

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

## Final Results

March 2019



- 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



- 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?

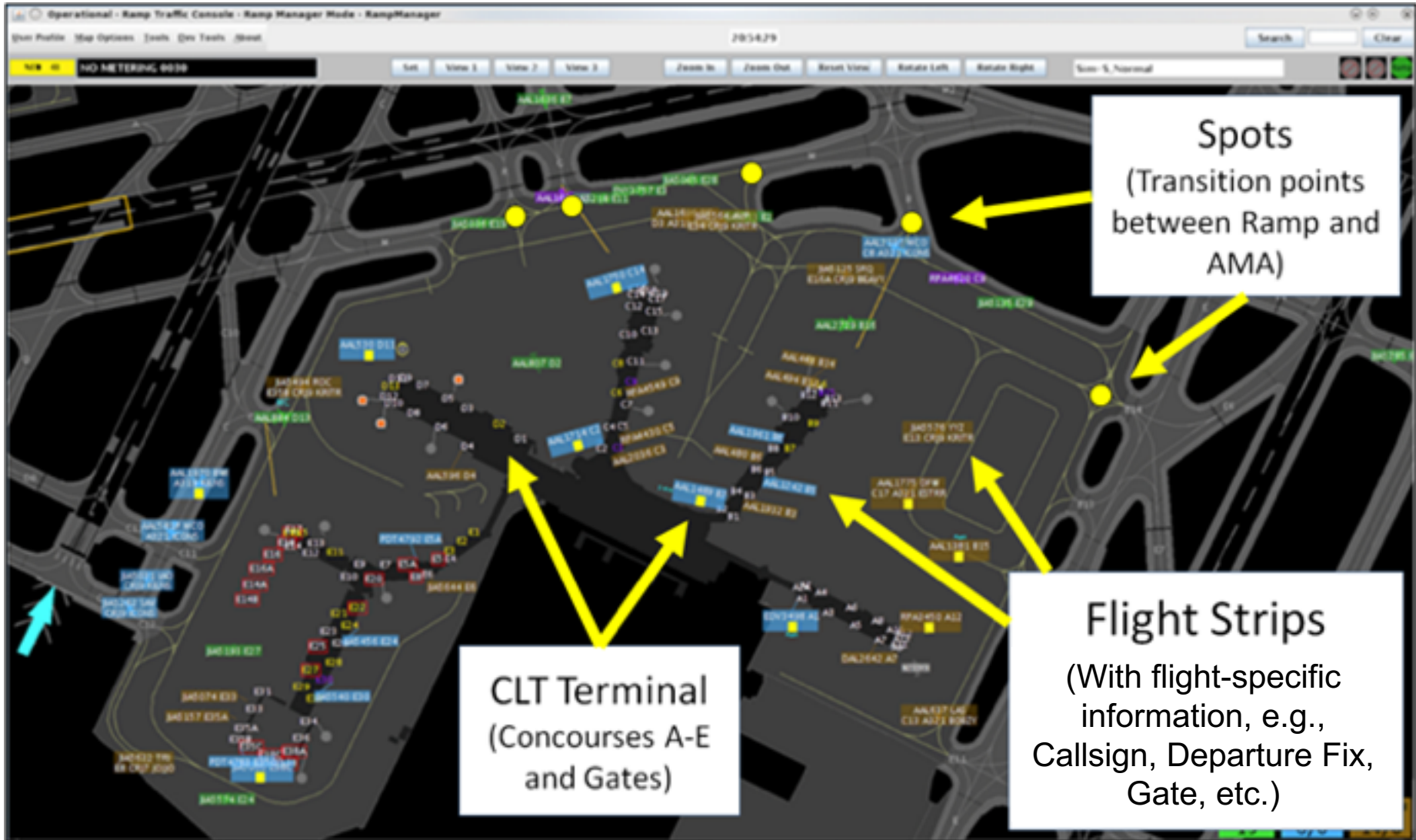


- **Baseline** Ramp Controllers instructed to operate as they would in normal, current-day operations
- **TOBT Compliance** During metering, Ramp Controllers instructed to focus on ensuring that flights push from the gate within  $\pm 2$  min. of the Target-Off-Block Time (TOBT) presented by the advisory
- **TOBT & TMAT Compliance** During metering, Ramp Controllers instructed to pushback flights in compliance with TOBT  $\pm 2$  min and to deliver flights to the spot at their Target Movement Area Times (TMAT) within  $\pm 5$  min



- 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

# ATD-2 Ramp Traffic Console (RTC) Display Used by Ramp Controllers in All Conditions



- 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 & TMAP	6/26 14:51	6/26 16:02	71min
3	C	Baseline	6/27 08:34	6/27 09:44	70min
4	B	TOBT & TMAP	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 & TMAP	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
- TMAAT compliance



- 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

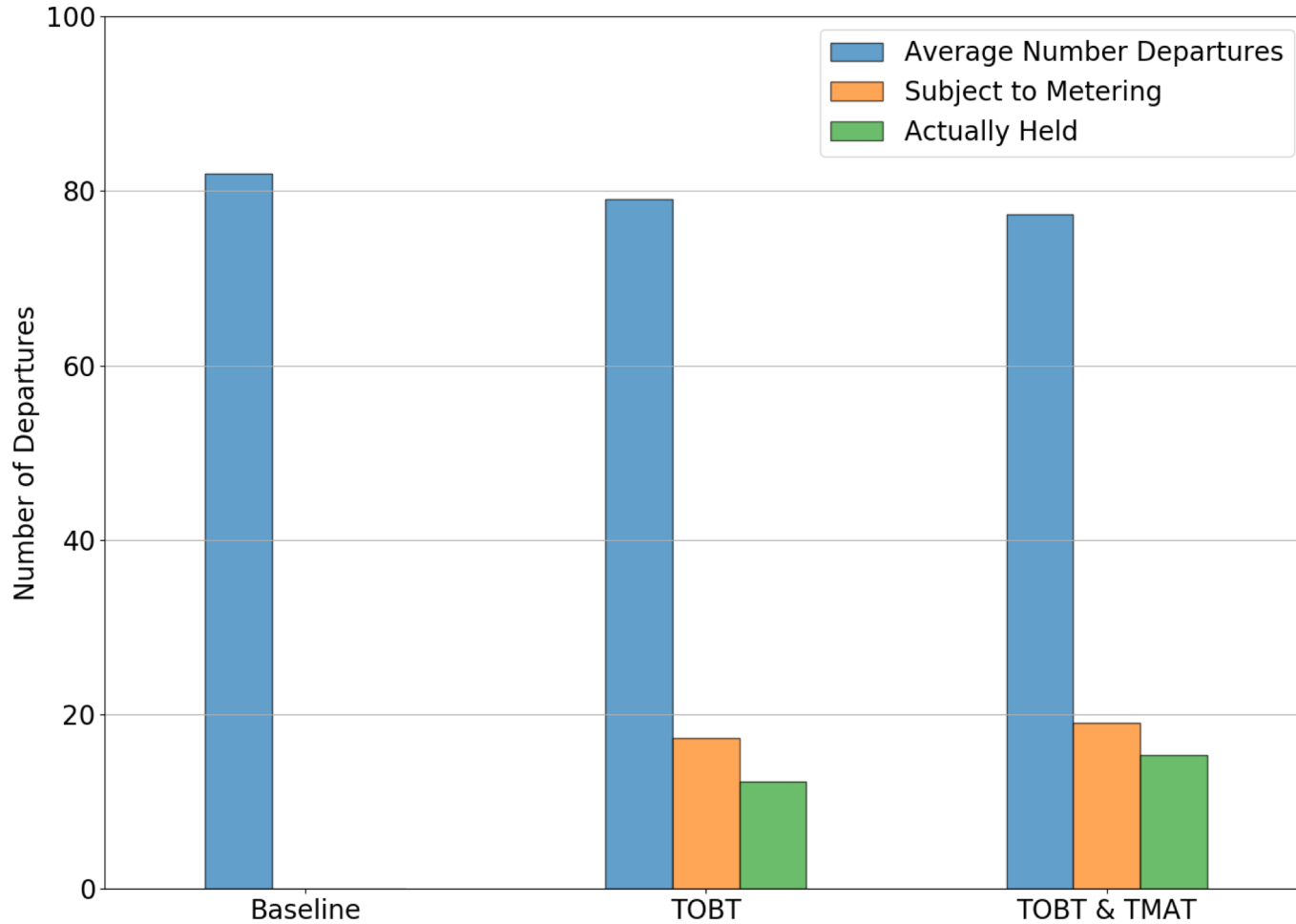


- Departure pushback times (intended variation)
- Movement area entry times at spots
- Ramp controller-initiated spot changes
- Departure runway separation times
- Runway crossing times at Runway 36C
- Missing arrivals
- Arrival landing times
- Traffic Management Initiative (TMI) flights
  - APREQ and/or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

# Results



- **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

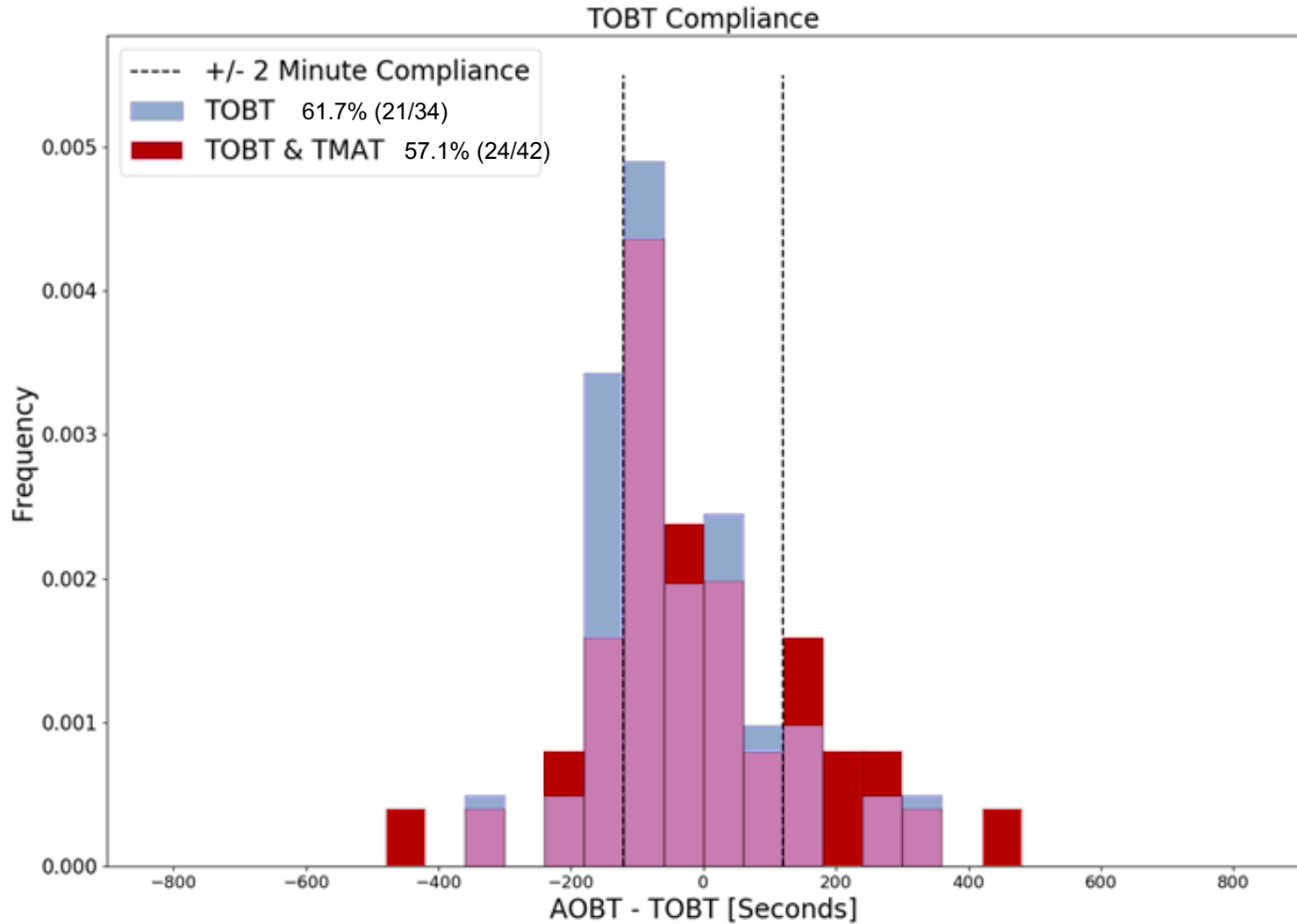


Compliance	TOBT Condition	TOBT & TMAT Condition	Sig. Level Chi Square
TOBT ( $\pm 2$ min)	61.7% (21/34)	57.1% (24/42)	$p = .68, 0.2$ (df 1)
TMAT ( $\pm 5$ min)	85.3% (29/34)	69.0% (29/42)	$p = .10, 2.7$ (df 1)
TMAT Given TOBT Compliance	95.2% (20/21)	75.0% (18/24)	$p = .07, 3.3$ (df 1)

- 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

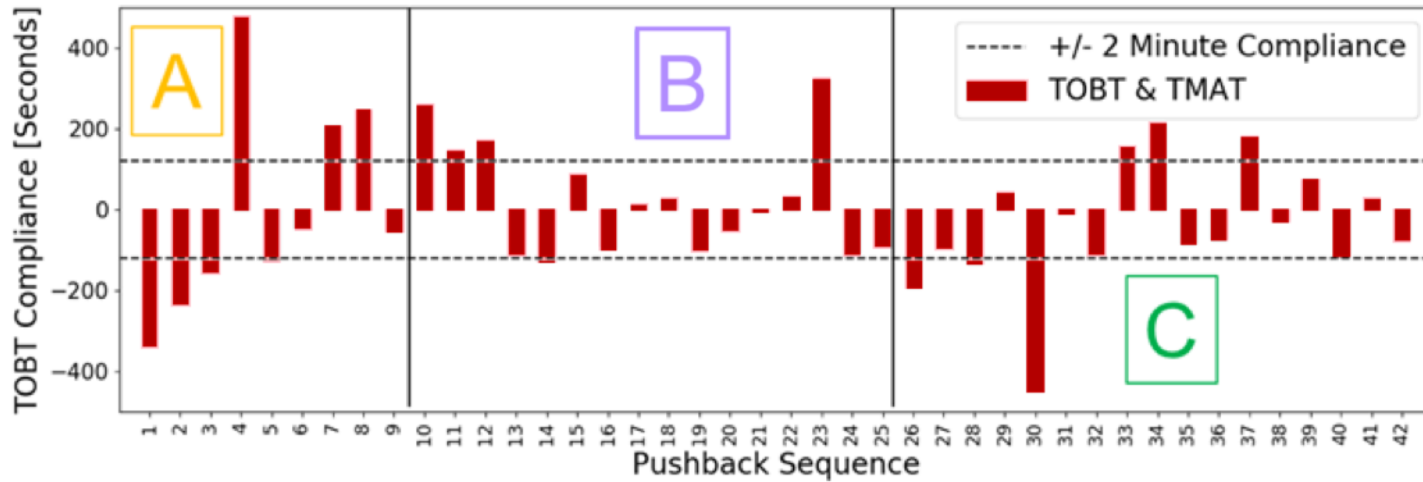
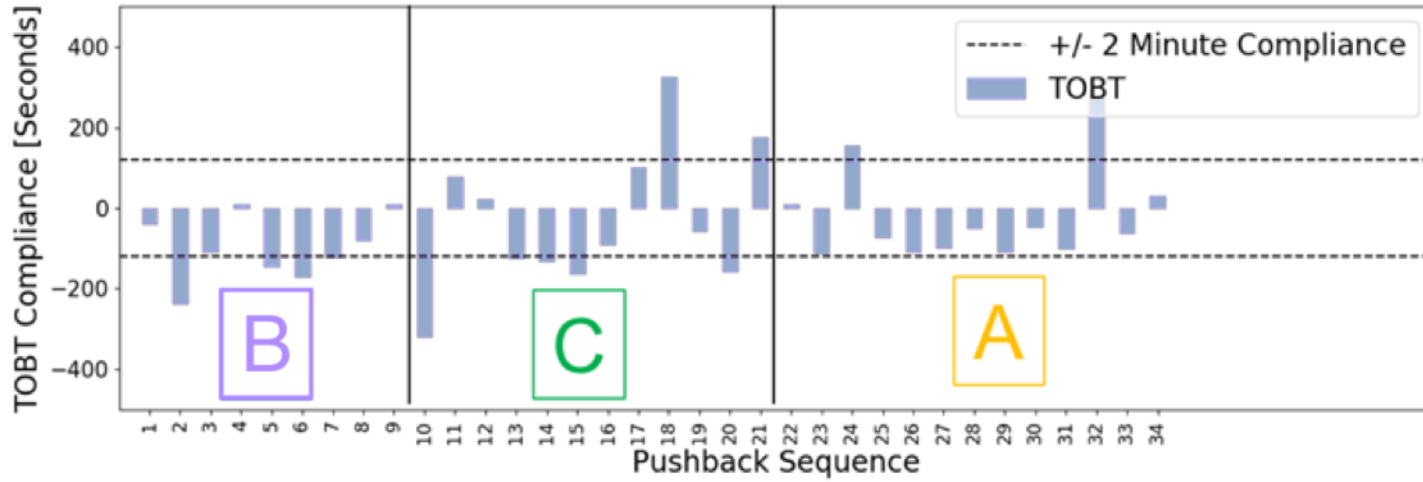
Coupe, W. J., Lee, H., Jung, Y., Chen, L., & Robeson, I.: Scheduling Lessons Learned During Phase 1 Field Evaluation of the ATD-2 Integrated Arrival, Departure, Surface Concept. 13<sup>th</sup> USA/Europe Air Traffic Management Research and Development Seminar, In Press (2019)

# Actual Off-Block Time and TOBT Compliance Histogram



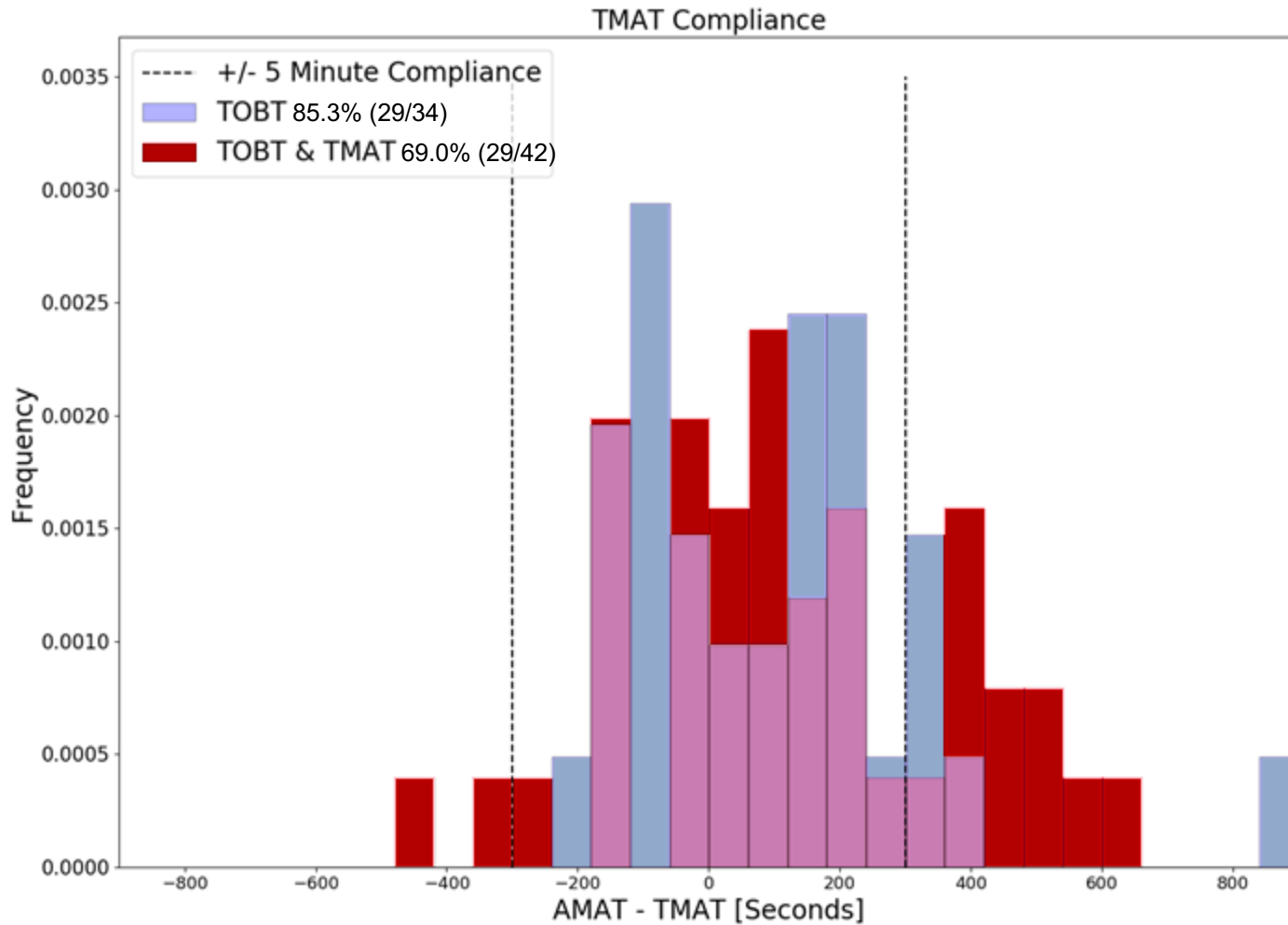
TOBT compliance was similar across the two conditions



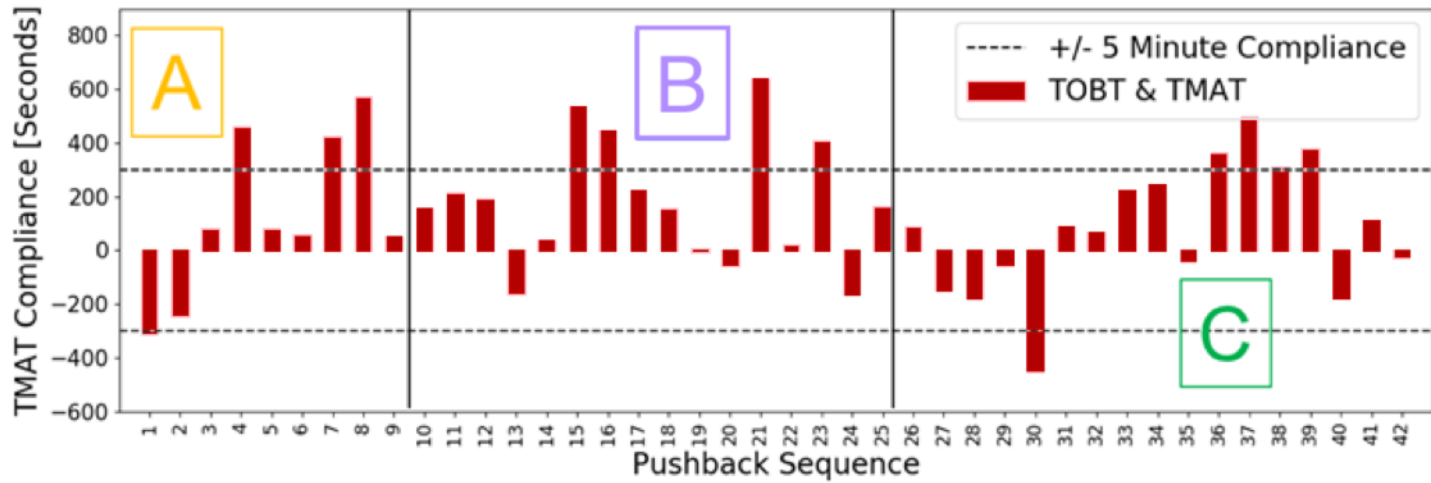
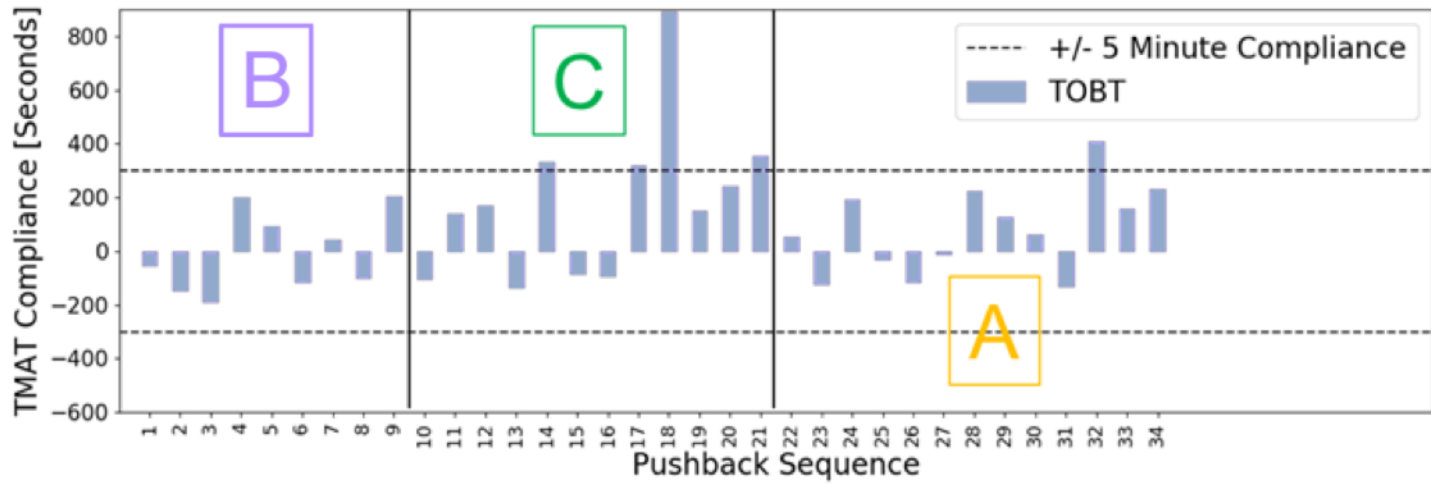


TOBT compliance as a function of pushback sequence in each of the three scenarios

# AMA Target Time and TMAT Compliance Histogram



TMAT compliance was higher in the TOBT condition compared to the TOBT & TMAT condition



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

## 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



- 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?



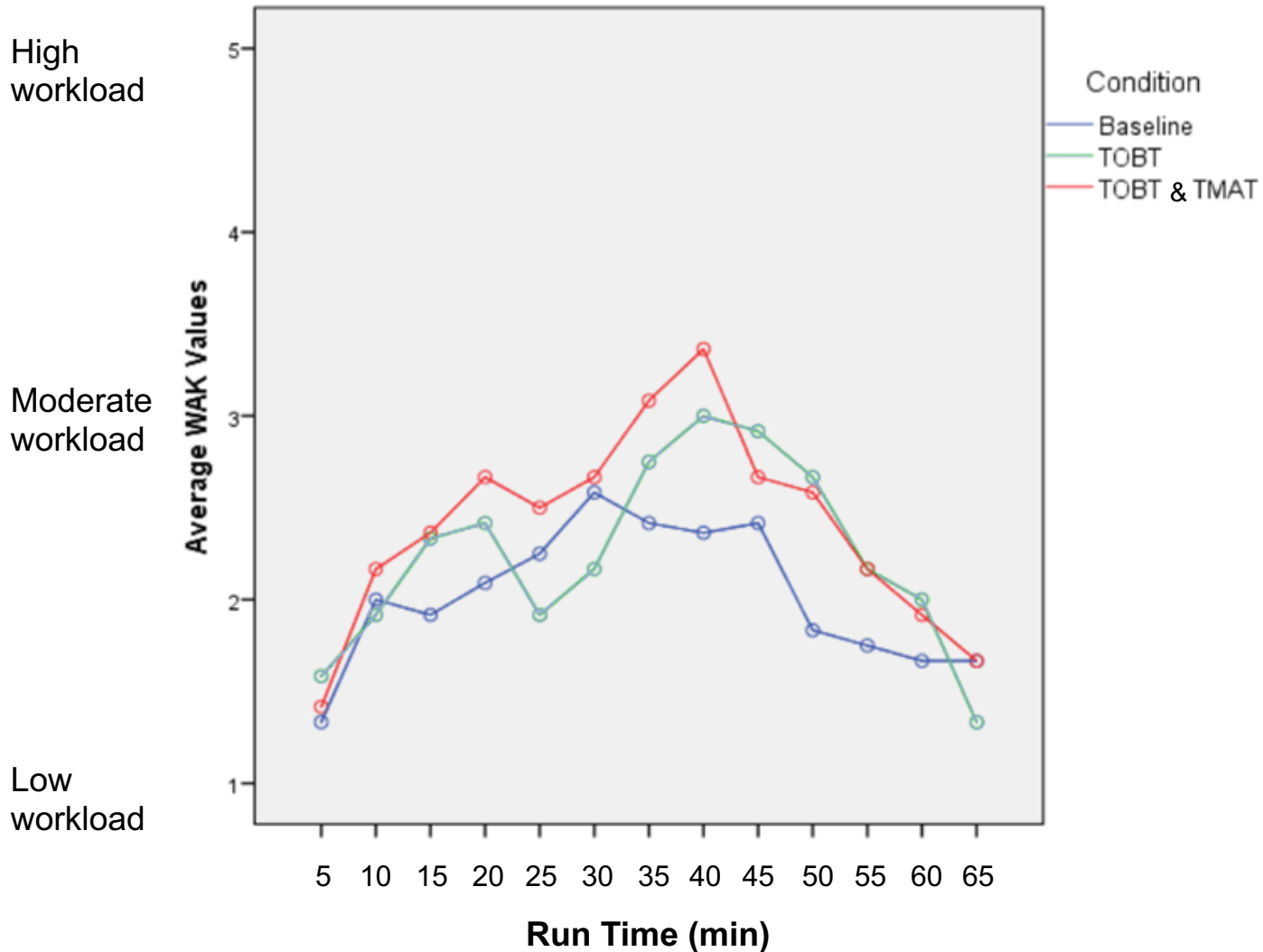
## Workload Assessment Keypad (WAK)

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

## All workload data collection

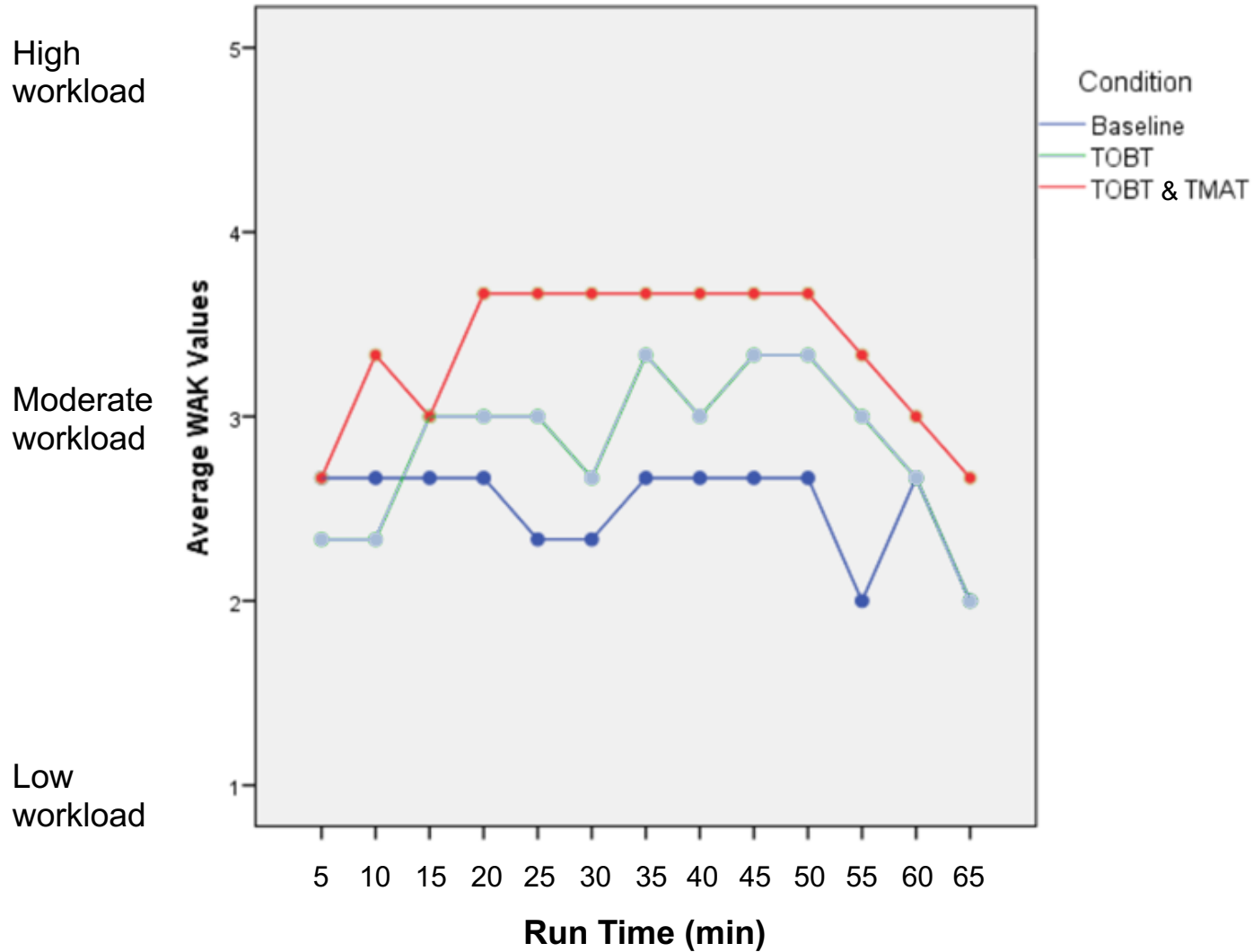
- Ramp personnel asked to consider a workload rating of “3”, or moderate, as comparable to nominal operations at CLT

# 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

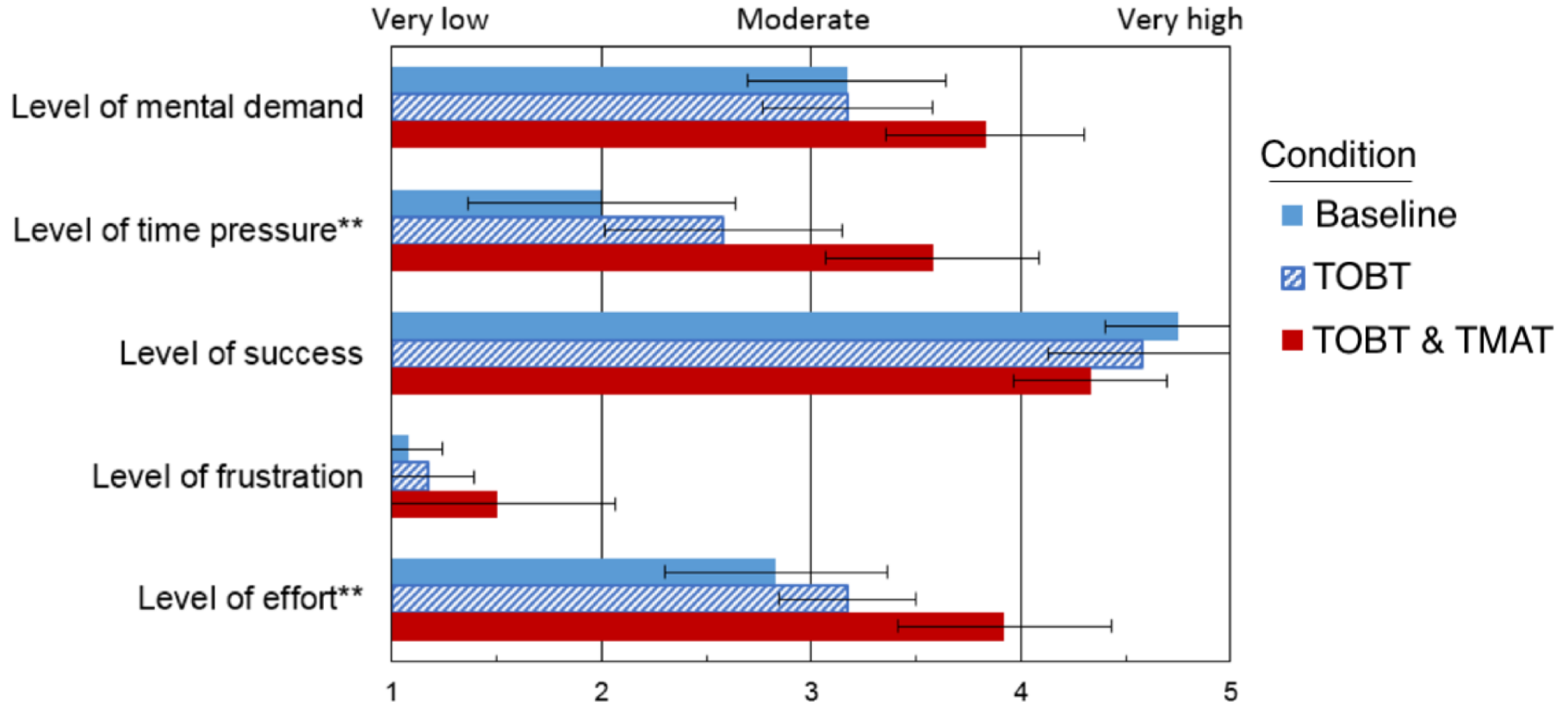


# Ramp Controller Post-Run Workload Ratings on NASA TLX



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



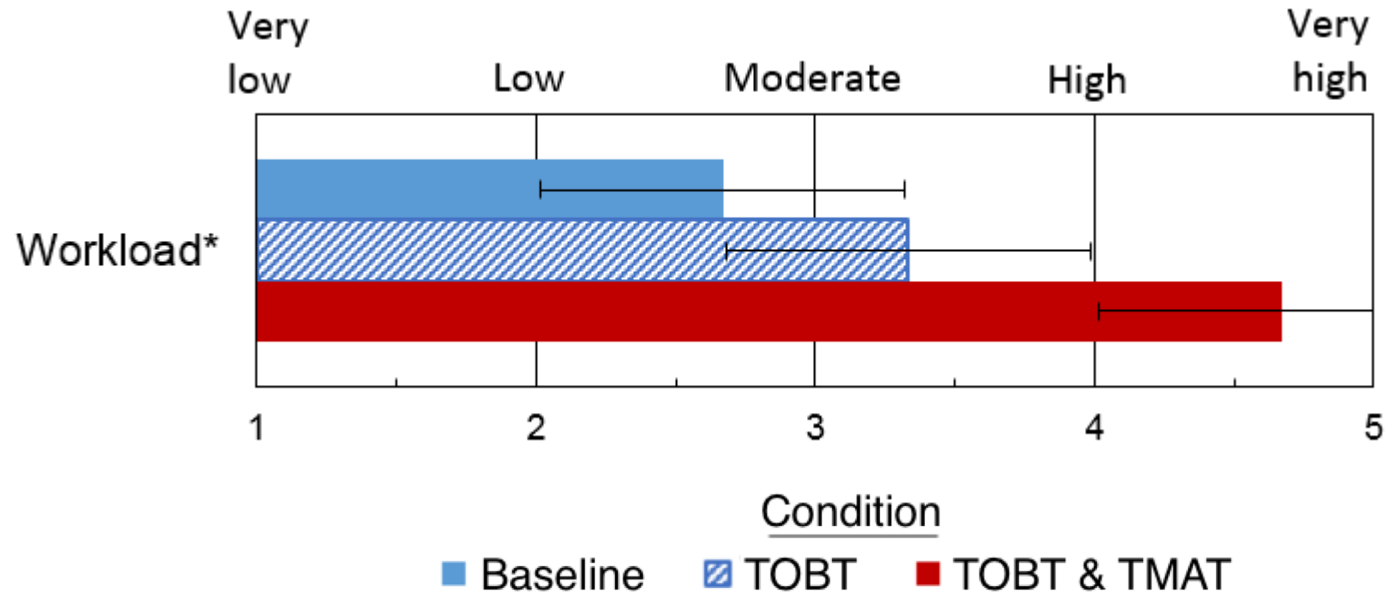
- Workload and Time Pressure
  - “Things were flowing a bit fast.. I didn’t have enough time to really sequence the TMAP times.”
  - “I think once the ramp got congested, it basically made the TMAP times insufficient. I would like to have had another way to get a few of them out thru the traffic.”
- Problems with TMAP Times
  - “Some of the flights’ TMAPs were exceeded upon push because they had to hold at the gate.”
  - “DAL2422 was sent to the spot (12) ~10 minutes prior to TMAP. If we held him back until TMAP it was probable he would have missed APREQ.”

# Ramp Controller Post-Simulation Ratings of Workload



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



“Trying to think about the TMAP 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 TMAP time is within limits. I think the system should monitor and adjust these numbers.”



## Ramp Controller workload and situation awareness

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



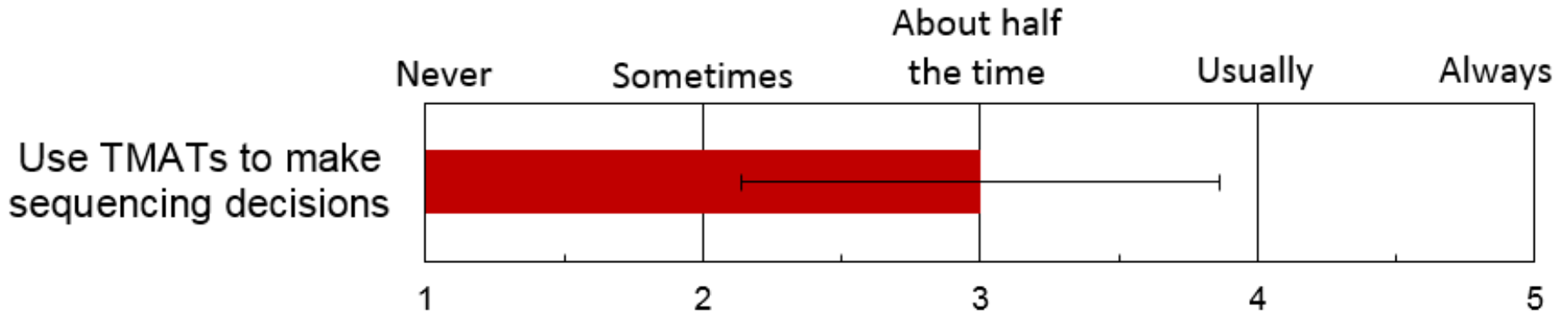
- Compliance with pushback advisories (TOBTs) and spot times (TMATs)
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  - Were the Ramp Controllers able to comply with the TMATs?
- Ramp Controller workload and situation awareness
  - What were the impacts of the conditions on Ramp Controllers' workload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

# Ramp Controller Post-Run Ratings of Frequency of TMAT Use for Sequencing



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.



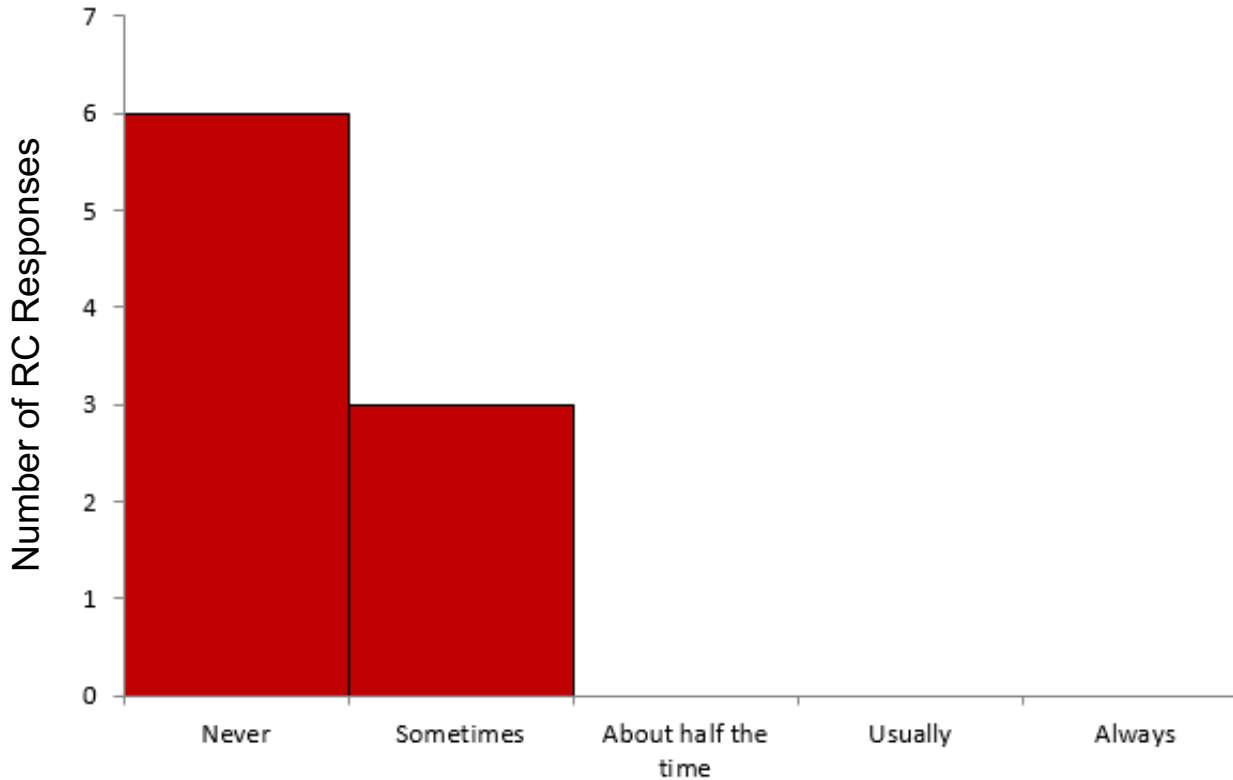
Ramp Controllers used TMATs about half the time to make decisions about sequencing aircraft



# 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?



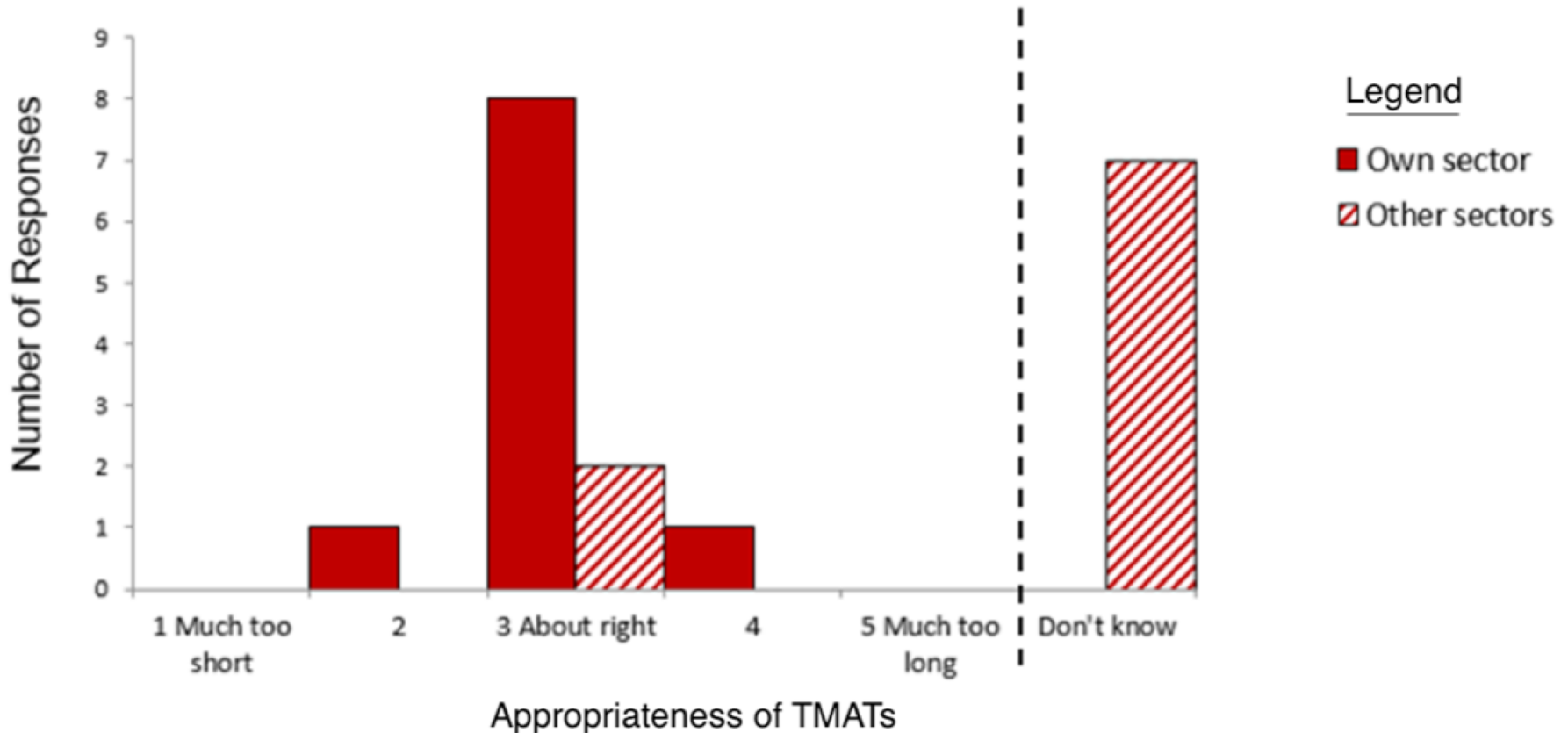
Frequency of Holding Aircraft in Sector to Achieve TMATs

Ramp Controllers rarely held aircraft in their sector to achieve TMATs

# Ramp Controller Post-Run Ratings of Appropriateness of TMATs



Please rate how appropriate the times of the TMATs were in this run for aircraft coming from the gates in your sector and from other sectors.

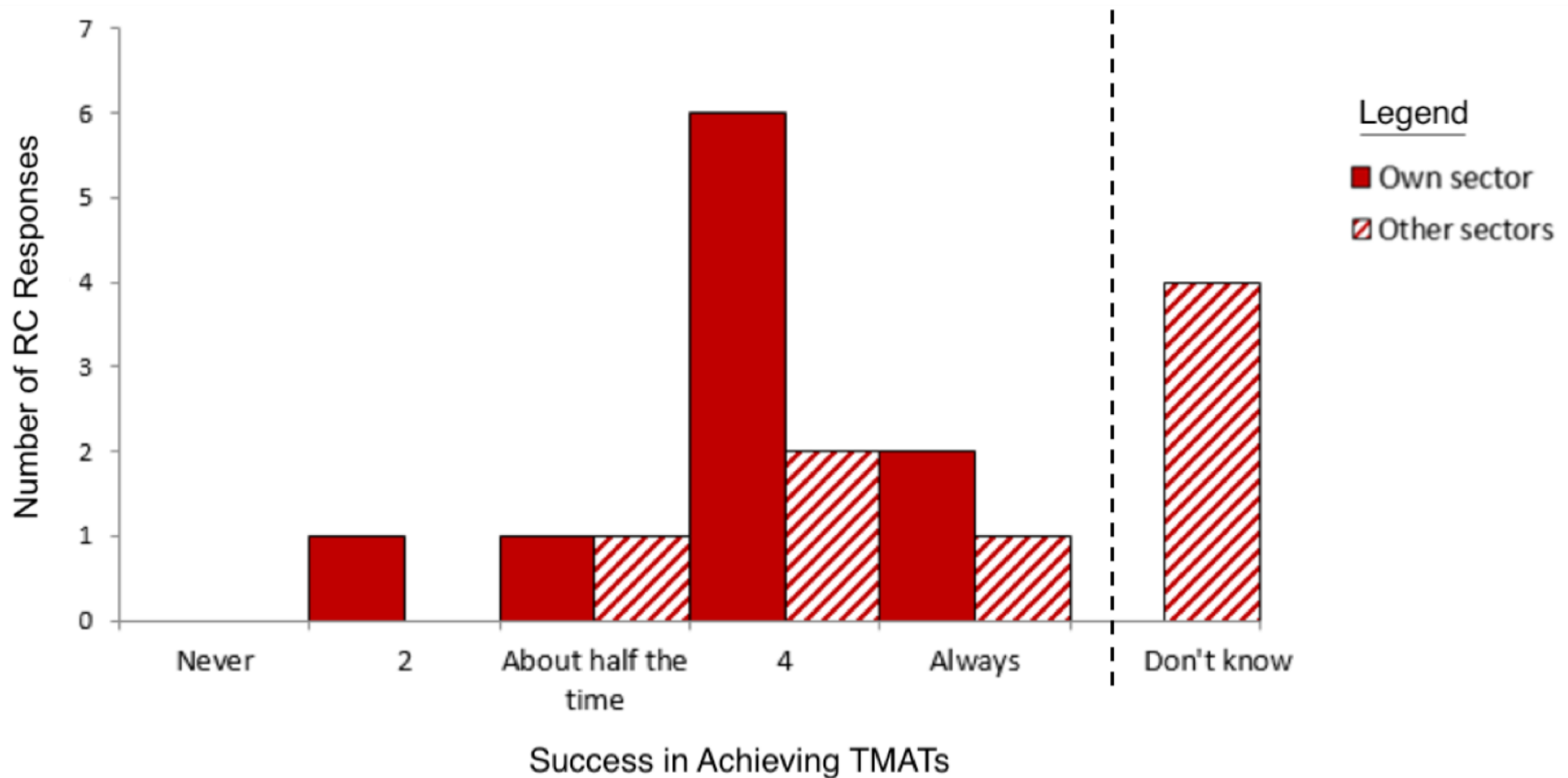


Ramp Controllers rated TMATs as “About Right” for their own sector;  
Ramp Controllers not aware of appropriateness of TMATs in other sectors

# Ramp Controller Post-Run Ratings of Success in Meeting TMATs



In this run, about how often were you successful in achieving TMATs for aircraft coming from gates in your sector and from other sectors?

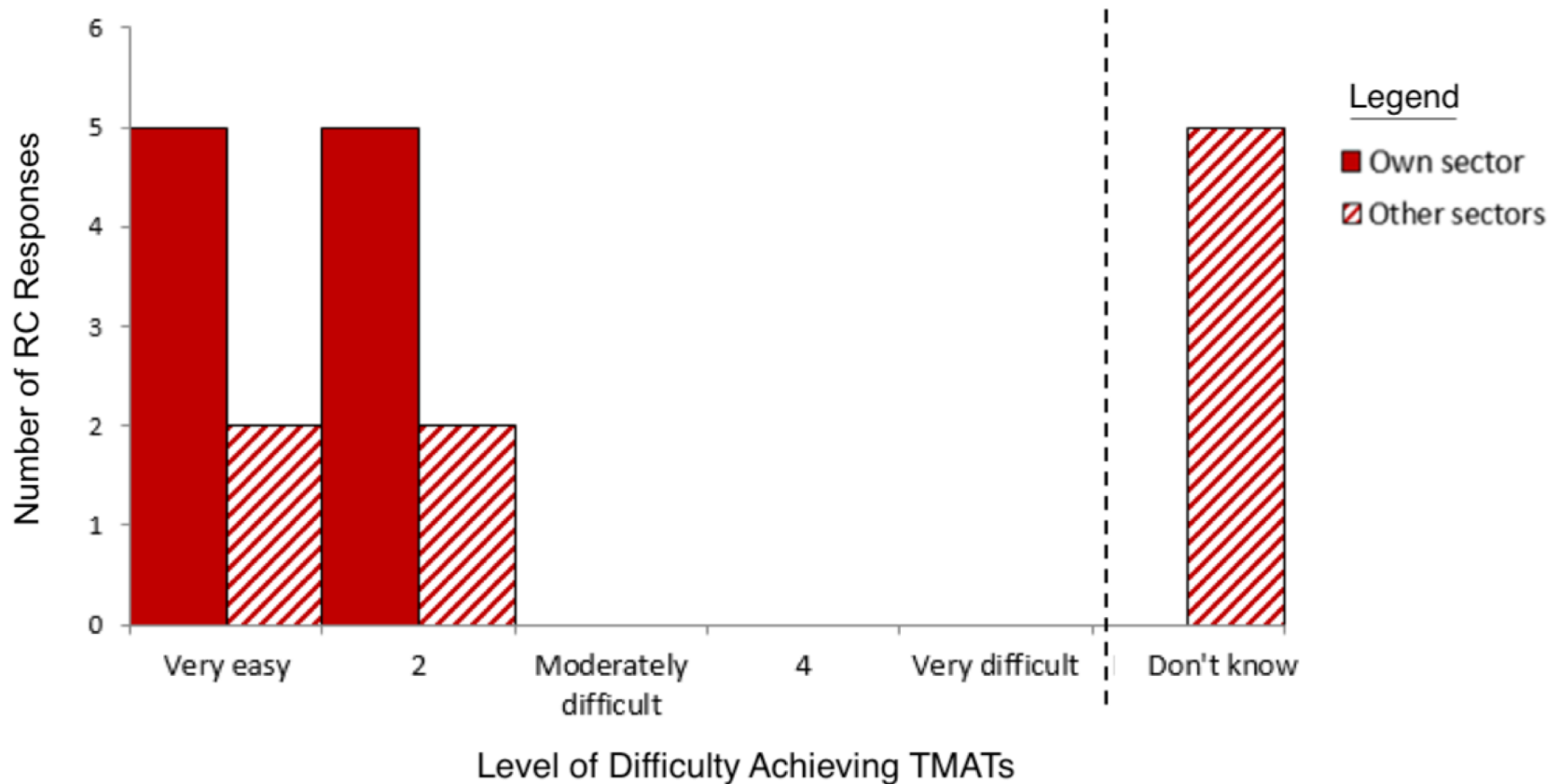


Ramp Controllers rated themselves fairly successful in meeting TMATs in their own sector

# Ramp Controller Post-Run Ratings of Level of Difficulty Achieving TMATs



In this run, how difficult was it to arrange for a flight to meet its TMAT from aircraft coming from gates in your sector and from other sectors?

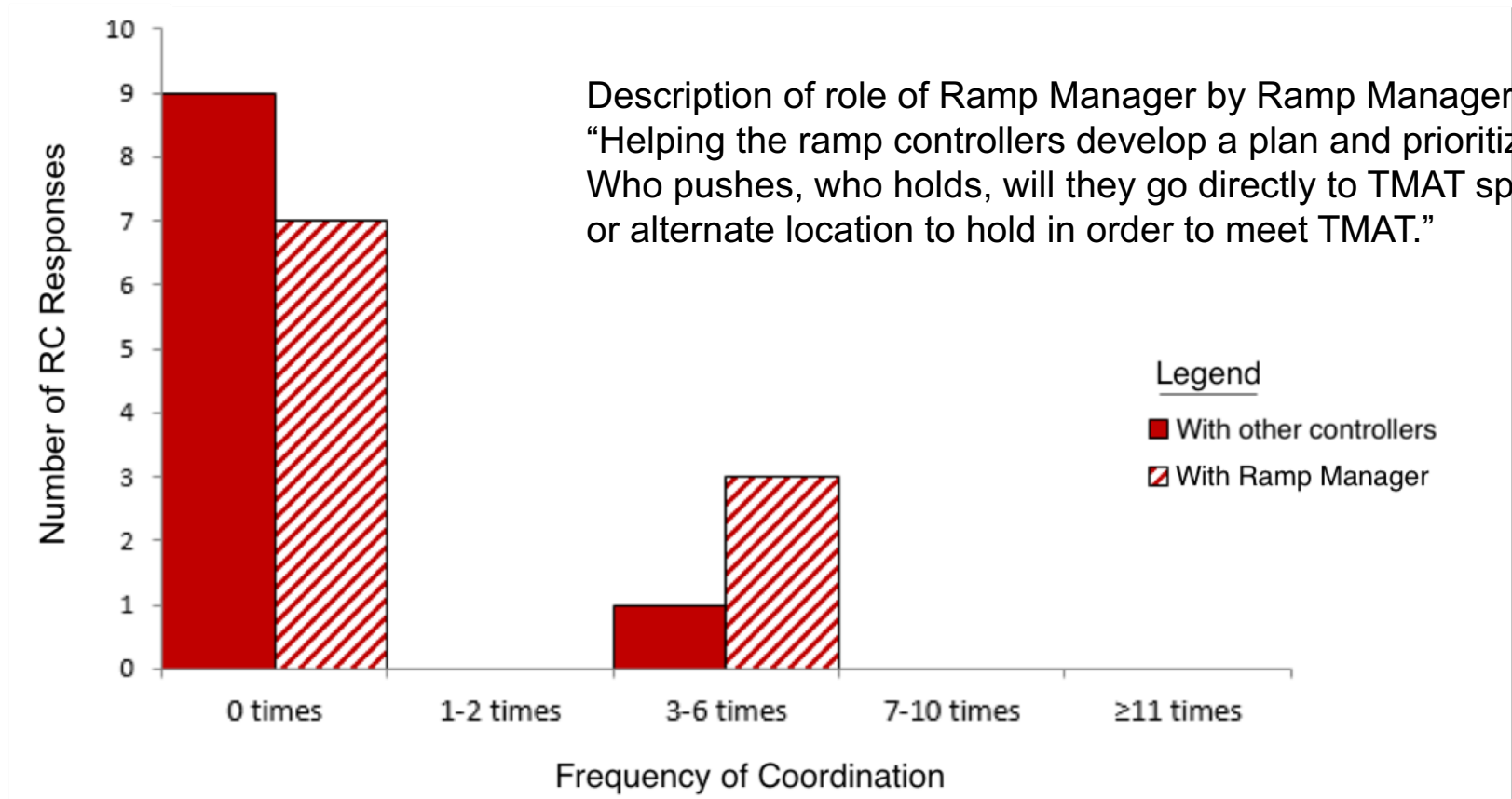


Ramp Controllers rated achieving TMATs in their own sector as easy

# Ramp Controller Post-Run Perception of Frequency of TMAT Coordination



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

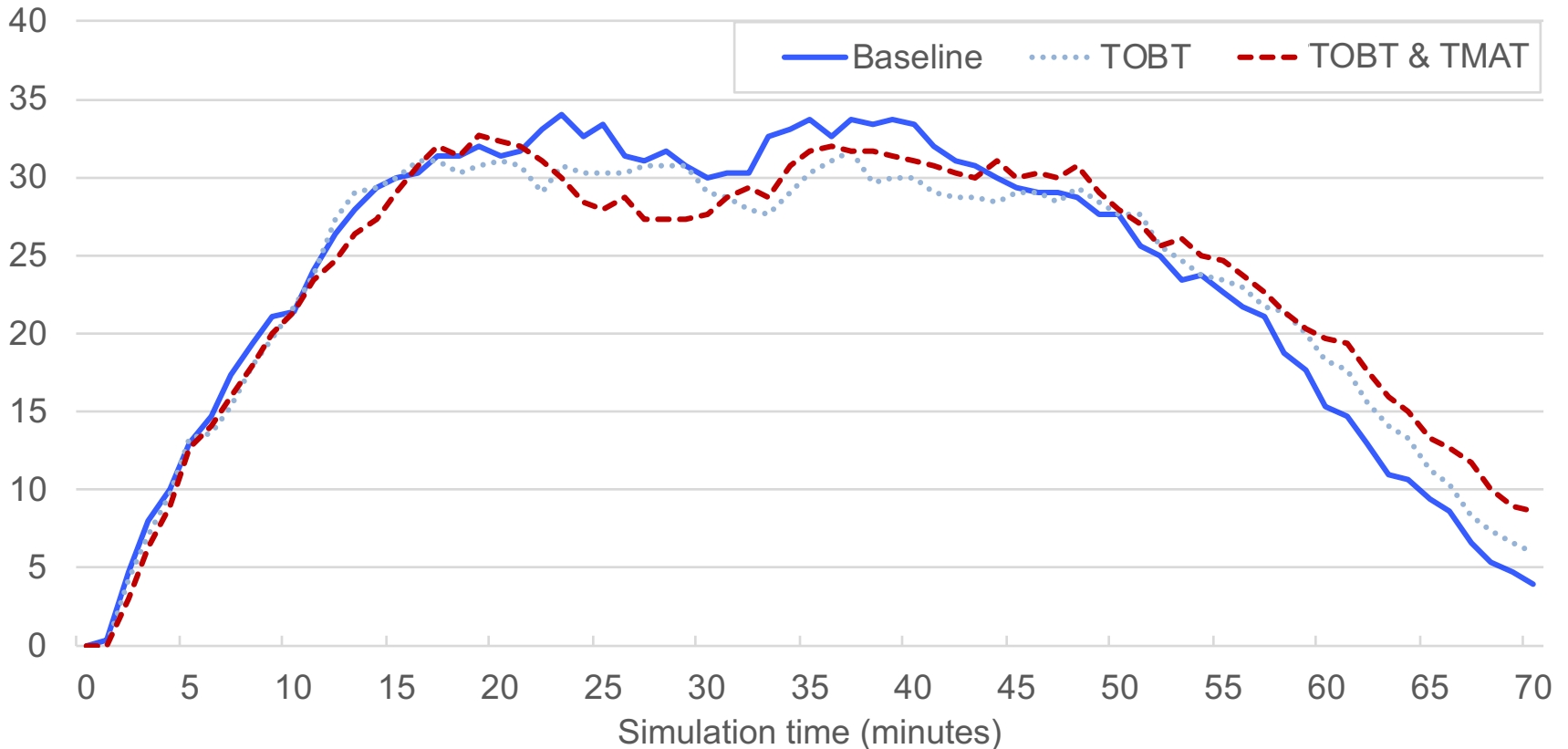
- Used TMATs about half the time to make decisions about sequencing aircraft
- Rated TMATs as “About Right” for their own sector;
- Rarely held aircraft in their sector to achieve TMATs
- Rated achieving TMATs in their own sector as easy and as being successfully accomplished
- Self-reported infrequent coordination with other controllers or the Ramp Manager to achieve TMATs

# Appendix

## Scenario Metrics

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

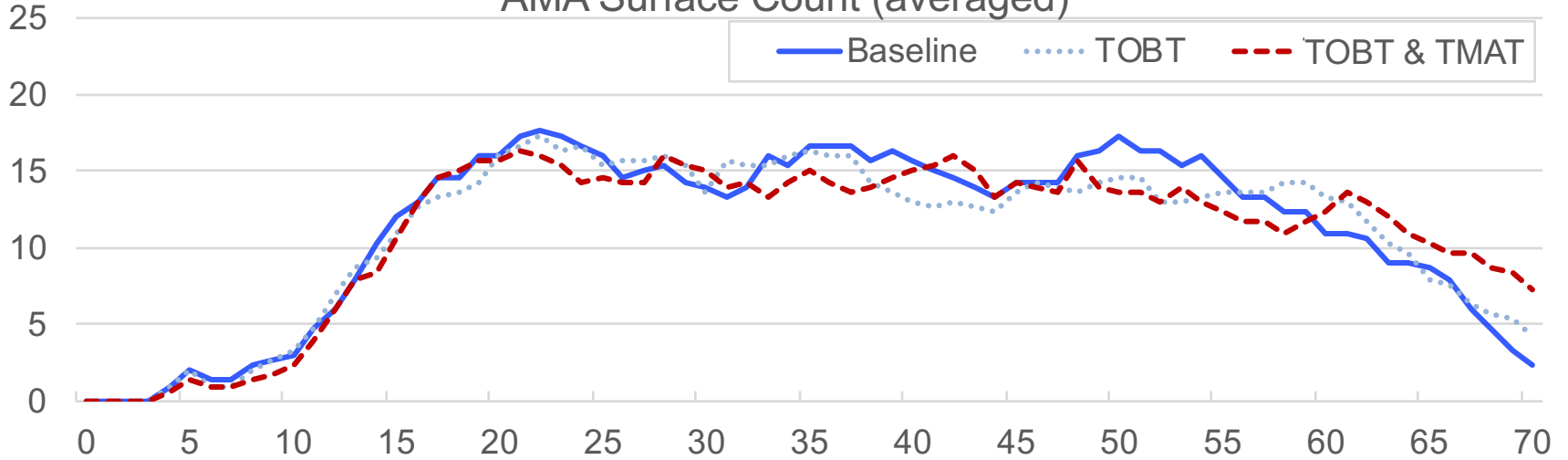
Total Surface Count (averaged)



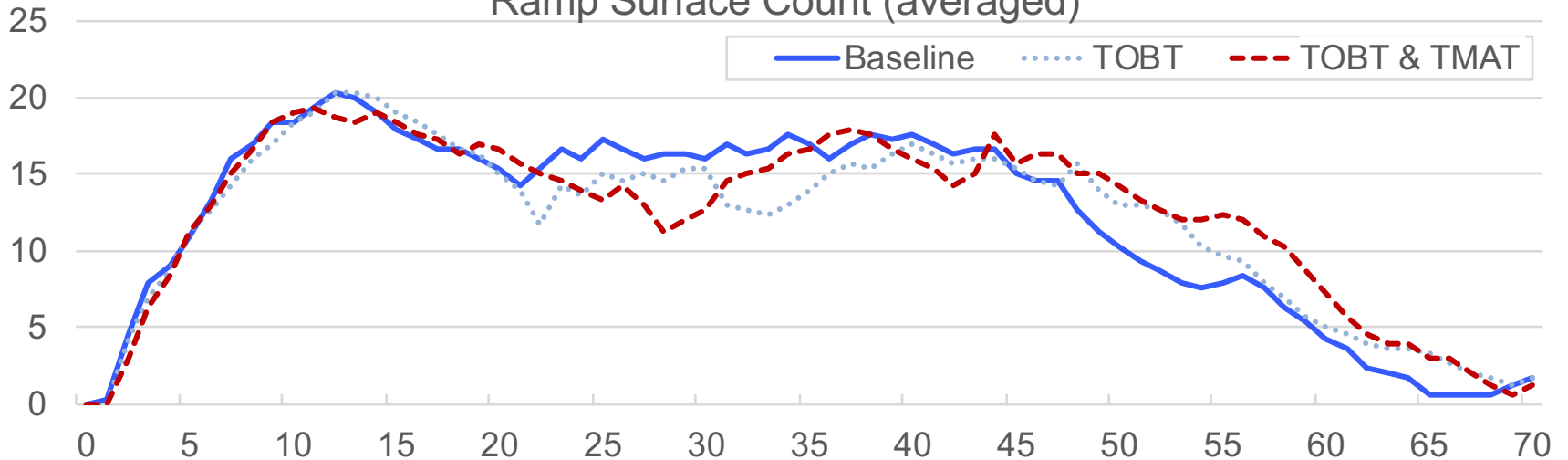


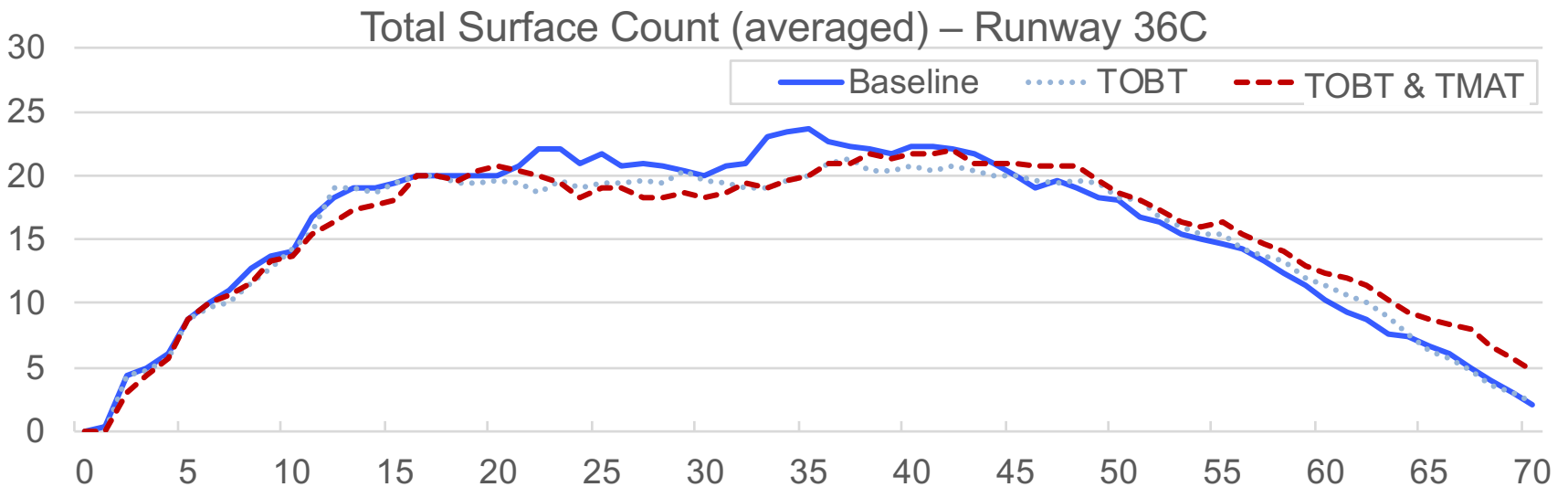
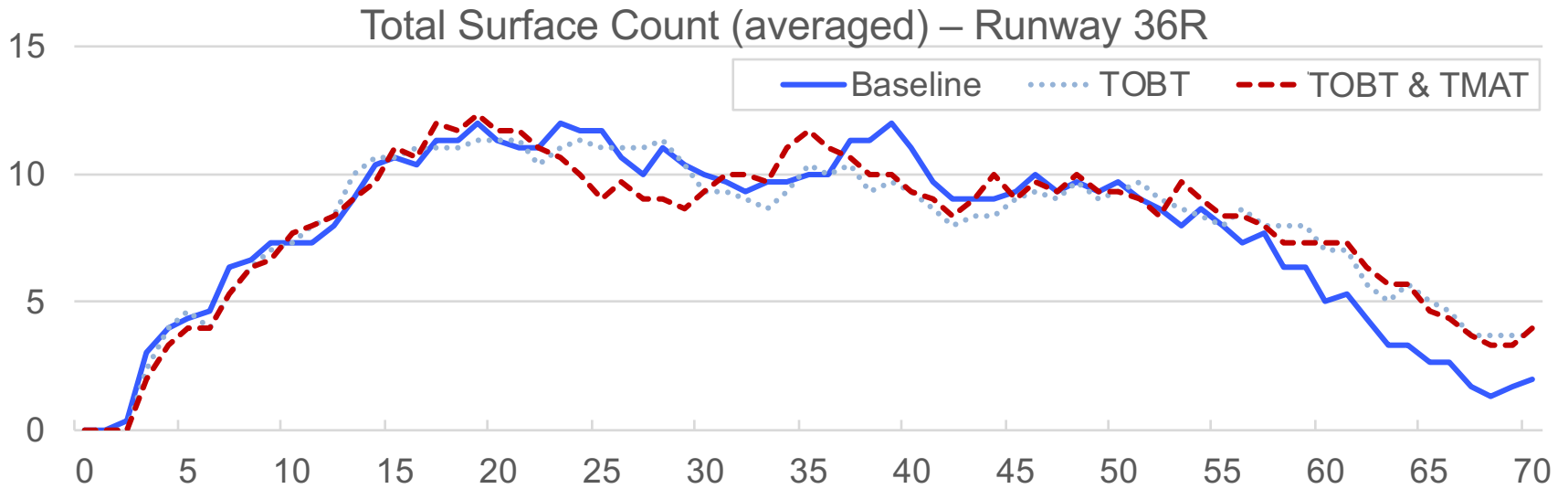


AMA Surface Count (averaged)

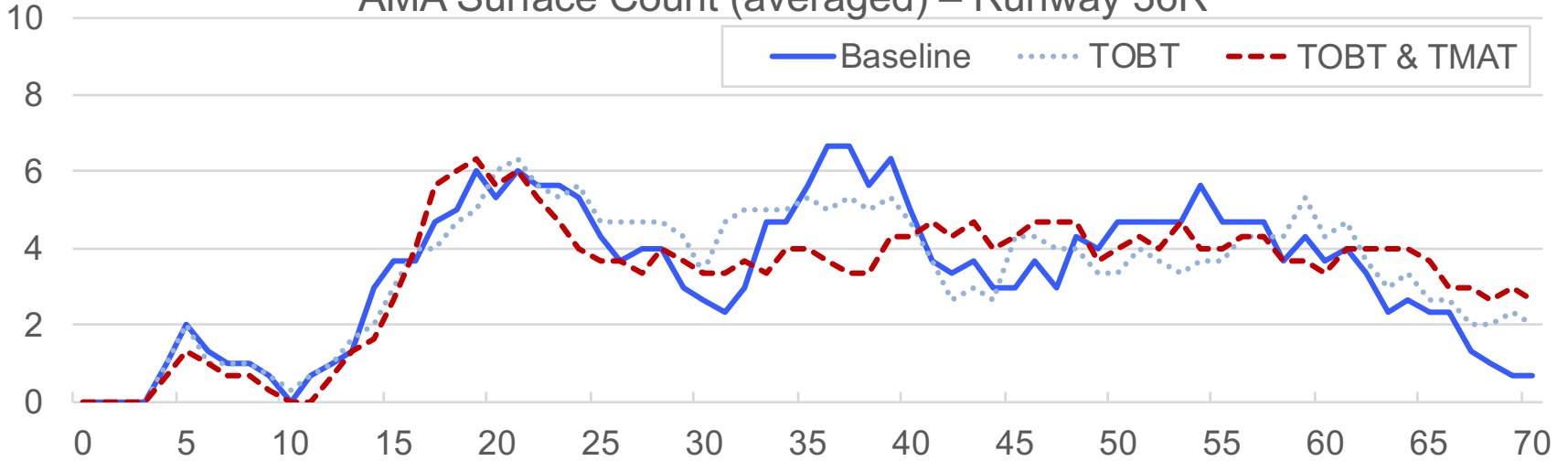


Ramp Surface Count (averaged)

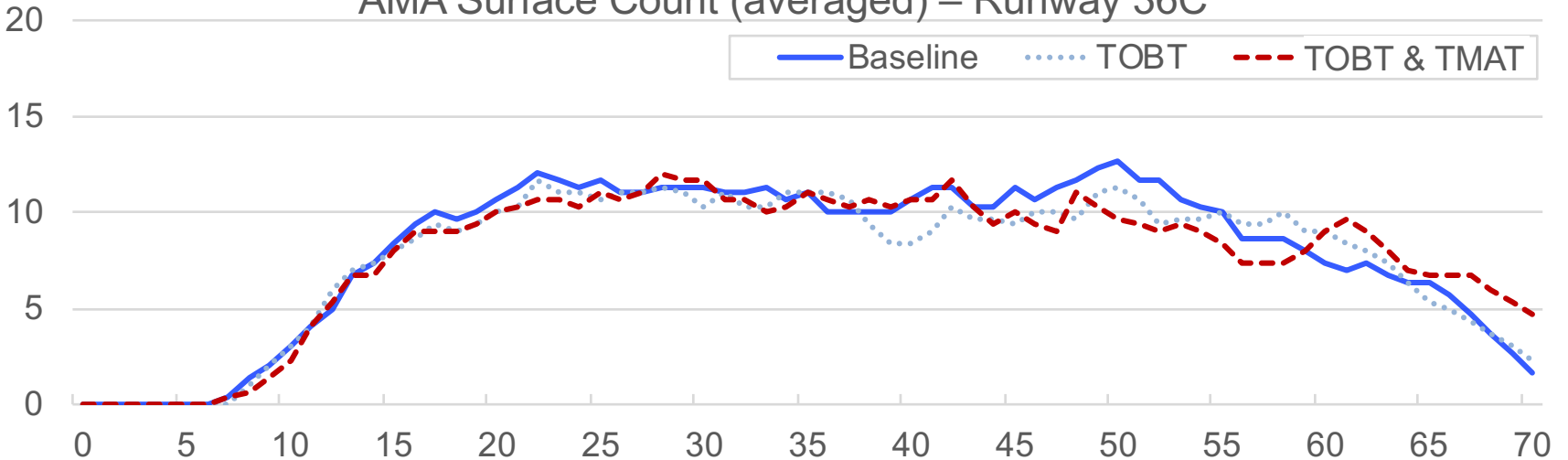




AMA Surface Count (averaged) – Runway 36R



AMA Surface Count (averaged) – Runway 36C



- 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

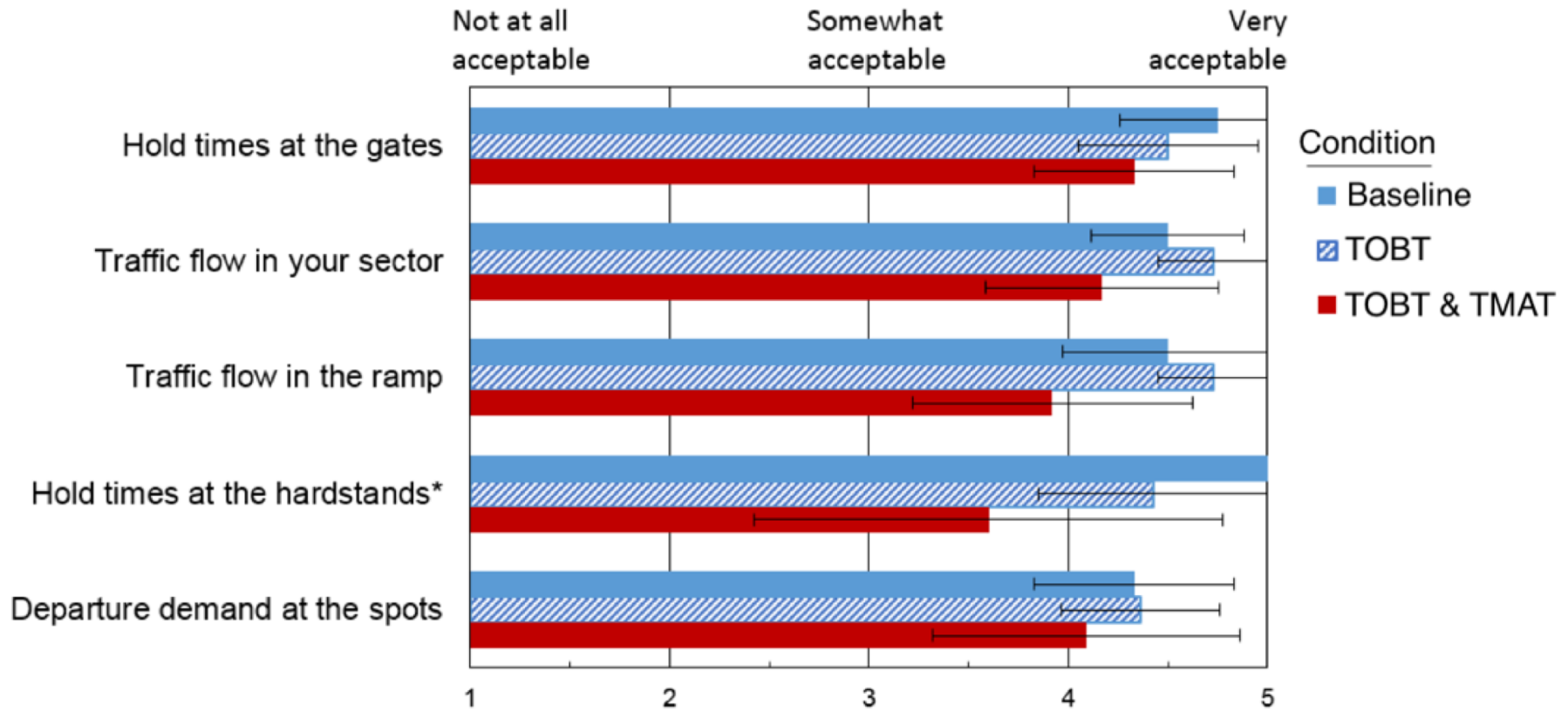
Condition	Spot Changes (total)
Baseline	11
TOBT	6
TOBT/TMAT	7

# Ramp Controller Post-Run Ratings of Acceptability of Hold Times



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

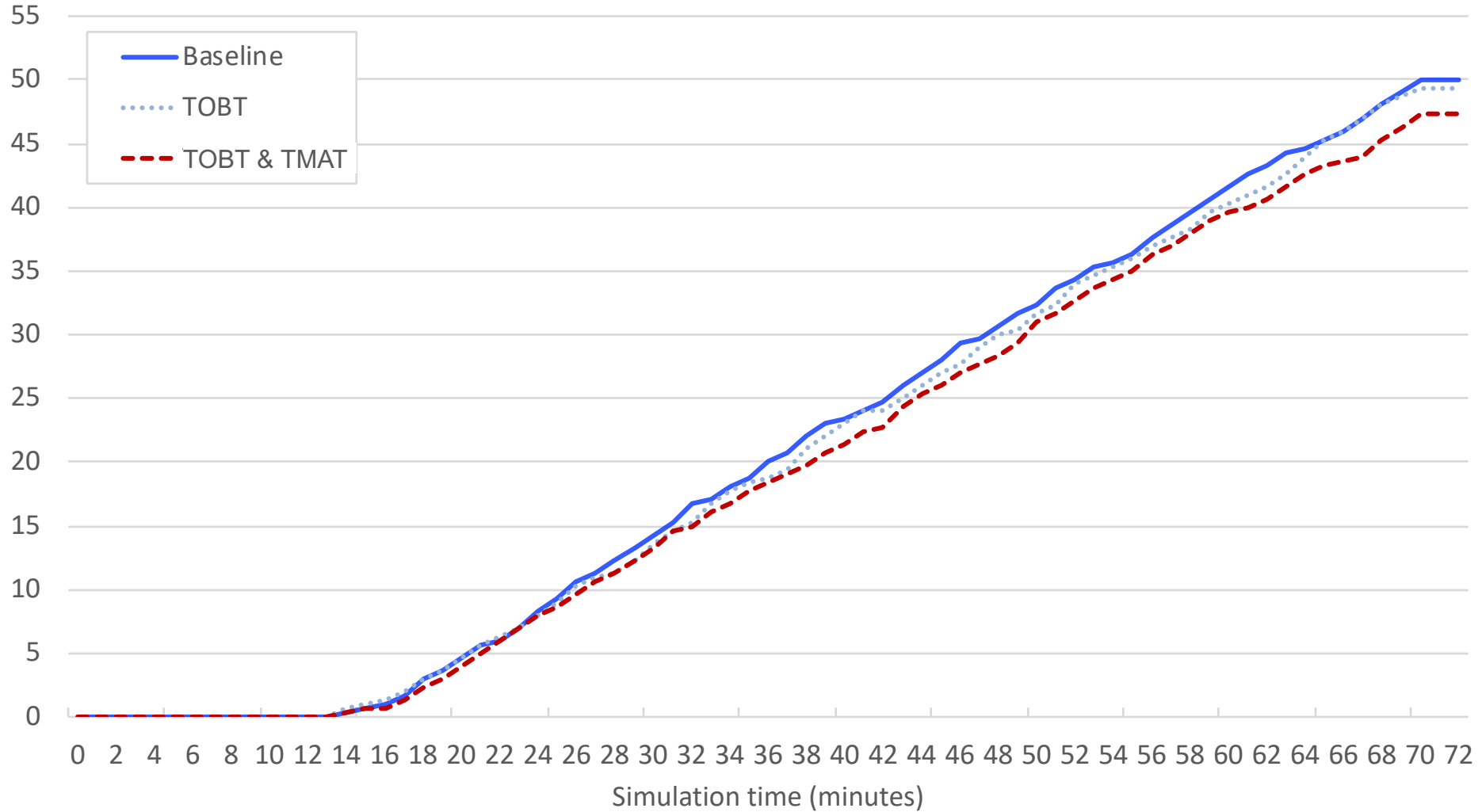
Ns = 12 ratings for each item in each condition; error bars = 95% CIs.



# Dedicated Departure Runway Throughput – 36C



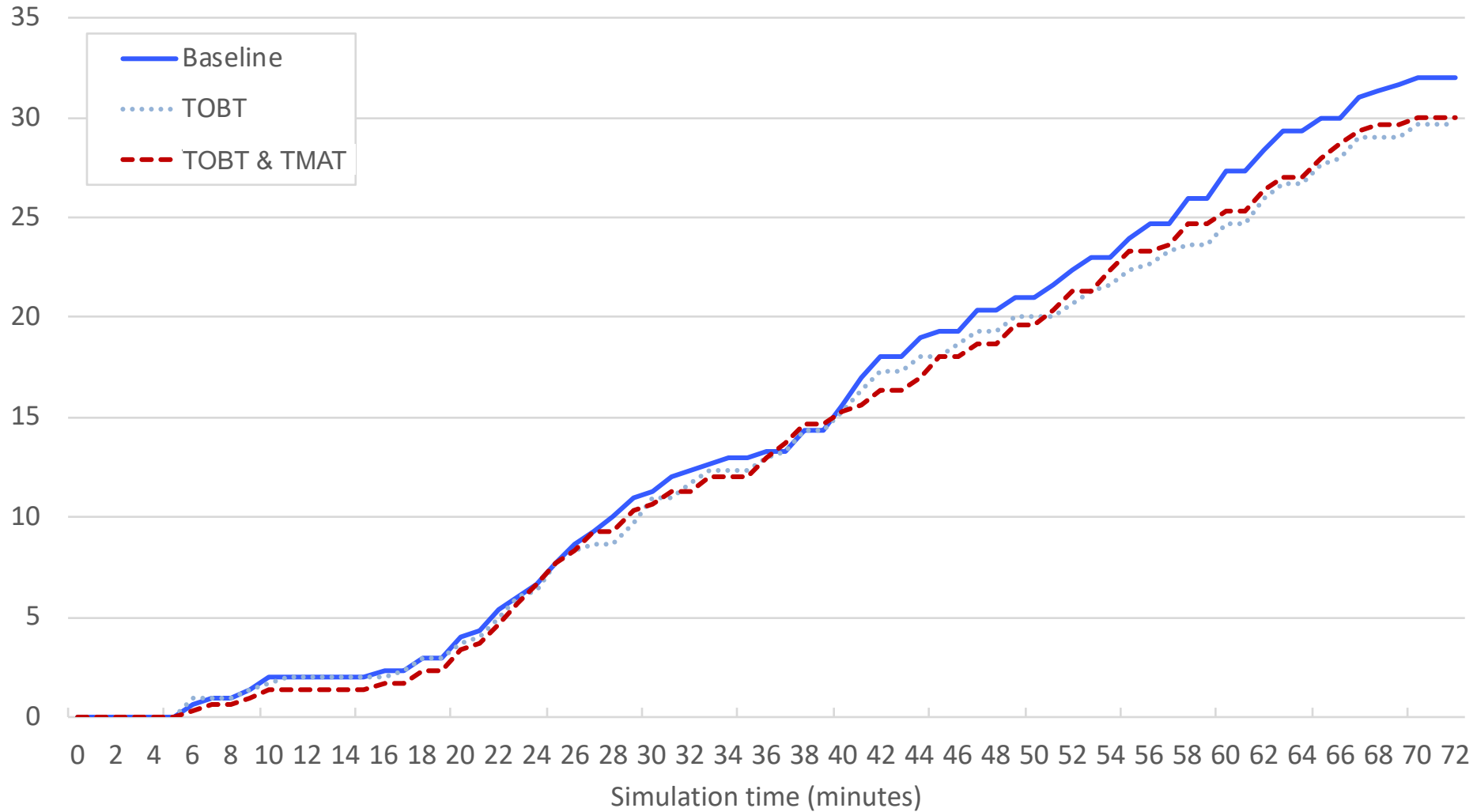
Accumulated Runway Throughput - Runway 36C



# Dual Use Arrival & Departure Runway Departure Throughput – 36R

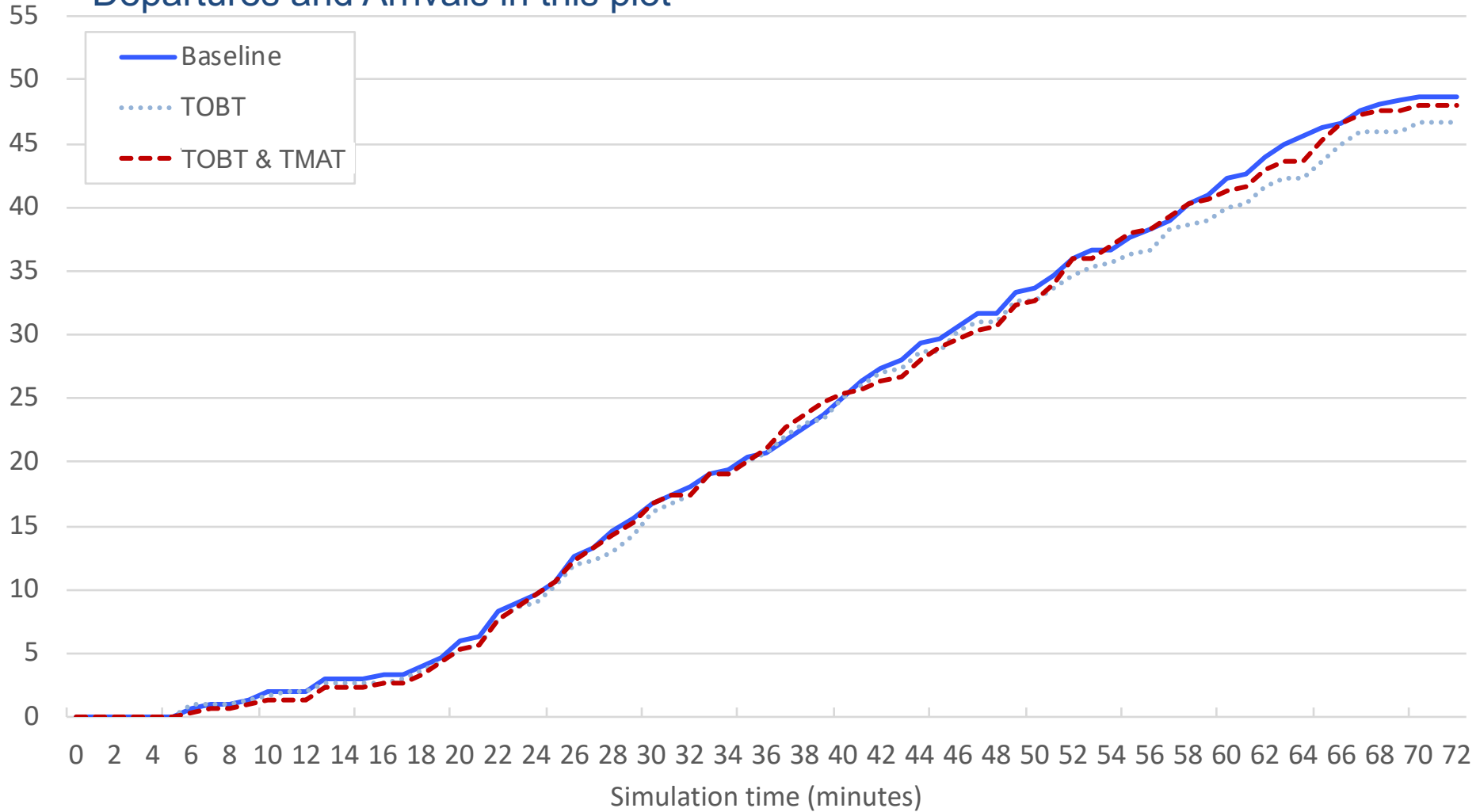


Accumulated Runway Throughput - Runway 36R



Accumulated Runway Throughput - Runway 36R

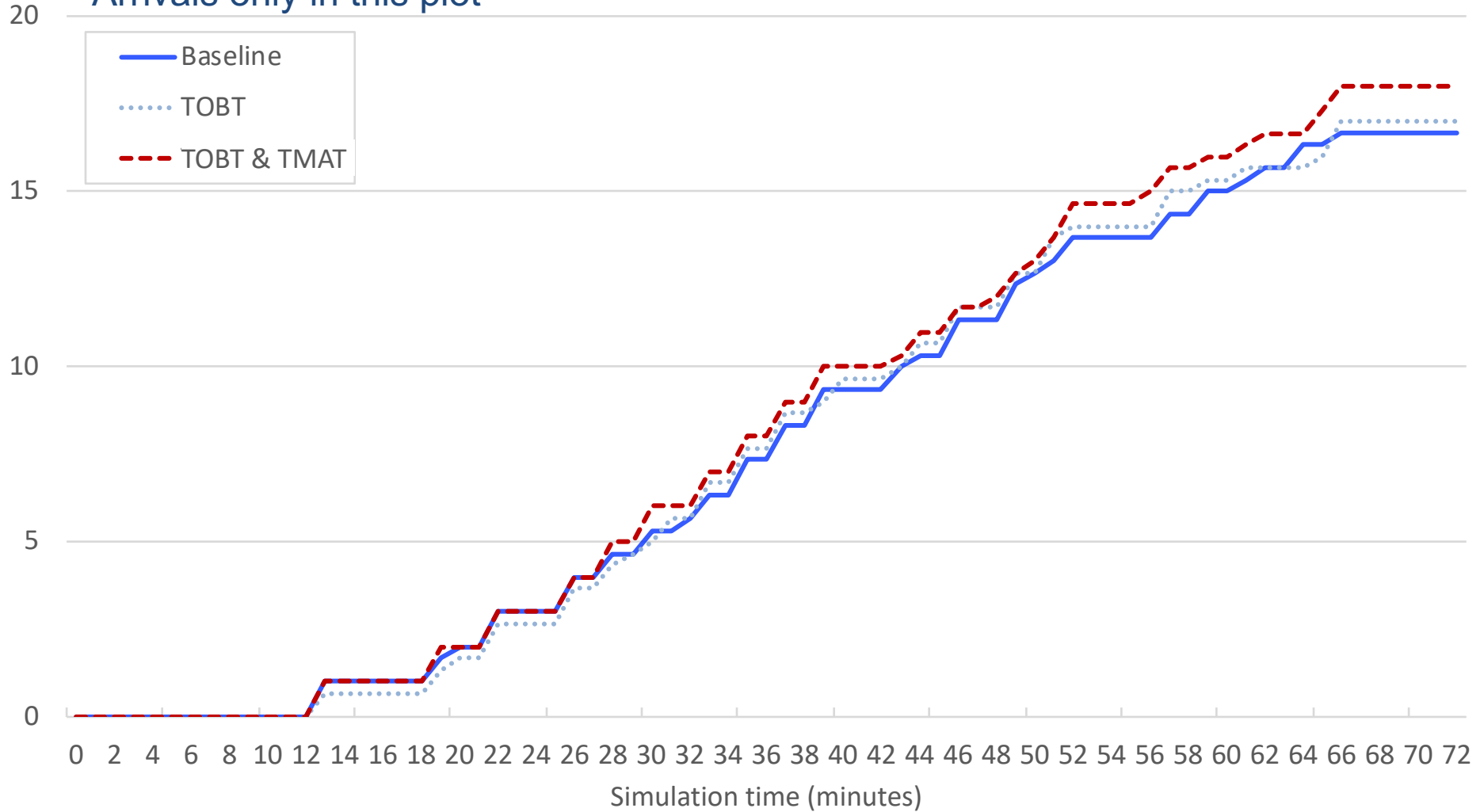
Departures and Arrivals in this plot





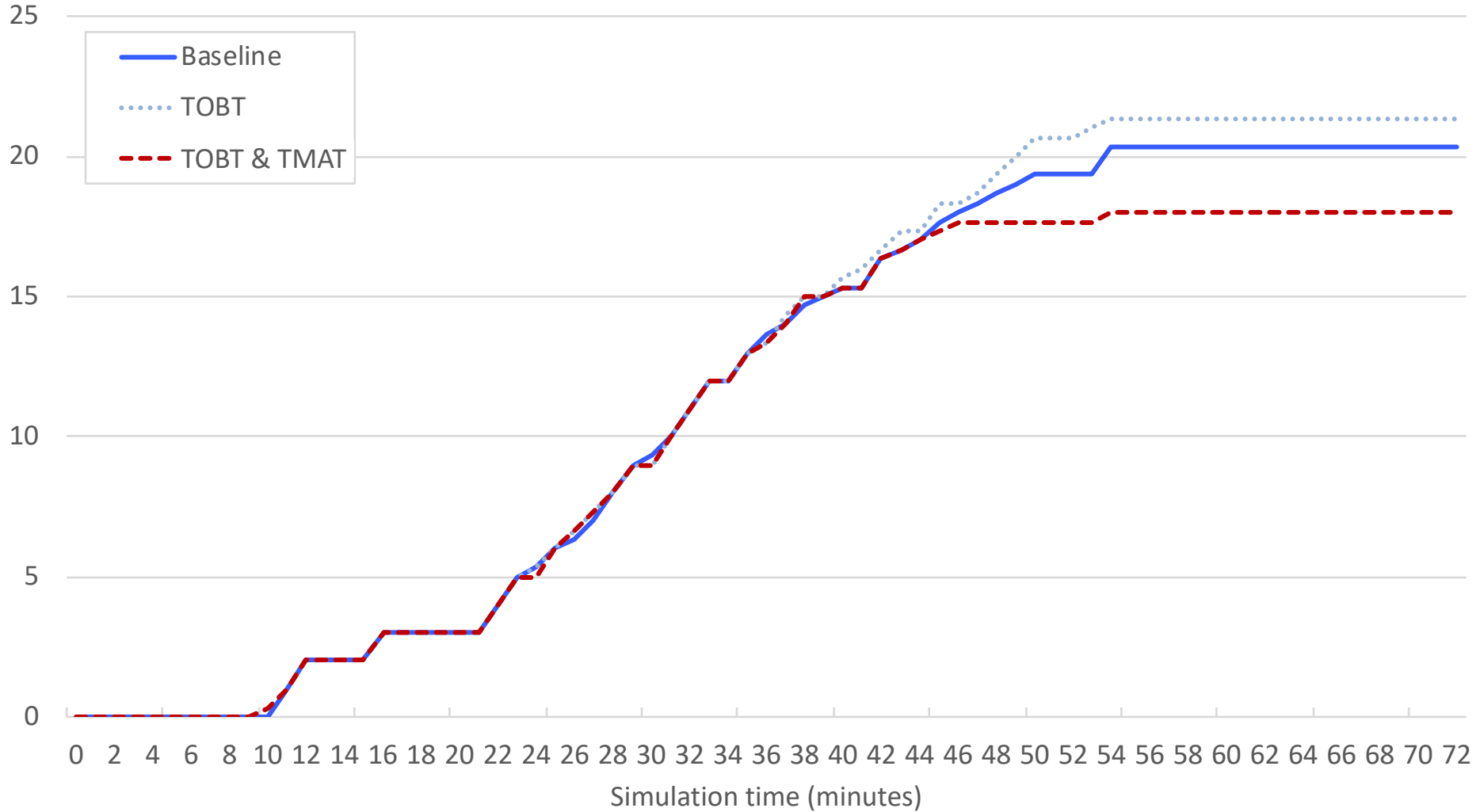
Accumulated Runway Throughput - Runway 36R

Arrivals only in this plot





Accumulated Runway Throughput - Runway 36L

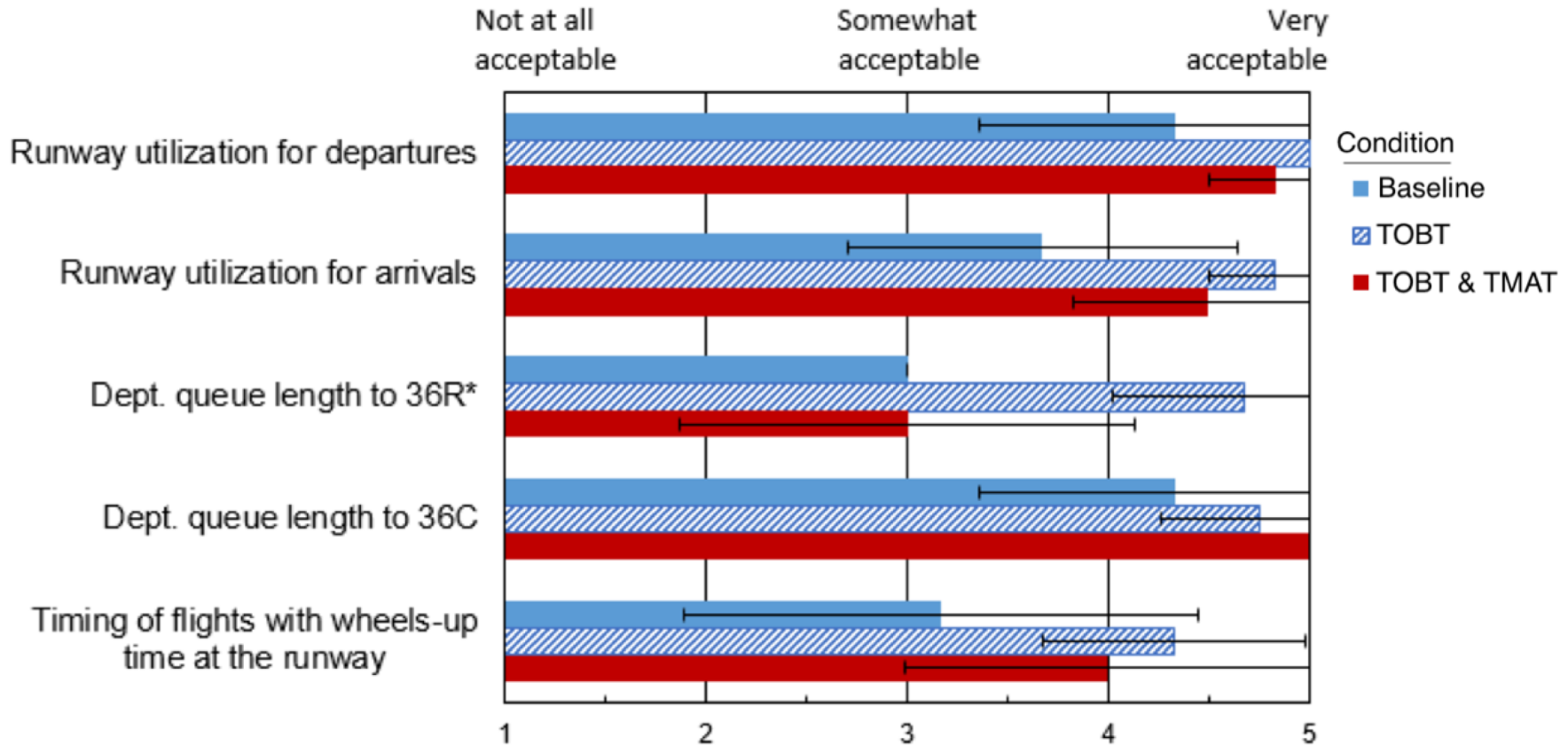


# Local Controllers Post-Run Ratings of Operational Efficiency



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.

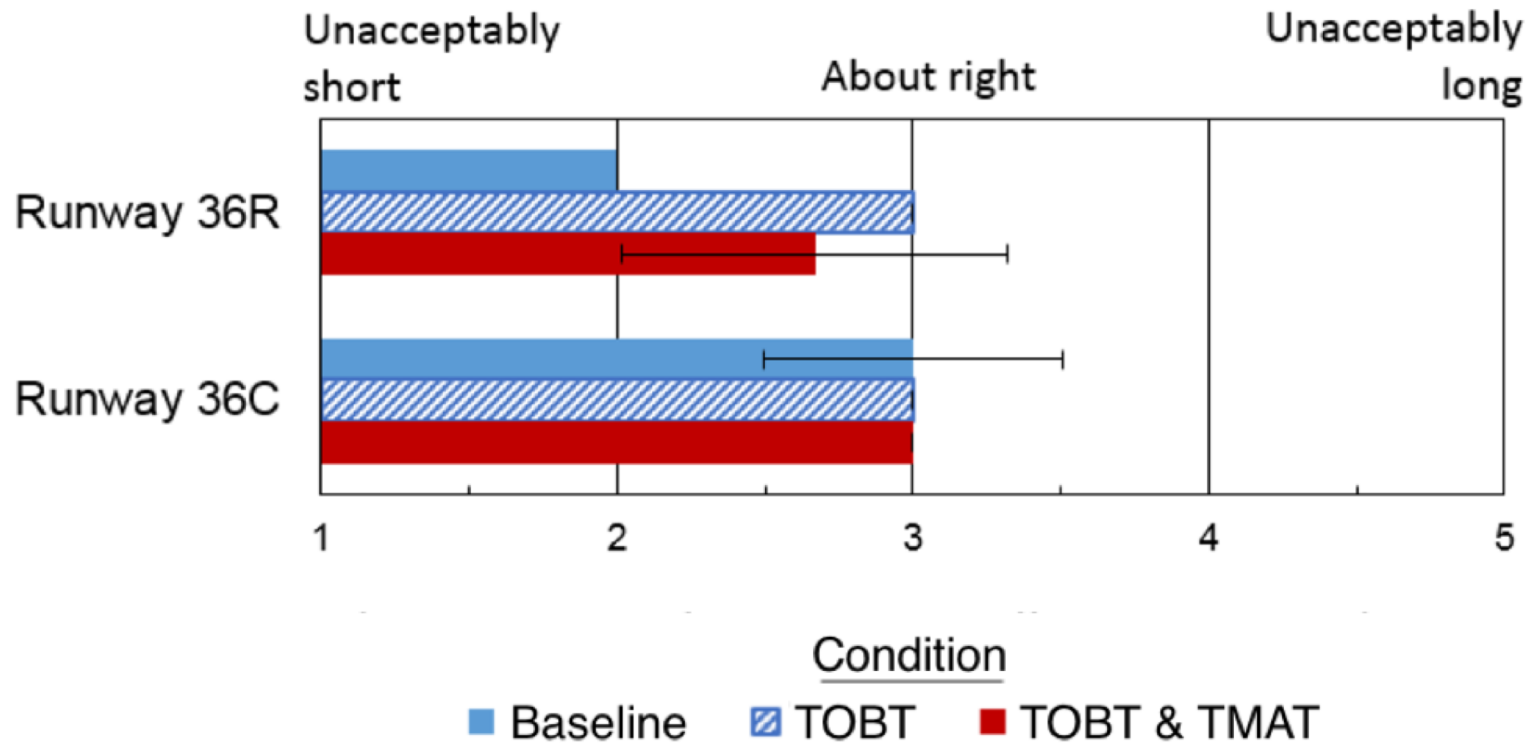


# Local Controller Post-Run Ratings of Runway Queue Lengths



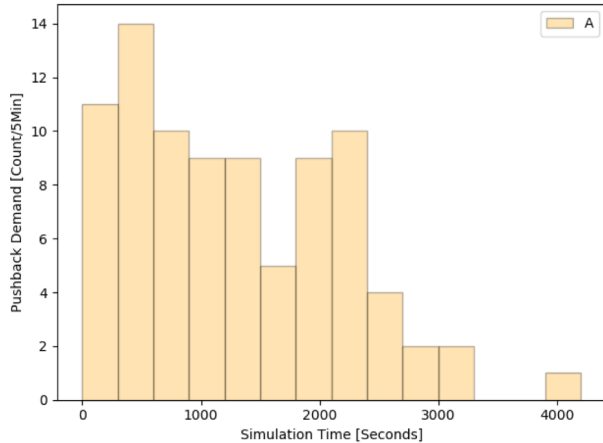
Please describe more specifically the lengths of the runway queues during the busiest time in this run.

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.

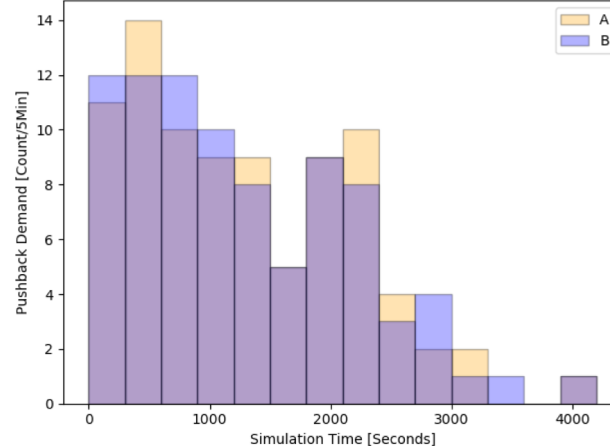


- Three scenarios
  - Scenario A: based on actual operations data at Feb 13, 2018 Bank 2
  - Scenarios B & C
    - Random variations in flight ready times from Scenario A, keeping the same level of departure pressure
    - Same call sign, gate and runway assignment
    - Same arriving flight data

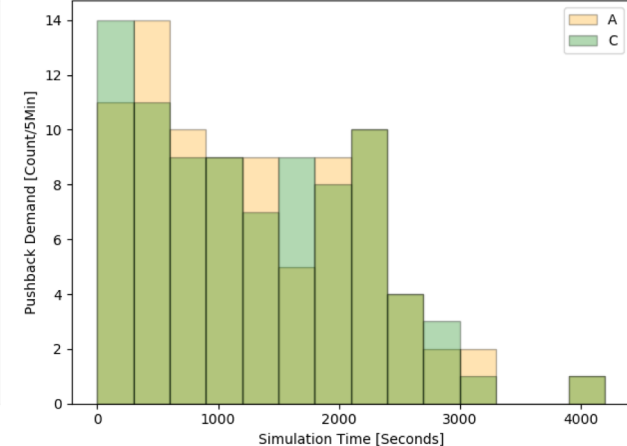
Scenario A



Scenario B



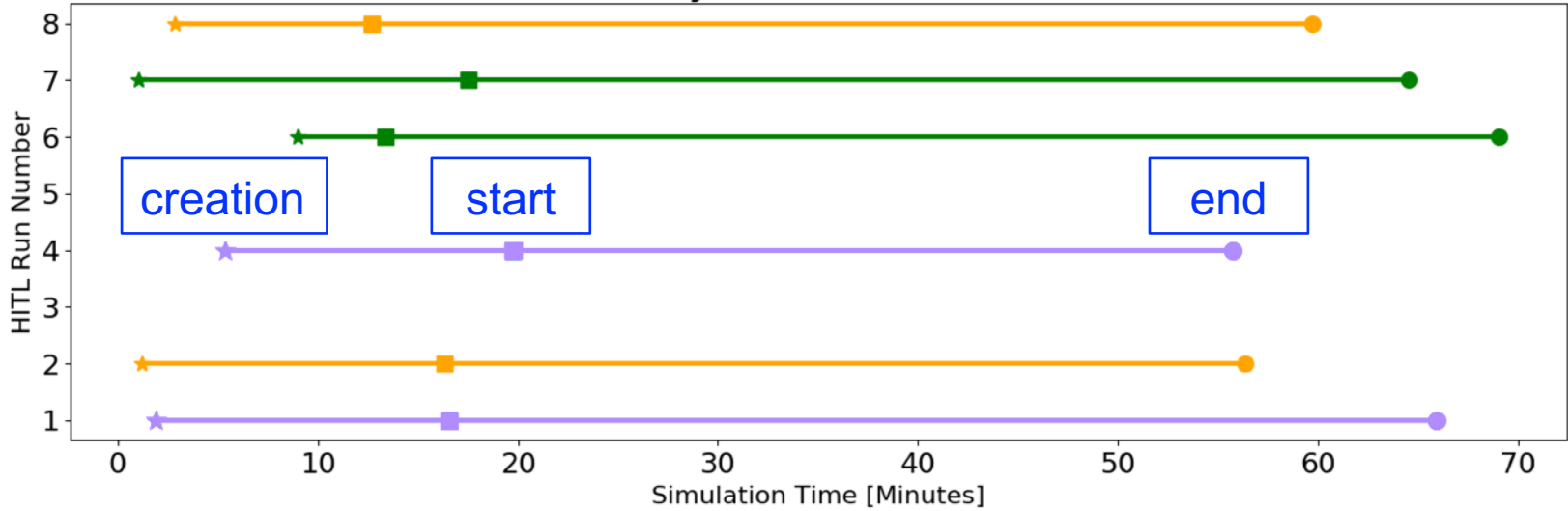
Scenario C



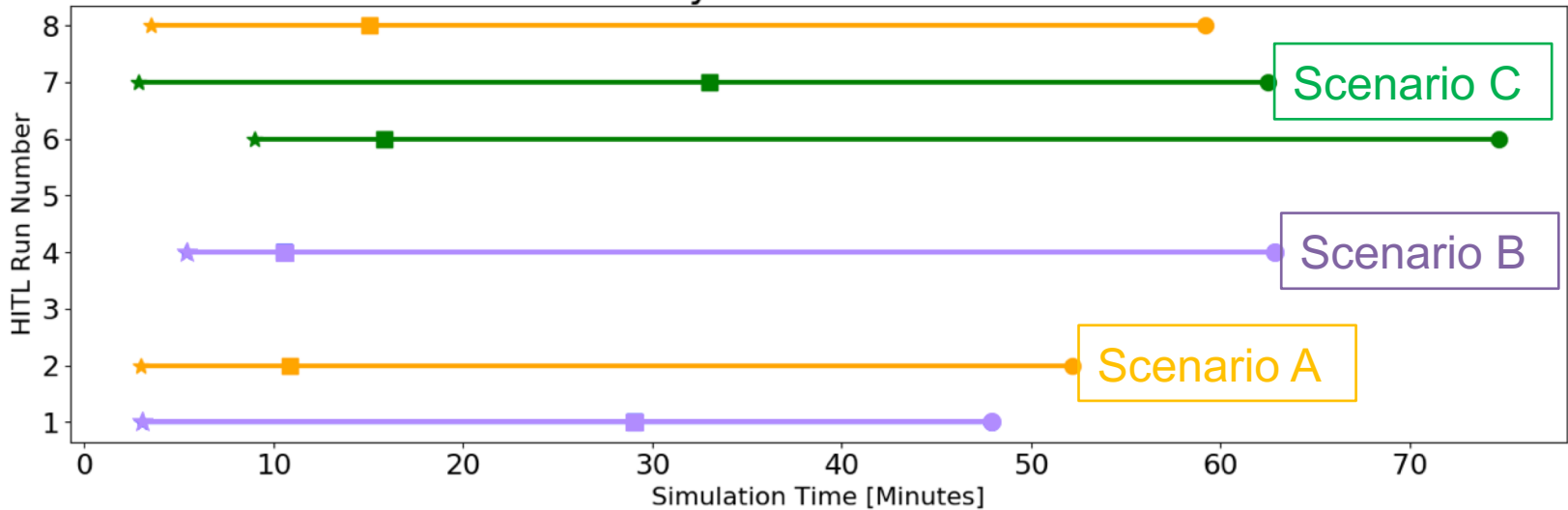
# SMP Creation, Start & End Times, Varied Slightly by Runway, Scenario, and Condition



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