AIAA AVIATION Forum
June 15-19, 2020, VIRTUAL EVENT
AIAA AVIATION 2020 FORUM

10.2514/6.2020-3204

Objective Measurement Assessment of Departure Advisories for Ramp Controllers from a Human-In-The-Loop Simulation

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NASA has developed and demonstrated an integrated arrival, departure, and surface concept and technology for efficient air traffic management in busy terminal environments under the Airspace Technology Demonstration 2 (ATD-2) subproject. In April/May 2019, NASA conducted a human-in-the-loop (HITL) simulation with ramp and tower controllers having experience at Dallas/Fort Worth International Airport (DFW). The purpose of this HITL was to evaluate the impacts of various surface metering goals in ramp operations at DFW and test new features of the ATD-2 ramp controller decision support tools. This paper evaluates the quantitative metrics from the simulation results related to airport performance and surface metering given various departure scheduling advisories for ramp controllers. The objective measurements compared include the controller's compliance with the target times for pushback and spot arrival, the number of metered flights, aircraft gate hold and taxi time, runway throughput, and the number of aircraft on the surface. The simulation results show that there were no statistically significant benefits from surface metering at DFW for airport performance due to several simulation artifacts notably different from real operations. Considering controller workload and situation awareness, following either gate pushback or spot arrival advisory could be a better metering option than utilizing both advisories when surface metering is applied at DFW.

I. Introduction

NASA has identified that inefficiency and lack of predictability are the two most challenging issues that the National Airspace System (NAS) faces under heavy air transportation demands. To improve the efficiency and predictability in complex, multi-airport environments, NASA, in close collaboration with the Federal Aviation Administration (FAA) and industry partners, has been developing an Integrated Arrival, Departure, and Surface (IADS)

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traffic management concept and technology as part of the Airspace Technology Demonstration 2 (ATD-2) subproject [1-3]. The IADS concept was built upon previous NASA research, that include Terminal Sequencing and Spacing (TSAS) [4], Precision Departure Release Capability (PDRC) [5], and Spot and Runway Departure Advisor (SARDA) [6, 7], each of which focused on individual airspace domains. The ATD-2 team has been conducting an operational field test of the IADS traffic management system since September 2017, which has demonstrated benefits for a complex terminal environment [8]. The ATD-2 field demonstration also previews several aspects of the FAA Terminal Flight Data Manager (TFDM) system such as Surface Collaborative Decision Making (Surface CDM) departure metering, the Advanced Electronic Flight Strip system (AEFS) user interface in the Airport Tower, and data sharing with the aviation industry via the TFDM Terminal Publication (TTP) service.

NASA has been conducting the ATD-2 field demonstration in three phases. The Phase 1 baseline IADS system demonstrated enhanced operational efficiency and predictability of flight operations through data exchange and integration, tactical surface departure metering at Charlotte Douglas International Airport (CLT) by the American Airlines Ramp Tower and the FAA's Airport Traffic Control Tower (ATCT), as well as departure scheduling and automated coordination of release times of controlled flights for overhead stream insertion at the meter points in the Washington Air Route Traffic Control Center (ARTCC). The second phase extended the tactical surface metering into strategic surface metering by extending its planning horizon, provided two-way interface with tower electronic flight strips, and expanded overhead stream insertion of departures to the Atlanta ARTCC. The final phase demonstrates a terminal departure scheduling capability that considers multiple airports and terminal boundary constraints. This third phase of field demonstration is currently being conducted at Dallas/Fort Worth Terminal Radar Approach Control (TRACON), Fort Worth ARTCC, Dallas/Fort Worth International Airport (DFW) and Dallas Love Field Airport (DAL) ATCTs, and American and Southwest Airlines facilities at DFW and DAL airports, respectively [9].

Several human-in-the-loop (HITL) simulations have been conducted to support the development of the IADS system and ensure the success of the ATD-2 field demonstration. In March 2017, NASA conducted a HITL simulation to evaluate the operational procedures and information requirements for the tactical surface metering tool and data exchange between the American Airlines' Ramp Tower and the FAA's ATCT at CLT [10]. Results from this HITL simulation helped establish the best set of the configurable metering parameter values that could be used as the nominal metering values to meet target excess queue time set on the ramp controller decision support tool, given the runway configuration and desirable departure excess queue time. The next HITL simulation was conducted in June 2018 to assess various strategies for ramp controllers at CLT to deliver departing aircraft at a specified time to the spot, which is a handover point from the ramp to the ATCT controllers, located between the ramp area and the airport movement area [11].

Before these ATD-2 subproject experiments, HITL simulations had been used to evaluate the effectiveness of the SARDA concept. The SARDA concept was initially developed for ATCT controllers' decision support at DFW by providing runway usage advisories to local controllers and spot release advisories to ground controllers. This concept was evaluated in HITL simulations performed with retired DFW ATCT controllers in 2010 and 2012 [12-14]. The simulation results showed that the SARDA advisories could reduce taxi delay at DFW while reducing tower controller workload. Later, the SARDA concept was extended to provide ramp controllers with pushback or gate-hold advisories for individual departures, taking operational constraints into consideration, such as taxiway congestion, departure runway queue lengths, and Traffic Management Initiative (TMI) constraints. In September/October 2014, the departure pushback decision support tool for ramp controllers based on this concept was developed and evaluated in a HITL experiment with ramp and tower controllers experienced at CLT [7]. The simulation results showed that the pushback advisories helped reduce both departure taxi time and fuel consumption without increasing controller workload.

In April/May 2019, NASA conducted a new HITL simulation with ramp and tower controllers who had experience at DFW. The purpose of this HITL simulation was to evaluate the impacts of various metering goals in ramp operations at DFW and test new features in the ATD-2 ramp controller decision support tools. In this HITL, two metering advisories, gate pushback advisory and spot arrival advisory, were considered as potential metering options to help manage ramp traffic efficiently and mitigate the congestion on the surface. For the gate pushback advisory, the Target Off-Block Times (TOBTs) calculated from the ATD-2 tactical surface scheduler were provided to ramp controllers. For the spot arrival advisory, the Target Movement Area entry Times (TMATs) of departures were provided. As it might be more useful for the users to receive both pushback and spot arrival advisories, providing both TOBTs and TMATs to users was also considered an option. The HITL simulation experiment contrasted four different conditions listed in Table 1 to determine which advisory display would be most helpful for ramp controllers. The Baseline condition providing no advisories was used to evaluate the effectiveness of the surface metering advisories.

Table 1. Four Different Conditions for Ramp Controllers

Conditions	Description
Baseline	Ramp controllers instructed to operate as they would in normal, current day operations
TOBT Compliance Only	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) advisory
TMAT Compliance Only	During metering, ramp controllers instructed to deliver flights to the spot at their Target Movement Area entry Times (TMAT) within ± 5 min
TOBT+TMAT Compliance	During metering, ramp controllers instructed to pushback flights in compliance within ± 2 min of their TOBTs and to deliver flights to the spot at their TMATs within ± 5 min

These four conditions were compared and evaluated using both objective and subjective measurements. This paper summarizes results from the HITL simulation, specifically assessing the objective measurements related to airport performance and surface metering. The subjective measurements related to human factors impacts, which were obtained by various workload ratings, post-surveys, and debriefs, will be discussed in a separate paper [15].

In this paper, Section II describes the HITL simulation design, including airport layout, traffic scenarios, participants, simulation facilities and equipment, and the ramp controller decision support tool for surface metering. The objective performance metrics from the simulation are shown in Section III. Section IV provides a detailed discussion of the simulation results. Lastly, Section V provides conclusions with closing remarks.

II. Human-In-The-Loop Simulation Design

A. DFW Operations

The HITL simulation was conducted using Dallas/Fort Worth International Airport (DFW). DFW is the 4th busiest airport in the world by aircraft movements [16] and is the largest hub airport for American Airlines. DFW is a target site for the ATD-2 Phase 3 field demonstration, and this research was part of the investigation of ATD-2 surface metering concept and technology at a major hub airport, given a projected increase in traffic demand.

As shown in Fig. 1, DFW has seven runways with five main terminals A through E in the center. For runway operations, the South flow configuration is preferred. The most frequently used runway configuration is (Arrivals: 13R, 17C, 17L, 18R | Departures: 17R, 18L) where the two runways closest to the main terminals, 17R and 18L, are dedicated to departures [17]. In this configuration, arrival aircraft from runway 17C and 17L mainly use perimeter (end-around) taxiways around the south end of runways 17R and 17C to avoid crossing the active departure runway 17R [18].

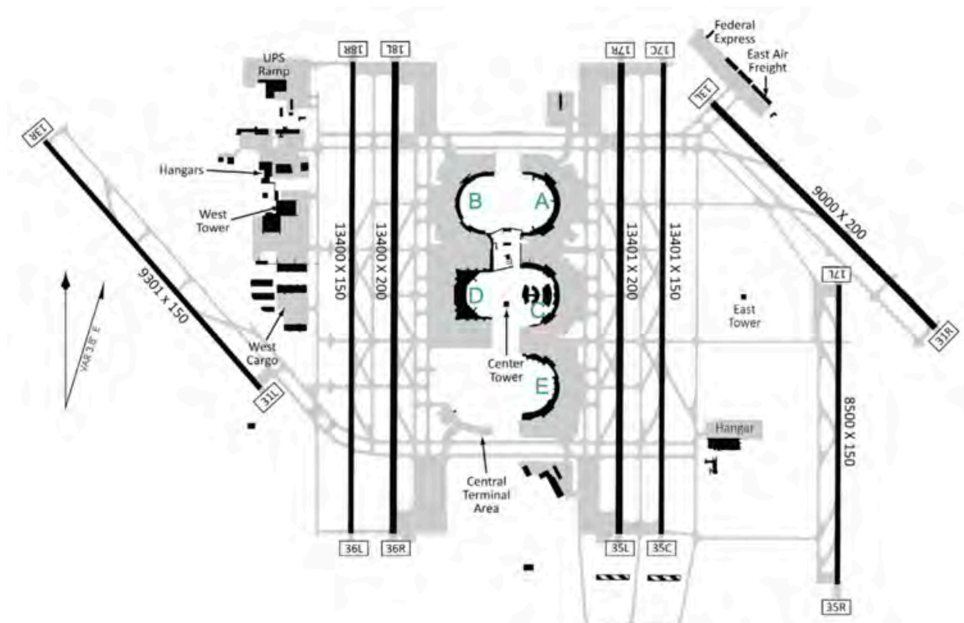


Fig. 1 DFW airport plan view.

B. Traffic Scenarios

The traffic scenarios used in the HITL simulation were from actual operations data in the South traffic flow configuration at DFW, using five different scenarios from the busiest days in June to September 2018. As can be seen in Fig. 2, the traffic demand at DFW has consistent peak and valley patterns (banks) on a daily basis, which is one of the main operational characteristics at major carriers' hub airports, like DFW. The traffic scenarios in the simulation came from the second peak period in the day, called Bank 2, between 8:30am and 10am local time.

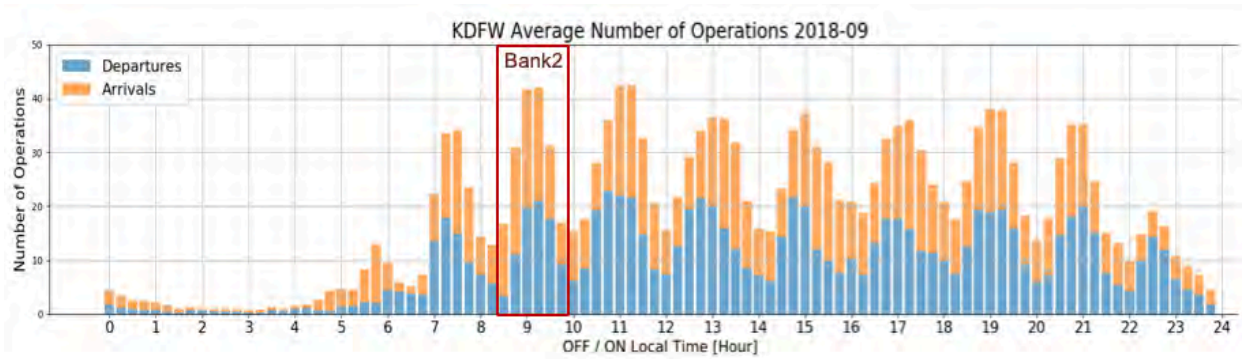


Fig. 2 Average number of operations at DFW (as of September 2018).

For the HITL simulation, we assumed clear weather conditions with no wind. The traffic demand was neither compressed nor decompressed, but the traffic volume was increased by 15%, reflecting projected increases in traffic operations at DFW. As a result, in each scenario, six more departures were added to either Terminal A or C. Regarding Traffic Management Initiative (TMI) restrictions, only one Expect Departure Clearance Time (EDCT) flight was present in each scenario. For surface metering, the target excess queue time was predetermined as eight minutes for each runway, which means that up to eight departures were expected in the departure runway queue, given the assumption that every subsequent departure on a dedicated departure runway is separated by approximately 60 seconds, and other departures in ready-to-push status were advised to be held at their gates.

C. Simulation Environments and Participants

The HITL simulation was conducted at Future Flight Central (FFC), a research facility at NASA Ames Research Center that provides a 360-degree full-scale, real-time simulation of an airport control tower [19]. The American Airlines Ramp Tower for DFW was configured in the FFC Tower Cab on the second floor and provided a 360-degree out-the-window view of the airport. A "mini tower," showing a 270-degree out-the-window view of DFW East ATCT, provided a simulation environment for tower controllers and a traffic manager at a different location within the facility.

The HITL simulation was conducted over two weeks with a different set of three ramp controllers and one ramp traffic manager for each week. Therefore, there were a total of six ramp controllers and two ramp traffic managers, all of whom had operational experience at DFW. They were in charge of controlling flights in the ramp area on the east side of the airport, i.e., Terminals A, C, and E, as shown in Fig. 3. The out-the-window view for each ramp controller was adapted to show each terminal and the alley between terminals for better observation. In addition to the out-the-window view, the ramp controllers were provided a variety of ATD-2 tools, including the Ramp Traffic Console (RTC), Ramp Manager Traffic Console (RMTC), Surface Trajectory Based Operations (STBO) Client, and Surface Metering Display (SMD). The RTC is an interactive map display with electronic flight strips used by ramp controllers for increased situation awareness, collaboration, and data exchange and integration. The metering advisories (i.e., the pushback advisory in support of the TOBT and the spot arrival advisory in support of the TMAT) were also displayed in the RTC display.

Four retired ATCT controllers, who also had operational experience at DFW, participated in the HITL simulation as local and ground controllers throughout the two-week experiment, and rotated positions in every run. Each week, one active DFW ATCT Traffic Management Coordinator (TMC) participated in the simulation to coordinate between the Tower and Ramp Traffic Manager. ATCT controllers used the STBO Client map display, which emulated the Airport Surface Detection Equipment, Model X (ASDE-X) and Advanced Electric Flight Strip (AEFS).

There were 13 pseudo pilots who communicated with controllers via radio and controlled both departure and arrival aircraft on the ramp and airport movement area in a different room separated from tower controllers. Some of them communicated with confederate ATCT and ramp controllers regarding traffic on the west side of the airport.

In addition to the HITL instruction to comply with gate and spot advisories, ramp controllers were also reminded to use their best judgement in managing ramp traffic and gate conflicts. For example, if a departure flight with a gate hold advisory was expected to have 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. If necessary, spot assignments could be changed for a flight. Other HITL participants such as ATCT ground and local controllers were instructed to operate as they would in normal, current-day operations.

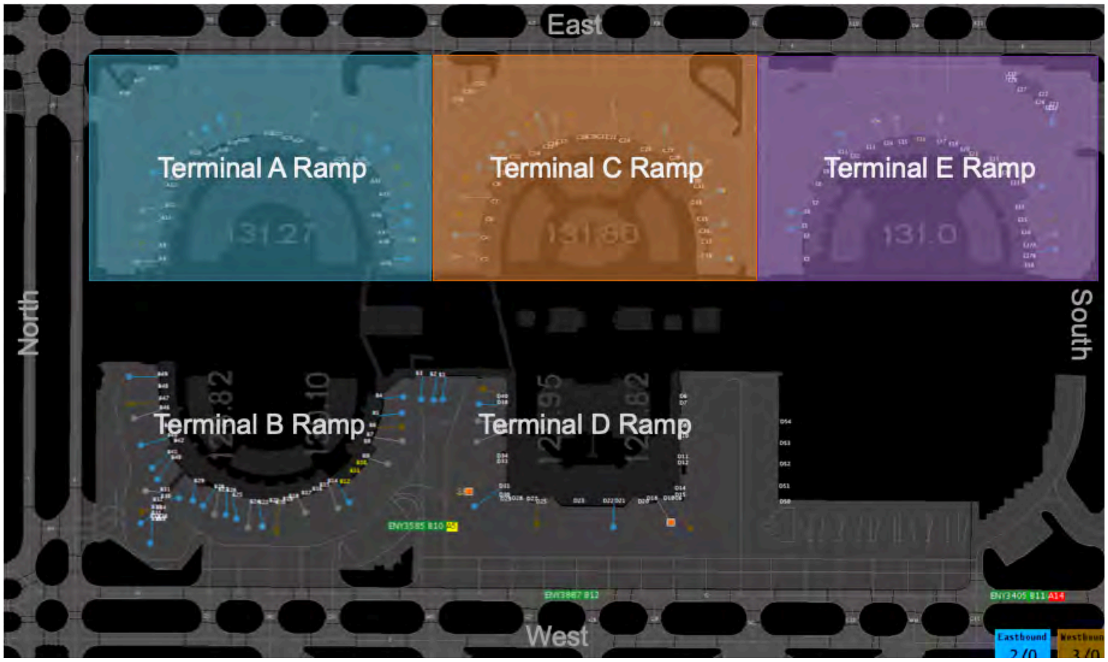


Fig. 3 DFW ramp sectors.

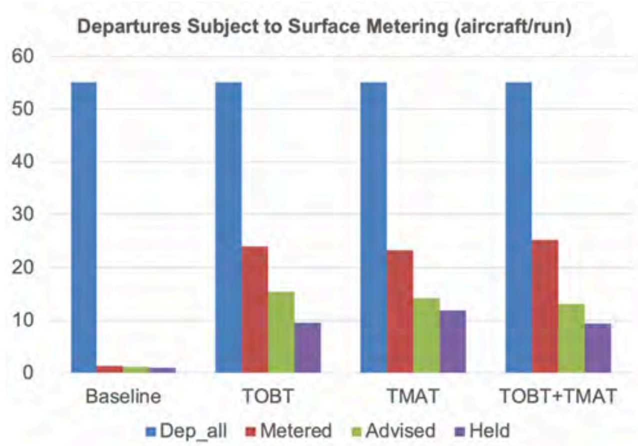
III. Simulation Results

This section details the HITL simulation results of various objective measurements. A total of 28 runs, each about 80 to 90 minutes long, were used for data analysis, which resulted in seven runs for each of the four metering conditions described earlier. The quantitative performance metrics, including average gate hold, the number of metered flights, aircraft taxi-out and taxi-in times, the number of departures on the surface, runway throughput, and TOBT and TMAT compliance, were compared between metering conditions.

A. Gate Holding

The left and right graphs in Fig. 4 show the average number of metered flights and the average gate hold time per departure in each condition, respectively. Among all the 55 scheduled departures in Terminals A, C, and E per run (blue bars on the left graph), an average of about 24 departures were considered to be subject to surface metering (red bars), but fewer departures were advised to hold at their gates (green bars). Depending on the operational constraints that impacted pushback processes such as traffic behind the gate and gate conflicts, fewer aircraft were actually held at the gates than were advised (purple bars). Furthermore, controllers were allowed to issue a pushback clearance when the remaining time to the given TOBT was within 2 minutes. This guideline also led to fewer aircraft held at gates.

Each advisory condition shows different patterns in both the number of metered flights (left graph) and the average gate hold (right graph), with respect to the actual gate hold compared to the advised gate hold. As can be seen on the right graph in Fig. 4, ramp controllers tended to release aircraft earlier than the gate advisory in the TOBT only condition. On the other hand, in the TMAT only condition, controllers actually held more departing aircraft than in the other metering conditions, and released them later than would be recommended for them to meet the ± 5-minute TMAT advisory, although their compliance with TMAT was still high (about 86%), which will be shown later. Note that since pushback advisories were not provided to ramp controllers in the TMAT only condition, the advised gate holds shown in the graph were from internal calculations of the scheduler. It is also remarkable that in the TOBT+TMAT condition, the actual gate holding time for the flights actually held was almost the same as the advised holding time. It seems that ramp controllers were more willing to accept the given gate hold advisories in this condition, mainly due to the higher workload to meet both TOBTs and TMATs.



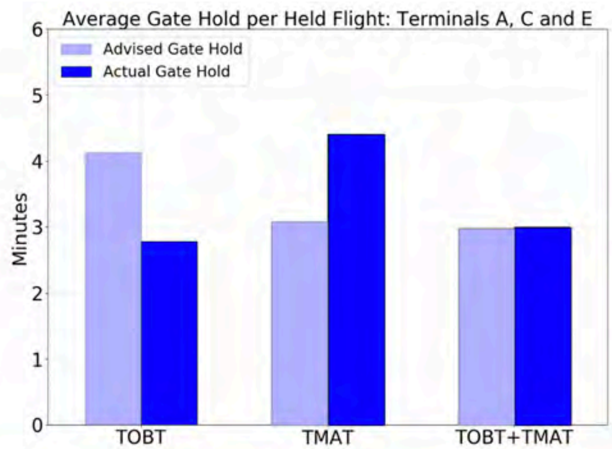
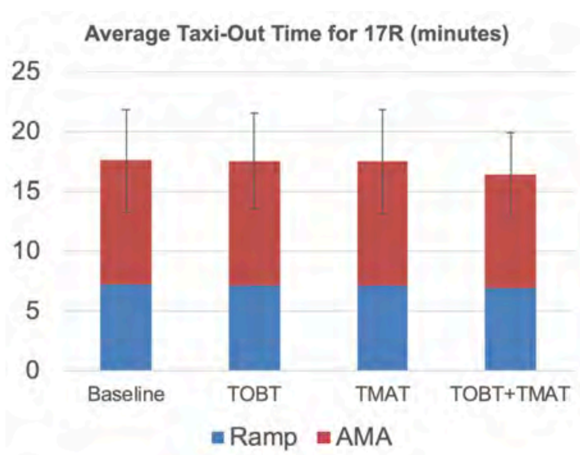


Fig. 4 Average number of departures subject to surface metering per run (left) and average gate hold for departures in Terminals A, C, and E (right).

B. Taxi-out/in Times

Fig. 5 shows the average taxi-out times in the ramp and movement area of the departures from Terminals A, C, and E to each departure runway, 17R (left) and 18L (right), by metering condition. It was expected that the taxi-out time would be reduced by surface metering, but the results showed that the average taxi-out times were not very different between the four conditions although the data sample size is limited to seven runs each. As can be seen in Fig. 5, the ramp taxi-out times (blue color) were almost the same regardless of condition. For the departures going to Runway 17R, the AMA taxi-out times were shorter in the TOBT+TMAT condition, but the other metering conditions did not show any taxi time reduction compared to the Baseline condition. For the flights toward Runway 18L, the average taxi-out times were increased instead, even though some departures were held at their gates during peak times. In the TOBT only condition, the flights held at gates in the east side terminals and released later had the longer AMA taxi time while merging with other flights from the west terminals in the departure queue for Runway 18L. Generally, it seems that the benefits of surface metering, which are actually seen in the field at CLT, were not evident in this HITL simulation for DFW. This appears to be mainly due to simulation artifacts, which will be discussed in Section IV. Note that in general, the Airport Movement Area (AMA) taxi times (red color) for Runway 18L (right graph) are longer than for Runway 17R (left graph) because the departing aircraft from Terminals A, C, and E have to cross the taxiway bridges to get to the west side runway.



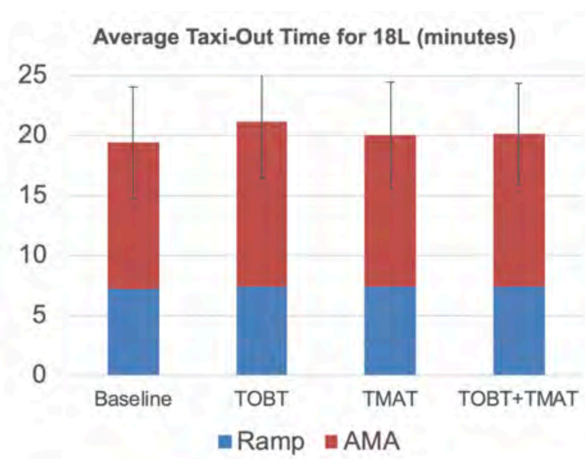


Fig. 5 Average taxi-out time of departures from Terminals A, C, and E to Runways 17R (left) and 18L (right). Error bars are standard deviations for total taxi-out times.

Fig. 6 illustrates the average taxi-in times in the ramp and movement area of the arrival flights taxiing to the gates in Terminals A, C, and E by metering condition. Similar to the departure taxi-out time results, there are no statistically significant differences observed among conditions. This result means that surface metering did not make an impact on the arrivals, even though gate conflicts occurred in a few cases during the simulation.

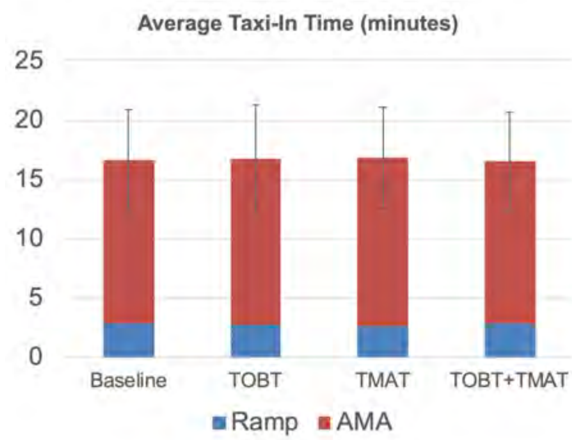


Fig. 6 Average taxi-in time of arrivals going to Terminals A, C, and E. Error bars are standard deviations for total taxi-in times.

C. Surface Counts

The number of departing aircraft on the airport surface was also measured. The airport surface counts were categorized by the number of departures in the ramp area by terminal, the number of departures on the AMA between spots and runway for each departure runway, and the number of departures in the departure runway queues for each runway. As a representative result, the average numbers of aircraft in departure runway queues, along with the simulation time, are shown in Fig. 7 for each departure runway. Note that the number of departures in Fig. 7 includes the aircraft from all terminals to each runway. With the metering advisories provided, the queue lengths for both departure runways were maintained below the target queue size (about eight aircraft) for most of the simulation time, whereas the Baseline case reached nine aircraft in the queue for Runway 17R several times during the peak period. For Runway 17R, the TOBT+TMAT condition showed relatively lower departure queue sizes by controlling both pushback times and spot crossing times. For Runway 18L, on the contrary, the TOBT only condition showed higher queue sizes after 50-minutes of simulation time. Both observations are consistent with the differences in average AMA taxi-out time observed in Fig. 5.

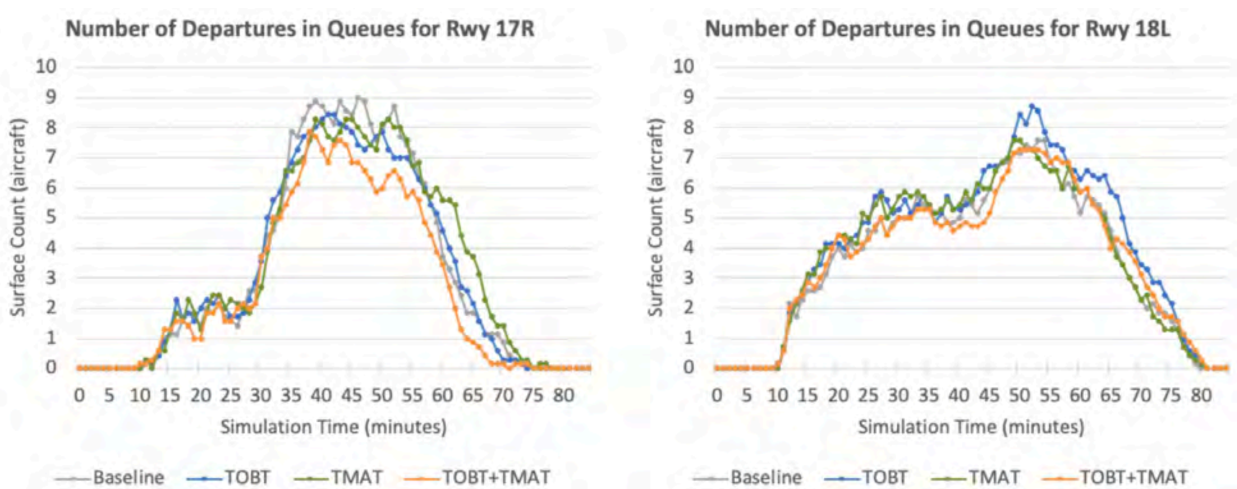


Fig. 7 The average number of aircraft in departure runway queues for Runways 17R (left) and 18L (right) per condition.

D. Runway Throughput

Fig. 8 shows the average accumulated runway throughput curves over the simulation time by metering condition for each departure runway. Although there are small deviations between metering conditions, the runway throughput is similar for both runways, regardless of the metering advisory condition, because the runways consistently had departures during this peak period in traffic demand. The small deviations are mainly due to the arrivals crossing the active departure runway or using the diagonal runway 13R for landing.

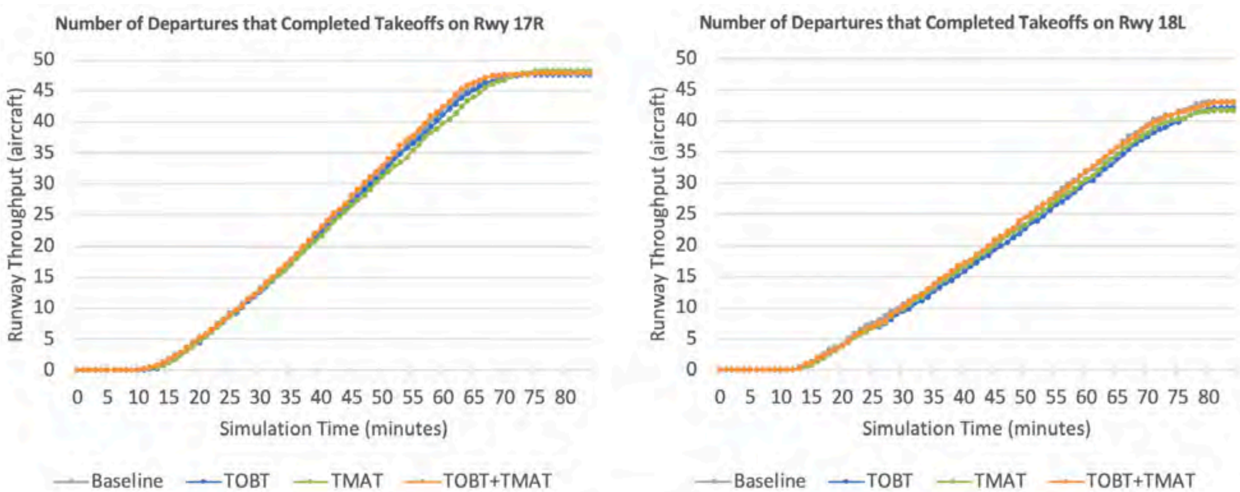


Fig. 8 The average number of aircraft in each condition that completed takeoffs on Runways 17R (left) and 18L (right) over the simulation time.

E. TOBT/TMAT Compliance

The main research questions of this HITL simulation were about the compliance with pushback advisories (TOBTs) being within ±2 minutes and/or spot arrival time advisories (TMATs) being within ±5 minutes in the three different metering conditions. Fig. 9 shows the compliance with the TOBTs generated by the tactical surface scheduler for the departures in Terminals A, C, and E. In the TOBT only and TOBT+TMAT conditions, ramp controllers' compliance with the advised TOBTs (within ± 2 min, marked as black vertical dash lines in the graph) was similar at 60% and 61%, respectively. Ramp controllers had the worst TOBT compliance (47%) in the TMAT only condition because the TOBT advisories from the scheduler were not displayed on the RTC in this condition and they had to use their best estimation based on the expected pushback and ramp taxi times to meet the given TMATs.

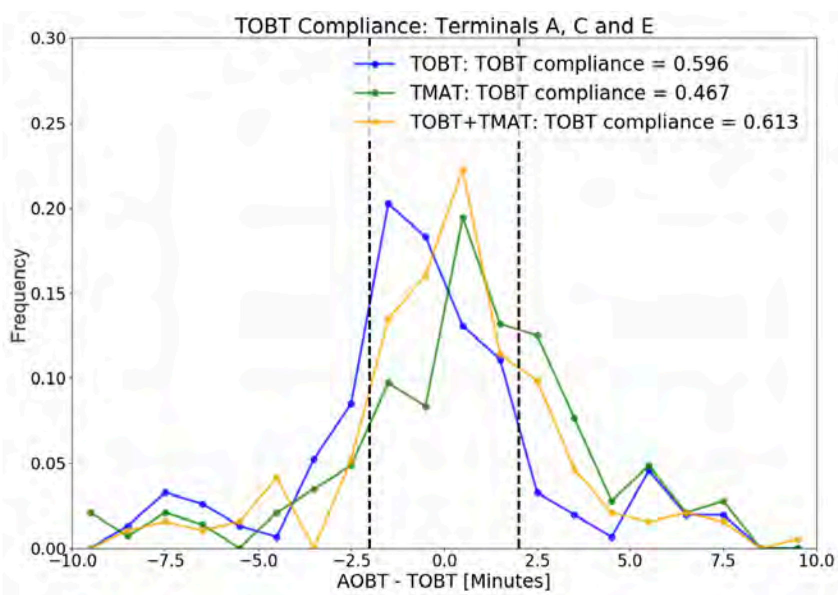


Fig. 9 TOBT compliance for departures from Terminals A, C, and E.

Fig. 10 shows the TMAT compliance for the departures in Terminals A, C, and E in different metering advisory conditions. In the TOBT only, TMAT only, and TOBT+TMAT conditions, ramp controllers' compliance with the advised TMATs were similar to each other at 89%, 87%, and 91%, respectively. The TMAT compliance tended to be on the later side of the ± 5-minute compliance window in the TMAT only condition (light green line), which means that actual spot crossing times were relatively later than the target times provided by the tactical scheduler. On the other hand, as shown in Fig. 9, ramp controllers tended to release aircraft at the gate earlier in the TOBT only and TOBT+TMAT conditions, compared to the TMAT only condition. Aircraft that were initially compliant with the given TOBTs at the gates had higher TMAT compliances at the spot, with 99%, 100%, and 99% TMAT compliance for the TOBT only, TMAT only, and TOBT+TMAT conditions, respectively. This result encourages ramp controllers to comply with the pushback advisories at gates as much as possible for better controllability and predictability in the ramp area.

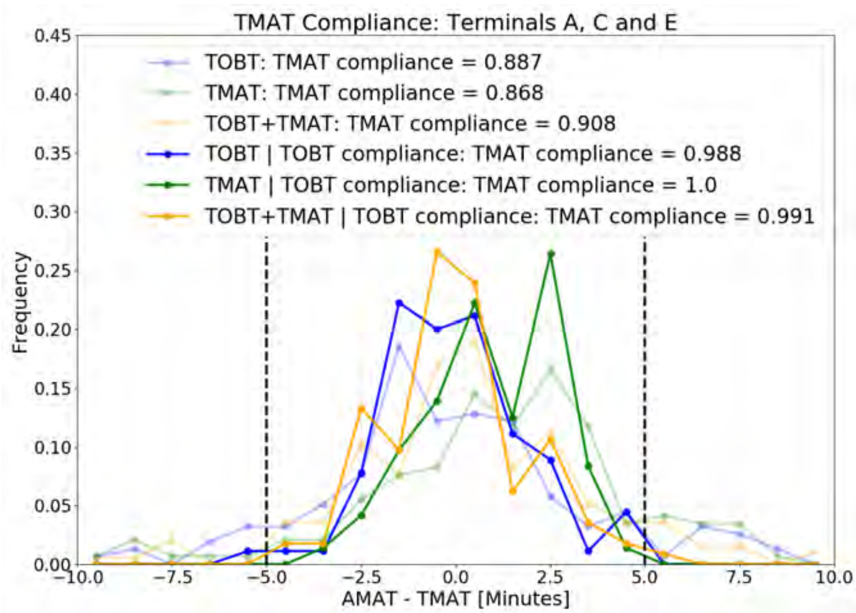


Fig. 10 TMAT compliance for departures from Terminals A, C, and E.

IV. Discussion

It was expected that metering conditions would show better airport performance in terms of objective metrics such as taxi time and departure queue length than the Baseline condition, which had neither pushback nor spot arrival advisories. However, the simulation results showed that there were no noticeable benefits from metering advisories in the performance metrics such as taxi times, runway throughput, and departure queue size. Several simulation artifacts, which made the HITL simulation environment different from real operations at DFW, are likely to have contributed to this lack of effect.

First, as reported in the debrief meeting after the simulation, ramp controller participants reported that the simulated pushback times were too long. At most airports, departing aircraft are pushed back by a tug and then engines are started for spooling up after completing pushback. The HITL simulation also followed these pushback procedures. However, the DFW airport allows departing aircraft to start their engines early, even while pushing back from gates, so as to save the pushback process time. Based on feedback from active ramp controllers after the shakedown simulation, the engine spool-up times were reduced by 1-2 minutes, but this issue remained during the data collection simulation. This lengthy spool-up time could have caused ramp controllers to hold more departures at the gates for a longer time in the TMAT only condition because they expected departing aircraft would be able to reach the assigned spots sooner based on their mental model and experience at DFW. Future simulations of DFW operations will consider further reducing or adjusting for the engine spool-up practices by collecting truth data at the field.

Second, the simulation and surface scheduler couldn't realize the controller's tactics to achieve smooth surface traffic operations. For example, departures at DFW, especially at the gates located in the alley between terminals, have multiple choices for the direction of the pushback, with different distances from the gate to the designated area for taxi start, to prevent departures from blocking other traffic. In the simulation environment, however, ramp controllers had limited options in pushback direction, taxi routes, and taxi speed in the ramp area. As a result, ramp controllers were not able to push back aircraft as they would like to even in the Baseline condition, and ended up holding aircraft at the gate, effectively metering departures. In addition, the tactical surface scheduler computed the TOBTs and TMATs based on the limited information available when the flights were at the gates. For instance, the scheduler assumed that aircraft followed the taxi routes defined by the assigned spot and runway. Whenever needed, however, ramp controllers changed the spot assignments. During the simulation, it was found that the spot changes for the departures from Terminals A, C, and E occurred 4.7, 6.0, 6.1, and 4.9 times on average in the Baseline, TOBT only, TMAT only, and TOBT+TMAT conditions, respectively. Furthermore, the scheduler did not take into account the arrivals crossing the active departure runway or landing on the converging arrival runway in the west of the airport, resulting in additional differences in takeoff time prediction.

Third, the HITL simulation focused on the east side of the airport only, whereas DFW has two Airport Traffic Control Towers for both east and west sides. The surface scheduler calculated the TOBTs and TMATs for all the departures from Terminals A through E, and the confederate ATCT and ramp controllers who were dedicated to the west side of the airport communicated with pseudo pilots and followed the pushback and spot arrival advisories provided by the scheduler. However, the existence of an independent ATCT put additional uncertainties in surface operations. For instance, the departures that originated from Terminals B and D, crossed a long taxiway bridge, and entered the departure queue for Runway 17R might affect the sequencing and waiting time for takeoffs over this runway. This unique operational environment at DFW might lead to the suboptimal results of the surface metering in terms of the airport performance.

Lastly, during the HITL simulation, the traffic scenarios were simulated in a controlled environment and repeated several times with limited variations. On the other hand, real world operations have unexpected events with lots of uncertain factors, such as late passenger boarding, aircraft malfunction, delay in communication and pilot reaction, and ground vehicles and obstacles in the ramp area. Due to this difference, controllers reported that the simulation scenarios were easy, even though the traffic scenarios used in the simulation were from the busiest days with additional traffic. Their impression is captured by survey results that controllers rated relatively low workload in most conditions [15].

The differences and limitations listed so far made it challenging to realize sufficiently realistic ramp operations at DFW in the HITL simulation environment. Nevertheless, the HITL results still contributed to understanding better metering options for ramp controllers and the impacts on controller workload, which is supported by positive feedback from participants with respect to the simulation environment. With the lessons learned from this HITL, the fidelity of simulations will continue to improve through the increased ability to access operational data from the field.

V. Conclusions

Under the Airspace Technology Demonstration 2 (ATD-2) subproject, NASA conducted a human-in-the-loop (HITL) simulation of Dallas/Fort Worth International Airport (DFW) to assess the ramp controller's ability to deliver aircraft to the spot within the compliance window (± 5 minutes) around the Target Movement Area Entry Time (TMAT) under various metering conditions. The compliance at the spot was similar between the different metering conditions, ranging between 87% and 91%, and increased to 99 ~ 100% for aircraft that were initially compliant with pushback advisories at the gates. The metering benefits that exist in the field, such as taxi time reduction and lower departure queue size, were not apparent from the HITL simulation results, attributable to simulation artifacts. Surface metering at DFW with Target Off-Block Time (TOBT) only or Target Movement Area entry Time (TMAT) only could be equally effective in terms of objective metrics, and either would be a better option than the TOBT+TMAT condition, because this combined condition tends to increase controller workload and reduce situation awareness [15], without any measured benefits to airport performance.

References

[1] Aponso, B., Coppenbarger, R., Jung, Y., O'Connor, N., Lohr, G., Quon, L., and Engelland, S., "Identifying Key Issues and Potential Solutions for Integrated Arrival, Departure, Surface Operations by Surveying Stakeholder Preferences," AIAA 2015-2590, the 15th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, Dallas, TX, June 22-26, 2015.

[2] Jung, Y., Engelland, S., Capps, A., Coppenbarger, R., Hooey, B., Sharma, S., Stevens, L., Verma, S., Lohr, G., Chevalley, E., Dulchinos, V., Malik, W., and Morgan Ruszkowski, L., "Airspace Technology Demonstration 2 (ATD-2) Phase 1 Concept of Use (ConUse)," NASA/TM-2018-219770, February 28, 2018.

[3] Ging, A., Engelland, S., Capps, A., Eshow, M., Jung, Y., Sharma, S., Talebi, E., Downs, M., Freedman, C., Ngo, T., Sielski, H., Wang, E., Burke, J., Gorman, S., Phipps, B., and Morgan Ruszkowski, L., "Airspace Technology Demonstration 2 (ATD-2) Technology Description Document (TDD)," NASA/TM-2018-219767, March 31, 2018.

[4] Thipphavong, J., Jung, J., Swenson, H. N., Witzberger, K. E., Lin, M. I., Nguyen, J., Martin, L., Downs, M. B., and Smith, T. A., "Evaluation of the Controller-Managed Spacing Tools, Flight-Deck Interval Management, and Terminal Area Metering Capabilities for the ATM Technology Demonstration #1," 10th USA/Europe Air Traffic Management Research and Development Seminar, Chicago, IL, June 10-13, 2013.

[5] Engelland, S. A., Capps, R., Day, K. B., Kistler, M. S., Gaither, F., and Juro, G., "Precision Departure Release Capability (PDRC) Final Report," NASA/TM-2013-216533, June 2013.

[6] Jung, Y., Malik, W., Tobias, L., Gupta, G., Hoang, T., and Hayashi, M., "Performance Evaluation of SARDA: an Individual Aircraft-Based Advisory Concept for Surface Management," Air Traffic Control Quarterly, Vol. 22, No. 3, 2015, pp. 195–221.

[7] Hayashi, M., Hoang, T., Jung, Y., Malik, W., Lee, H., and Dulchinos, V. L., "Evaluation of Pushback Decision-Support Tool Concept for Charlotte Douglas International Airport Ramp Operations," 11th USA/Europe Air Traffic Management Research and Development Seminar, Lisbon, Portugal, June 23-26, 2015.

[8] Jung, Y., Coupe, W., Capps, A., Engelland, S., and Sharma, S., "Field Evaluation of the Baseline Integrated Arrival, Departure, Surface Capabilities at Charlotte Douglas International Airport," 13th USA/Europe Air Traffic Management Research and Development Seminar, Vienna, Austria, June 17-21, 2019.

[9] NASA, "Airspace Technology Demonstration 2 (ATD-2) Fact Sheet," NASA/FS-2019-04-03-ARC, April 2019. https://aviationsystemsdivision.arc.nasa.gov/research/atd2/ATD2_FS-2019-04-03-ARC_Final.pdf

[10] Verma, S., Lee, H., Martin, L., Stevens, L., Jung, Y., Dulchinos, V., Chevalley, E., Jobe, K., and Parke, B., "Evaluation of a Tactical Surface Metering Tool for Charlotte Douglas International Airport via Human-in-the-Loop Simulation," 36th Digital Avionics Systems Conference (DASC), St. Petersburg, FL, September 17-21, 2017.

[11] Stevens, L., "Assessment of Ramp Times 2 (ART-2) Human-in-the-Loop (HITL) Simulation – Final Results, March 2019. https://aviationsystemsdivision.arc.nasa.gov/publications/atd2/tech-transfers/4_Evaluation_Results/4.09%20ATD2_ART2_HITL_Results_2019-03-06.pdf

[12] Jung, Y., Hoang, T., Montoya, J., Gupta, G., Malik, W., Tobias, L., and Wang, H., "Performance Evaluation of a Surface Traffic Management Tool for Dallas/Fort Worth International Airport," 9th USA/Europe Air Traffic Management Research and Development Seminar, Berlin, Germany, June 2011.

[13] Gupta, G., Malik, W., Tobias, L., Jung, Y., Hoang, T., and Hayashi, M., "Performance Evaluation of Individual Aircraft Based Advisory Concept for Surface Management," 10th USA/Europe Air Traffic Management Research and Development Seminar, Chicago, IL, June 2013.

[14] Hayashi, M., Hoang, T., Jung, Y. C., Gupta, G., Malik, W., and Dulchinos, V. L., "Usability Evaluation of the Spot and Runway Departure Advisor (SARDA) Concept in a Dallas/Fort Worth Airport Tower Simulation," 10th USA/Europe Air Traffic Management Research and Development Seminar, Chicago, IL, June 2013.

[15] Parke, B. K., Bakowski, D. L., Jung, Y. C., Lee, H., Coupe, W. J., and Stevens, L. K. S., "Human Factors Impact of Different Ramp Controller Scheduling Advisories for ATD-2 Surface Metering in a Human-in-the-Loop Simulation," 2020 AIAA Aviation Forum, June 15-19, 2020.

[16] Airports Council International, "Aircraft Movement 2017 FINAL (Annual)," January 2019. https://aci.aero/data-centre/annual-traffic-data/aircraft-movements/2017-aircraft-movements-annual-traffic-data/

[17] Federal Aviation Administration (FAA), "Airport Capacity Profiles Report – Dallas/Fort Worth International Airport," 2018 (revised). https://www.faa.gov/airports/planning_capacity/profiles/

[18] Engelland, S. A., and Ruszkowski, L. M., "Analysis of DFW Perimeter Taxiway Operations," AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, Fort Worth, TX, September 13-15, 2010.

[19] Dorighi, N. S., and Sullivan B. T., "Future Flight Central: a Revolutionary Air Traffic Control Tower Simulation Facility," AIAA 2003-5598, AIAA Modeling and Simulation Technologies Conference and Exhibit, Austin, TX, August 11-14, 2003.