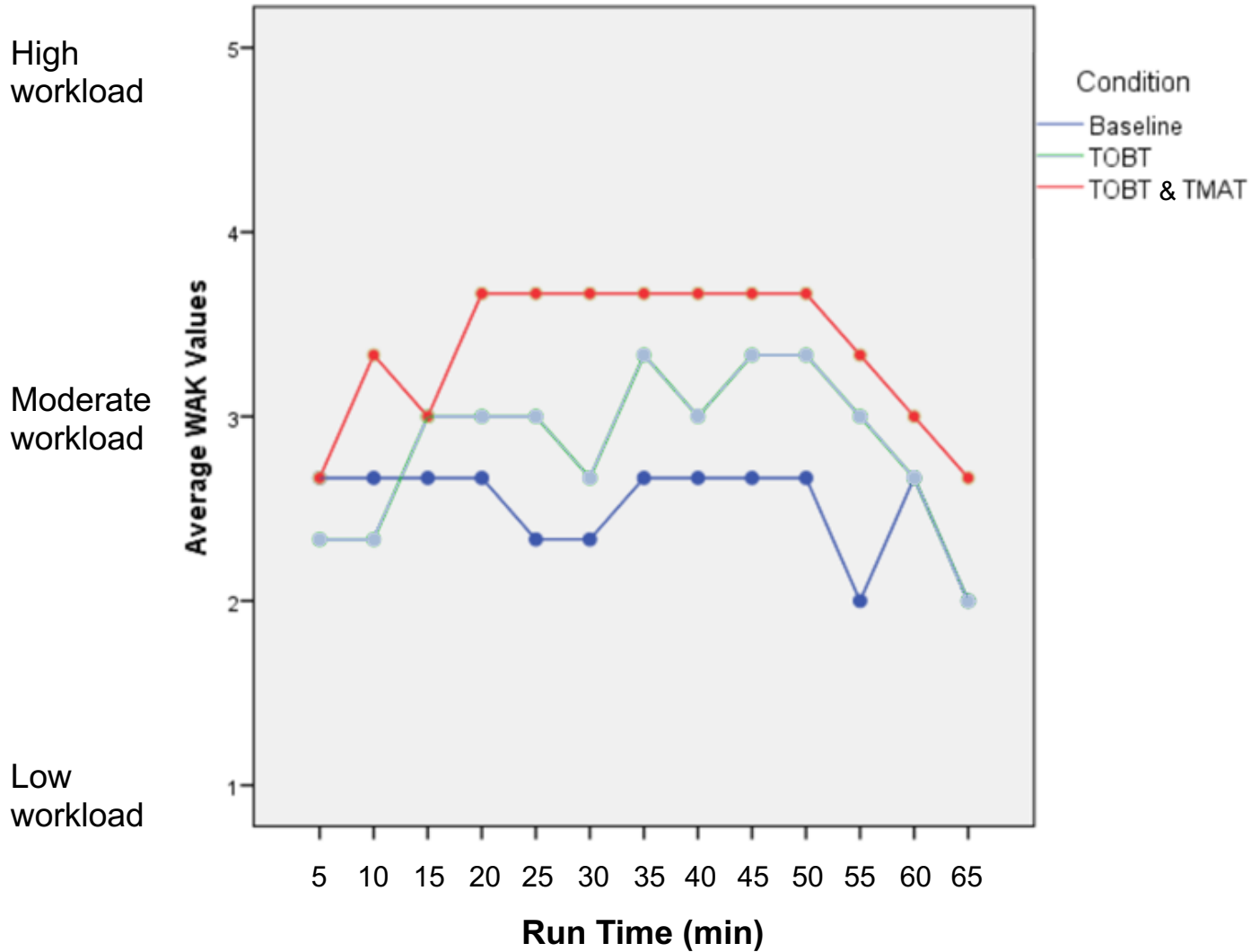
Ramp Manager workload highest in TOBT & TMAT condition

Please rate the following based on _when you were busiest_ during this run:

Error bars are 95% CIs. _N_ = 36 ratings, 12 in each condition for each item.
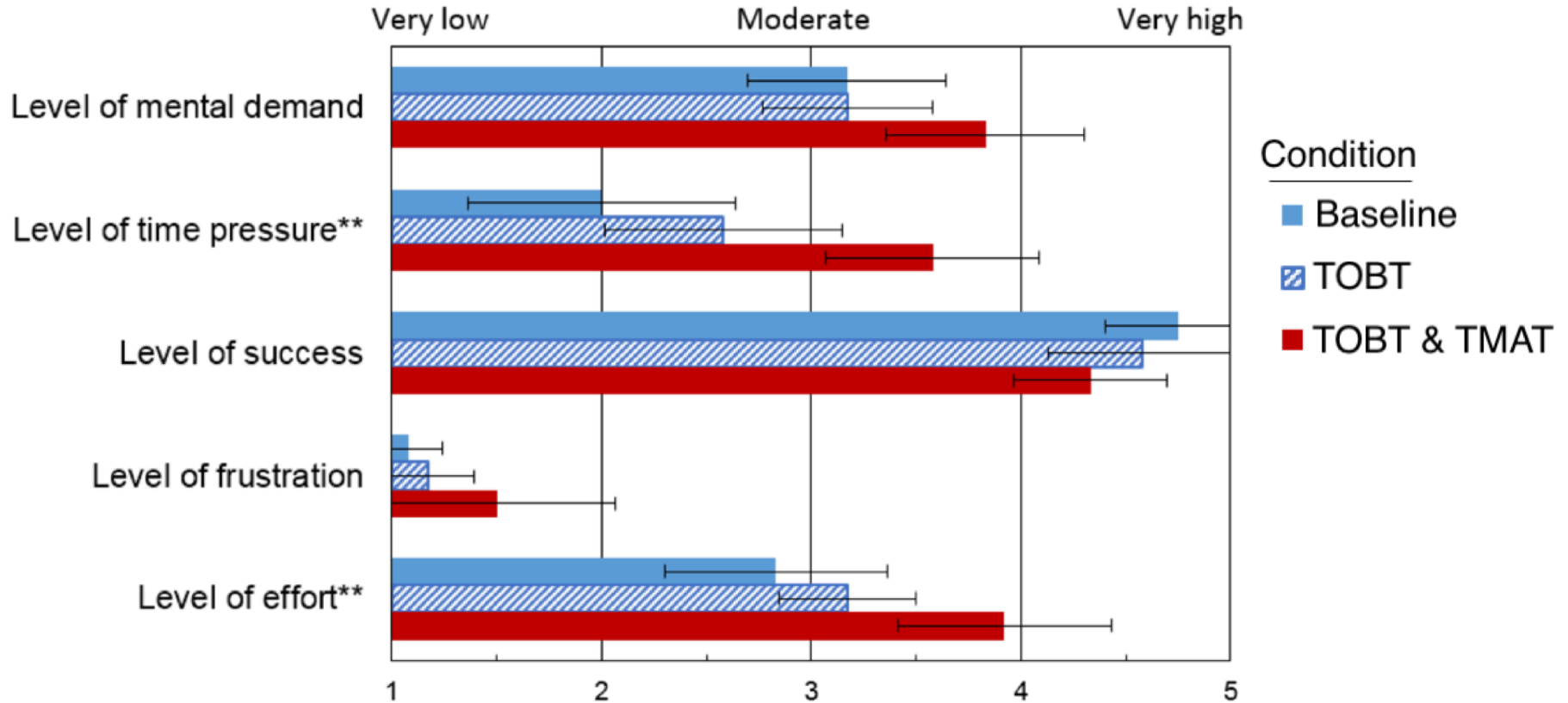
Ramp Controllers' ratings of "Time Pressure" and "Effort" were statistically significantly higher in TOBT & TMAT condition than Baseline

- Workload and Time Pressure
  - "Things were flowing a bit fast.. I didn't have enough time to really sequence the TMAT times."
  - "I think once the ramp got congested, it basically made the TMAT times insufficient. I would like to have had another way to get a few of them out thru the traffic."

- Problems with TMAT Times
  - "Some of the flights' TMATs were exceeded upon push because they had to hold at the gate."
  - "DAL2422 was sent to the spot (12) ~10 minutes prior to TMAT. If we held him back until TMAT it was probable he would have missed APREQ."

Please describe your workload at the busiest times in each of the conditions in this simulation.

Error bars = 95% CIs. N = 4. Repeated measures ANOVA sphericity not assumed, $F(2,2) = 28$, $p = .03$.
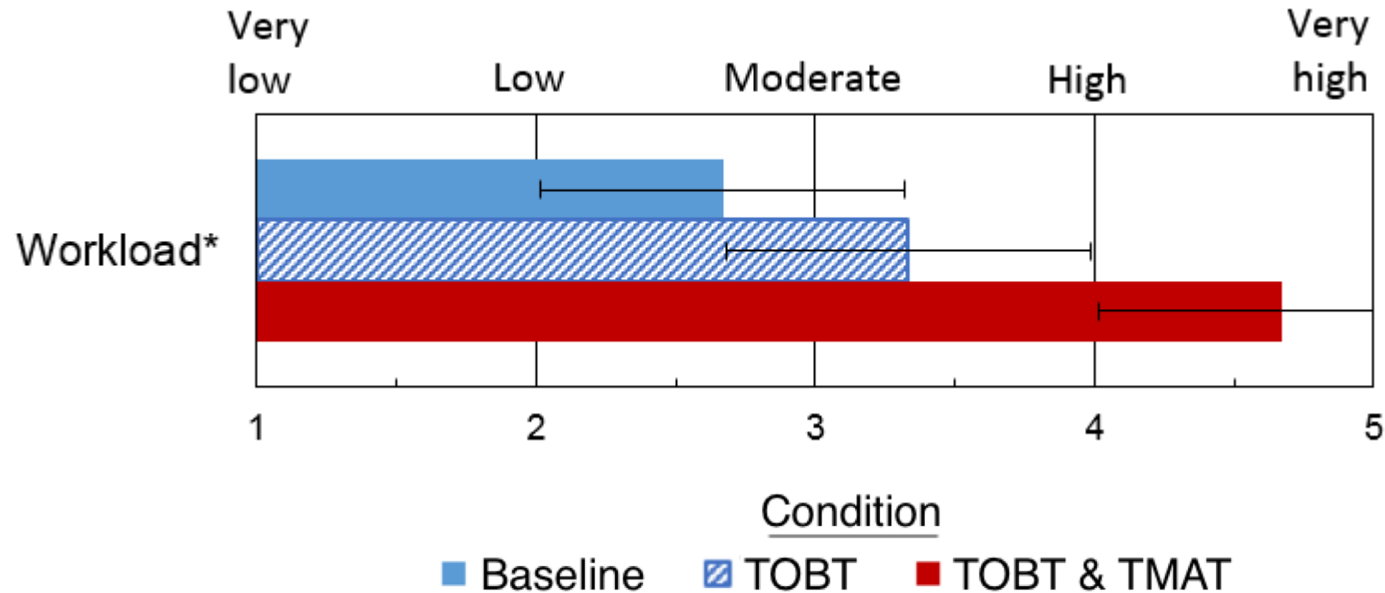
Ramp Controllers' ratings of general workload were statistically significantly higher in TOBT & TMAT condition

Ramp Personnel Post-Simulation Comment on TMAT Workload

"Trying to think about the TMAT times and keeping them in order without a clock can some times be demanding. Trying to keep order and recognize what other team members may have going on is demanding enough. Once I push and send an instruction to taxi, I usually don't have enough time to go back and see if the TMAT time is within limits. I think the system should monitor and adjust these numbers."

SART Rating Formula = Understanding + (Supply – Demand) of Attentional Resources, i.e., SA = U + (S-D)

N = 36, 12 in each condition ANOVA significant at p = .04, error bars are 95% CIs.

Ramp Controllers' ratings of situation awareness were statistically significantly lower in TOBT & TMAT condition than Baseline

Ramp Controller workload and situation awareness

- **What were the impacts of the conditions on Ramp Controllers' workload and situation awareness?**

  - In the TOBT & TMAT condition, the workload was statistically significantly higher and the situation awareness was statistically significantly lower than Baseline

  - In the TOBT condition, the workload and situation awareness were not statistically significantly different from Baseline

Questions

- Compliance with pushback advisories (TOBTs) and spot times (TMATs)
  - Were the Ramp Controllers able to comply with the TOBTs?
  - Were the Ramp Controllers able to comply with the TMATs?
- Ramp Controller workload and situation awareness
  - What were the impacts of the conditions on Ramp Controllers' workload and situation awareness?
- **What were the processes Ramp Controllers used to meet TMATs?**

How frequently in this run did you use TMATs to make decisions about sequencing aircraft?

Distribution: A chi square showed this to be significantly different by *participant number*, meaning that some controllers used the TMATs to make decisions nearly all the time and other did so very rarely if at all. $p = .04$ (df 2) = 22. $n = 12$ ratings.
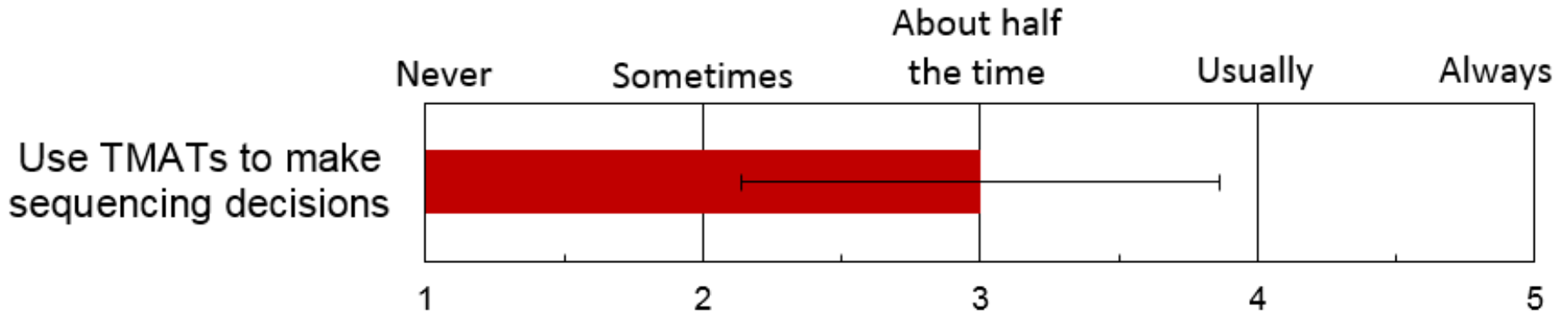
Ramp Controllers used TMATs about half the time to make decisions about sequencing aircraft

Ramp Controller Post-Run Ratings of Frequency of Holding Aircraft to Meet TMATs

In this run, once aircraft were off the gate, did you hold any in your sector to help achieve TMATs?

Frequency of Holding Aircraft in Sector to Achieve TMATs
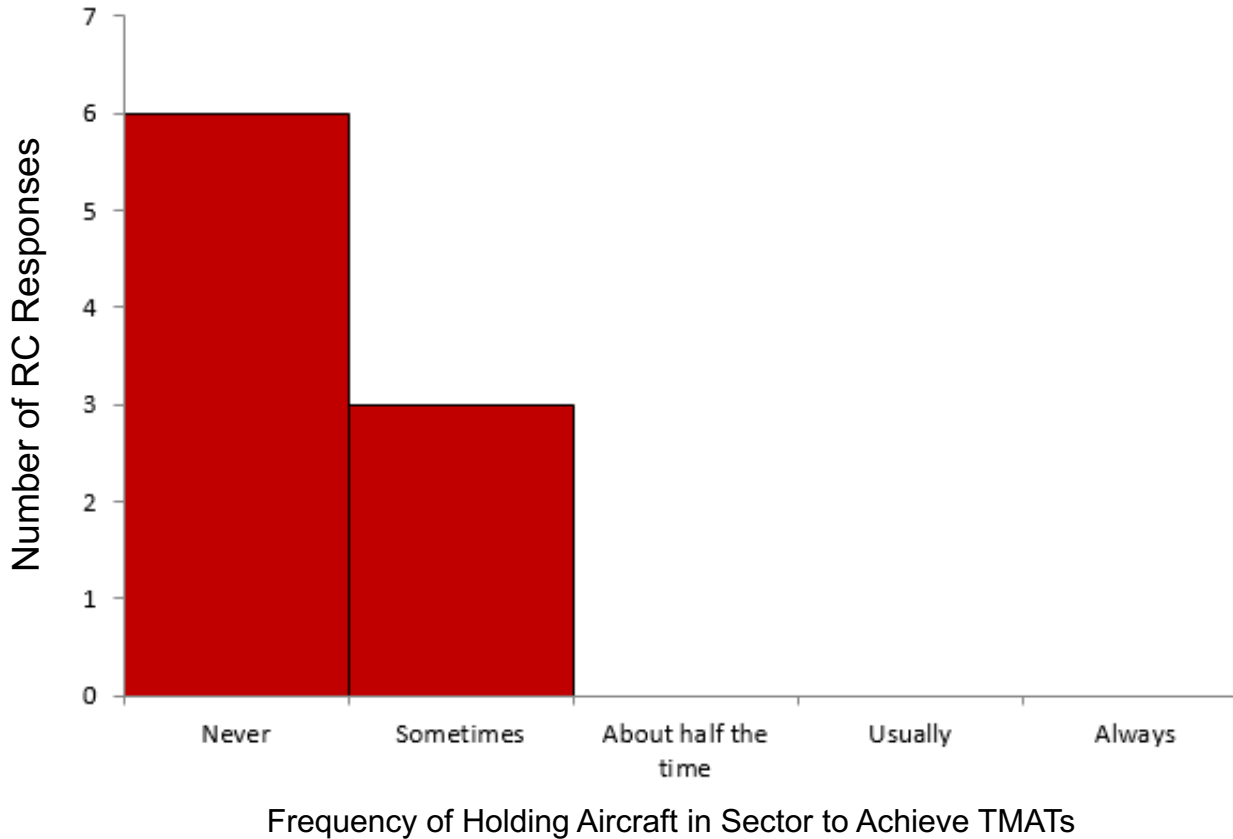
Ramp Controllers rarely held aircraft in their sector to achieve TMATs

Please rate how appropriate the times of the TMATs were in this run for aircraft coming from the gates in <u>your</u> sector and from <u>other</u> sectors.
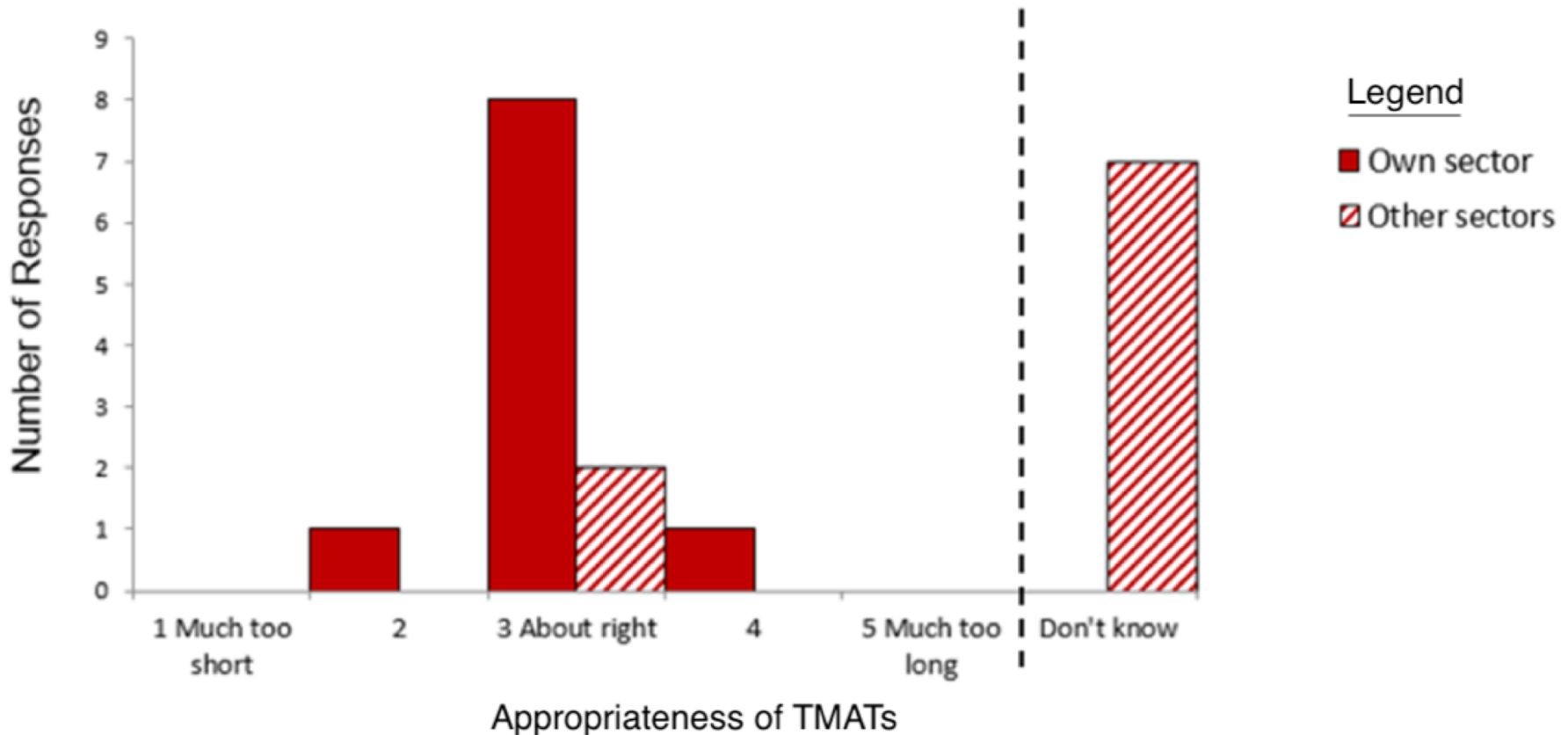
Ramp Controllers rated TMATs as "About Right" for their own sector; Ramp Controllers not aware of appropriateness of TMATs in other sectors

In this run, about how often were you successful in achieving TMATs for aircraft coming from gates in <u>your</u> sector and from <u>other</u> sectors?
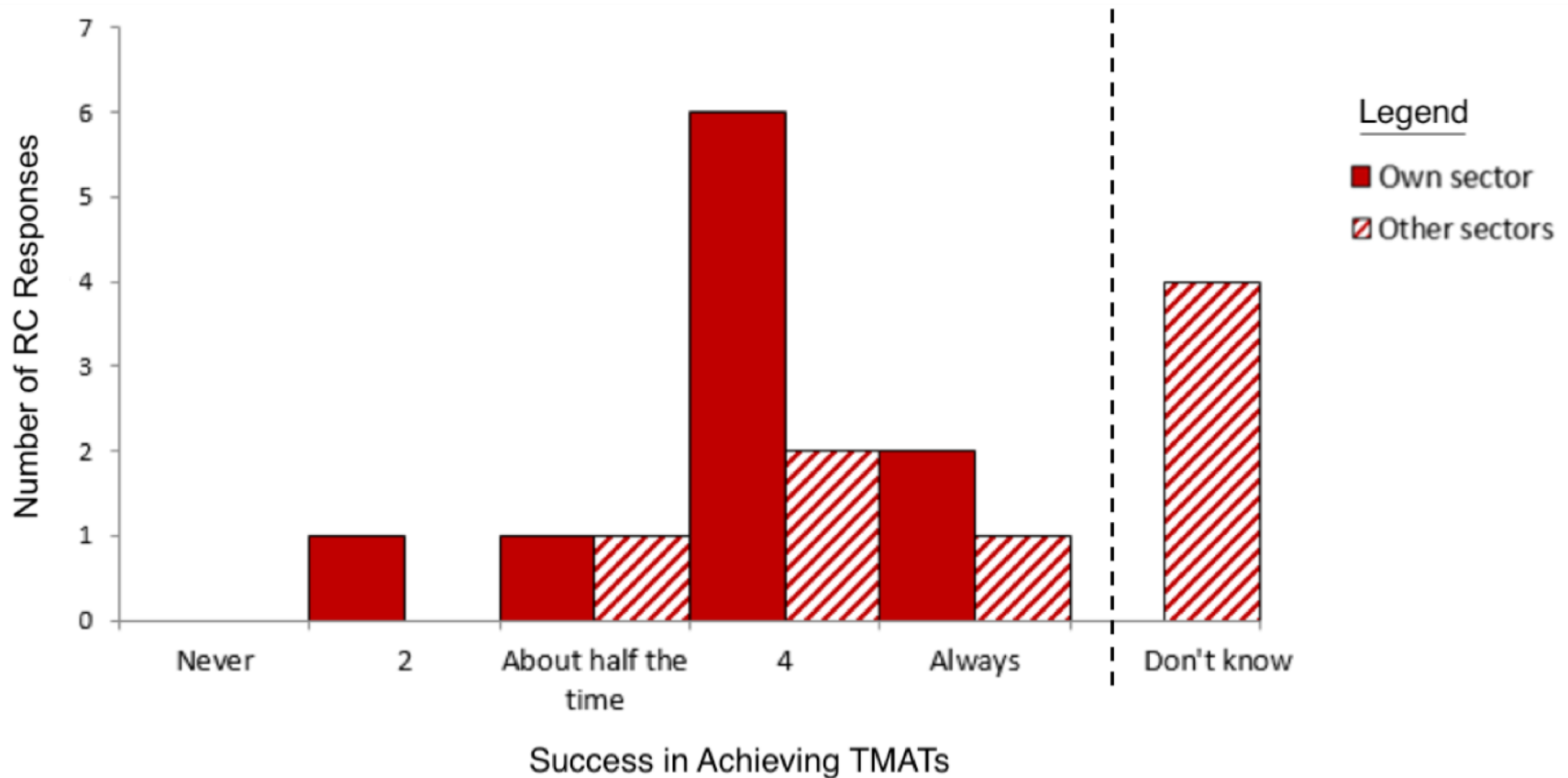
Ramp Controllers rated themselves fairly successful in meeting TMATs in their own sector

In this run, how difficult was it to arrange for a flight to meet its TMAT from aircraft coming from gates in <u>your</u> sector and from <u>other</u> sectors?
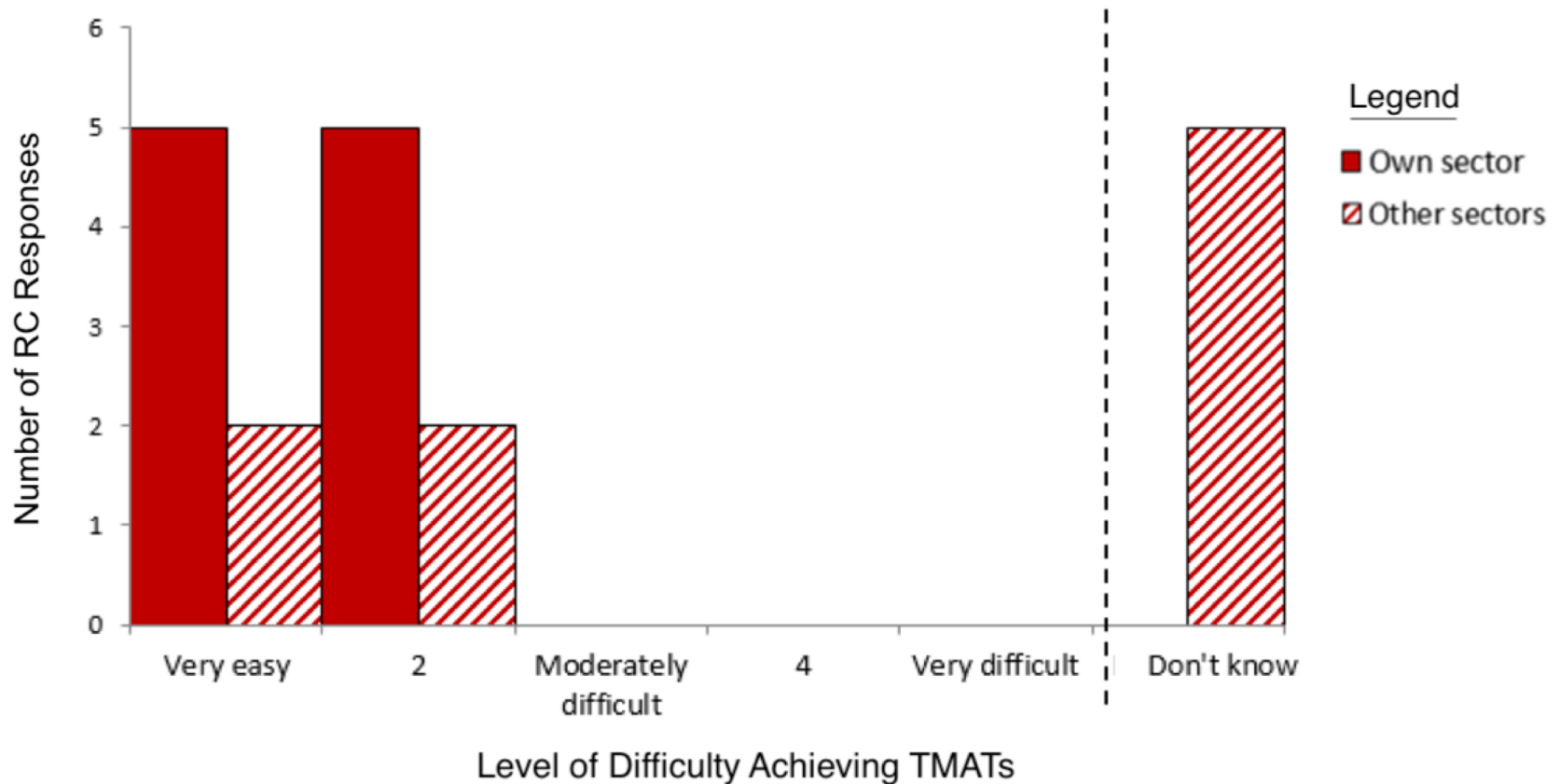
Ramp Controllers rated achieving TMATs in their own sector as easy

In this run, how often did you coordinate with others in an attempt to achieve the TMAT? With other controllers? With the Ramp Manager?

Description of role of Ramp Manager by Ramp Manager: "Helping the ramp controllers develop a plan and prioritize. Who pushes, who holds, will they go directly to TMAT spot or alternate location to hold in order to meet TMAT."

Legend
- With other controllers
- With Ramp Manager
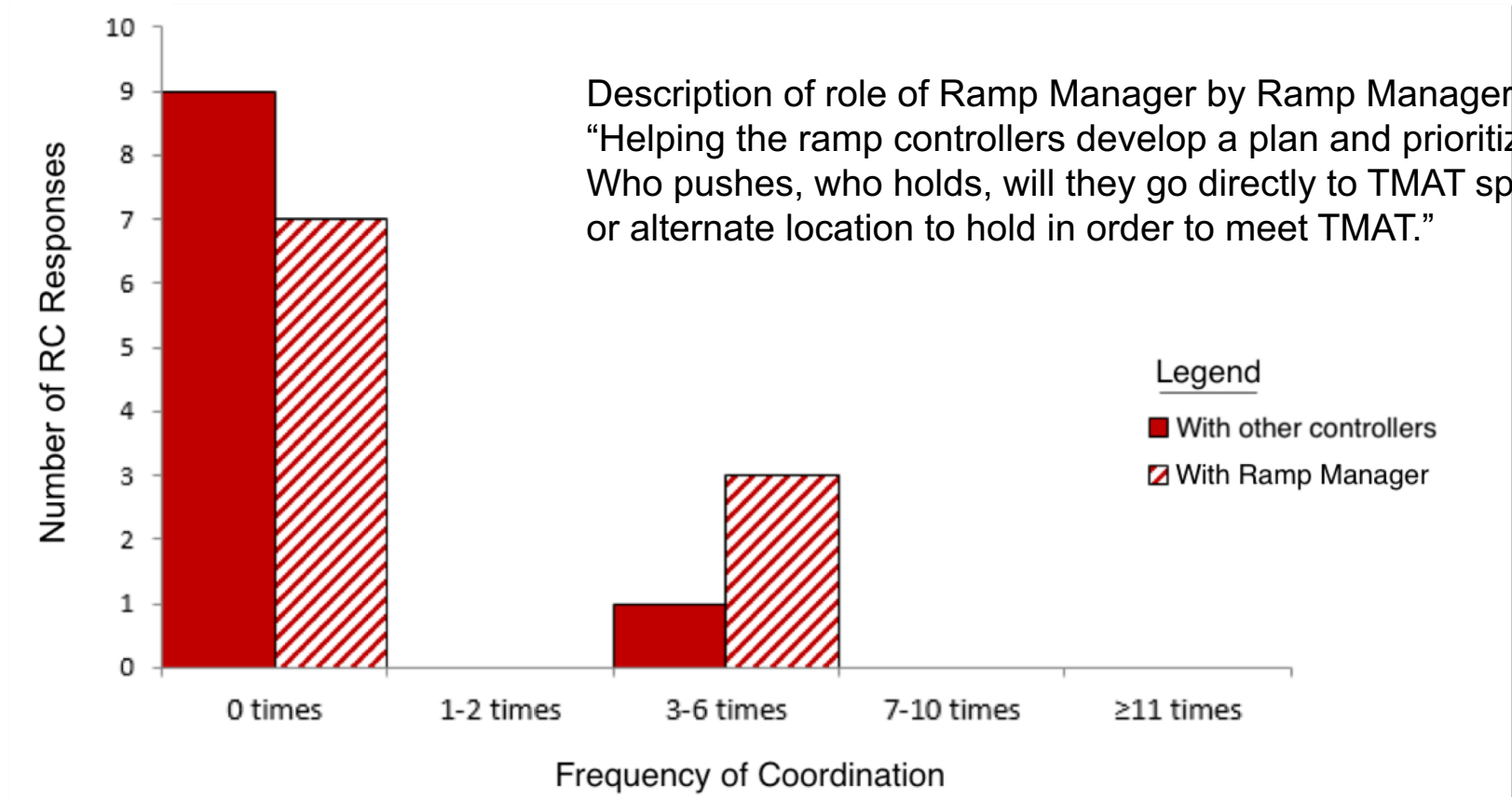
Ramp Controllers perceived low frequency of coordination for achieving TMATs, despite mid-run observations to the contrary

What were the processes Ramp Controllers used to meet TMATs?

- Used TMATs about half the time to make decisions about sequencing aircraft

- Rated TMATs as "About Right" for their own sector;

- Rarely held aircraft in their sector to achieve TMATs

- Rated achieving TMATs in their own sector as easy and as being successfully accomplished

- Self-reported infrequent coordination with other controllers or the Ramp Manager to achieve TMATs

Appendix

Scenario Metrics

Total Departure Surface Count

- Total number of departures on the surface at every minute
  - Grouped and averaged by condition

Total Surface Count (averaged)
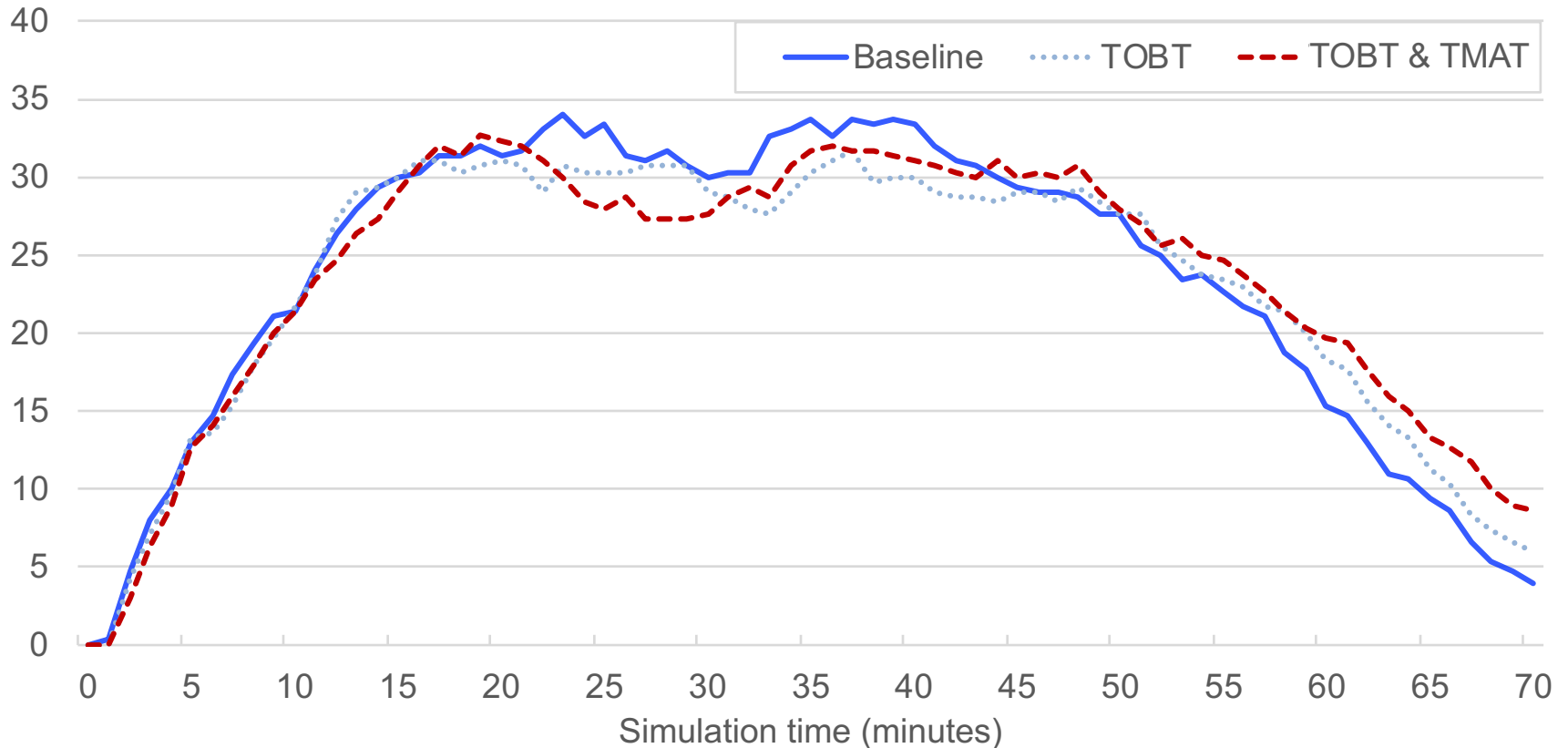
Departure Surface Count in AMA and Ramp

AMA Surface Count (averaged)

Baseline · · · · TOBT - - - TOBT & TMAT

Ramp Surface Count (averaged)

Baseline · · · · TOBT - - - TOBT & TMAT

Total Departure Surface Count by Runway

Total Surface Count (averaged) – Runway 36R

Total Surface Count (averaged) – Runway 36C

Legend: Baseline, TOBT, TOBT & TMAT

AMA Departure Surface Count by Runway
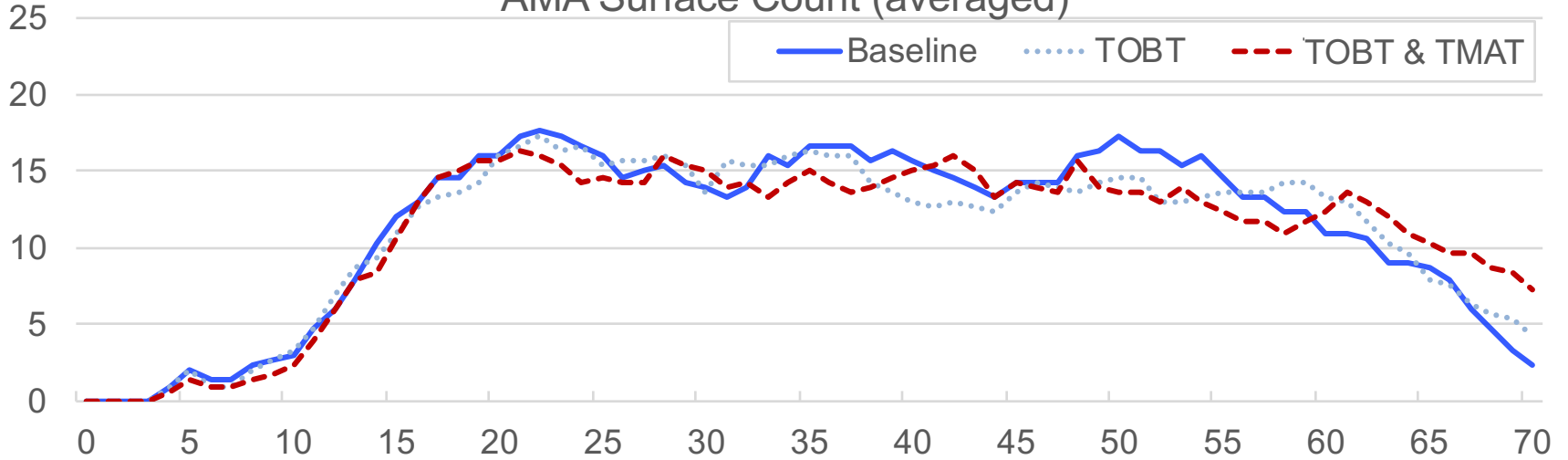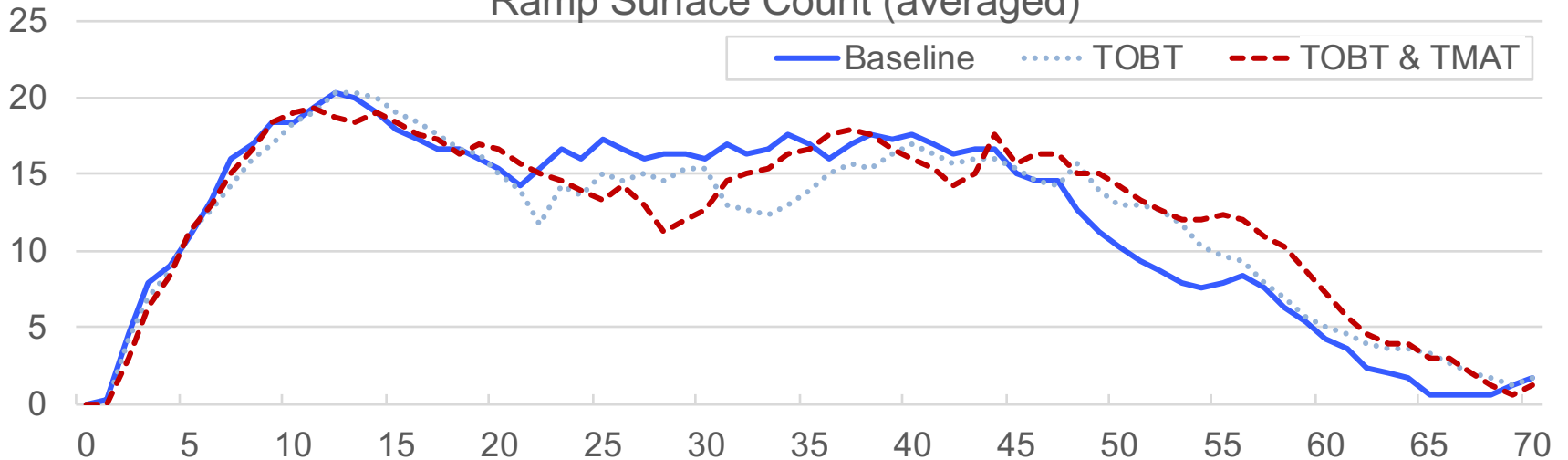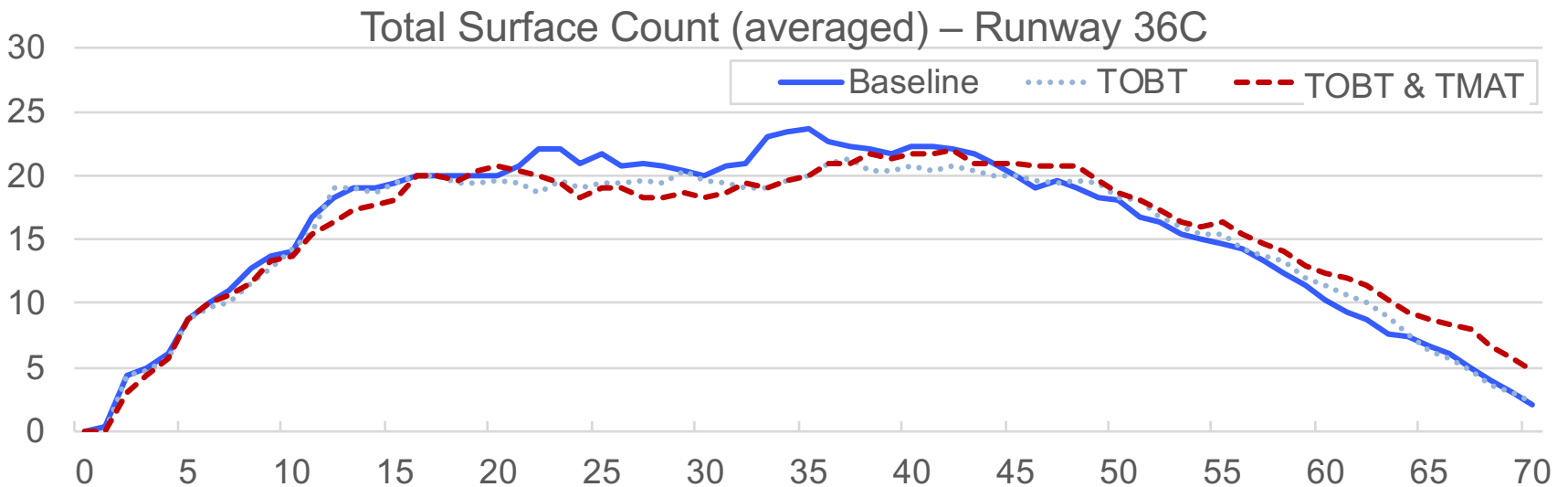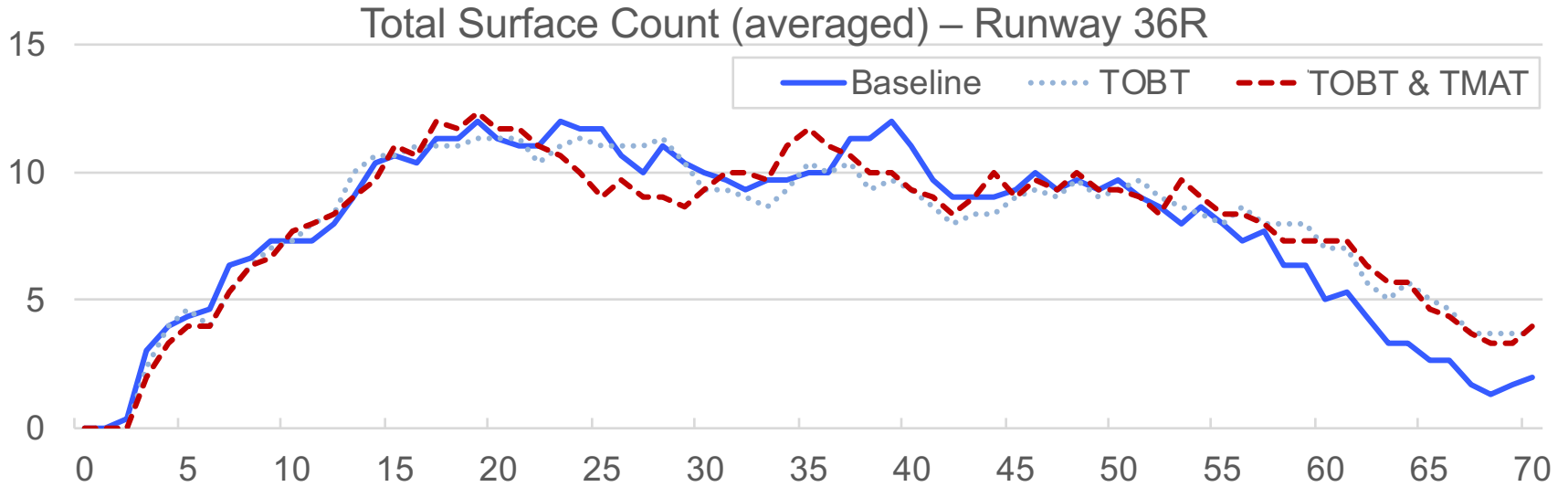
AMA Surface Count (averaged) – Runway 36R

AMA Surface Count (averaged) – Runway 36C

Spot Changes During HITL
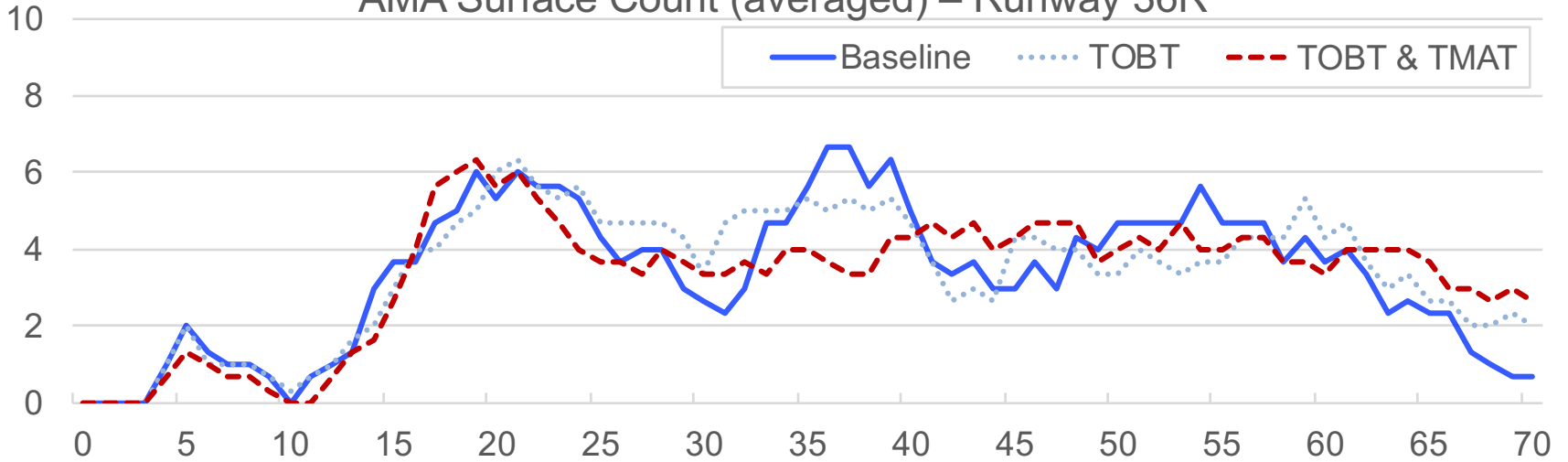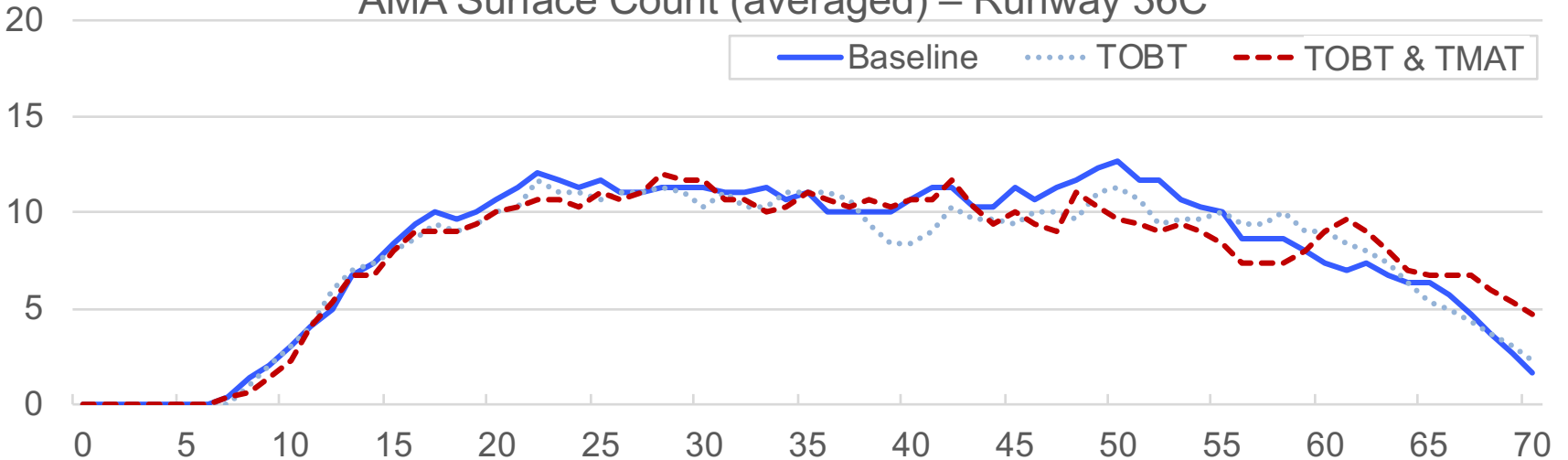
- Ramp controllers can change spots to reduce ramp congestion

- Expected spot changes (from actual operations playback)
  - From Spot 24 to Spot 27E
  - Departures from E-Concourse (E-Con) to detour the blocked single taxi lane near D-Con

- Actual spot changes (from HITL)
  - Between Spot 13, 22W, and 24
  - Departures from B/C-Con to Runway 36C to avoid ramp congestion between Spots 13 and 24

Condition	Spot Changes (total)
Baseline	11
TOBT	6
TOBT/TMAT	7

During the busiest time in this run, how acceptable were the following in terms of operational efficiency? Comments?

*N*s = 12 ratings for each item in each condition; error bars = 95% CIs.
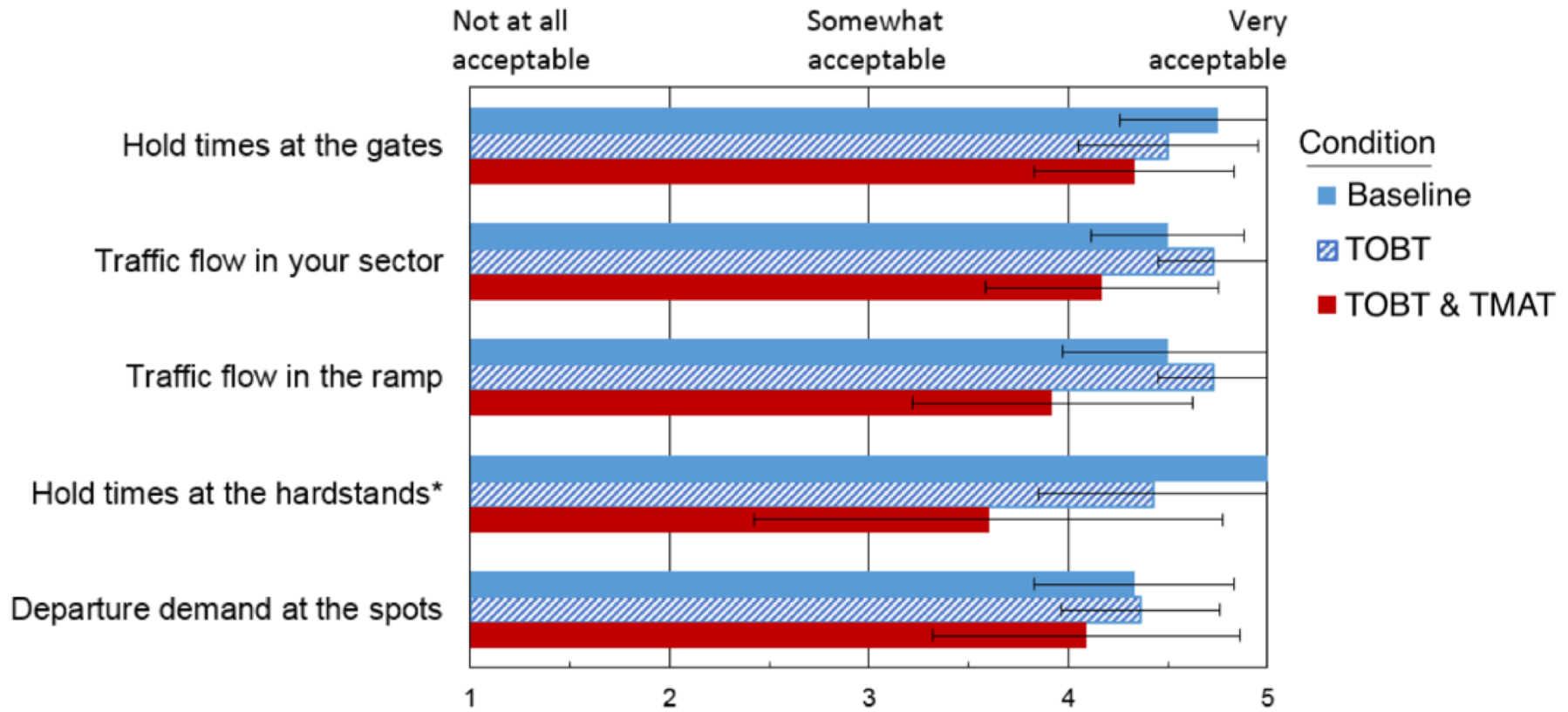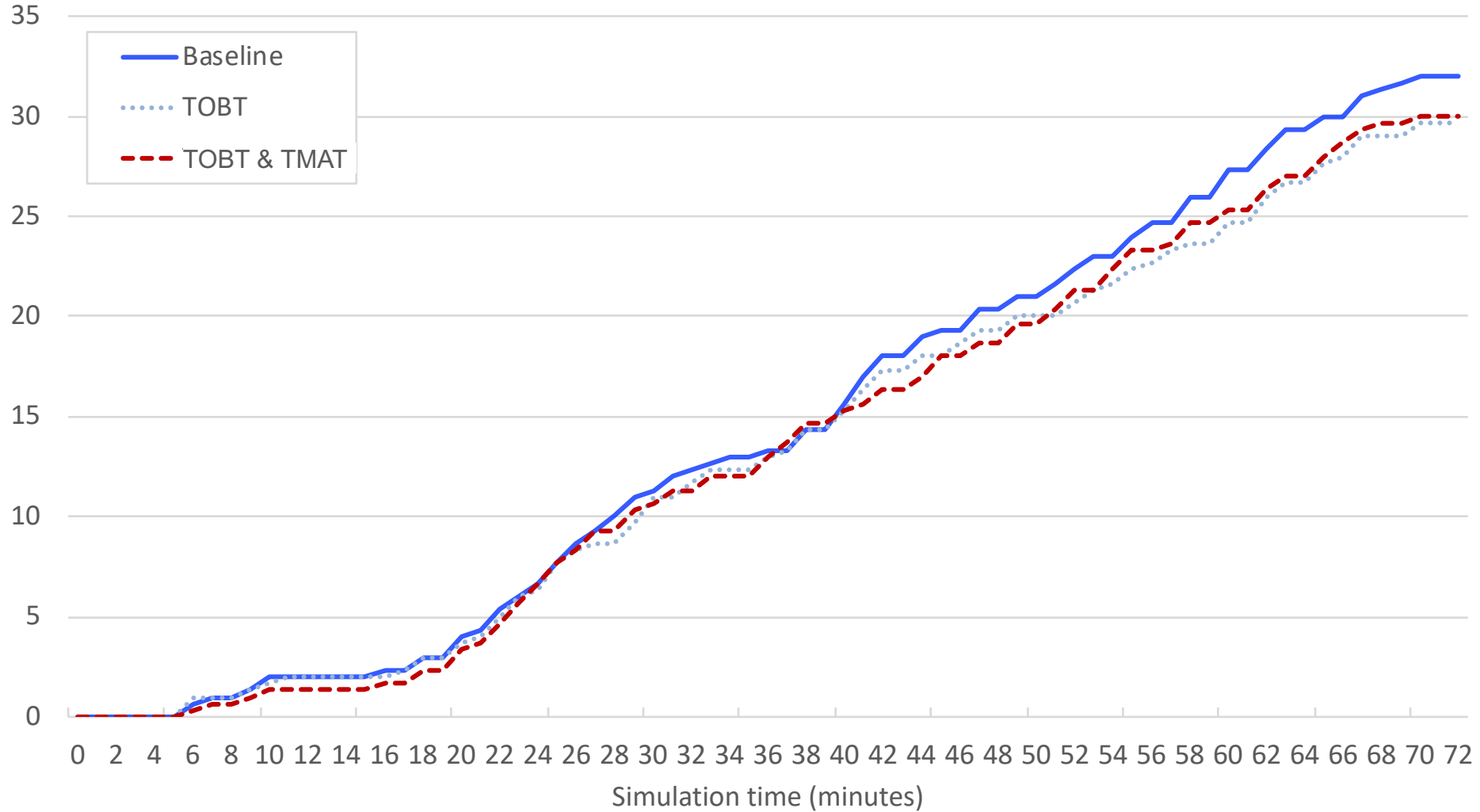
Dedicated Departure Runway Throughput – 36C

Accumulated Runway Throughput - Runway 36C

Legend:
- Baseline
- TOBT
- TOBT & TMAT

X-axis: Simulation time (minutes)
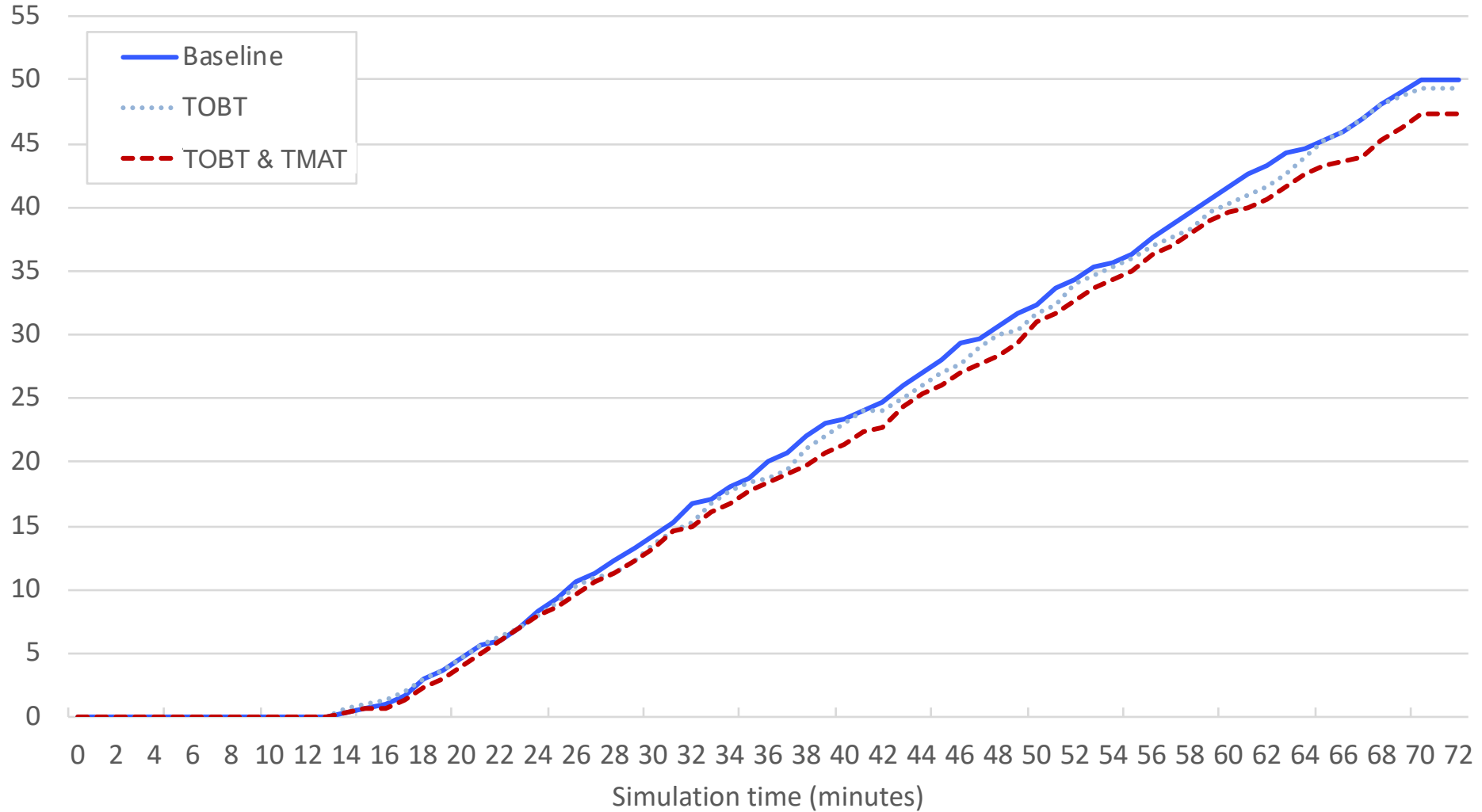
Dual Use Arrival & Departure Runway Departure Throughput – 36R

Accumulated Runway Throughput - Runway 36R

Legend:
- Baseline (solid blue line)
- TOBT (dotted light blue line)
- TOBT & TMAT (dashed red line)

X-axis: Simulation time (minutes)

Accumulated Runway Throughput - Runway 36R

Departures and Arrivals in this plot

Legend:
- Baseline
- TOBT
- TOBT & TMAT

X-axis: Simulation time (minutes)

Arrival Runway Throughput – 36R
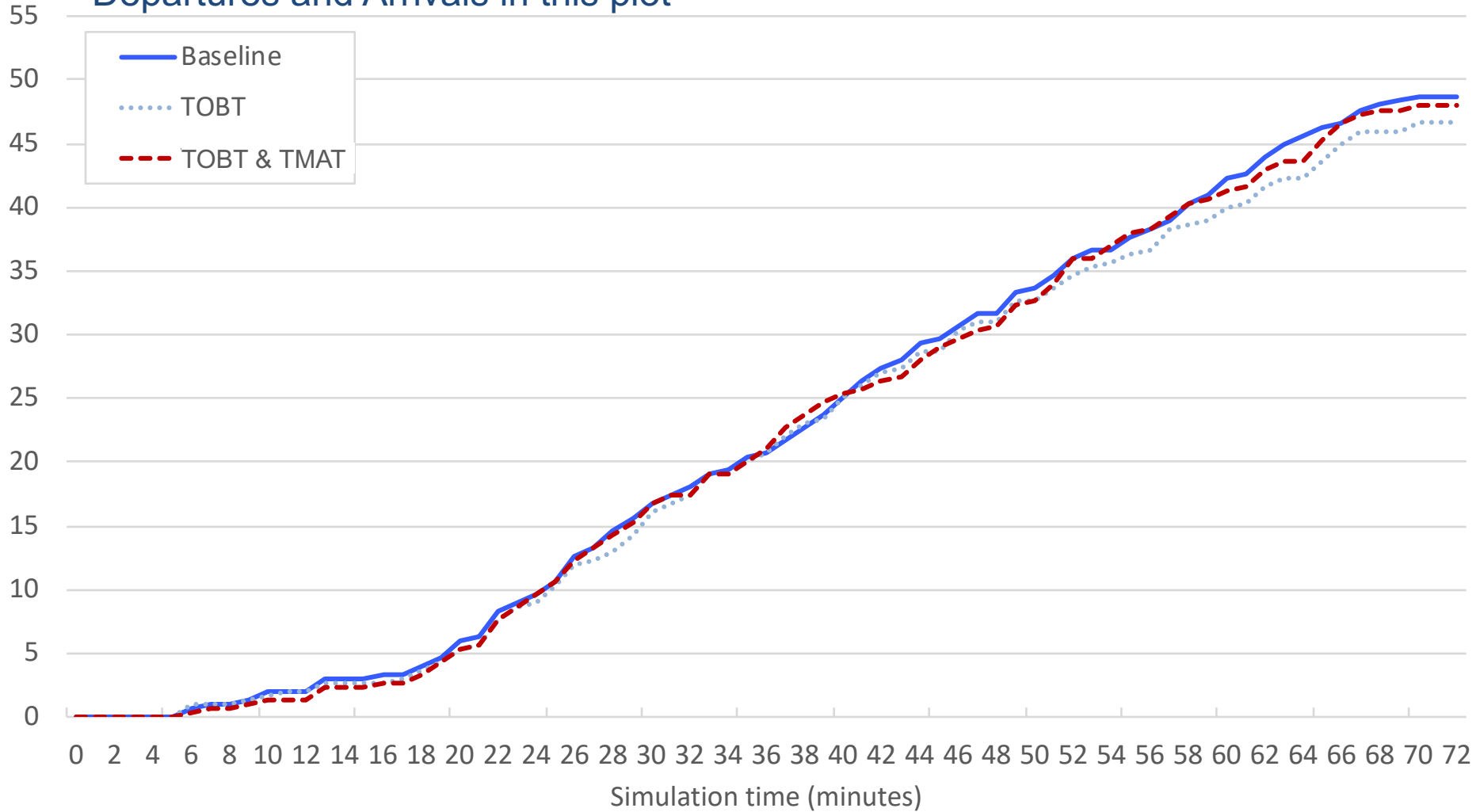
Accumulated Runway Throughput - Runway 36R

Arrivals only in this plot

Legend:
- Baseline
- TOBT
- TOBT & TMAT

X-axis: Simulation time (minutes)

Accumulated Runway Throughput - Runway 36L

Legend:
- Baseline
- TOBT
- TOBT & TMAT

X-axis: Simulation time (minutes)
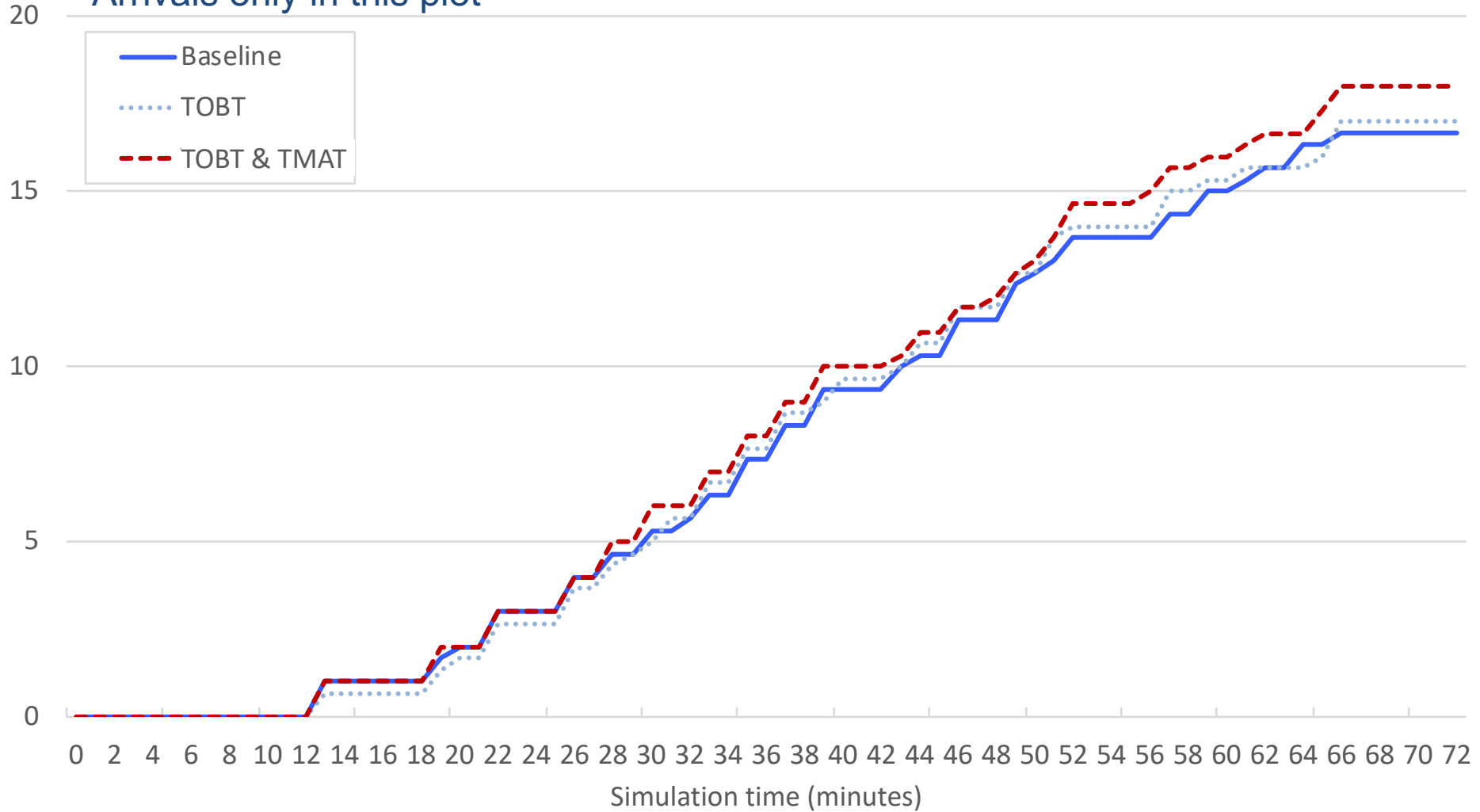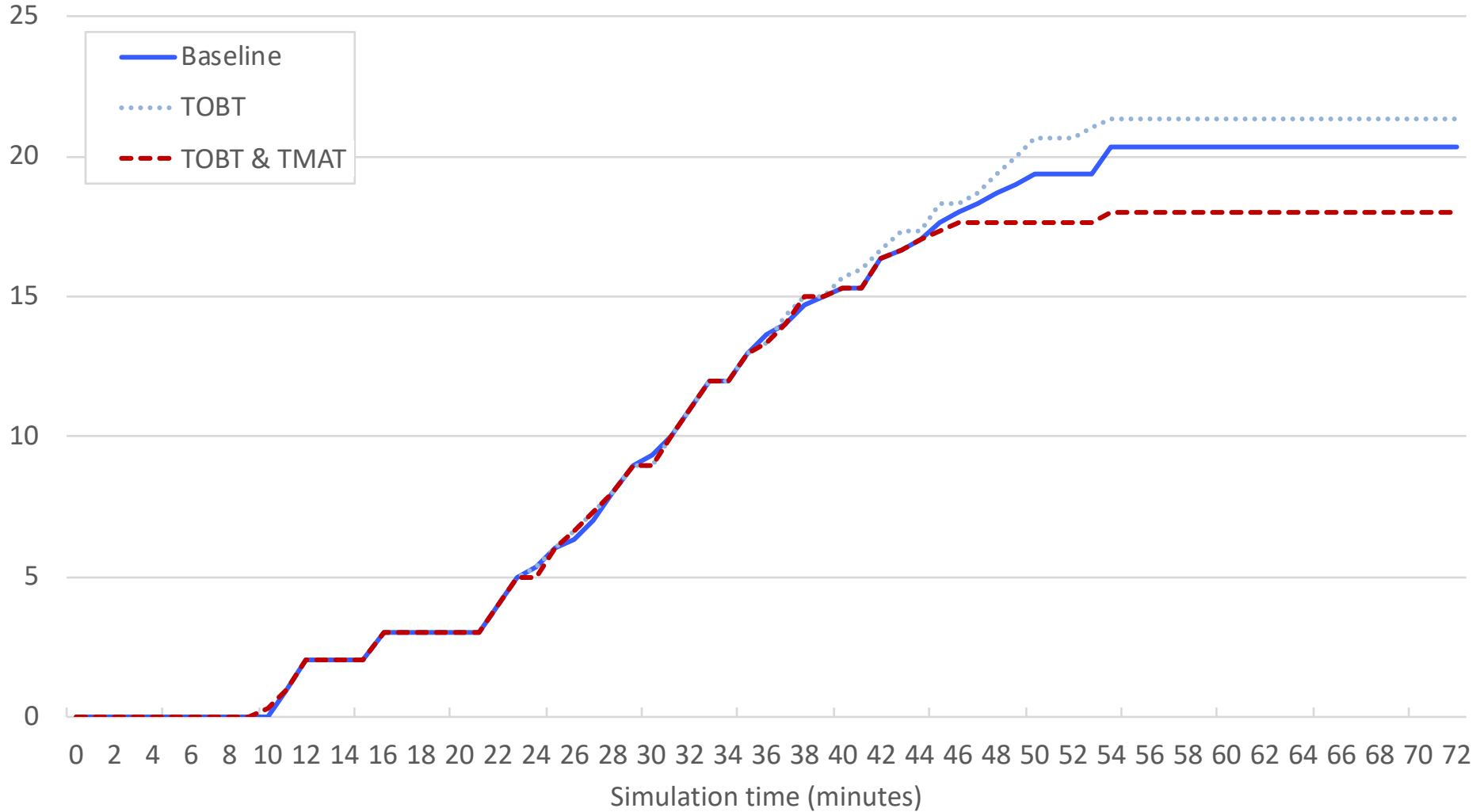
Local Controllers Post-Run Ratings of Operational Efficiency

During the busiest time in this run, how acceptable were the following in terms of operational efficiency? Comments?

Error bars = 95% Cis; Ns = 6 ratings for each item in each condition except for queue lengths: 36R n's = 3, 3, & 3; 36C n's = 6, 4, 4.
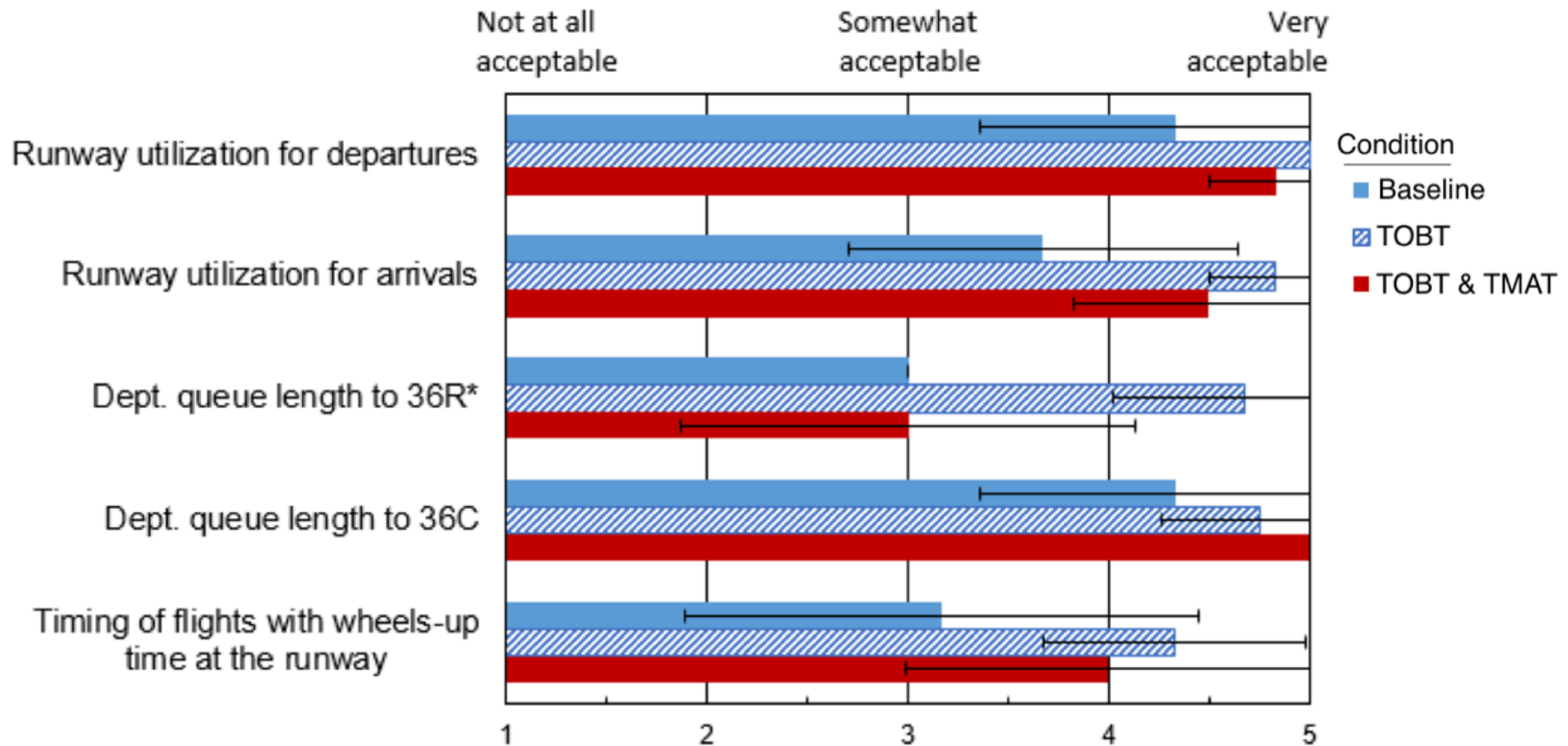
Local Controller Post-Run Ratings of Runway Queue Lengths

Please describe more specifically the lengths of the runway queues during the busiest time in this run.

Error bars are 95% CIs. n's = 3, 2, and 3 ratings for each condition for Runway 36R; and 6, 4, and 4 ratings in each condition for Runway 36C.
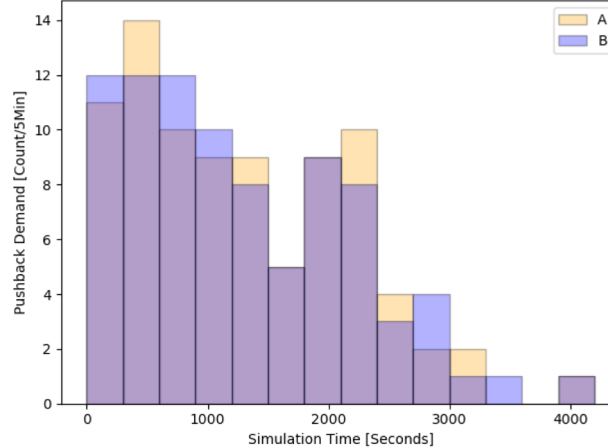
How Scenarios were Built
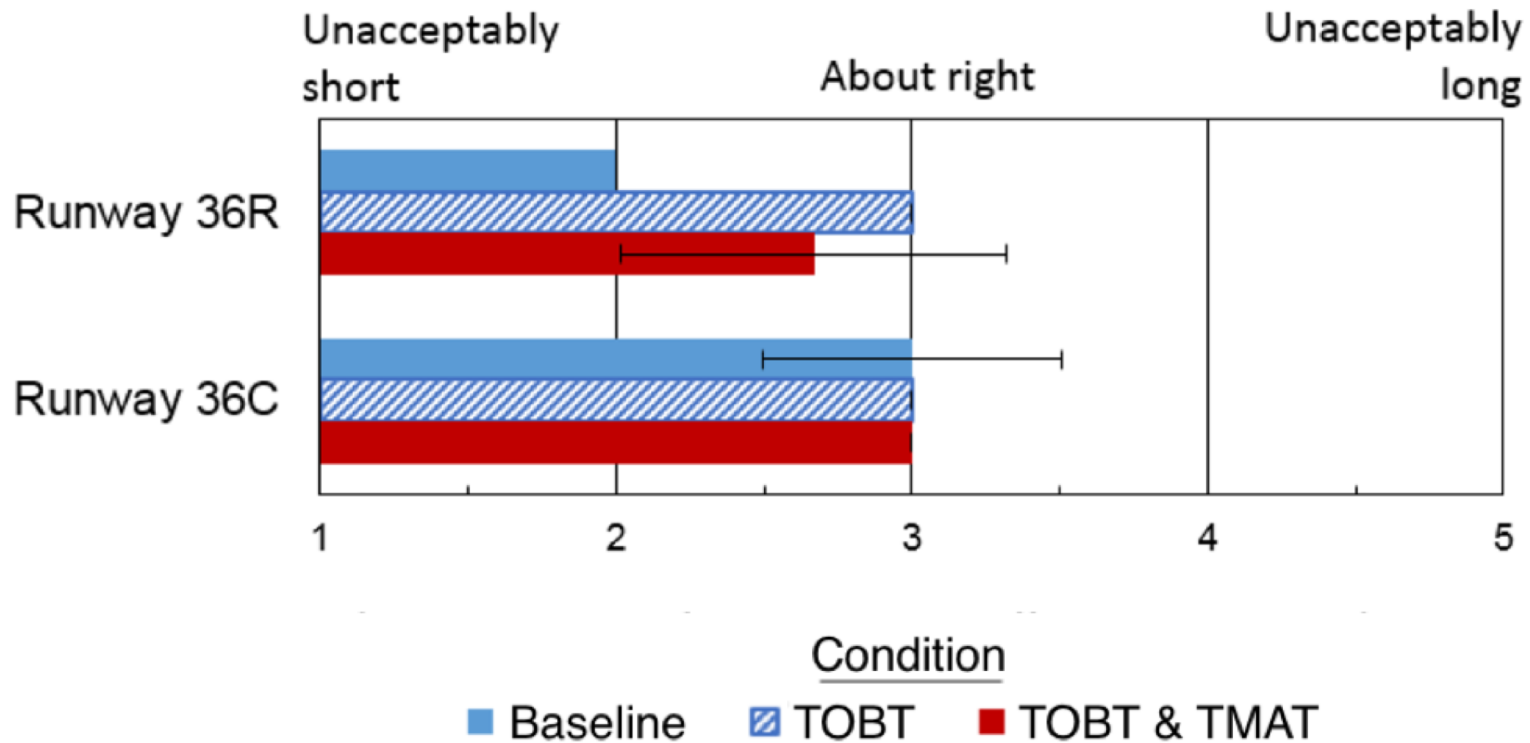
- Three scenarios
  - Scenario A: based on actual operations data at Feb 13, 2018 Bank 2
  - Scenarios B & C
    - Random variations in flight ready times from Scenario A, keeping the same level of departure pressure
    - Same call sign, gate and runway assignment
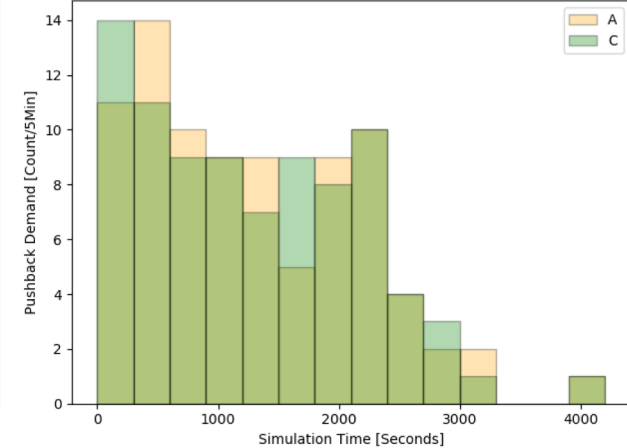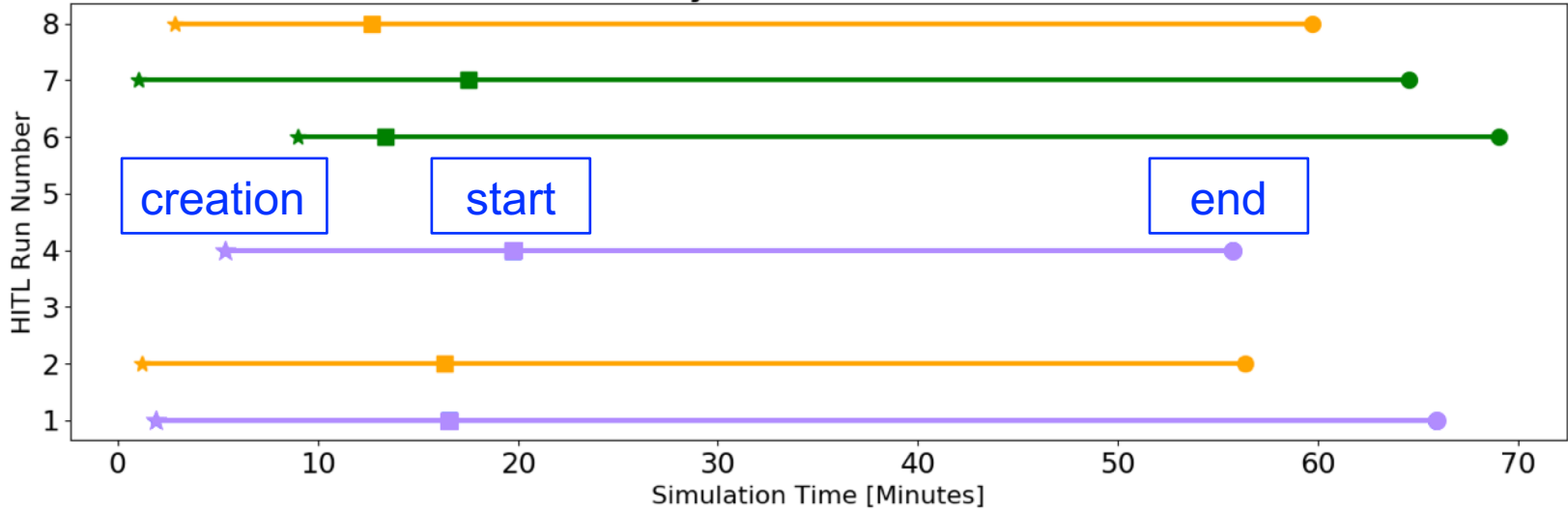   - Same arriving flight data
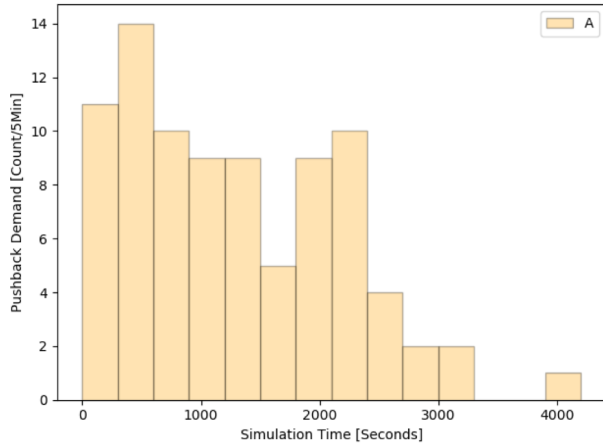
Runway 36C SMP Duration
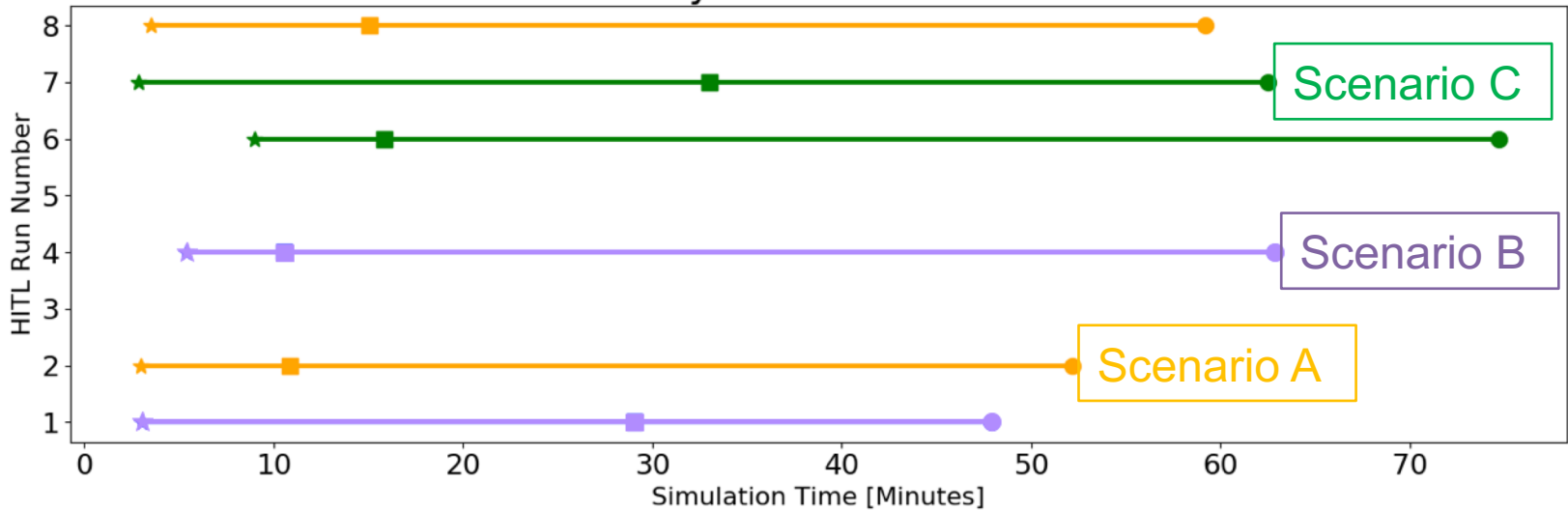
Runway 36R SMP Duration

- Ramp Personnel
  - Described TMAT Condition as least optimal for workload on the WAK, and trending towards least optimal on other measures of workload and acceptable ops
  - Perceived high but acceptable ramp controller workload in all conditions
  - Would prefer knowing the TMAT departure sequence early on