# Comparison of Taxi Time Prediction Performance Using Different Taxi Speed Decision Trees

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- Experiment set-up

- Three test runs with different taxi speed values

  - Run 1: Initial decision trees (baseline)

  - Run 2: Various taxi speeds by runway-spot-ramp area

  - Run 3: Constant taxi speed for each runway

- Prediction performance comparison

  - Spot/Off time for departures

  - Off time in unimpeded taxi-out condition

 - Spot/In time for arrivals

- Summary

Unimpeded Taxi Time Calculation in Tactical Surface Scheduler
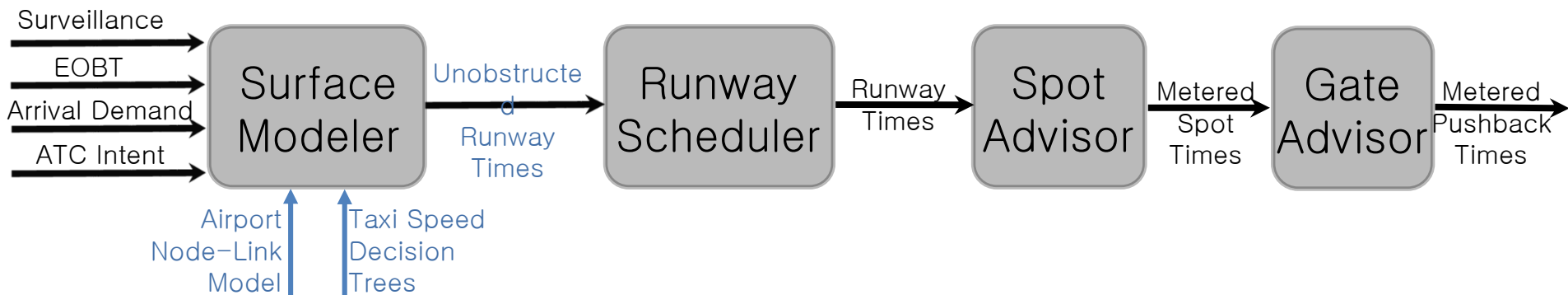
- ## Unimpeded taxi time estimates
  - Provide earliest feasible takeoff times for departures and earliest gate-in times for arrivals
  - (Remaining taxi distance) / (Nominal taxi speed)
    - Airport node-link model and taxi routes
    - Taxi speed decision trees

Initial Taxi Speed Decision Trees

- Taxi speed decision trees in STBO system
  - Two decision trees for estimating taxi-out times of departures and taxi-in times of arrivals
  - Each branch has two taxi speed values both in AMA and Ramp
- Various taxi speed values for each branch
  - Based on previous studies for taxi time analysis at CLT
  - Four criteria applied
    - Runway
    - Spot
    - Ramp area (subdivided sectors in each concourse)
    - Weight class
  - Used actual surface surveillance data at CLT in May through December, 2015 and taxi route data
    - 10th percentile taxi time values (90th percentile taxi speed)

- Research motivation
  - Initial taxi speed decision trees have not been updated.
    - Based on old surface surveillance data
    - More reliable data from STBO systems become available.
  - Taxi time prediction accuracy is not satisfactory.
    - Large variations on the difference between actual and predicted times
    - Longer taxi time prediction even in unimpeded conditions
    - Wrong takeoff sequence prediction (see the next slide)
- Objective
  - To find optimal taxi speeds for better taxi time estimation
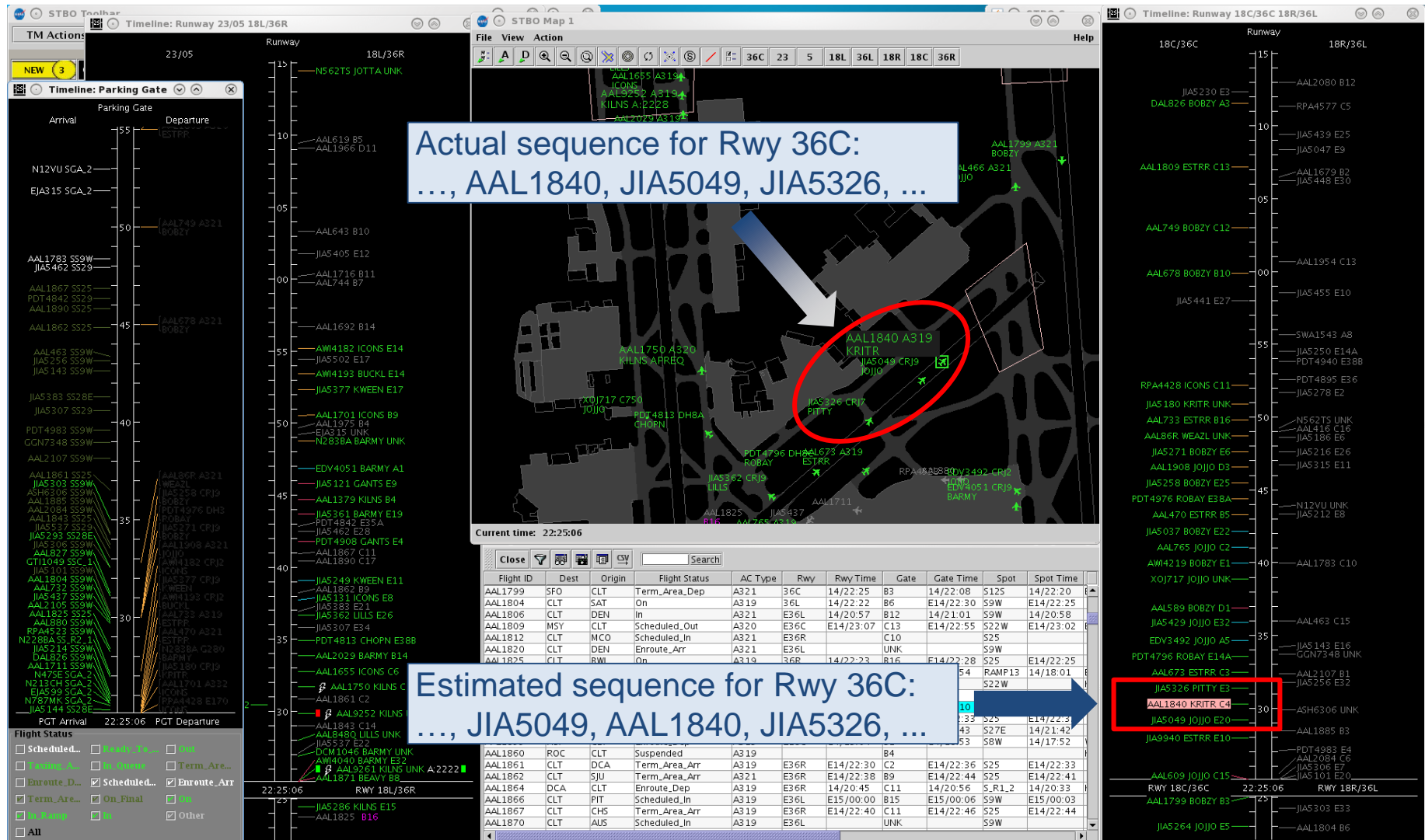
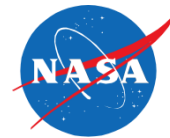< STBO Client Timeline and Map >

- Experiment procedure
  - Install STBO system software with different taxi speed settings in three test machines
    - Run 1: initial taxi speed decision trees (baseline)
    - Run 2: various taxi speeds by runway-spot-ramp area pairs
    - Run 3: constant taxi speed per runway
  - Run them with live data for a few days
  - Archive output data
    - Actual Spot/Off/In times
    - Undelayed Spot/Off/In times (unimpeded time estimates)
- Test run data
  - 2/13/2017 2PM ~ 2/20/2017 1AM (155 hours in total)

Three Different Taxi Speed Settings

- Run 1: initial taxi speed values (baseline)
  - Use old surface surveillance data (5/1/2015-12/31/2015)
- Run 2: various taxi speed values by runway-spot-ramp area pairs
  - Use recent STBO data (9/18/2016-12/31/2016)
  - 90th percentile taxi speeds in the Ramp and AMA for each runway-spot-ramp area pair
  - AMA taxi speed adjusted to avoid overtaking on taxiways
- Run 3: constant taxi speed values per runway
  - Simplified version of Run 2
  - Use recent STBO data (9/18/2016-12/31/2016)
  - 90th percentile taxi speeds in the Ramp and AMA for each runway

Run 1: Initial Taxi Speeds for Departures

- 89 branches depending on runway-spot-ramp area-weight class pair
- Various taxi speed values even in the same spot-runway pair, leading to takeoff sequence changes in runway queue
- Too low taxi speed generally, leading to longer taxi time prediction

Legend:
- Unimpeded Ramp Speed
- Unimpeded AMA Speed

Y-axis: Taxi Speed (knots)

- 145 branches depending on runway-spot-ramp area-weight class pair

Legend: Unimpeded Ramp Speed, Unimpeded AMA Speed
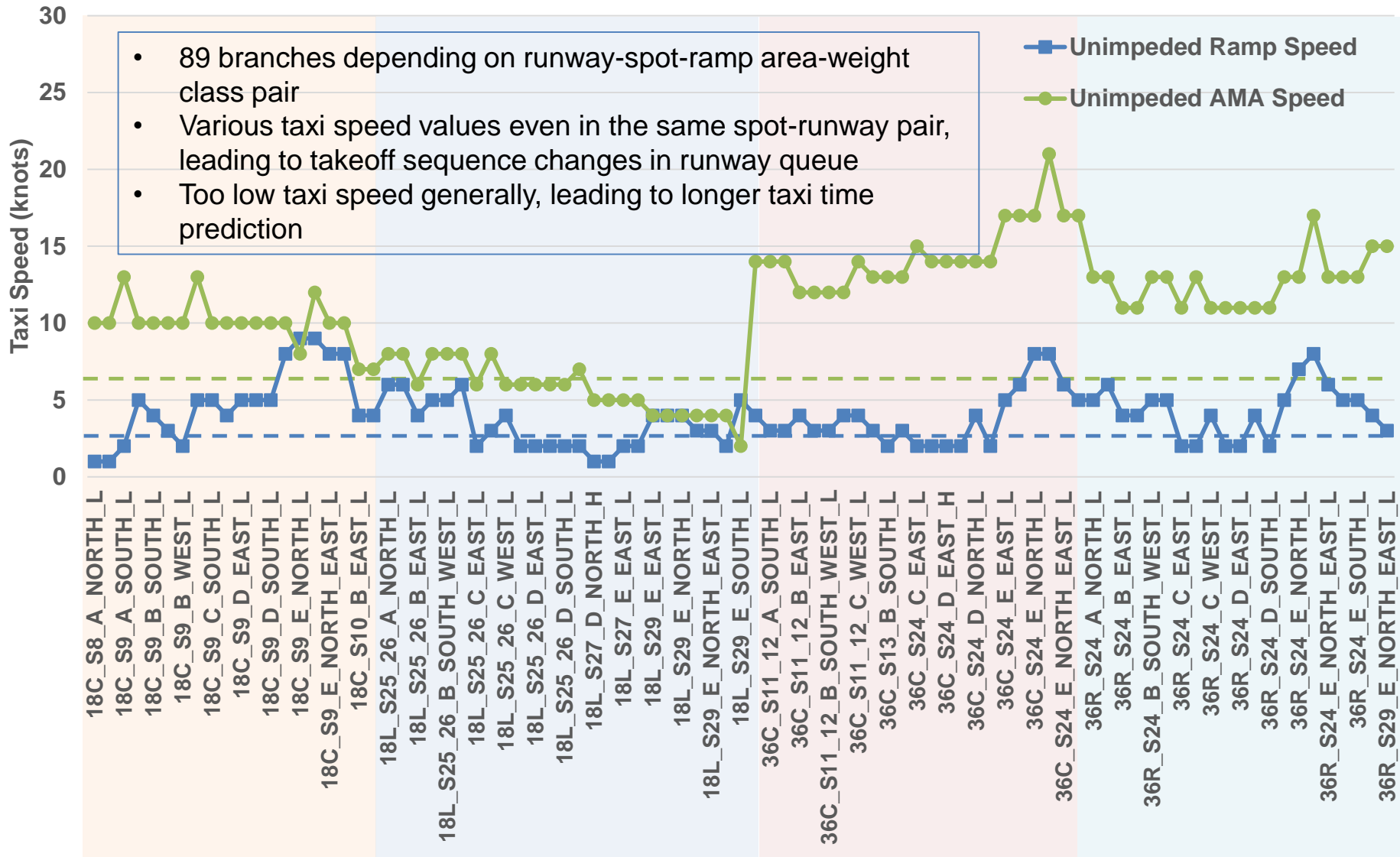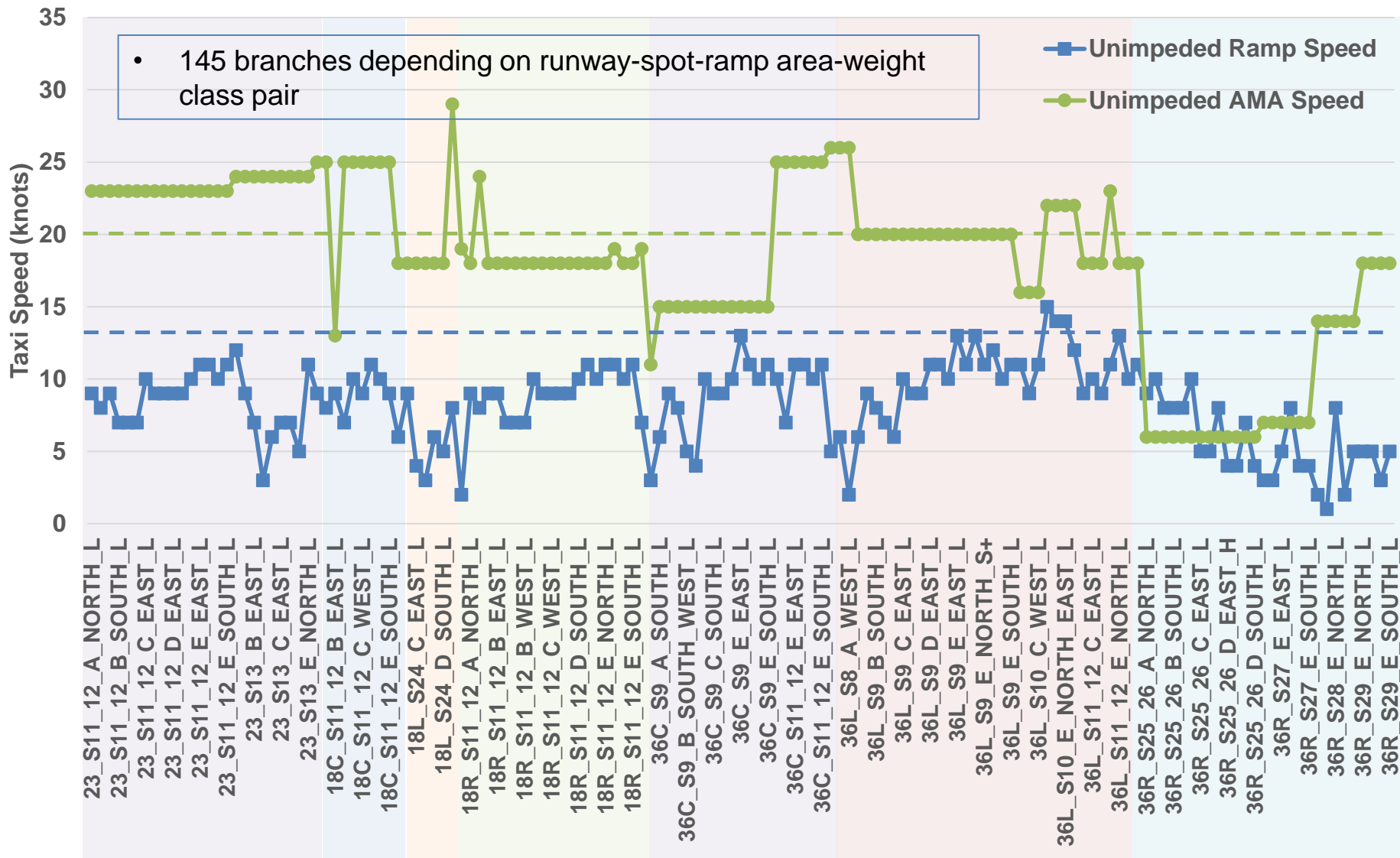
Run 2: Various Taxi Speeds for Departures

- 72 branches depending on runway-spot-ramp area pair
- Constant AMA taxi speeds per runway assumed to prevent flights toward the same runway from overtaking on taxiways

Legend:
- Unimpeded Ramp Speed
- Unimpeded AMA Speed

Y-axis: Taxi Speed (knots)

- 96 branches depending on runway-spot-ramp area pair
- Different runway-spot pairs can have different AMA taxi speeds, depending on the locations.

Run 3: Constant Taxi Speed per Runway
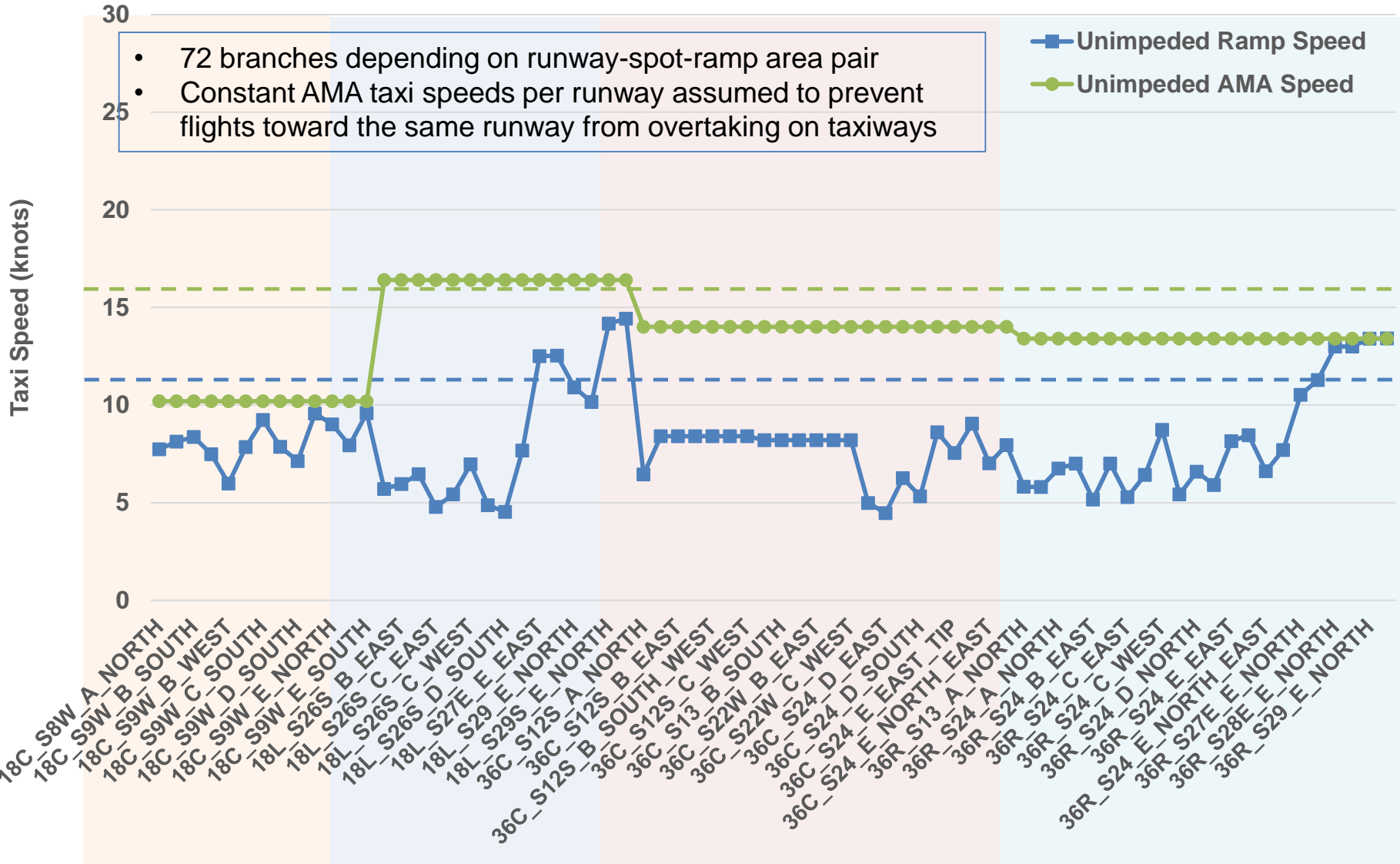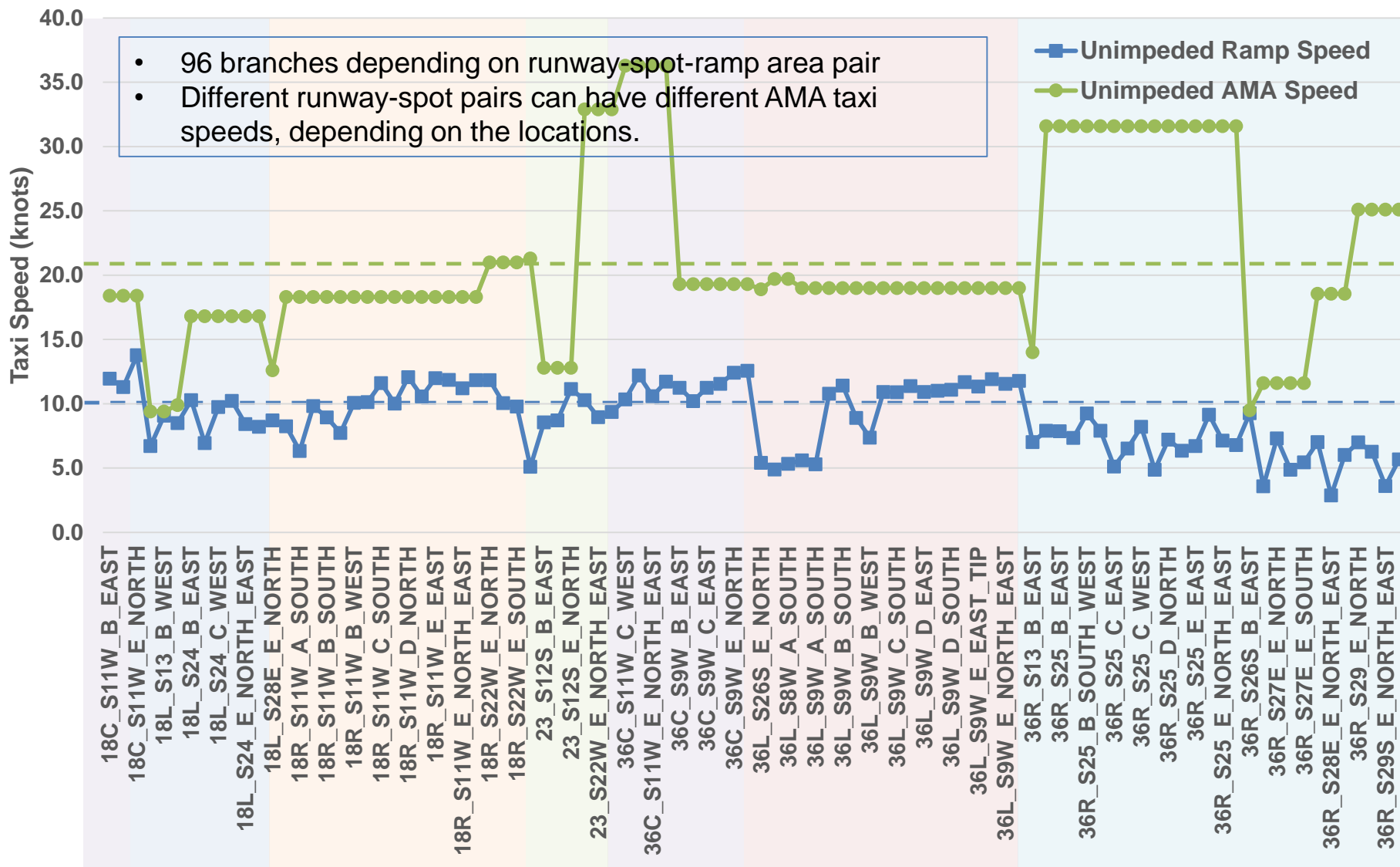
- Departures: 90th percentile value of taxi-out speeds for all departures going to each runway
- Arrivals: 90th percentile value of taxi-in speeds for all arrivals from each runway

Departure Runway	Taxi Speed (in knots)	
	AMA	Ramp
18C	10.2	8.3
18L	16.4	8.9
36C	14.0	8.4
36R	13.4	7.9
Default	13.6	8.3

Arrival Runway	Taxi Speed (in knots)	
	AMA	Ramp
18C	17.2	10.5
18L	13.9	8.5
18R	18.3	10.2
23	23.0	9.2
36C	24.8	10.3
36L	18.9	10.7
36R	25.4	7.4
Default	20.6	9.6

- Taxi-out time histograms
  - Very short ramp taxi time from Concourse A to Runway 18C/36C
  - Short AMA taxi time to Runway 18L
  - Long AMA taxi time to Runway 36C

Ramp Taxi Time Distribution by Runway

AMA Taxi Time Distribution by Runway
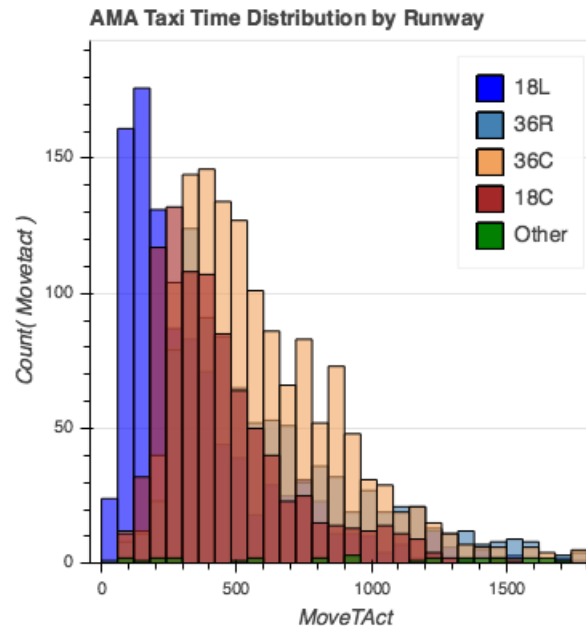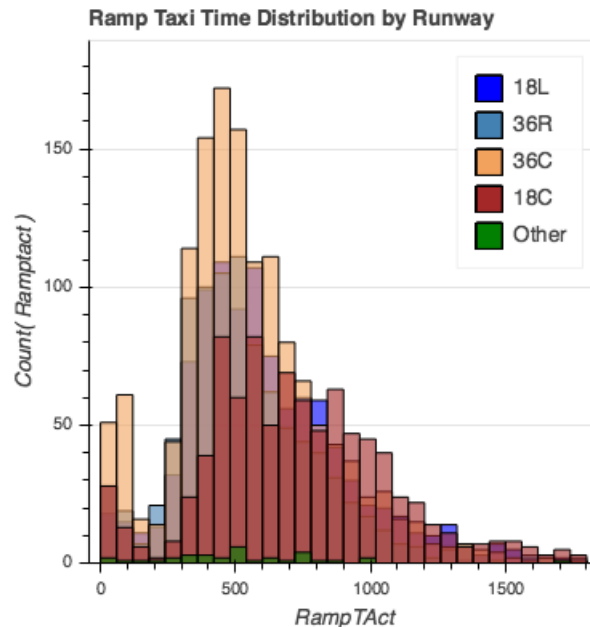
- Taxi-in time histograms
  - Shorter taxi times both in the Ramp and AMA, compared to departures
  - Longer taxi-in time from West due to longer taxi distance
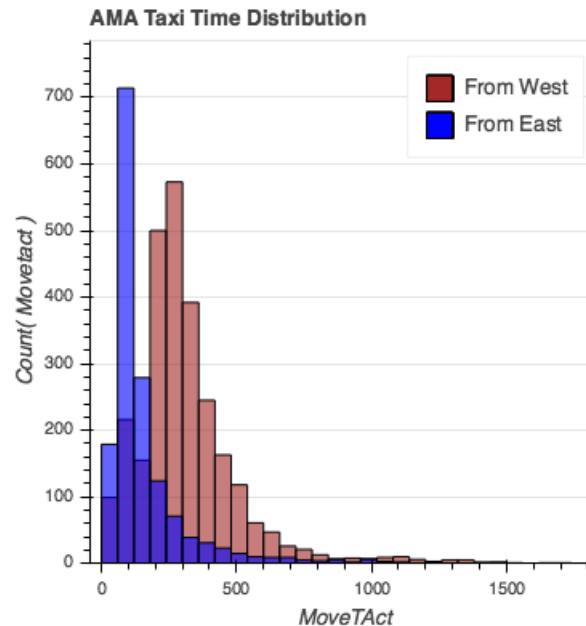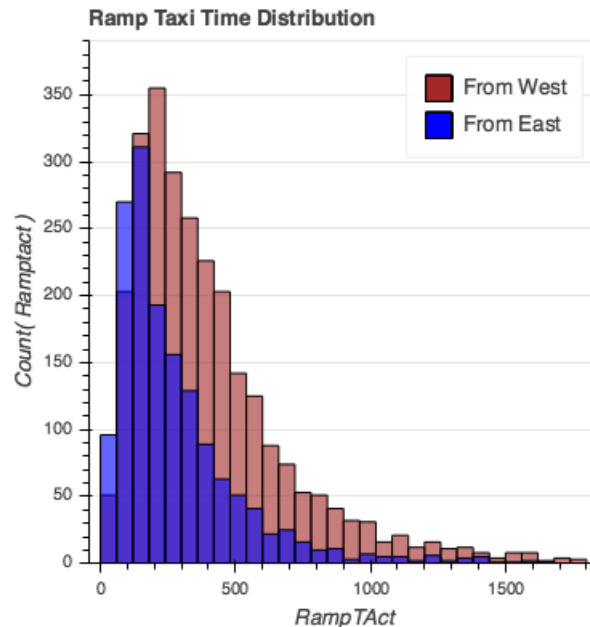
- Box plots for spot time difference at gate by concourse
  - Show ramp taxi-out time prediction accuracy
    - (Actual spot time) – (Undelayed spot time estimate)$_{@pushback}$
  - Run 1: longer ramp taxi times predicted
    - Negative values on y-axis for most flights

R1: Baseline   R2: Various speeds   R3: Constant speed
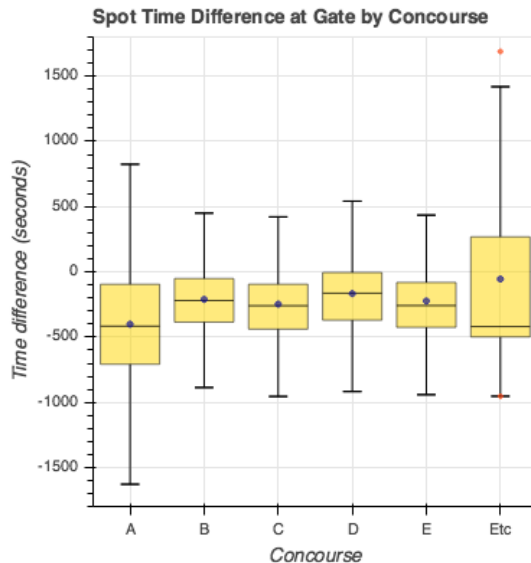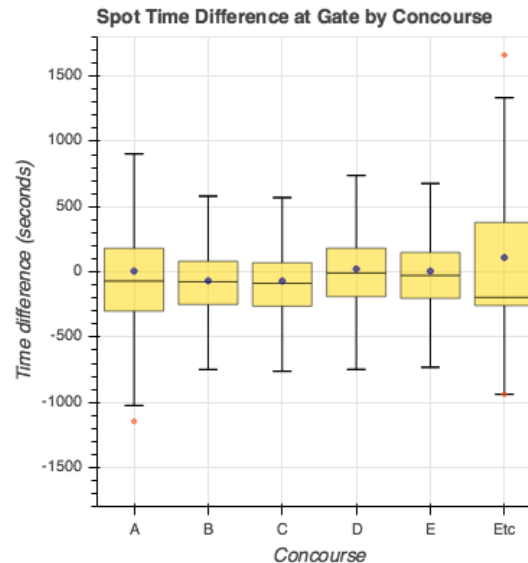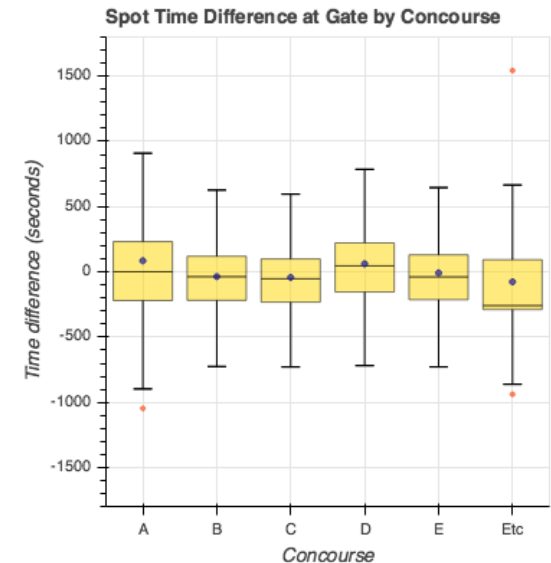
- Box plots for takeoff time difference at spot by runway
  - Show AMA taxi-out time prediction accuracy
    - (Actual off time) – (Undelayed off time estimate)$_{spot}$
  - Positive mean values are expected because runway separations are accumulated in actual off times.

R1: Baseline
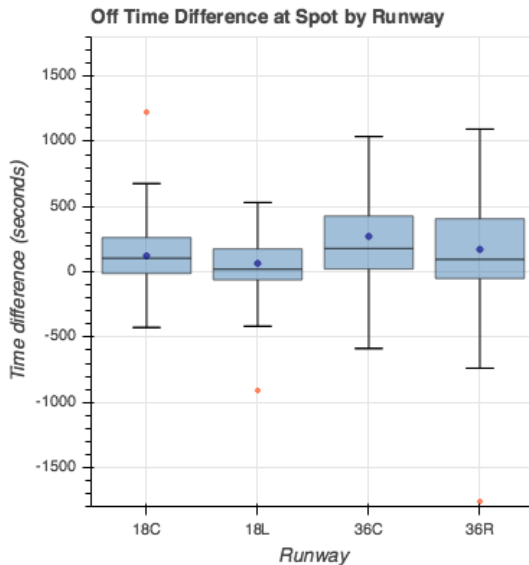
R2: Various speeds
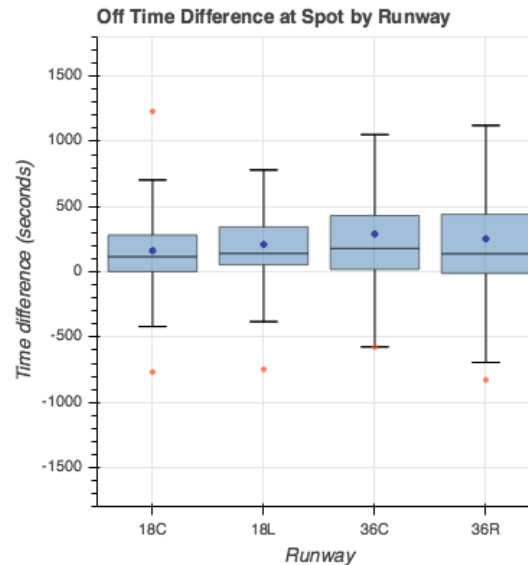
R3: Constant speed
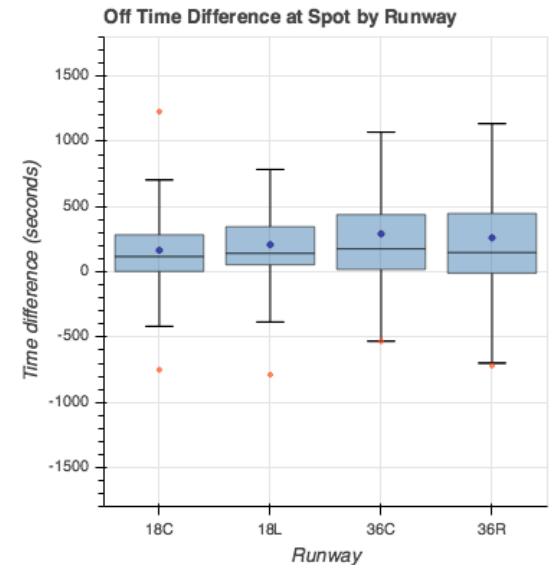
- Box plots for takeoff time difference at gate by runway
  - Show total taxi-out time prediction accuracy
    - (Actual off time) – (Undelayed off time estimate)@pushback
  - No significant difference by departure runway

R1: Baseline
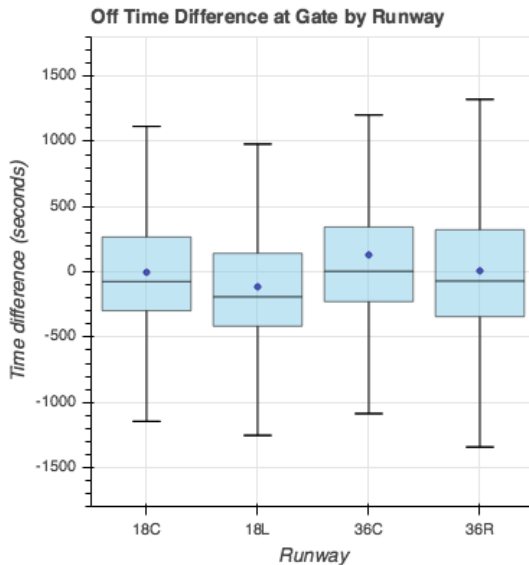
R2: Various speeds
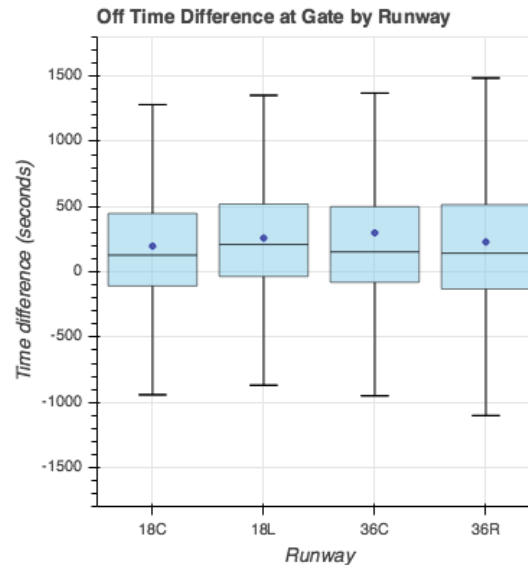
R3: Constant speed
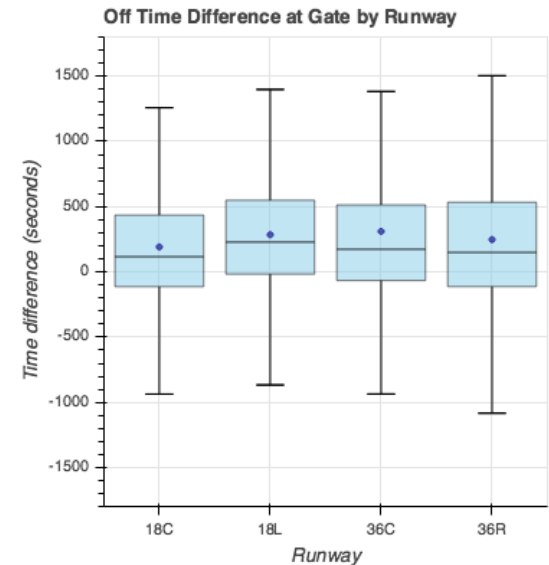
- Box plots for takeoff time difference at gate by concourse
  - Show total taxi-out time prediction accuracy
    - (Actual off time) – (Undelayed off time estimate)$_{@pushback}$
  - Large variations observed in Concourse A and Etc.
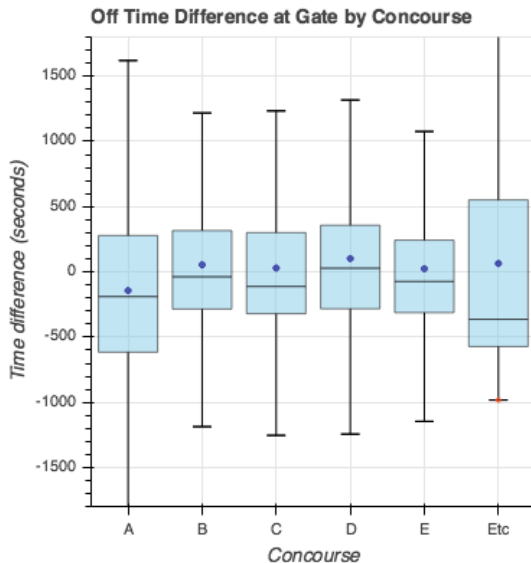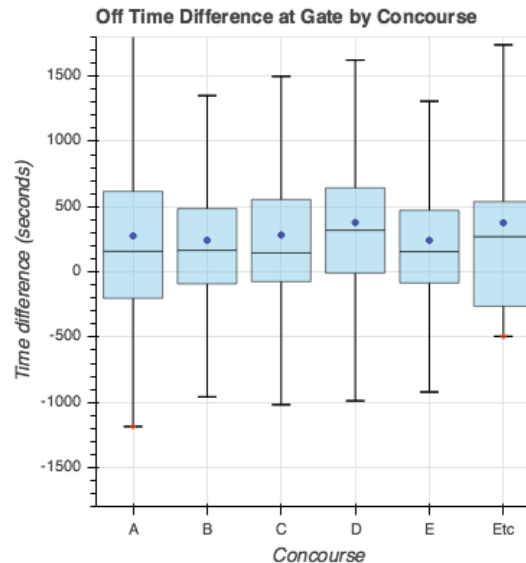
R1: Baseline   R2: Various speeds   R3: Constant speed
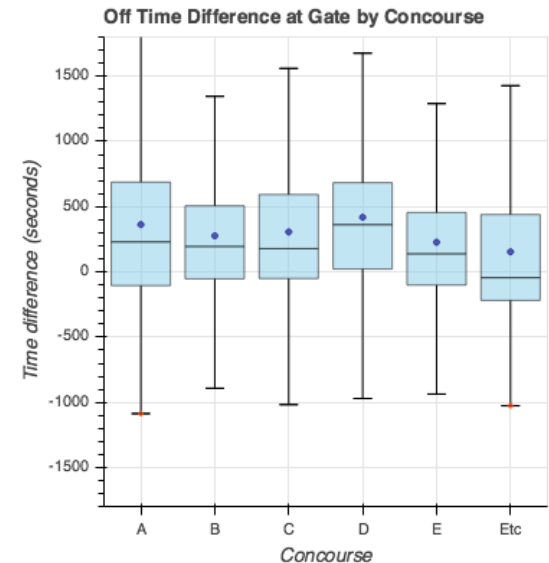
- Departure queue size histogram from test dataset
  - Count the number of departures going to the same runway on the surface when a flight pushes back from its gate
  - Queue size less than 4 aircraft is assumed to be in unimpeded taxi conditions.
    - Enable to better compare actual and undelayed OFF times

Queue size < 4: ~17%

Departure queue size from gate
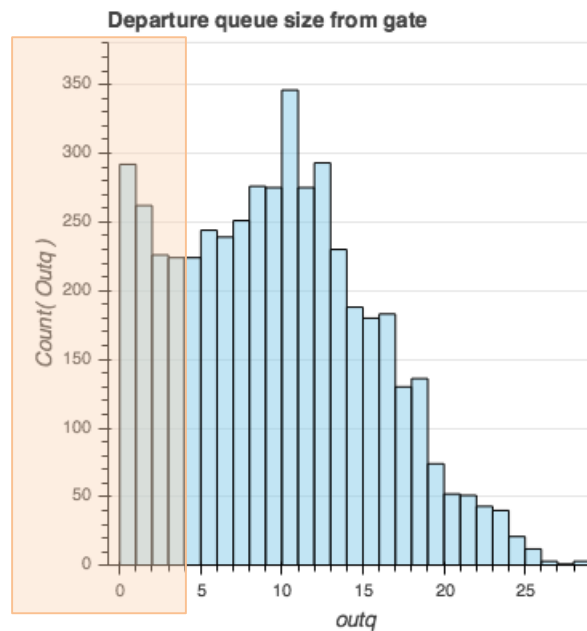
- Box plots for takeoff time difference at gate by runway
  - Departures only in queue size < 4 (from gate to runway)
  - Longer taxi-out times predicted in Run 1 (baseline)

R1: Baseline
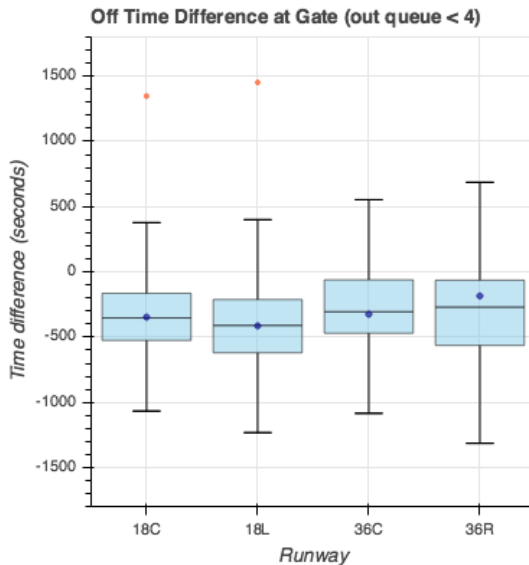
R2: Various speeds

R3: Constant speed

Off Time Prediction Errors at Spot
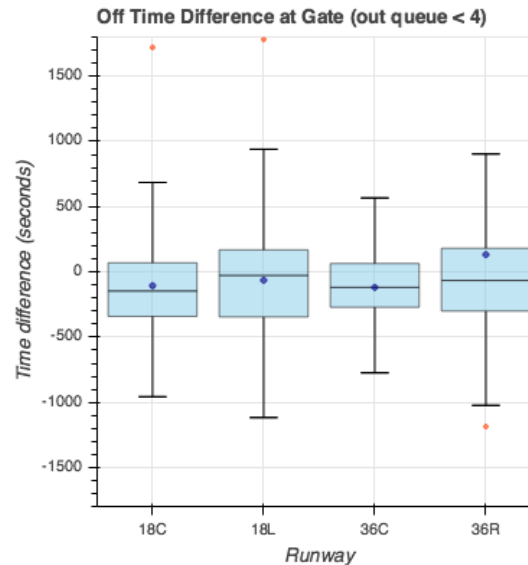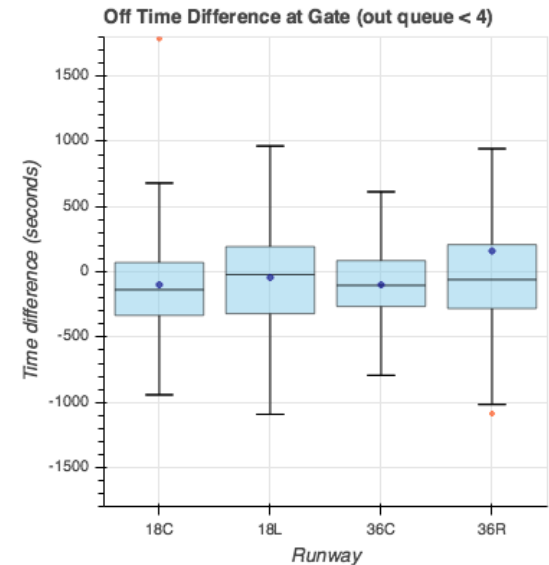
- Box plots for takeoff time difference at spot by runway
  - Departures only in queue size < 4 (from gate to runway)
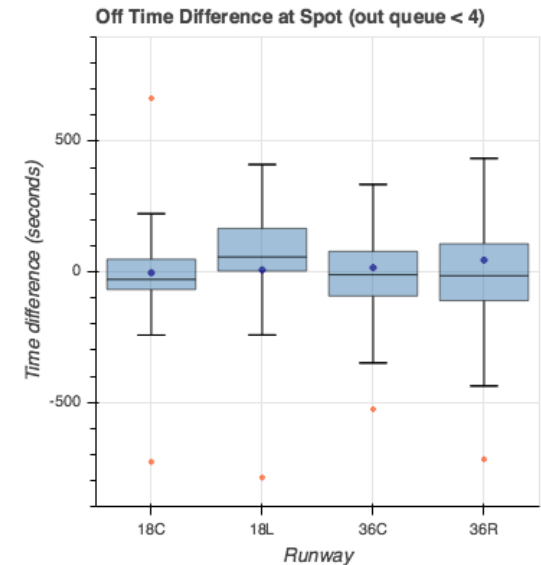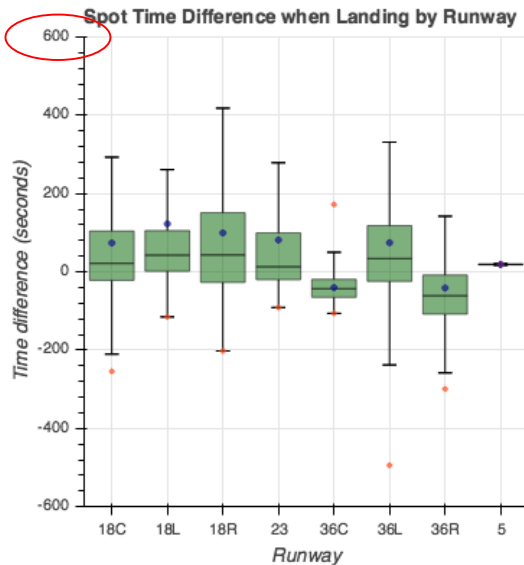 - Better prediction accuracy in Run 2 and 3 for Runway 36R

R1: Baseline
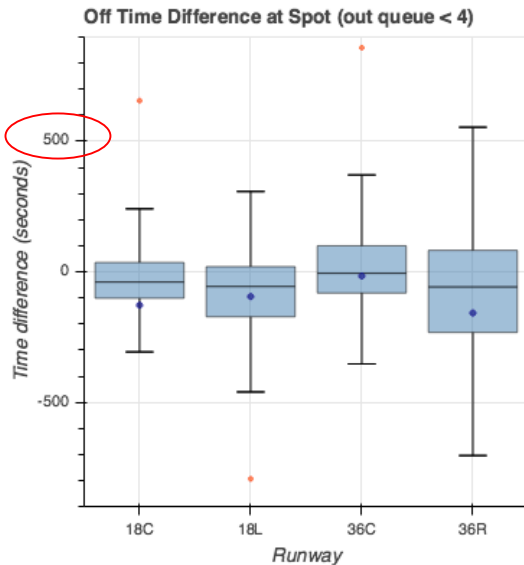
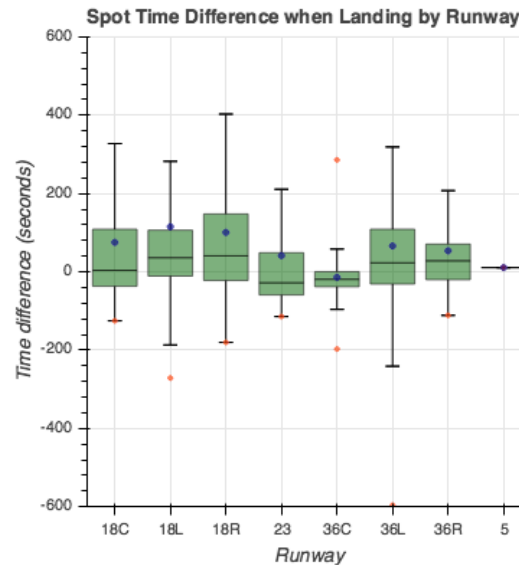R2: Various speeds
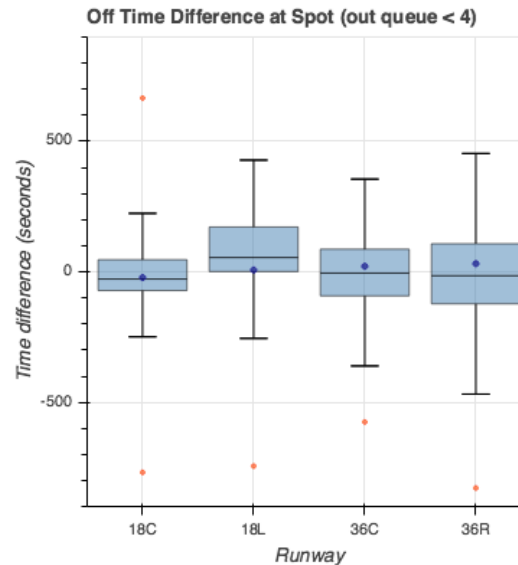
R3: Constant speed

- Box plots for spot time difference when landing, grouped by runway
  - Show AMA taxi-in time prediction accuracy
    - (Actual spot time) – (Undelayed spot time estimate)$_{@landing}$
  - Better prediction performance for arrivals than departures
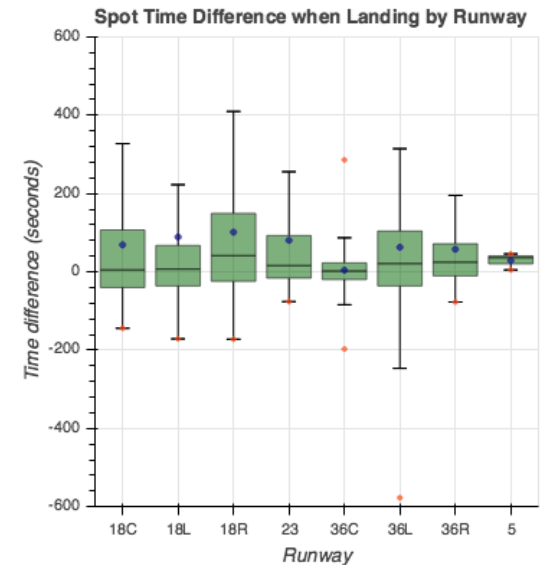
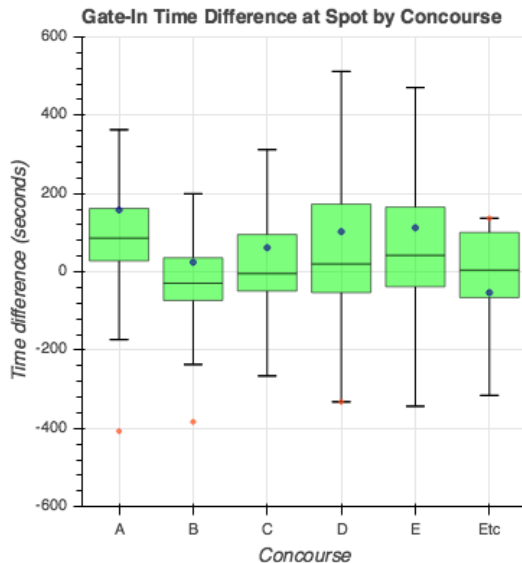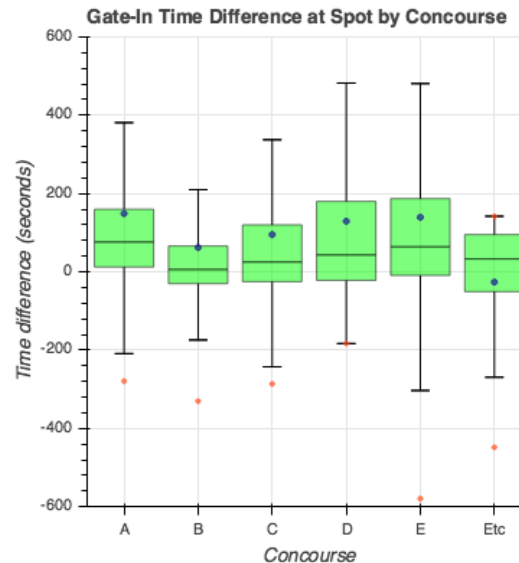R1: Baseline   R2: Various speeds   R3: Constant speed

- Box plots for gate-in time difference at spot by concourse
  - Show ramp taxi-in time prediction accuracy
    - (Actual gate-in time) – (Undelayed gate-in time estimate)$_{@spot}$
  - No significant difference between three runs
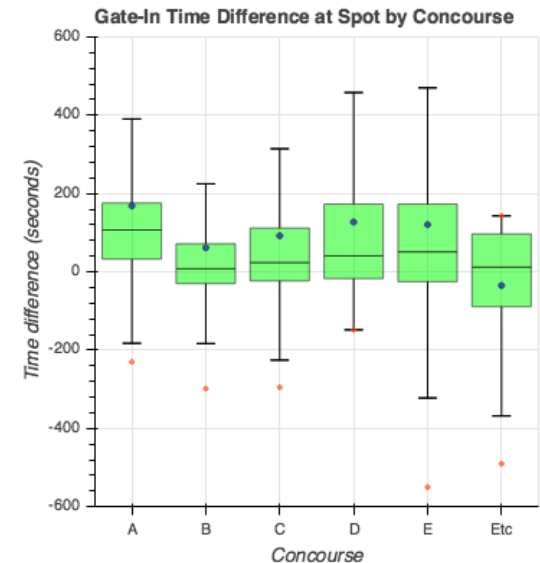   - Relatively poor performance for Concourse A
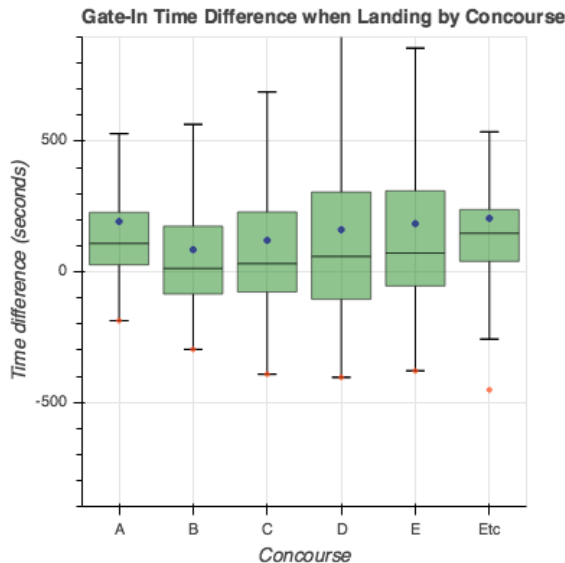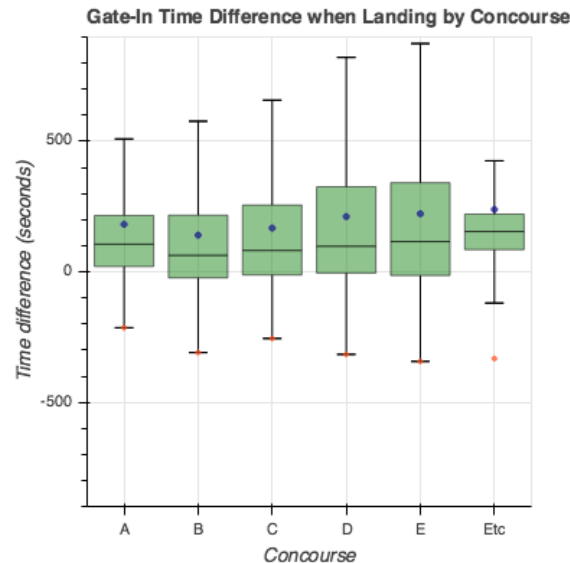
R1: Baseline

R2: Various speeds

R3: Constant speed

- Box plots for gate-in time difference when landing, grouped by concourse
  - Show total taxi-in time prediction accuracy
    - (Actual gate-in time) – (Undelayed gate-in time estimate)$_{@landing}$
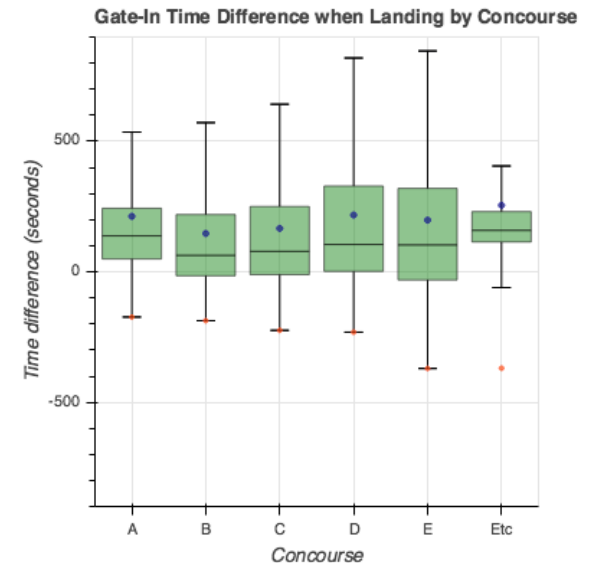
R1: Baseline

R2: Various speeds
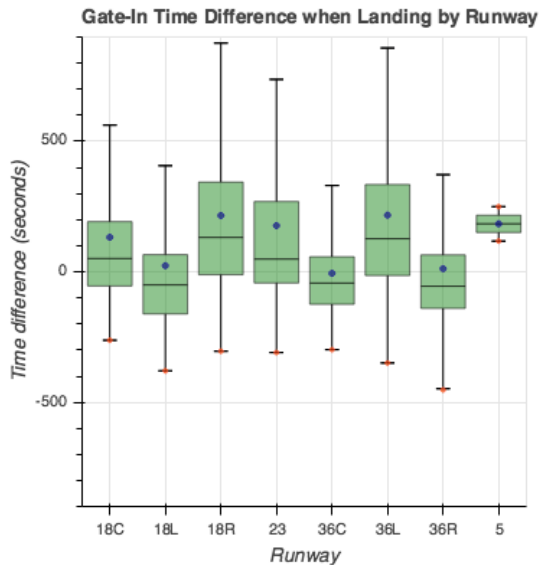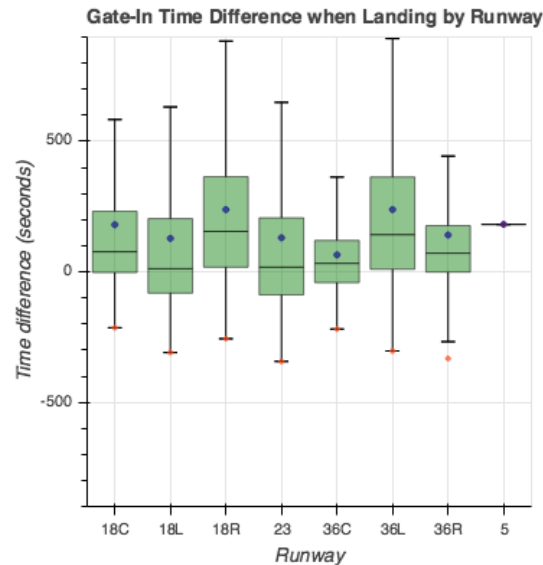
R3: Constant speed

- Box plots for gate-in time difference when landing, grouped by runway
  - Show total taxi-in time prediction accuracy
    - (Actual gate-in time) – (Undelayed gate-in time estimate)$_{@landing}$

R1: Baseline

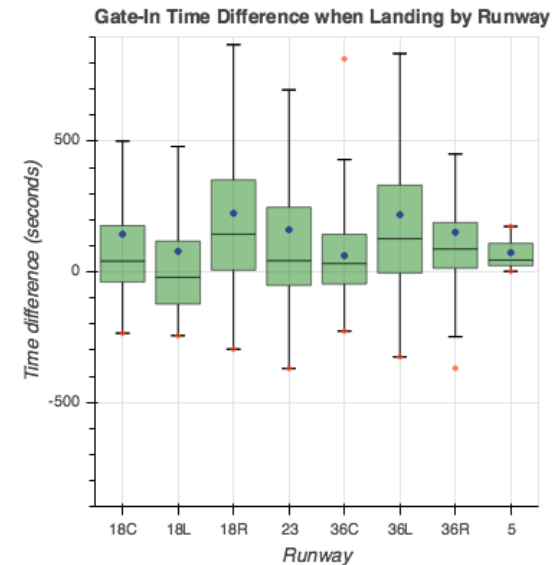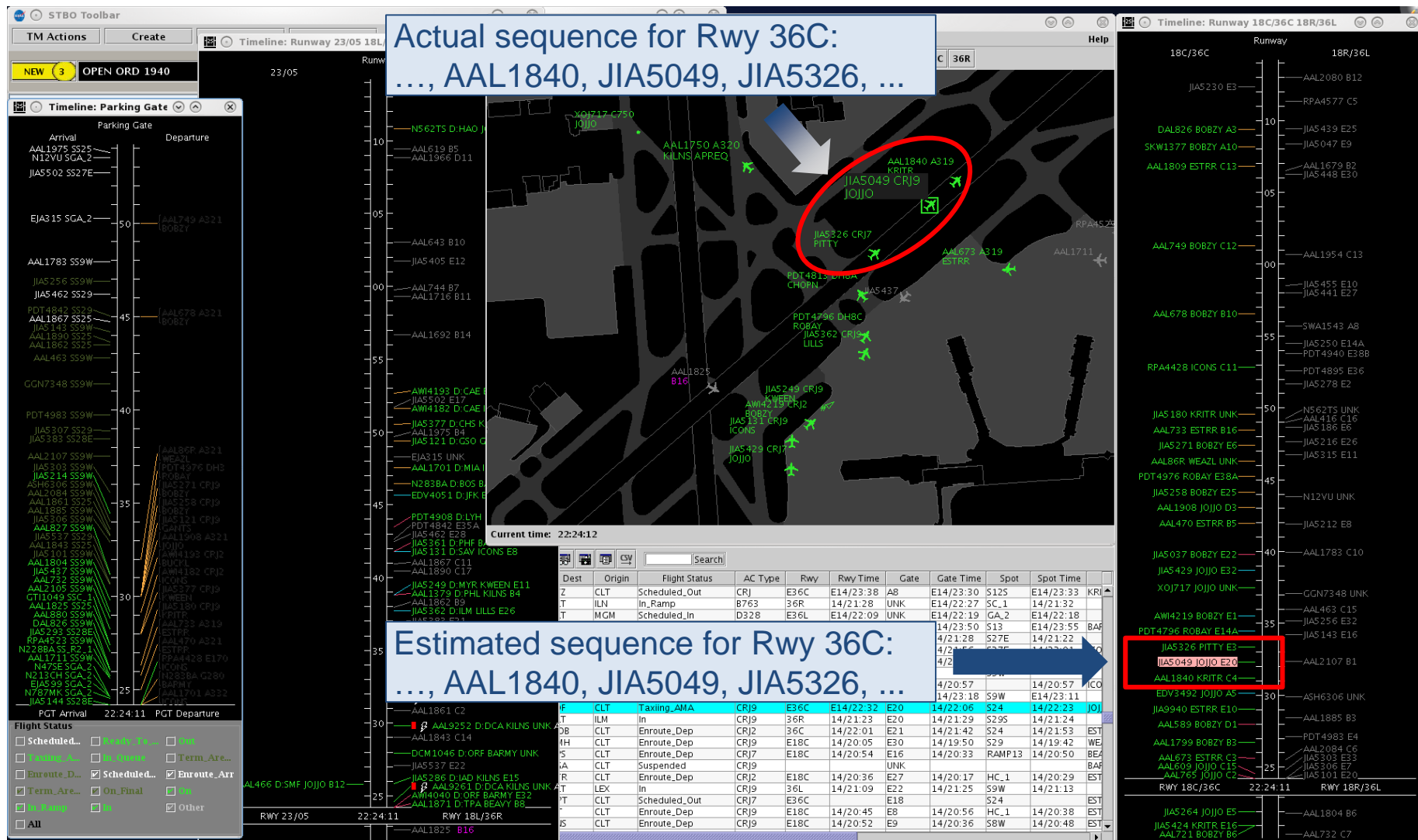R2: Various speeds

R3: Constant speed

< STBO Client Timeline and Map >

Summary

- Three different taxi speed settings were tested to obtain the better taxi time prediction.

- Test results showed that
  - The best prediction performance was obtained when using constant taxi speed for each runway (Run 3).
  - Arrivals showed the better prediction accuracy, but there was no significant difference between three runs.

- We still have much room to improve the prediction for:
  - Ramp taxi-out time for non-AAL flights
  - AMA taxi-out time with congestion factor in runway queues
  - Ramp taxi-in time for Concourse A
  - AMA taxi-in time from West (Runway 18C/18R/36L)