ATD-2 Integrated Arrival/Departure/Surface

Alternatives for Scheduling Departures for Efficient Surface Metering in ATD-2: Exploration in a Human-in-the-Loop Simulation

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Summary of Key Findings

- Background
  - Aircraft waiting in long runway queues waste fuel and increase CO2 emissions
  - NASA has introduced metering at Charlotte-Douglas International Airport to reduce this waste and improve scheduling
- Simulation question: which of the following times should Ramp Controllers use to meter aircraft to the spot (where Air Traffic Control takes over)?
  1. Gate departure advisory times?
  2. Gate departure advisory times plus advisory times to deliver aircraft to the "spot"?
- Simulation results
  - Ramp Controllers achieved the goal of delivering aircraft to the spot on time better in Condition 1
    - When they had advisory times for both the gate and the spot, it appeared to increase their workload and lower their situation awareness to the extent that their compliance with the time at the spot was actually lower

Background

- Surface Collaborative Decision Making (CDM) Concept
  - During a Surface Metering Program, aircraft absorb surface delay in the ramp area, ideally at the gate, instead of in the runway departure queue
    - Saves fuel and reduces carbon dioxide emissions
    - Improves schedule predictability elsewhere on surface
  - The Airspace Technology Demonstration-2 (ATD-2) at Charlotte Douglas International Airport (CLT) has shown that these savings occur when Ramp Controllers release aircraft from the gate at a specific time
    - Initial assessment: reduces 1,000# of fuel use; 3,000# of CO2 per bank (CLT has 9 departure banks/day)
  - To improve schedule predictability further, goal is to deliver aircraft to the "spot" where Air Traffic Control (ATC) takes control, within ±5 minutes of a scheduled time

Simulation Took Place in June, 2018, in Future Flight Central

National facility at NASA Ames Research Center which provides a 360-degree full-scale, real-time simulation of an airport

MD-11 as modeled in Future Flight Central

Participants

- 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

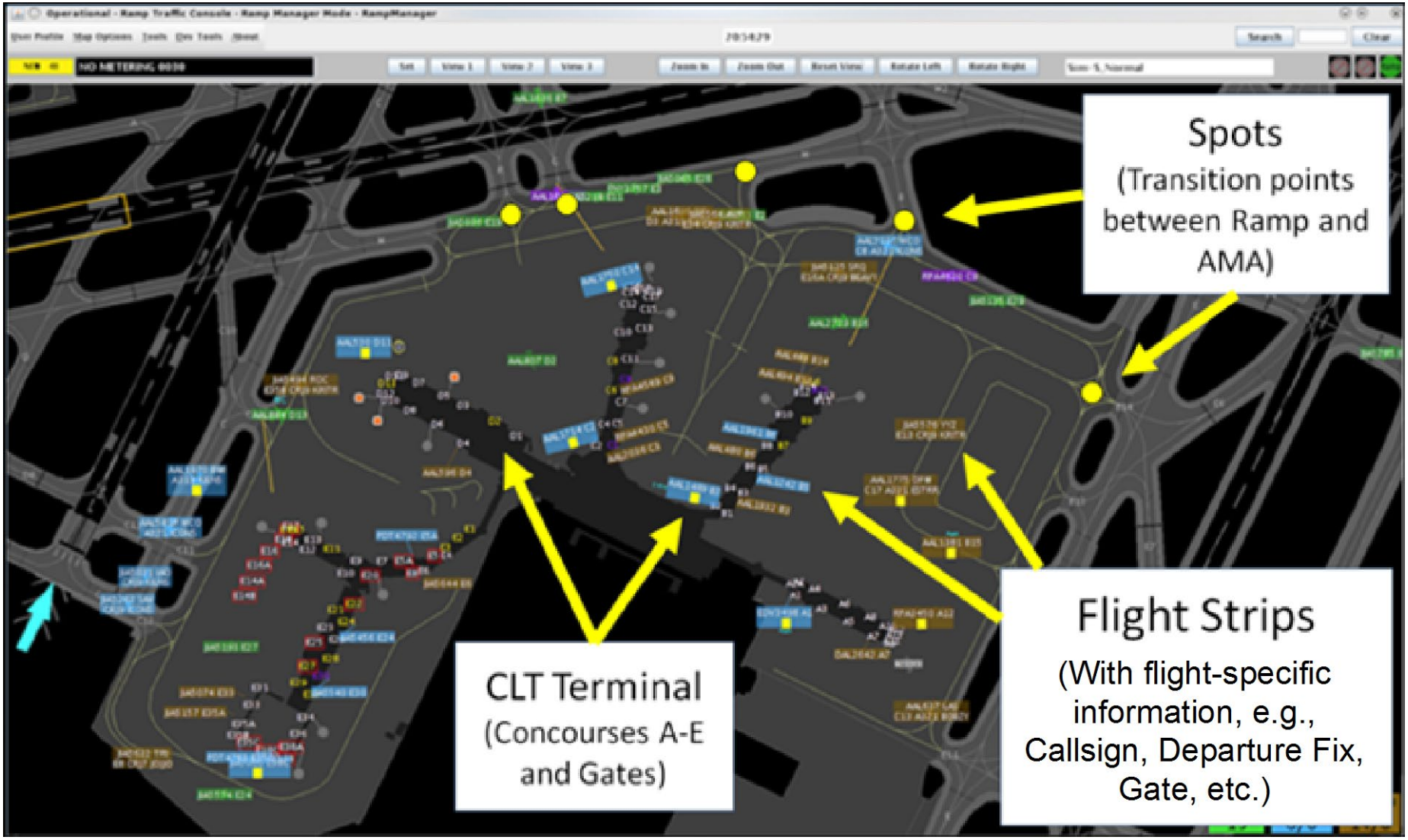
Simulation Compared Three Conditions

- **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.

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



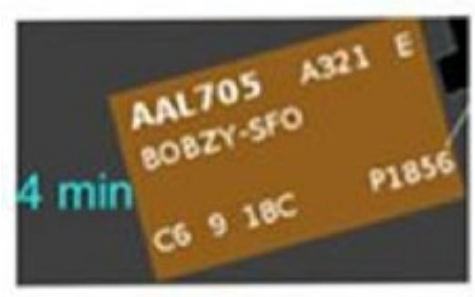
RTC Flight Displays

- Baseline (no advisories)

At gate prior to pushback

After pushback while taxiing

- Gate advisories



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

- Spot advisories

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

Nine Runs: Three 70 Minute Scenarios & 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 were 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

Metrics

- Quantitative
  - Compliance times
- Qualitative
  - 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 five 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

Results

Questions to Answer

- **What were the compliance rates for pushback advisories (TOBTs) and spot times (TMATs)?**
- What were the impacts of the conditions on Ramp Controllers' workload and situation awareness?
- What were the Ramp Controllers' perceptions of operational efficiency?
- What were the processes Ramp Controllers used to meet TMATs?
- What can we conclude?

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)

- TMAT compliance in the TOBT condition was higher than the TOBT & TMAT condition
- 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]

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 (2019)

Questions

- What were the compliance rates for pushback advisories (TOBTs) and spot times (TMATs)?
- **What were the impacts of the conditions on Ramp Controllers' workload and situation awareness?**
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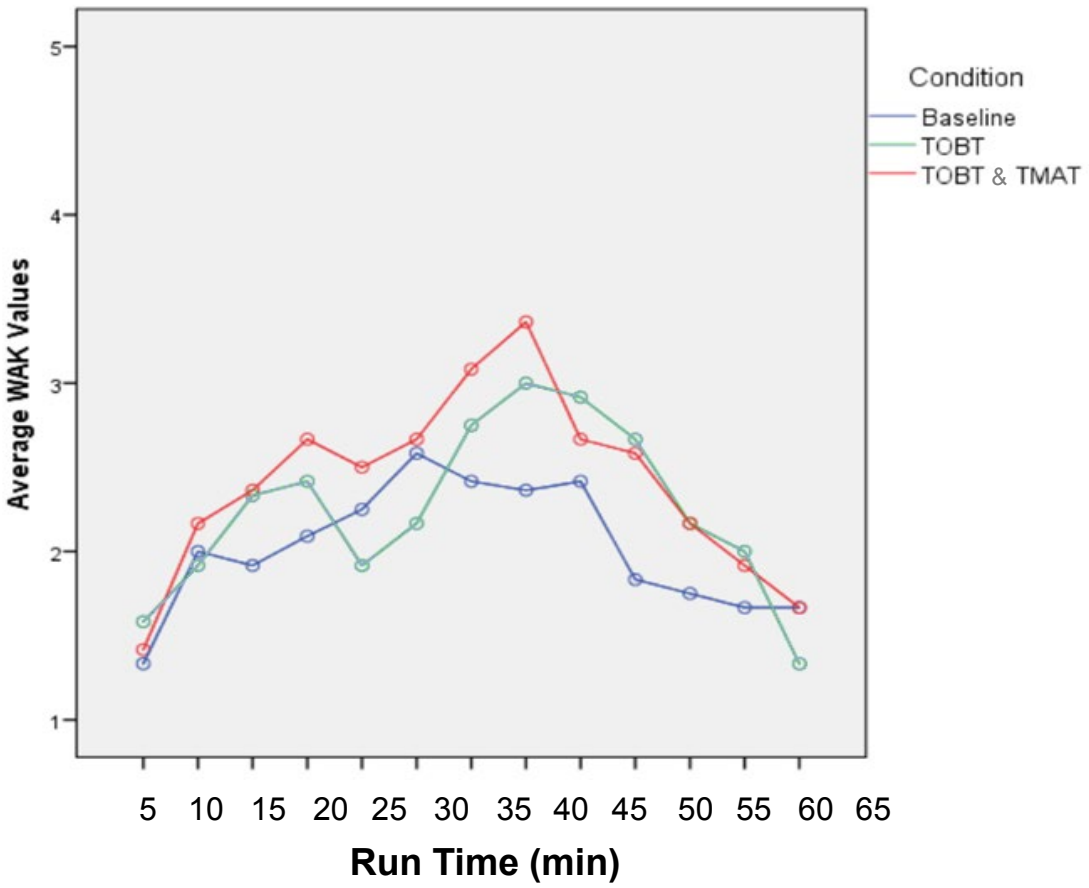
Average Ramp Controller Workload on WAK During Runs

n's = 154 per condition, ANOVA by condition $F(2,460) = 4.7$, $p = .01$

High workload

Moderate workload

Low workload



Ramp Controller workload was statistically significantly higher in the TOBT & TMAT condition than Baseline.

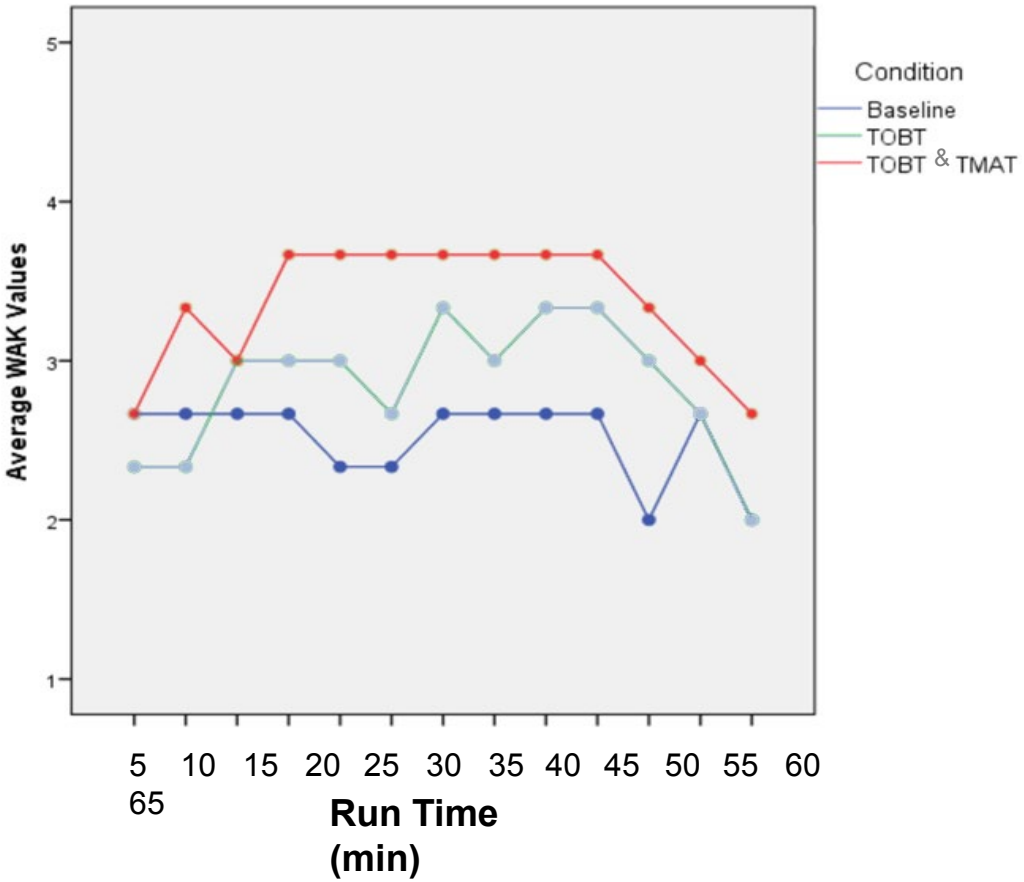
Average Ramp Manager Workload on WAK During Runs

n's = 39 in each condition, ANOVA by condition $F(2,114)= 13.1$, $p < .001$

High workload

Moderate workload

Low workload

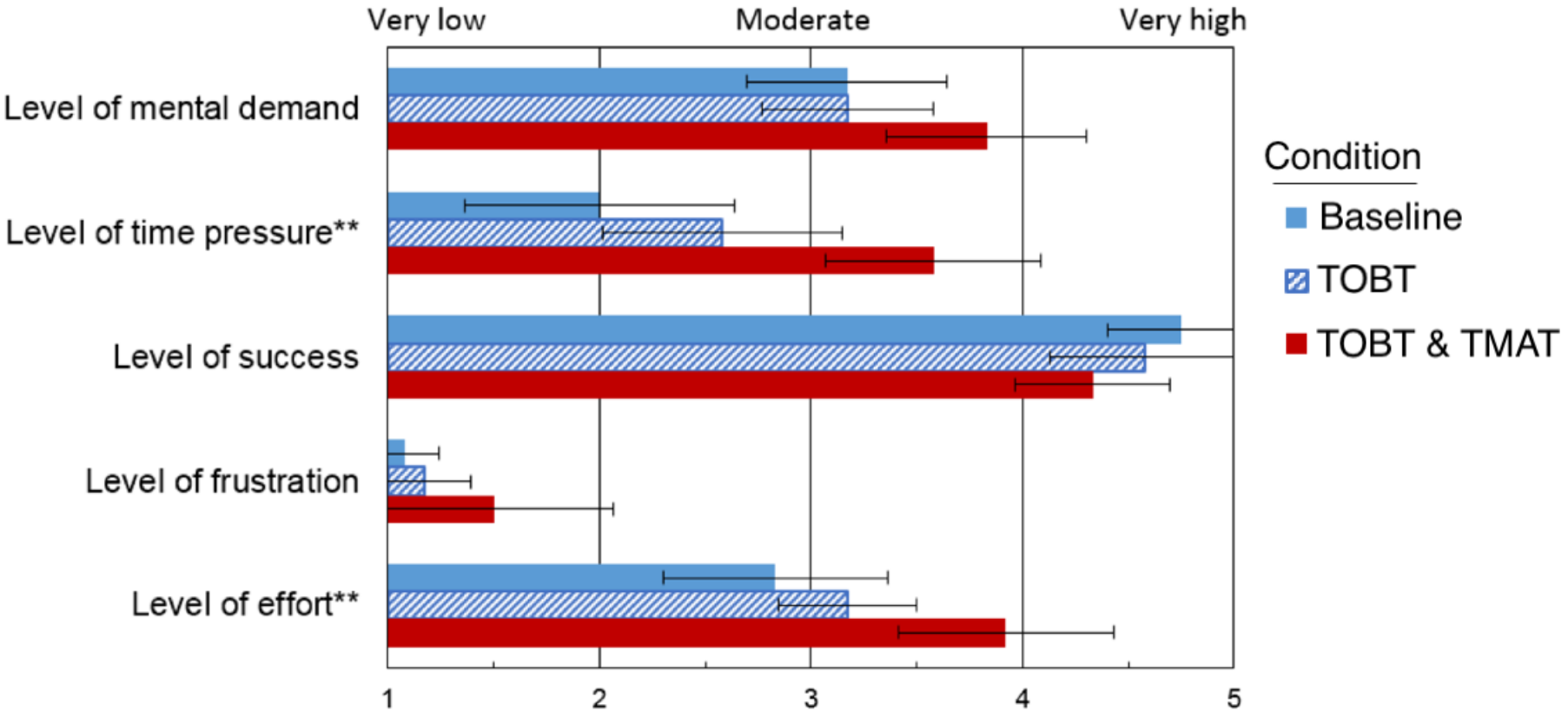


Ramp Manager workload was statistically significantly highest in the TOBT & TMAT condition.

Ramp Controller Post-Run Workload Ratings on Five NASA TLX Items

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.

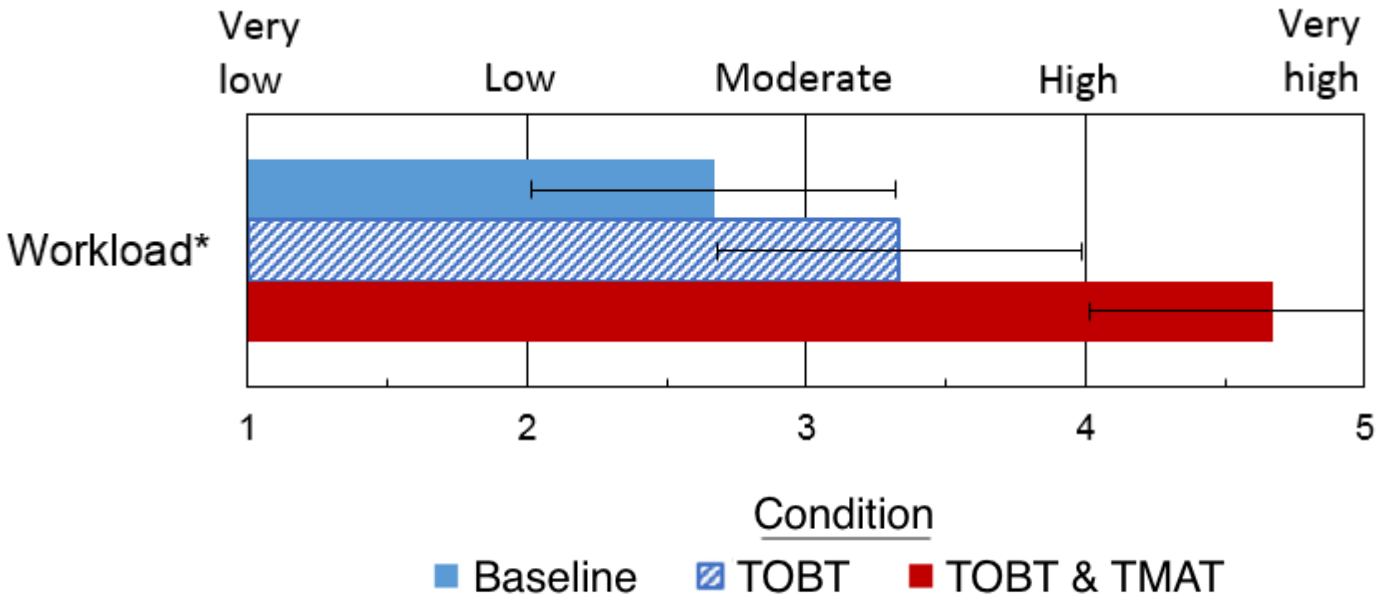


Ramp Controllers' ratings of "Time Pressure" and "Effort" were statistically significantly higher in the TOBT & TMAT condition than Baseline

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, $F(2,2) = 28$, $p = .03$.

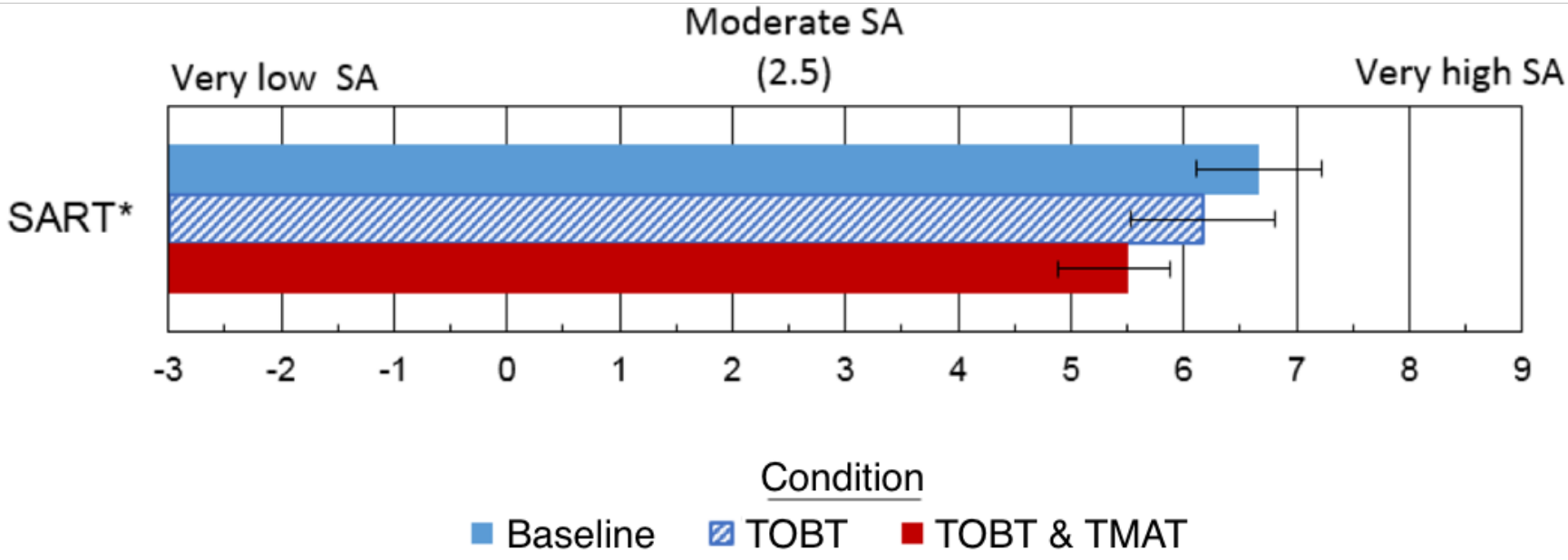


Ramp Controllers' ratings of general workload were statistically significantly higher in TOBT & TMAT condition than the other two conditions.

Ramp Controller Post-Run Situation Awareness Ratings on SART

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 the TOBT & TMAT condition than Baseline

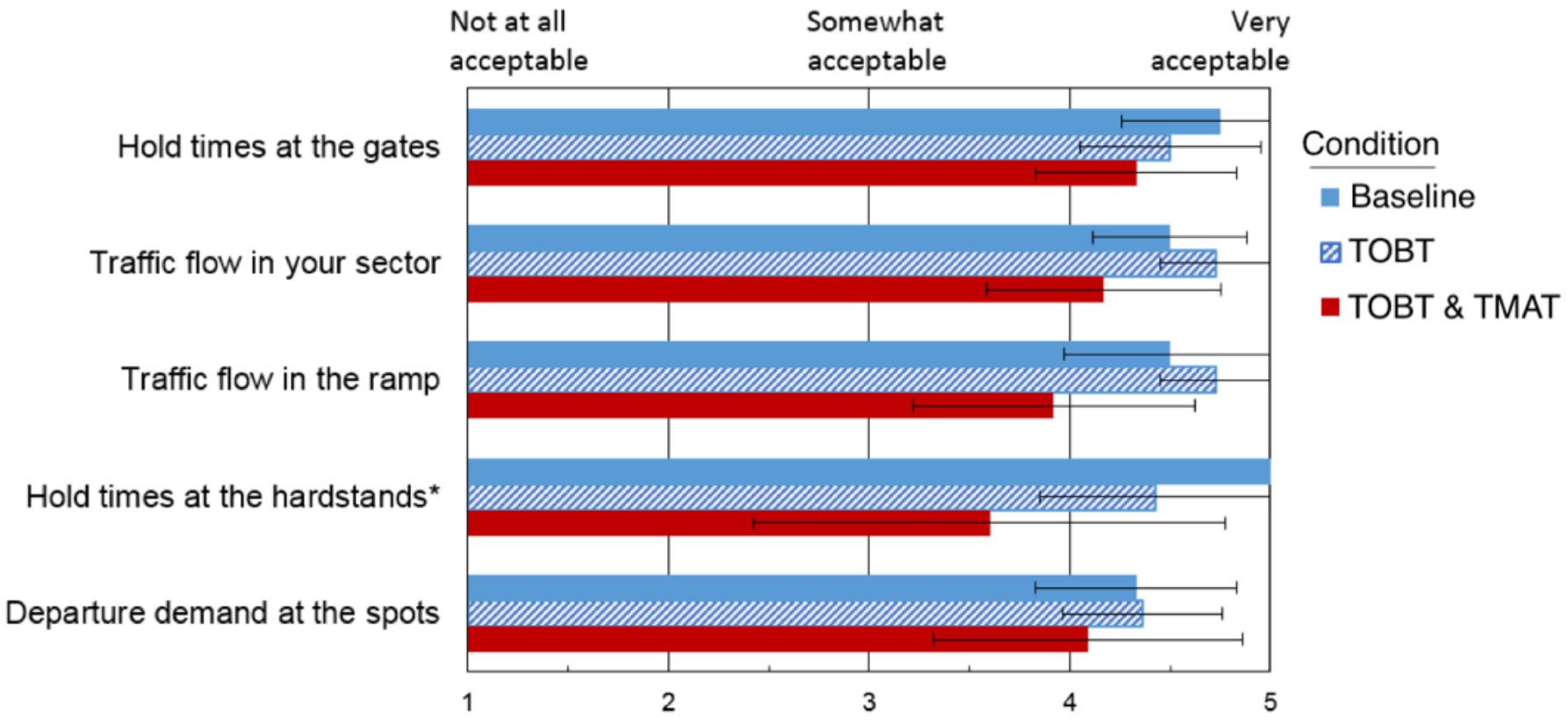
Questions

- What were the compliance rates for pushback advisories (TOBTs) and spot times (TMATs)?
- What were the impacts of the conditions on Ramp Controllers' workload and situation awareness?
- **What were the Ramp Controllers' perceptions of operational efficiency?**
- What were the processes Ramp Controllers used to meet TMATs?
- What can we conclude?

Ramp Controller Post-Run Ratings of Acceptability of Operational Efficiency

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

*N*s = 12 ratings for each item in each condition; error bars = 95% CIs.



TOBT & TMAT condition trends towards lowest in operational efficiency; significantly lower than Baseline regarding hold times at the hardstands.

Questions

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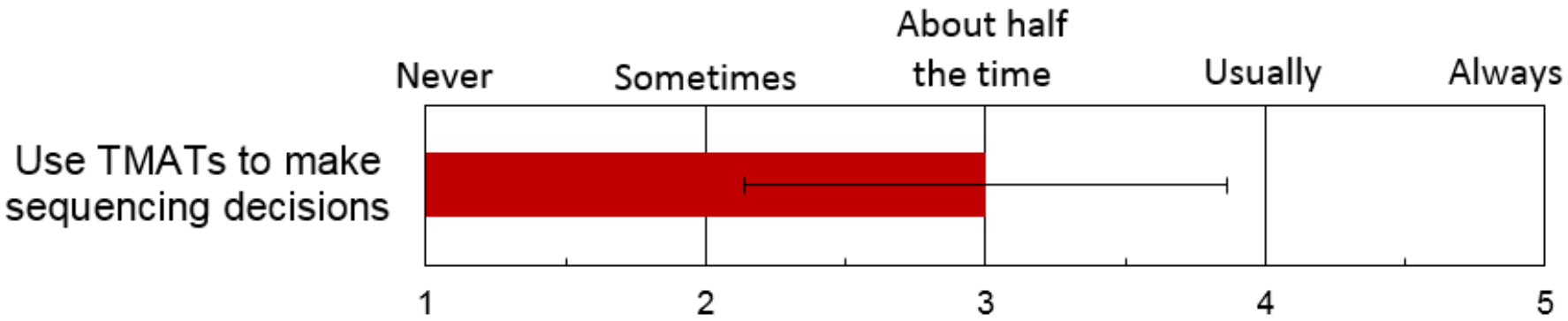
Ramp Controller Post-Run Ratings of Frequency of TMAT Use for Sequencing

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.



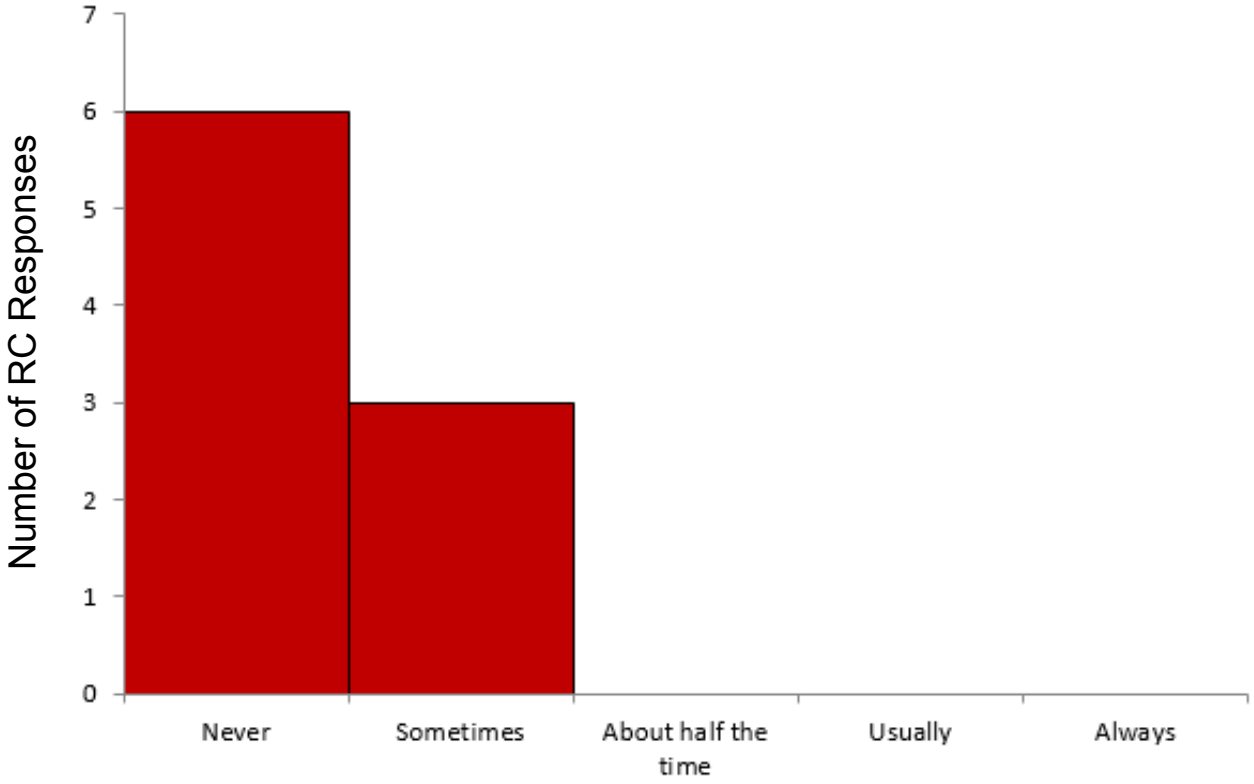
Ramp Controllers used TMATs only about half the time to make decisions about sequencing aircraft.

Ramp Personnel Post-Run Comments for TOBT & TMAT Condition

- Workload and Time Pressure
  - "Things were flowing a bit fast.. I didn't have enough time to really sequence the TMAT times."
  - "Trying to think about the TMAT times and keeping them in order . . .can some times be demanding. Trying to keep order and recognize what other team members may have going on is demanding enough."

Ramp Controller Post-Run Ratings on 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?

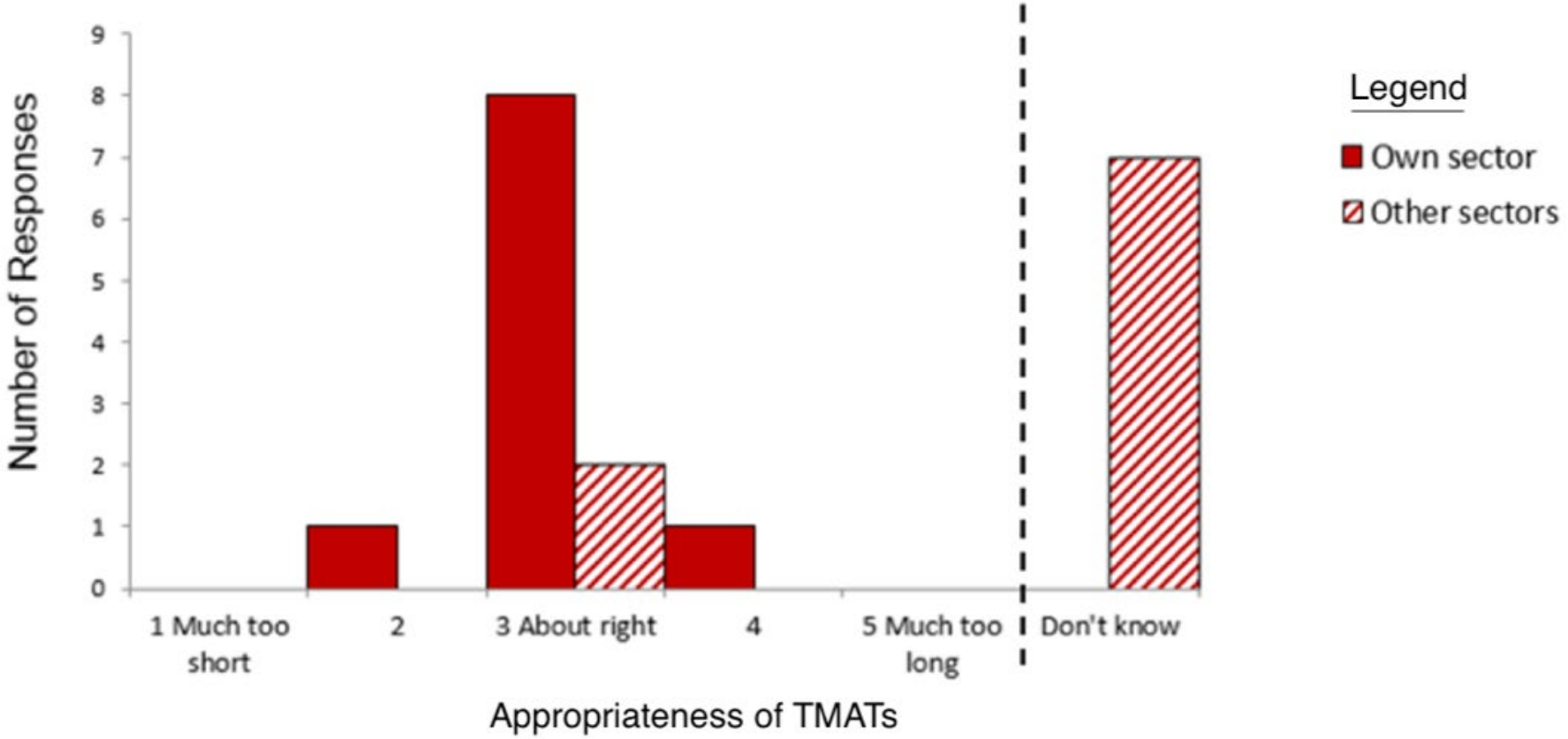


Frequency of Holding Aircraft in Sector to Achieve TMATs

Ramp Controllers rarely held aircraft in their sector to achieve TMATs.

Ramp Controller Post-Run Ratings of Appropriateness of TMATs

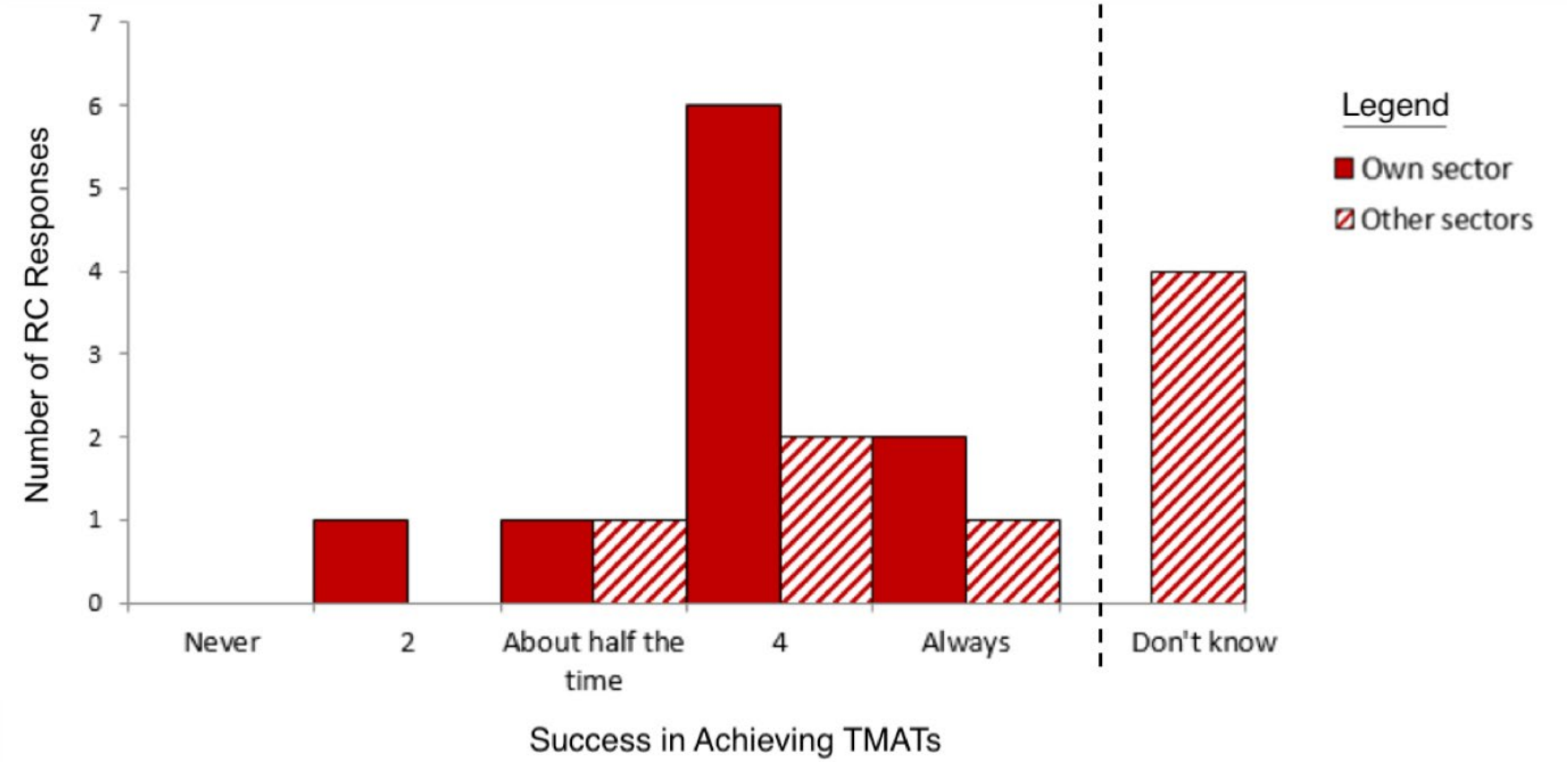
Please rate how appropriate the times of the TMATs were in this run for aircraft coming from the gates in your sector and from other sectors.



Ramp Controllers rated TMATs as "About Right" for their own sector. Ramp Controllers were not aware of the appropriateness of TMATs from gates 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 for aircraft from gates in their own sector. They did not know about aircraft from gates in other sectors.

Conclusion

- What were the compliance rates for pushback advisories (TOBTs) and spot times (TMATs)?
- What were the impacts of the conditions on Ramp Controllers' workload and situation awareness?
- What were the Ramp Controllers' perceptions of operational efficiency?
- What were the processes Ramp Controllers used to meet TMATs?
- **What can we conclude?**

Conclusion

- The TOBT & TMAT condition
  - Had lower compliance rates at the spot than the TOBT condition
  - Had a higher controller workload than Baseline
  - Trended towards being the least acceptable on measures of perceived operational efficiency
  - Had reduced controller situation awareness on the SART measure
    - Controllers were able to sequence aircraft for TMATs only half the time
    - Controllers frequently “Did not know” much about TMATs for aircraft coming from other sectors
- Providing TOBT advisories alone was the best strategy in terms of both compliance times at the spot and controller resilience