Airspace Technology Demonstration 2 (ATD-2)

Simulation and Modeling Used in Surface Analysis

September 5, 2019

Outline

- Fast-Time Simulation Overview

- Case Study 1
  - *“Impact of Earliest Off-Block Time (EOBT) Quality”*
  - Presented by **Hanbong Lee** (NASA ATD-2)

- Case Study 2
  - *“ATD-2 Benefits Assessment”*
  - Presented by **Aditya Saraf** (ATAC)

Fast-Time Simulation in ATM

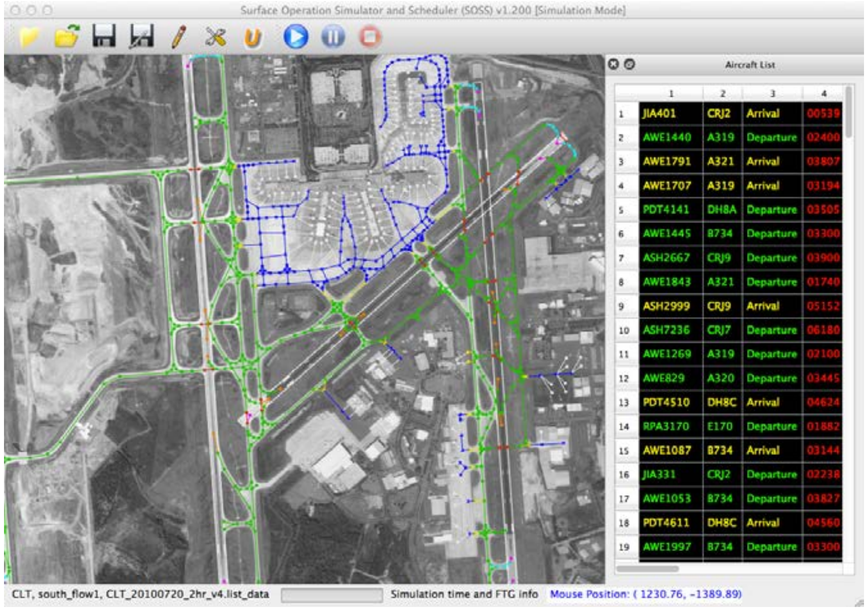
- Fast-time simulation for air traffic management (ATM) studies
  - An efficient, flexible, and cost-effective method to evaluate current/future concepts of operations in air traffic management
  - Can provide insights for a particular research question and visualize air traffic movements
  - Need to validate models and parameters used in simulation

- Simulation tool examples
  - SIMMOD (Airport and Airspace Simulation Model)
  - TAAM (Total Airport and Airspace Modeller)
  - AirTOp (ATC Fast Time Simulator and Air Traffic Optimizer)
  - SOSS (Surface Operations Simulator and Scheduler)

ATD2 Integrated Arrival/Departure/Surface

SOSS

- Surface Operations Simulator and Scheduler (SOSS)
  - A simulation tool for air traffic movements on airport surface, developed by NASA
  - Used to develop, analyze, and test concepts for airport surface traffic management, as well as runway scheduling algorithms
  - https://software.nasa.gov/software/ARC-16808-1A



SOSS simulation for Charlotte International Airport (CLT)

Potential Applications of SOSS

- Assessment of benefits of ATD-2 concept
- Impact of estimated flight ready time (EOBT) uncertainty on surface metering
- Impact of General Aviation (GA) flights on airport performance
- Surface traffic movements in de-icing operations
- Effects of various uncertainties in surface operations
  : Flight ready time, pushback process times, aircraft taxi speeds, runway separations and crossings, etc.

Evaluating the Impact of Estimated Flight Ready Time Uncertainty on Surface Metering

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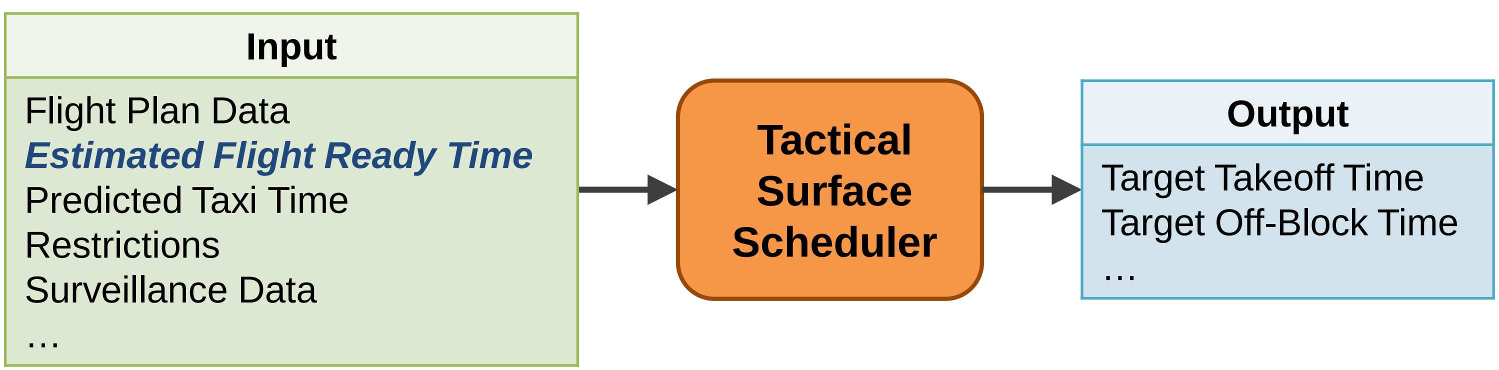
Zhifan Zhu, and **Vaishali Hosagrahara**
(KBRWylie/SGT)

Surface Metering

- Surface metering for efficient airport operations
  - Reduce excess taxi-out time by shifting wait time in departure queue to gates while engines are off
  - Enabled by a tactical surface scheduler (e.g., ATD-2)

- Tactical surface scheduler
  - Calculate Target Takeoff Times (TTOT) of departures, considering unimpeded takeoff times and constraints
  - Provide pushback advisories to controllers



Earliest Off-Block Time (EOBT)

- Earliest Off-Block Time (EOBT)
  - Estimated flight ready time of departures
  - Provided by airlines based on flight readiness status
  - Used as input for a tactical surface scheduler

- EOBT accuracy
  - One of key factors determining scheduler performance
  - Affected by uncertainties in actual flight operations
  - It is difficult to see direct impacts of the EOBT accuracy on scheduling in real operations

  → Use ***fast-time simulation***!

Research Objectives

- To develop an EOBT model representing actual EOBT data characteristics

- To integrate a fast-time simulation model with the EOBT model and ATD-2 tactical surface scheduler

- To evaluate the impact of EOBT accuracy on airport performance and benefits of surface metering

EOBT Quality Model Development

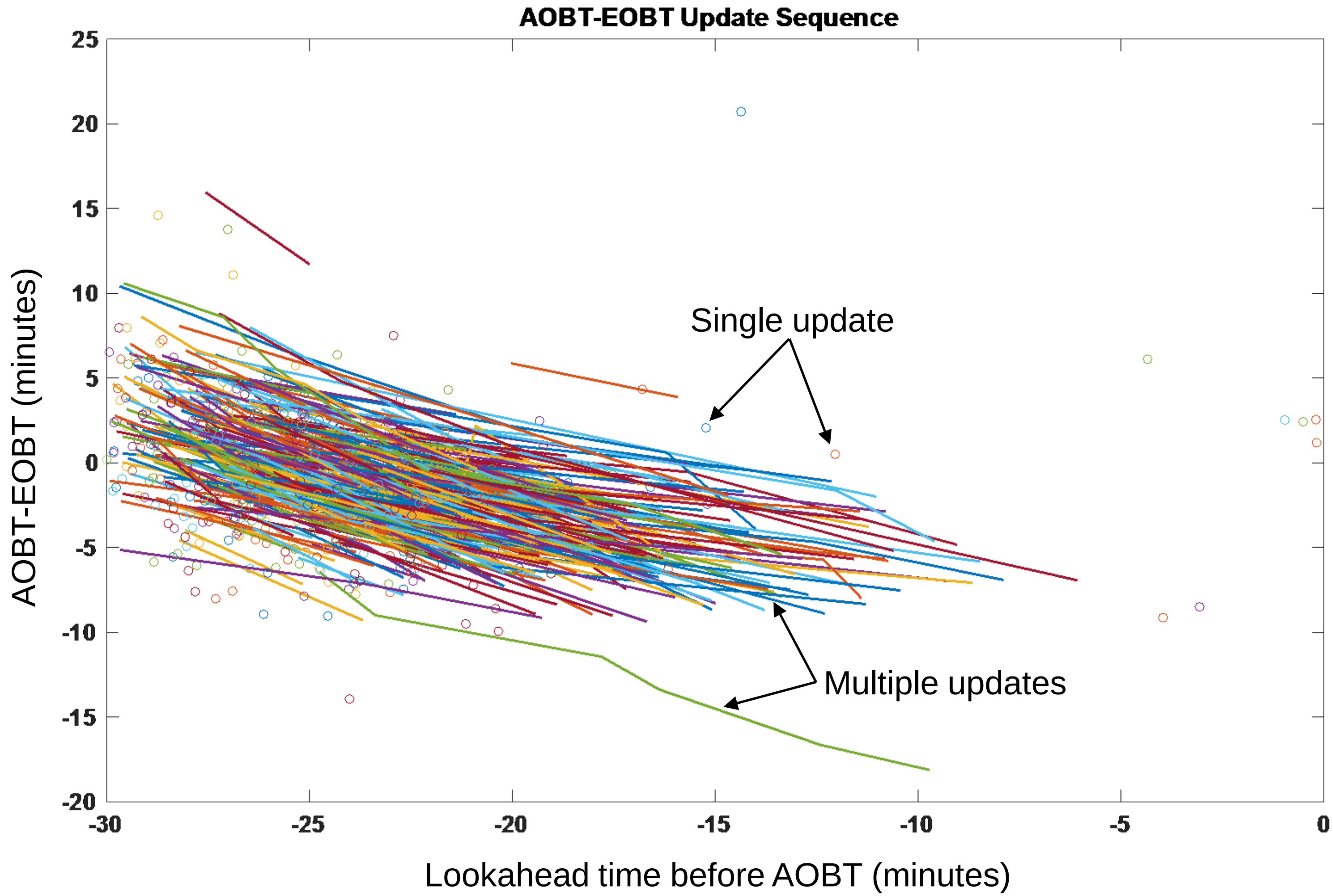
EOBT Data

- Data source
  - EOBT data from one-week flight data at Charlotte Douglas International Airport (CLT) in February 12-18, 2018
  - Sample size after data filtering
    - Total flights: 2,280
    - EOBT updates: 3,761

- Variables
  - EOBT update times
  - Number of EOBT updates
  - EOBT accuracy = AOBT – EOBT
    - AOBT: Actual Off-Block Time (actual pushback time)
    - EOBT: Earliest Off-Block Time (estimated flight ready time)

EOBT Accuracy with Update Sequence

- Key elements: EOBT update time, update frequency, and accuracy
- EOBT becomes conservative as it approaches AOBT



EOBT Model Development

- Two-step approach
  1. Model EOBT update times
     - Define the number of EOBT updates per flight
     - Determine the lookahead time when EOBT is updated
  2. Model EOBT accuracy at the update times
     - Assume a normal distribution with zero mean at each time bin within 30 minutes before AOBT
     - Estimate a sigma value for all lookahead times

- Linear regression model for EOBT accuracy

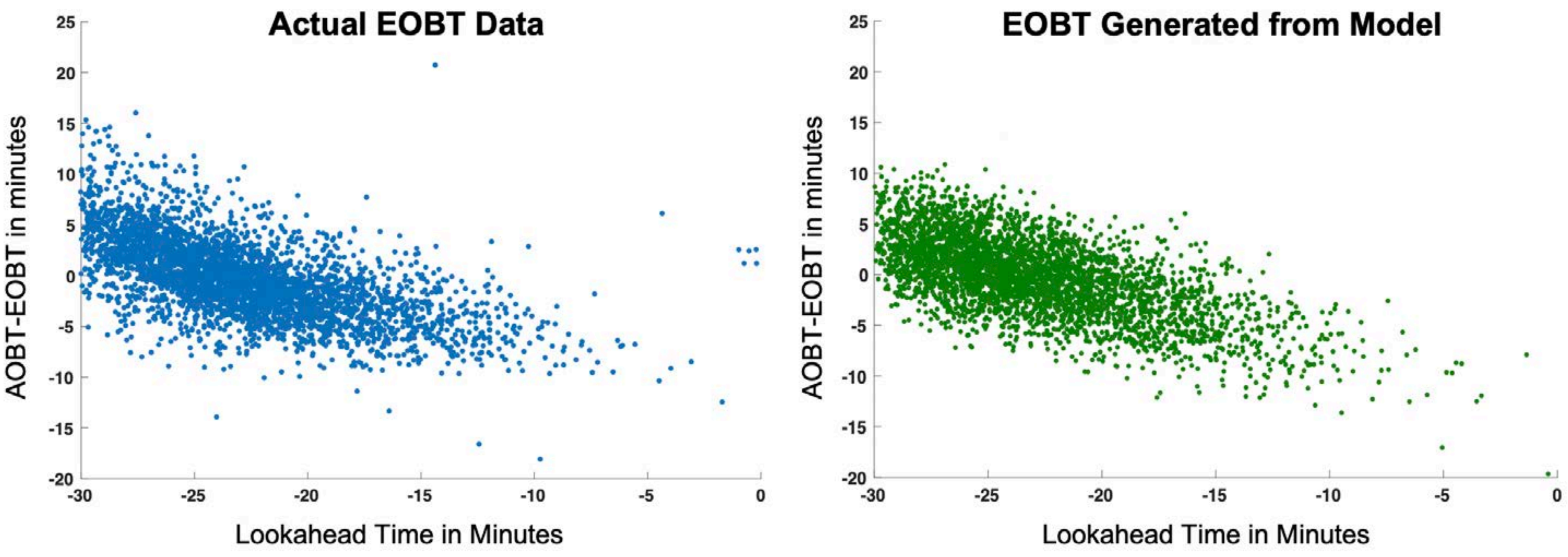
  $$Y = c_0 + c_1 * X_k + Normal(0, \sigma)$$

  - Y : EOBT accuracy
  - X_k : EOBT update time, $k = 1, 2, \ldots, n$
  - n : number of EOBT updates

EOBT Model Validation

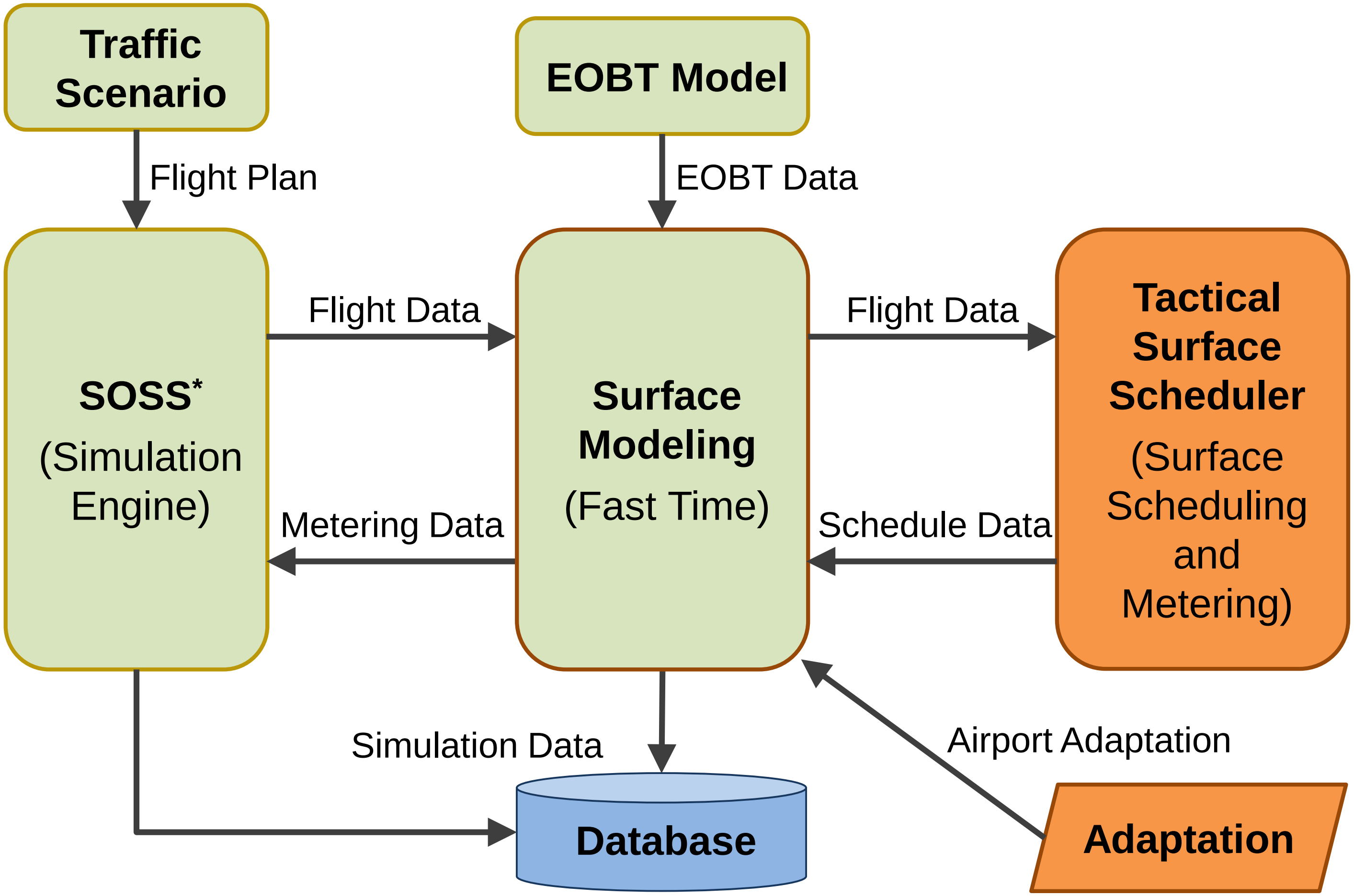
Linear regression model: $Y = c_0 + c_1 * X_k + Normal(0, \sigma)$

- EOBT update frequency: 1.65 per flight in 30 minutes
- Sigma value for EOBT accuracy model: 3.02 minutes
- Coefficients fitted to actual data: c_0 = -12.67, c_1 = -0.54



Fast-Time Simulation Platform

Fast-Time Simulation Platform

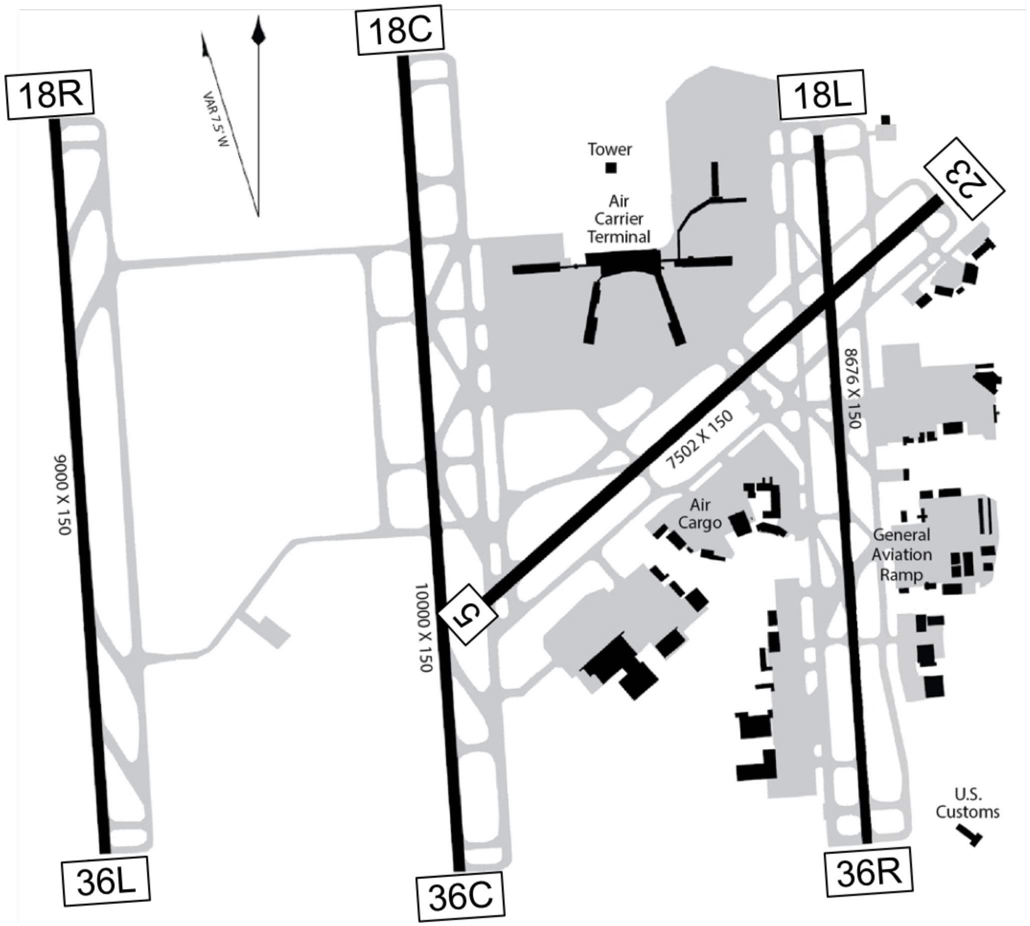


* SOSS: Surface Operations Simulator and Scheduler

Simulation Scenarios

- Four days with heavy traffic at CLT (9-11am)
- South flow configuration
  - Departures: 18C, 18L
  - Arrivals: 18R, 18C, 18L

Date	Dep #	Arr #
1/22/2018	92	95
1/23/2018	91	84
2/12/2018	98	95
2/14/2018	91	78



Simulation Model Validation

- Assumptions for validation
  - Departure Flight Ready Time = Actual Off-Block Time
  - Surface metering: OFF
- Operational parameters for tuning
  - Adjusted taxi speeds and pushback times
  - Adjusted runway separation times
- Validation
  - Compared simulation output with actual operations data in terms of various performance metrics
  - Showed a good match with each other

EOBT Accuracy Impact Evaluation Using Fast-Time Simulation

Simulation Setup and Performance Metrics

- Simulation setup

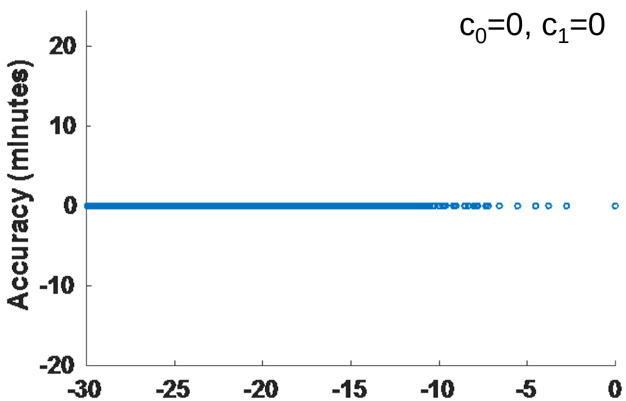
4 Scenarios		4 EOBT model configurations		20 runs		320 runs in total
South flow at CLT, Heavy traffic at 9-11am, Fixed target excess taxi time parameter	×	Different EOBT accuracy levels, controlled by EOBT model	×	Perturbated flight ready times (normal distribution)	=	for data collection and post analysis

- Performance metrics
  - Gate hold
  - Taxi-out times
  - Takeoff delay
  - Target takeoff time predictability

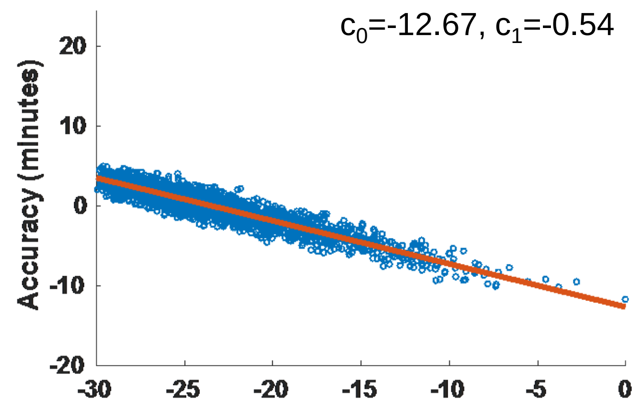
EOBT Model Configurations

Test 4 cases with different EOBT accuracy levels

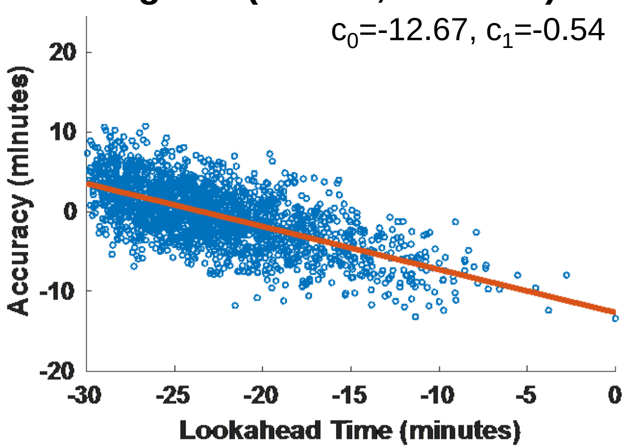
Sigma0 (σ=0, perfect EOBT)



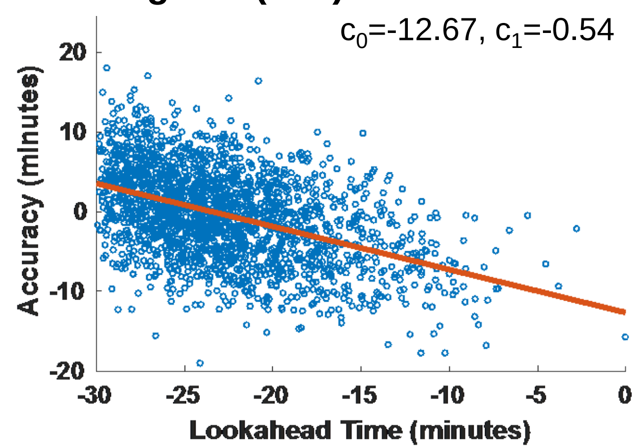
Sigma1 (σ=1)



Sigma3 (σ=3.02, baseline)

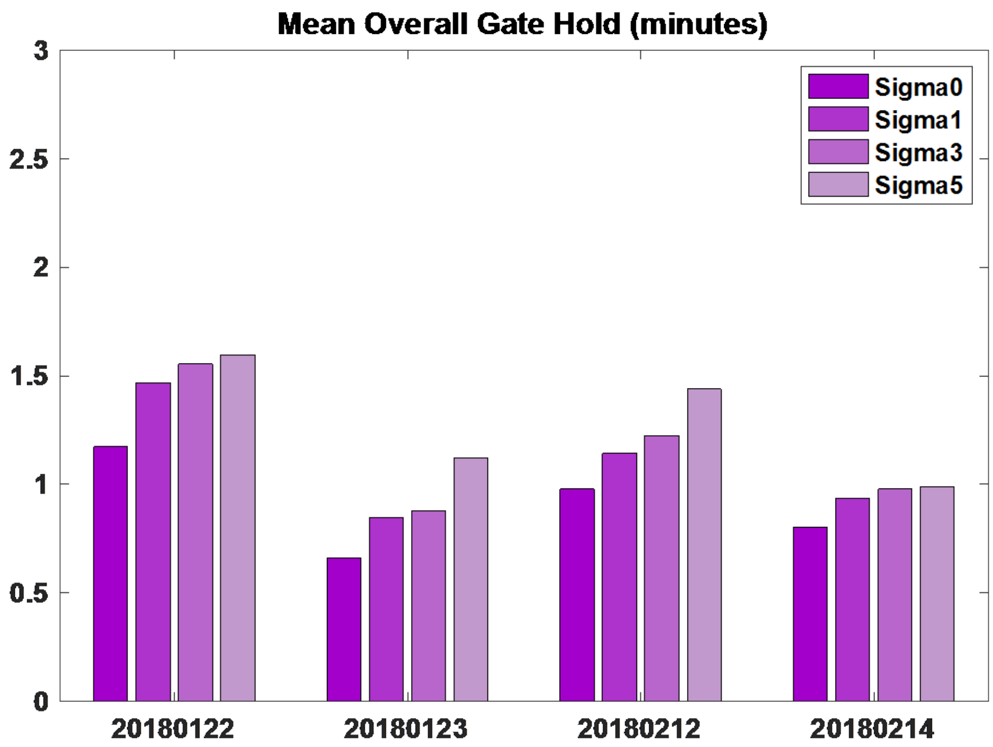


Sigma5 (σ=5)



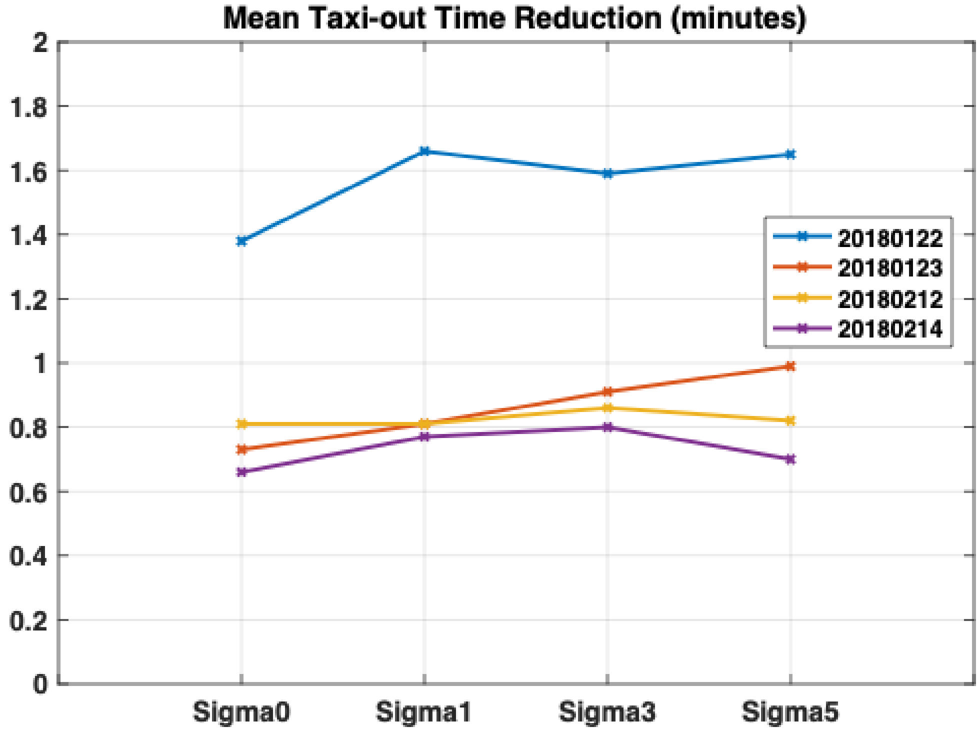
Gate Hold Times

- Numbers of metered flights are almost constant, with the fixed target excess taxi time parameter
- Gate hold = Target Off-Block Time – Flight Ready Time
  - Gate hold in Sigma0 is due to heavy traffic demand
  - Additional gate hold is induced by EOBT uncertainty



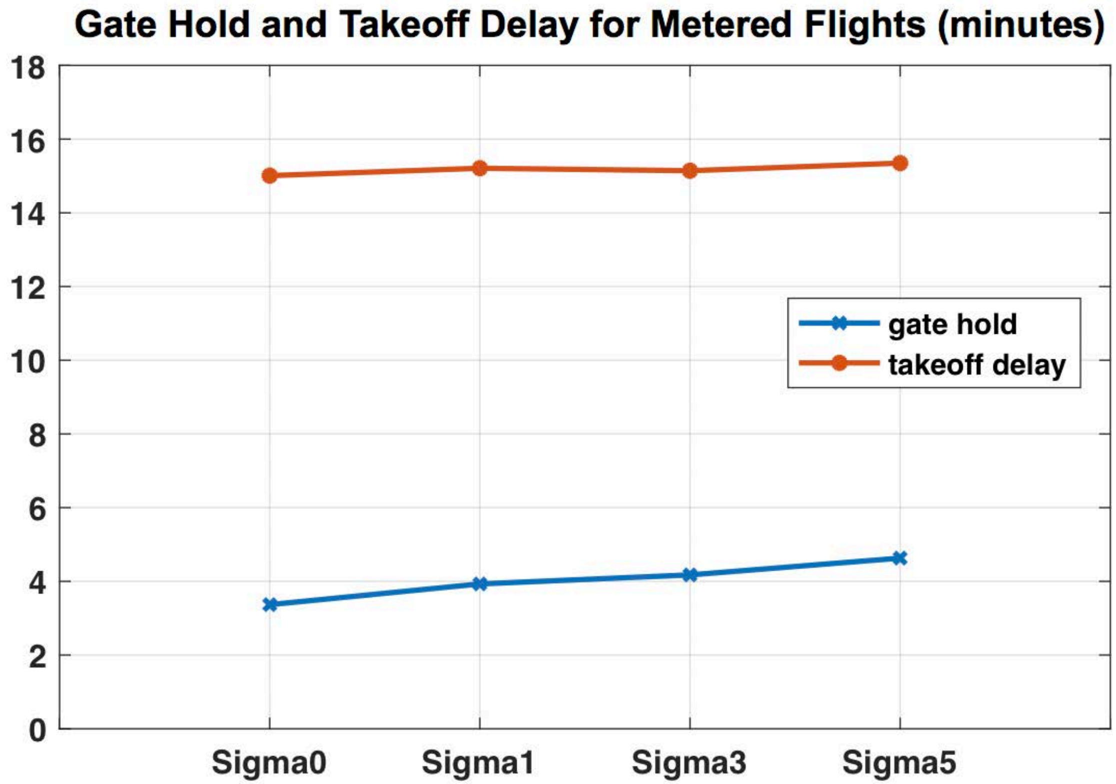
Taxi-Out Time Reduction

- Mean taxi-out time reduction by gate holding, compared to no surface metering
- Surface metering reduces taxi-out times
- Additional gate hold induced by EOBT uncertainty can sometimes help reduce taxi time



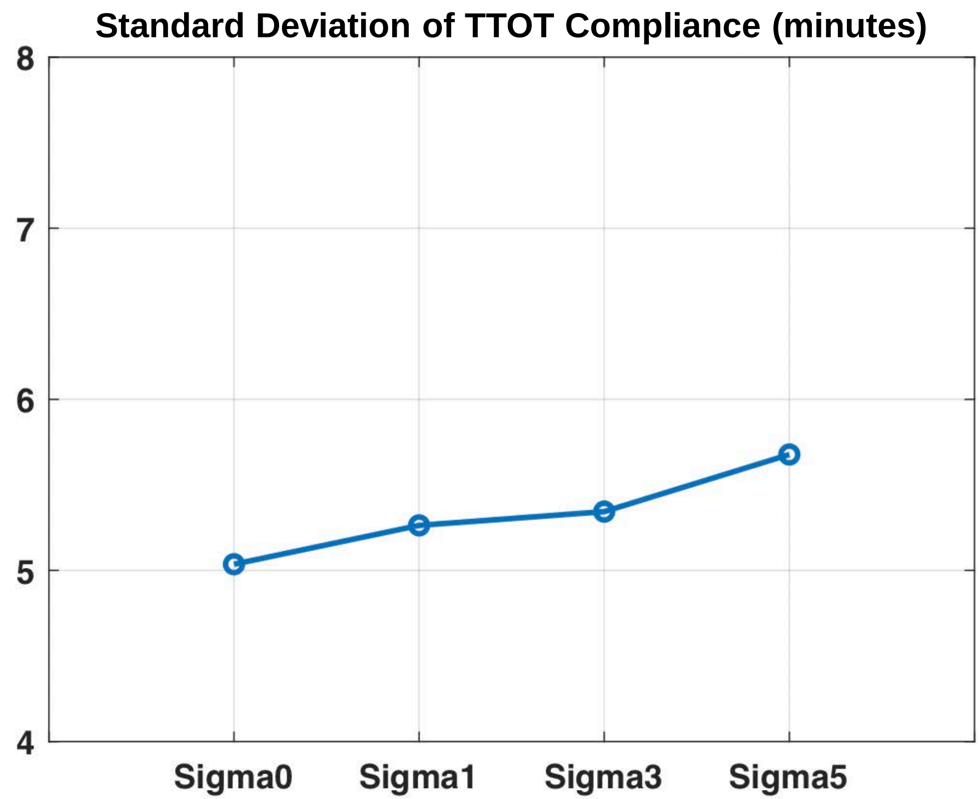
Takeoff Delay for Metered Flights

- Takeoff delay is not affected by EOBT accuracy, but dominated by traffic demand
- No significant correlation between gate hold and takeoff delay due to taxi time reduction



Target Takeoff Time (TTOT) Predictability

- Measured by the standard deviation of TTOT compliance (= difference between actual and target takeoff times)
- Better EOBT quality can help better TTOT predictability, making scheduler predict takeoff times more accurately



Summary

- Developed a linear regression EOBT model
- Integrated the EOBT model with fast-time simulation engine and a tactical surface scheduler
- Evaluated the impacts of EOBT accuracy on surface metering performance through fast-time simulations
- Simulation results showed that EOBT uncertainty might
  – Increase gate hold times,
  – Help reduce taxi-out time sometimes,
  – Make no impact on takeoff delay, and
  – Lower scheduler's takeoff time predictability

Q & A

Thank You!

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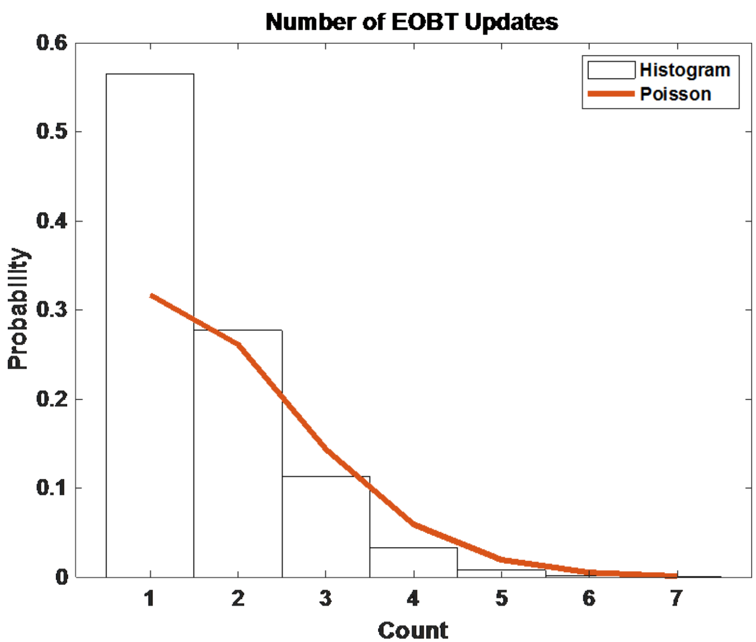
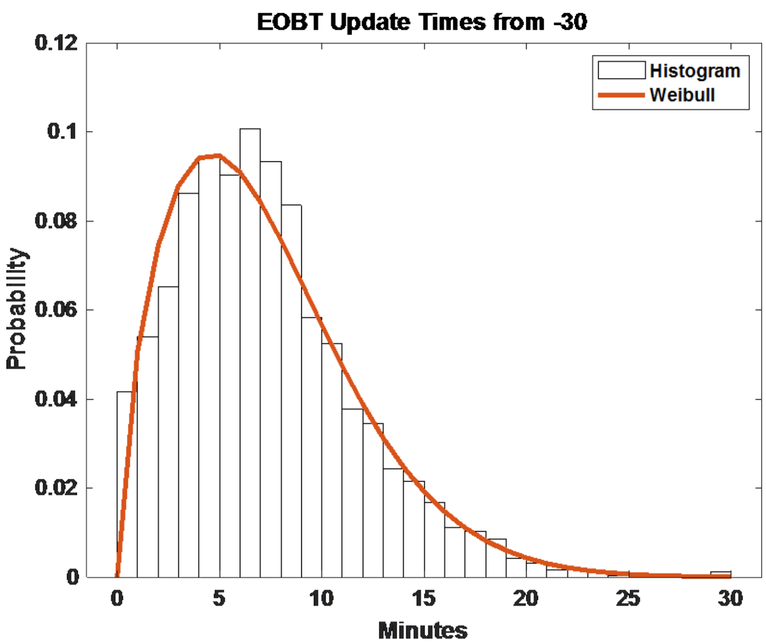
Backup

Step 1: EOBT Update Time Modeling

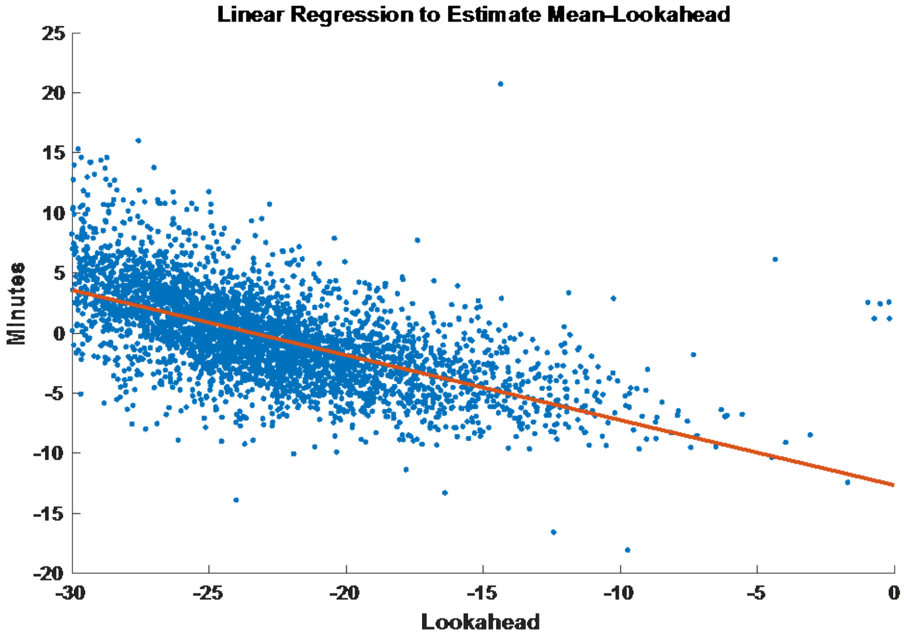
- Fit a probability distribution, *PD1*, as the number of EOBT updates (per flight) → Poisson distribution
- Fit another probability distribution, *PD2*, as the time elapsed from the reference time (-30min before AOBT) to the EOBT update time → Weibull distribution
- For each flight, sample the two distributions to obtain
  - Update time X_k = -30 + *random(PD2)*, *k = 1, 2, ..., random(PD1)*

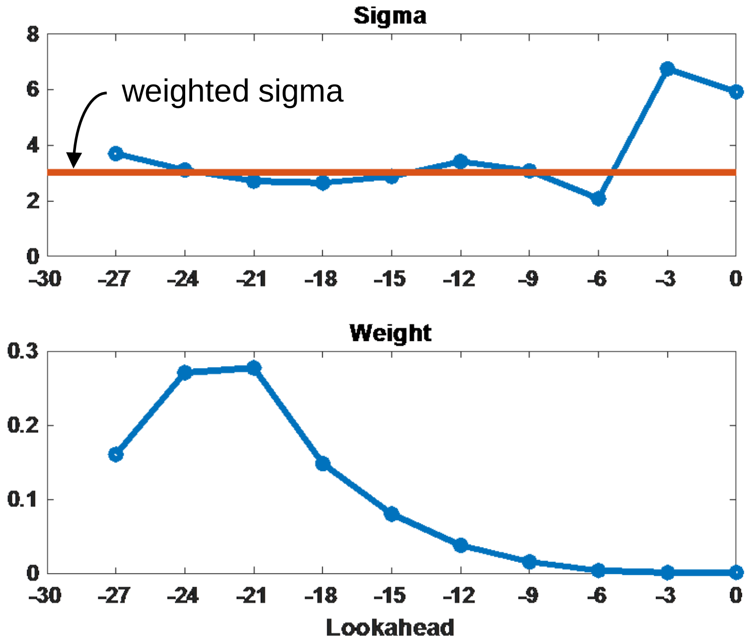




Step 2: EOBT Accuracy Modeling

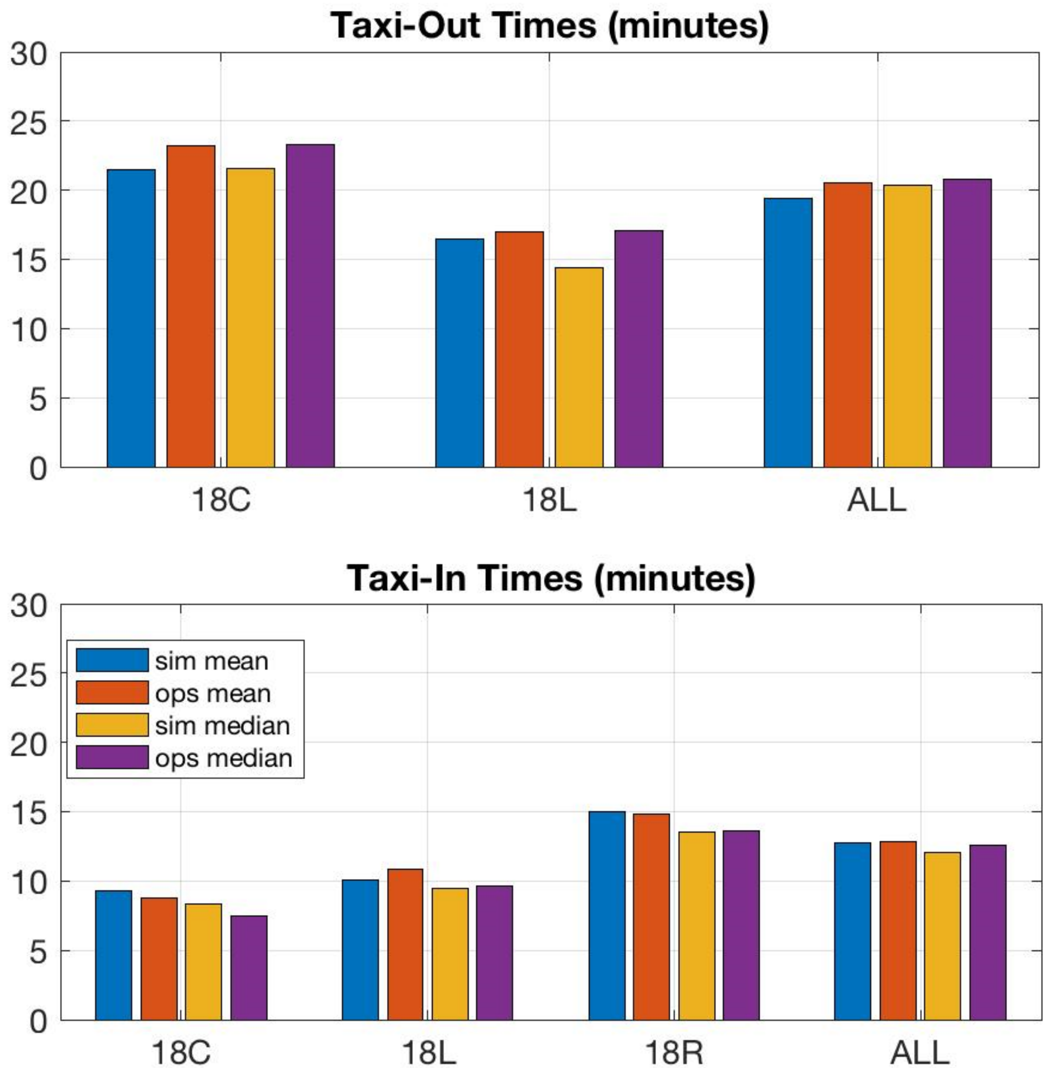
- Fit a sequence of probability distributions in 3-min bins within [-30, 0]
- Calculate the mean weighted by the data sample size in each time bin to obtain an overall weighted sigma (red line)
- Make a probability distribution, *PD3*, with zero mean and weighted sigma value
- Linear regression model for EOBT accuracy along lookahead time
  - EOBT accuracy $Y = c_0 + c_1 * X_k + random(PD3), X_k$: EOBT update time





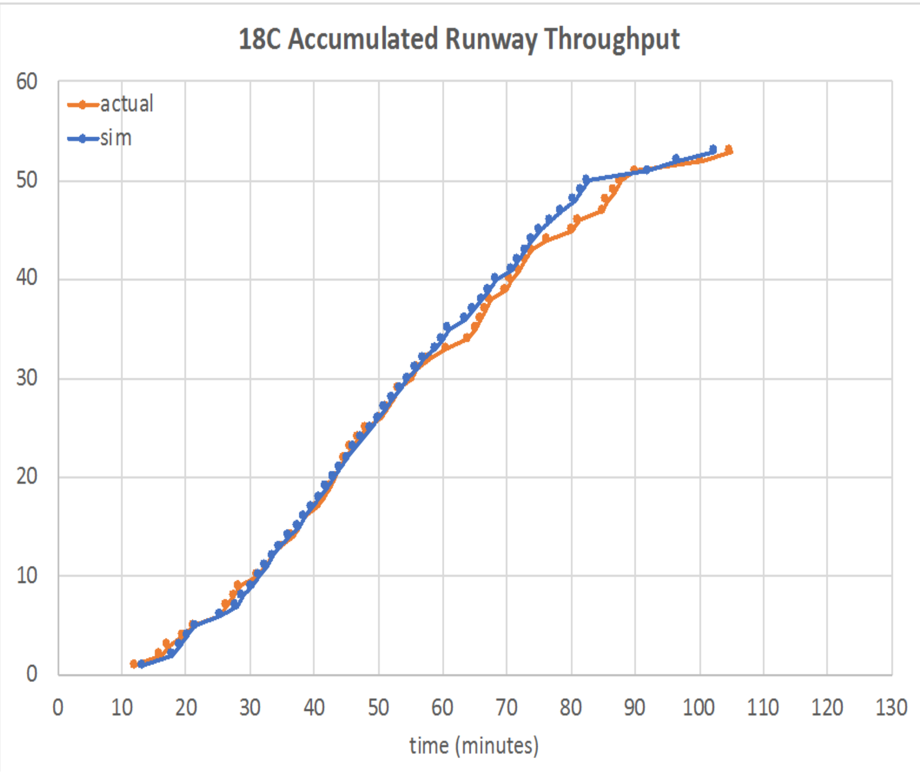
Simulation Model Validation: Taxi-Out/In Time Comparison

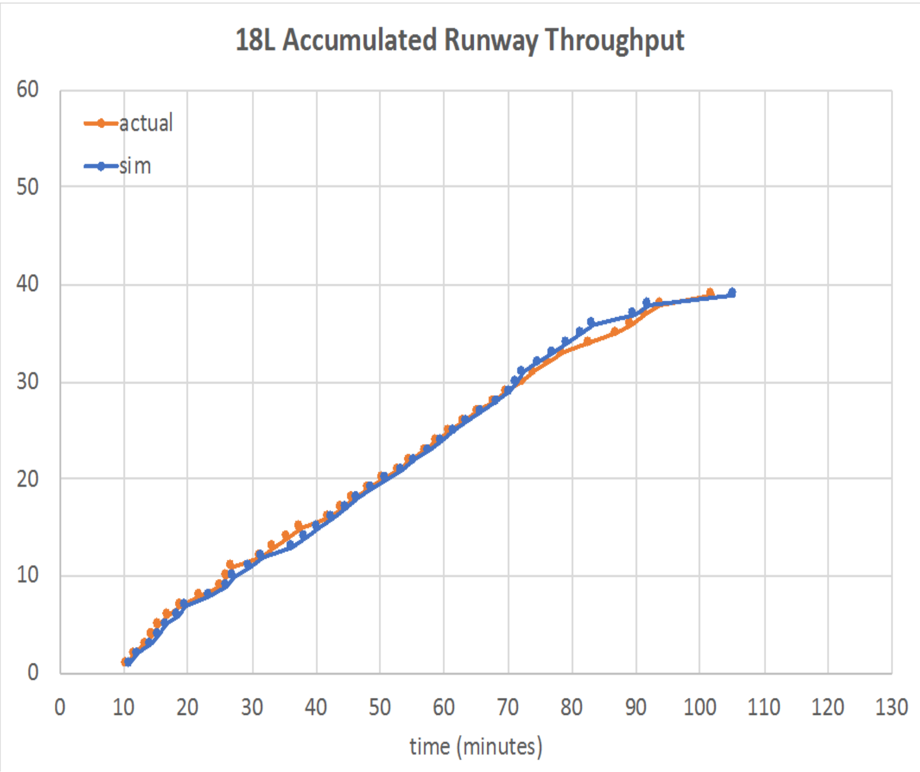
- Example scenario: 20180122



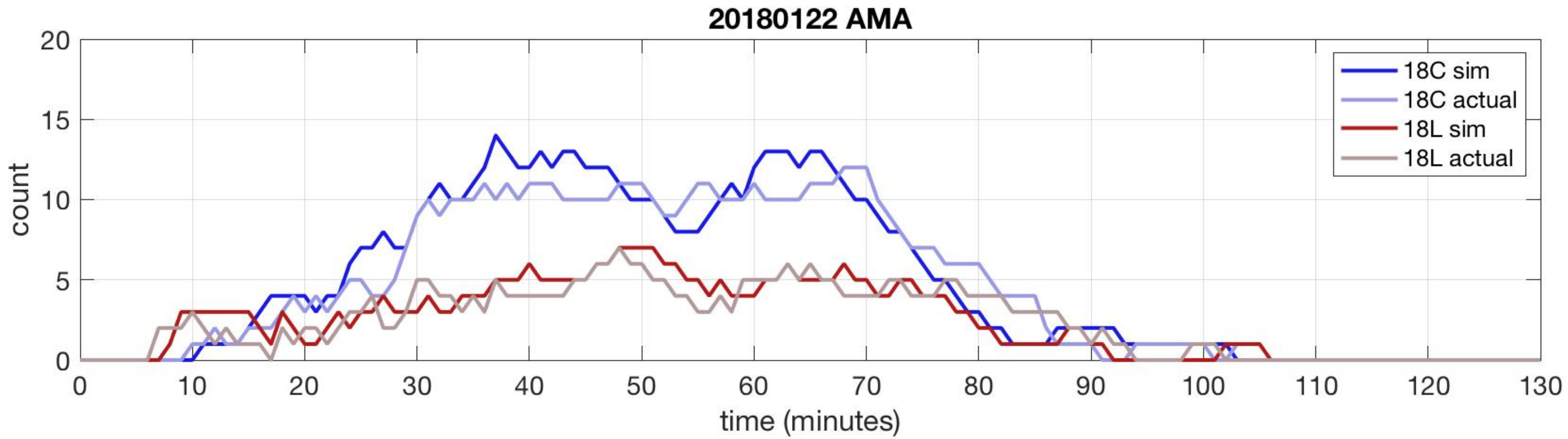
Simulation Model Validation: Departure Runway Throughput Comparison

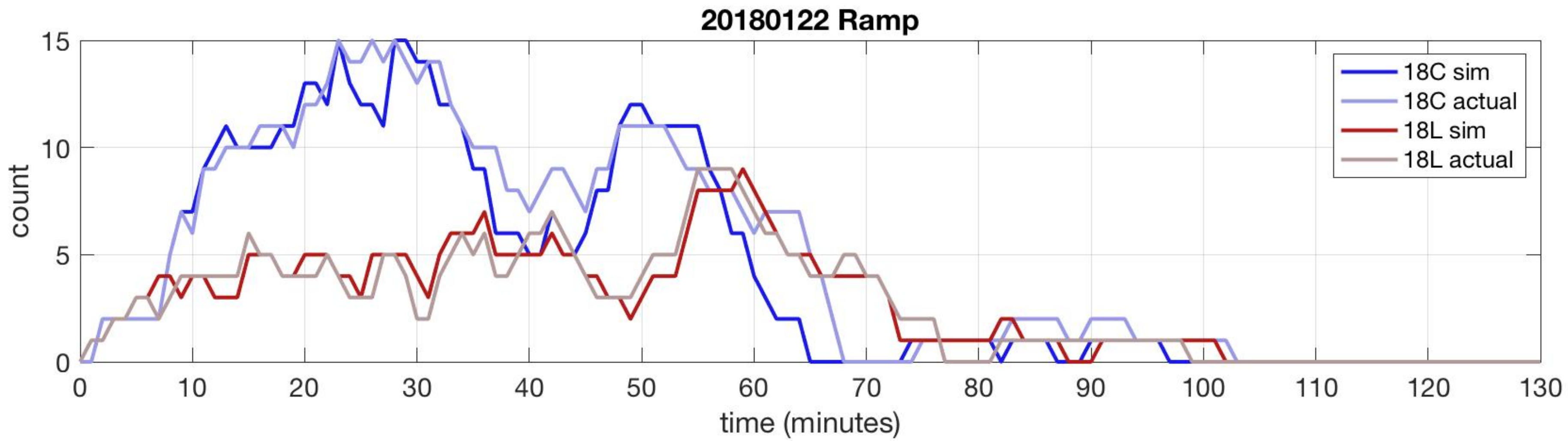
- Example scenario: 20180122





Simulation Model Validation: Departure Surface Count Comparison

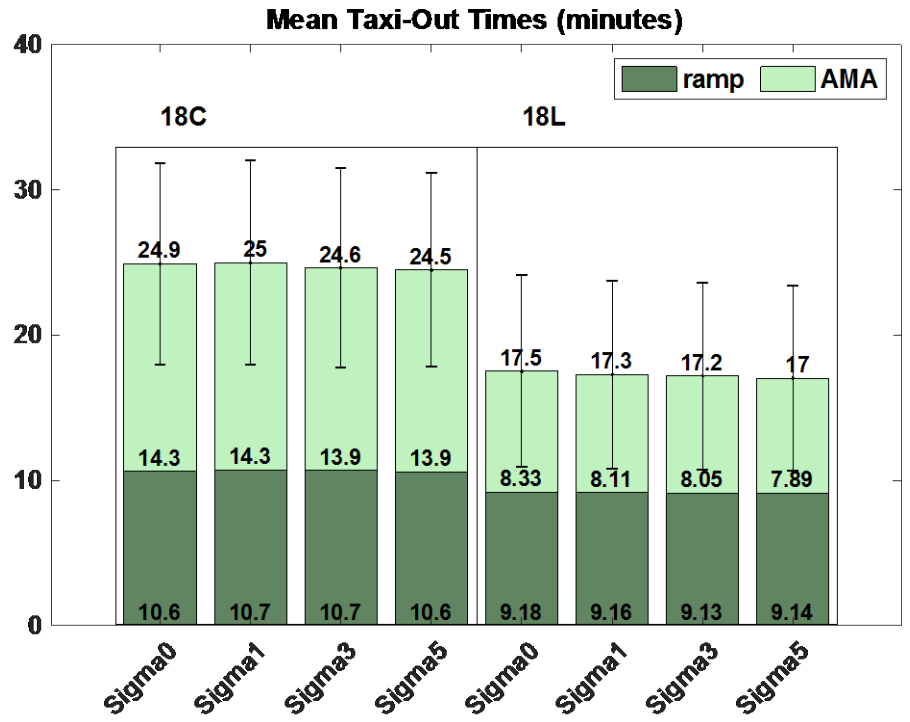




Taxi-Out Times

- Average taxi-out times look constant, regardless of EOBT accuracy
- Departure queue size and AMA taxi time are maintained by the given target excess taxi time parameter

Example Scenario: 20180122



TTOT Compliance and Predictability

- Target takeoff time (TTOT) compliance
  - Actual Takeoff Time – Target Takeoff Time
  - Not affected by EOBT accuracy
- TTOT predictability
  - Measured by the standard deviation of TTOT compliance
  - Better EOBT quality can help better TTOT predictability