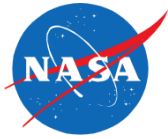


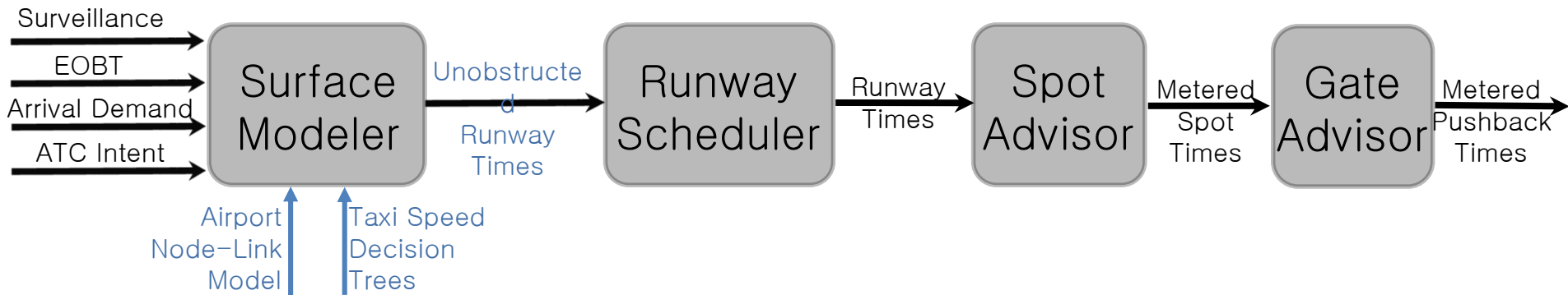
Comparison of Taxi Time Prediction Performance Using Different Taxi Speed Decision Trees

Hanbong Lee

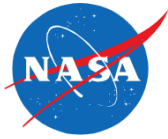
4th Joint Workshop for KARI-NASA ATM Research Collaboration
Korea Aerospace Research Institute, Daejeon, Korea
May 23-25, 2017



- Motivation
- 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



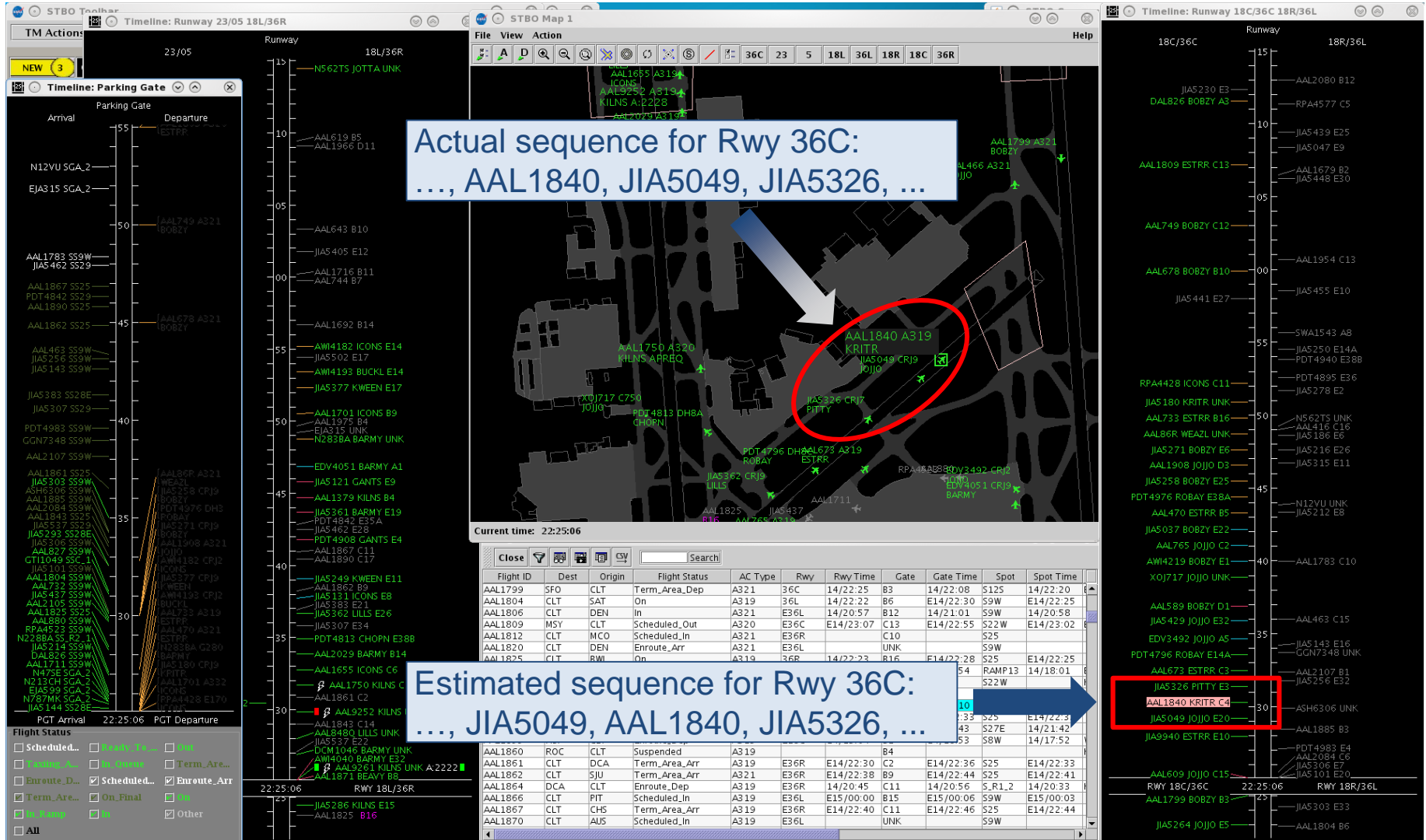
- Unimpeded taxi time estimates
 - Provide earliest feasible takeoff times for departures and earliest gate-in times for arrivals
 - $(\text{Remaining taxi distance}) / (\text{Nominal taxi speed})$
 - Airport node-link model and taxi routes
 - Taxi speed decision trees



- 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)

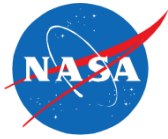


- Research motivation
 - Initial taxi speed decision trees have not been updated.
 - Based on old surface surveillance data
 - More reliable data from STBO systems become available.
 - Taxi time prediction accuracy is not satisfactory.
 - Large variations on the difference between actual and predicted 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

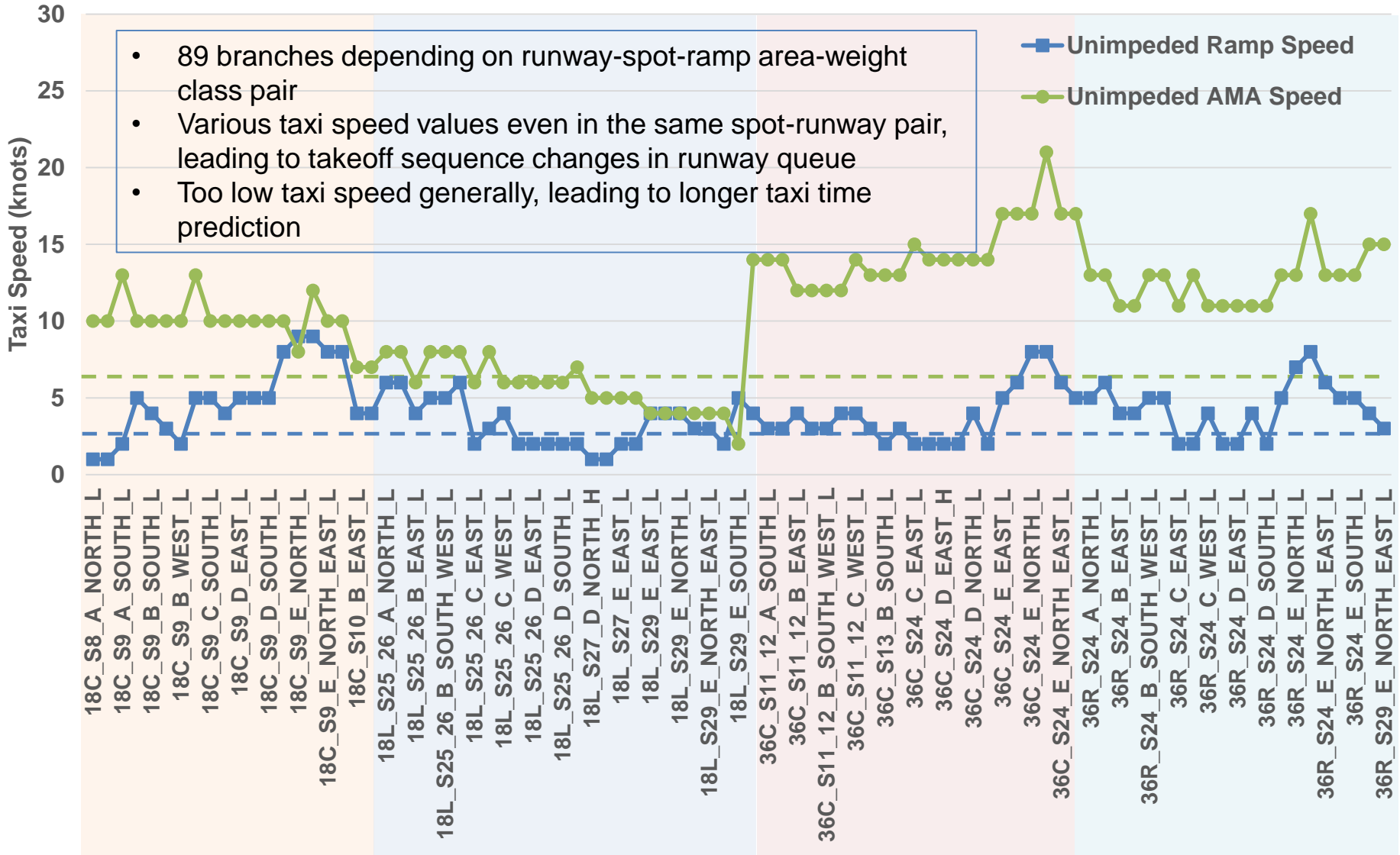


< STBO Client Timeline and Map >

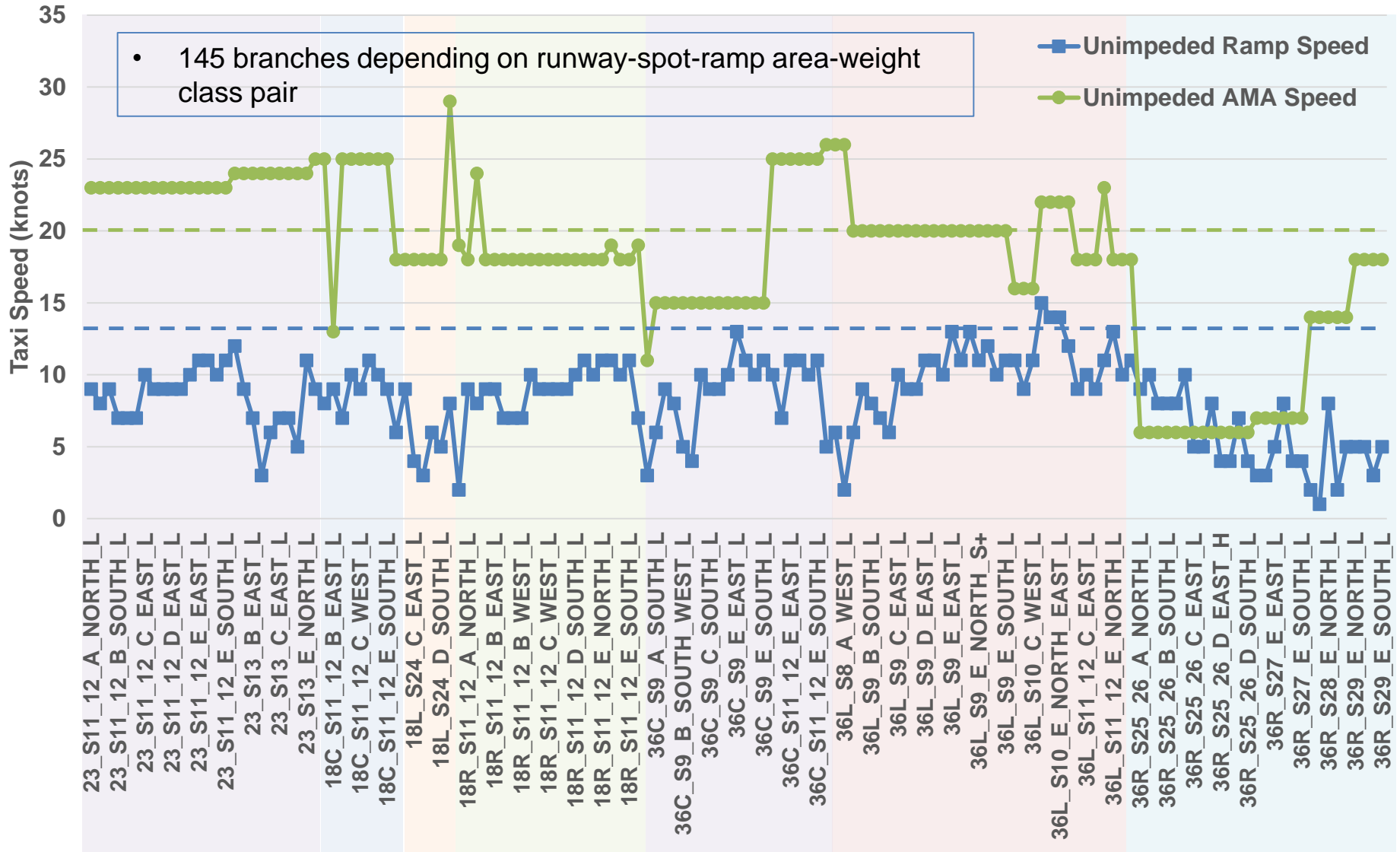
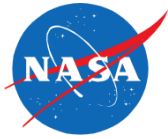
- Experiment procedure
 - Install STBO system software with different taxi speed settings in three test machines
 - Run 1: initial taxi speed decision trees (baseline)
 - Run 2: various taxi speeds by runway-spot-ramp area pairs
 - Run 3: constant taxi speed per runway
 - Run them with live data for 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)

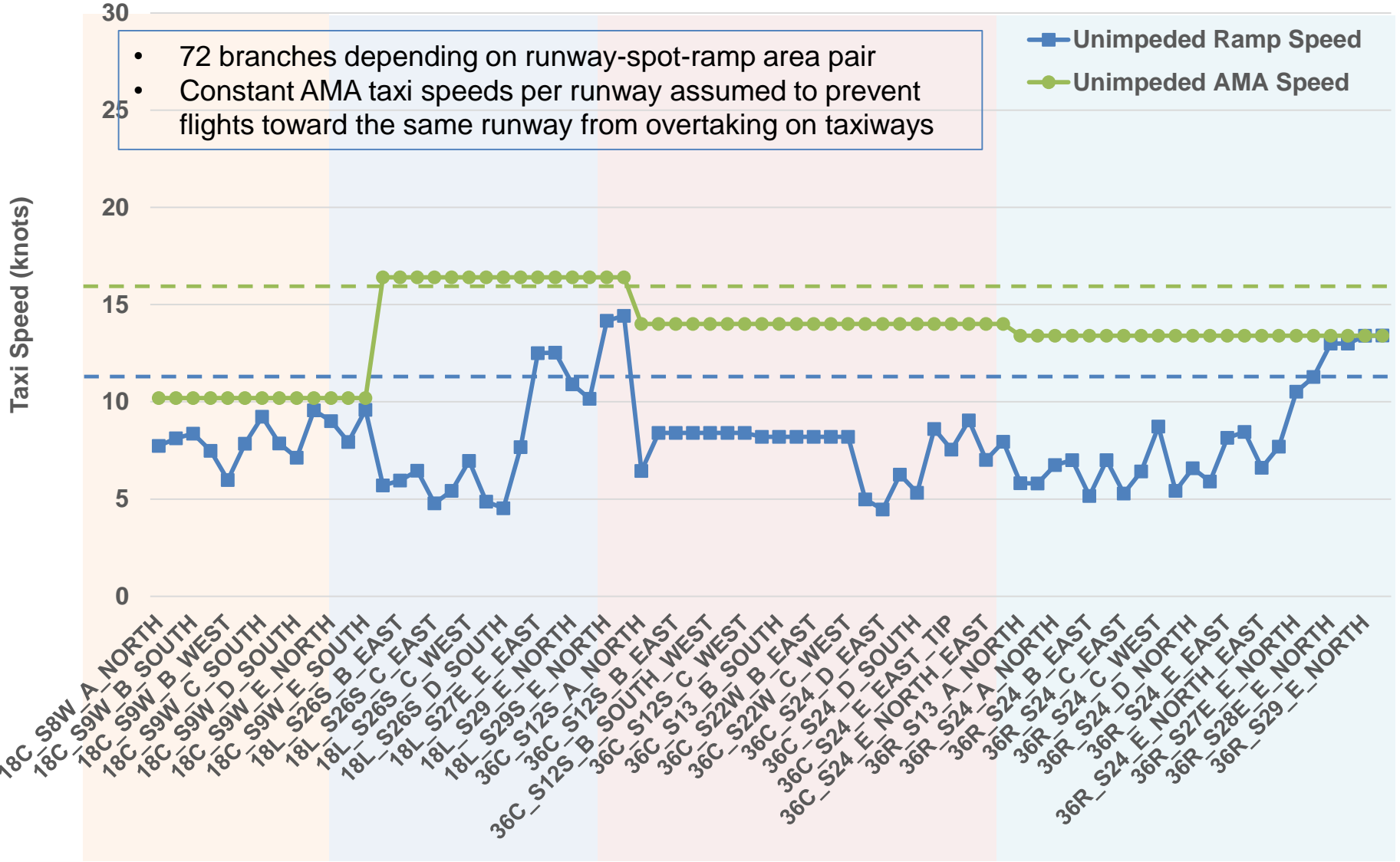


- Run 1: initial taxi speed values (baseline)
 - Use old surface surveillance data (5/1/2015-12/31/2015)
- Run 2: various taxi speed values by runway-spot-ramp area pairs
 - Use recent STBO data (9/18/2016-12/31/2016)
 - 90th percentile taxi speeds in the Ramp and AMA for each runway-spot-ramp area pair
 - 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

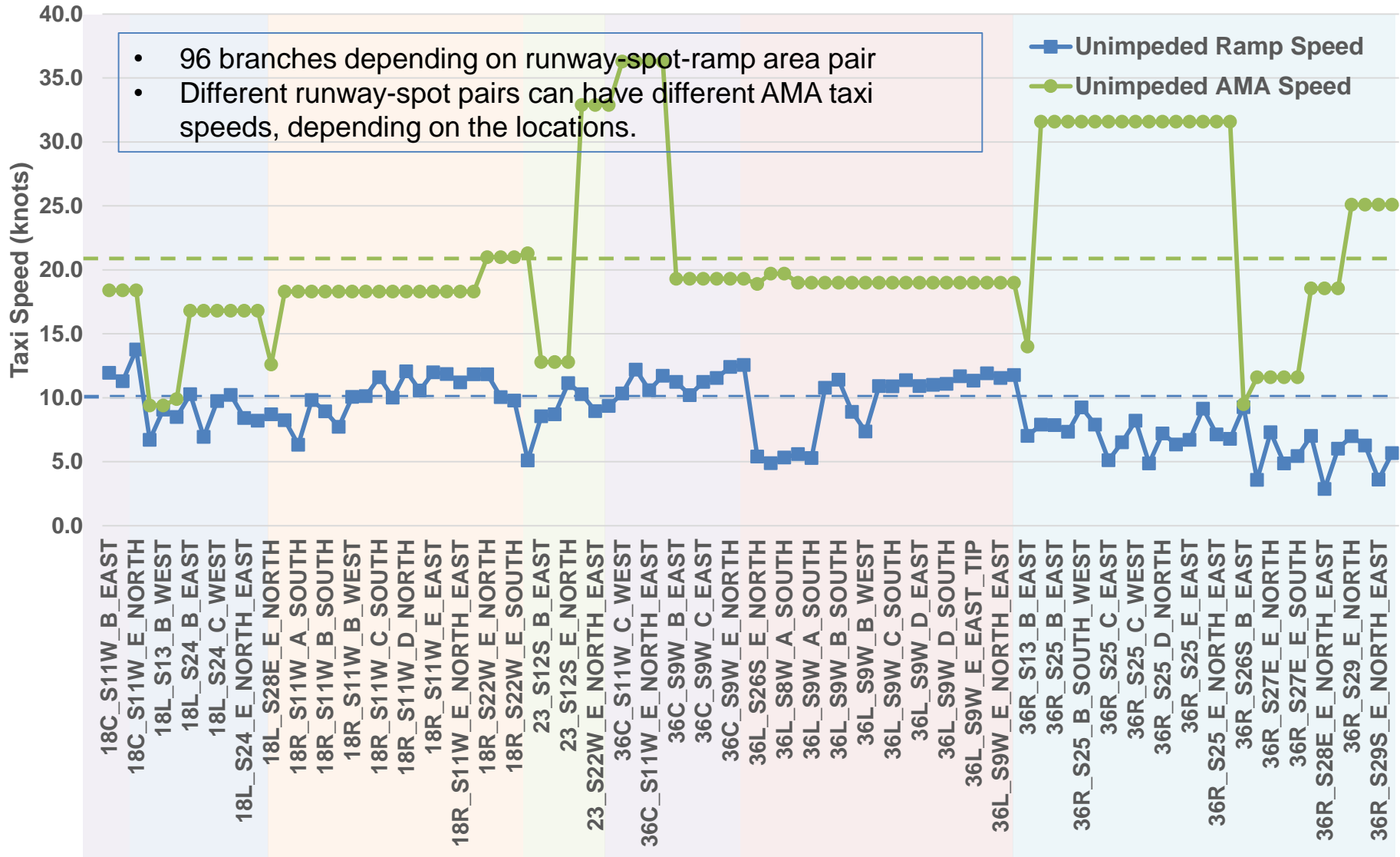
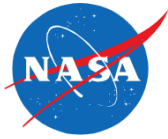


Run 1: Initial Taxi Speeds for Arrivals





Run 2: Various Taxi Speeds for Arrivals



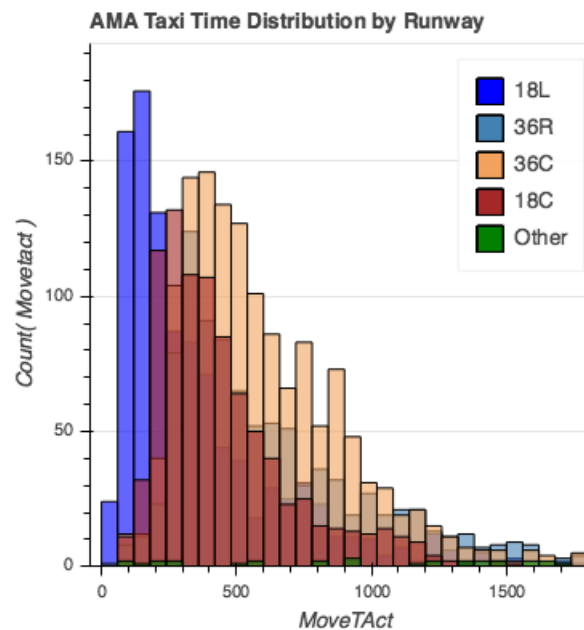
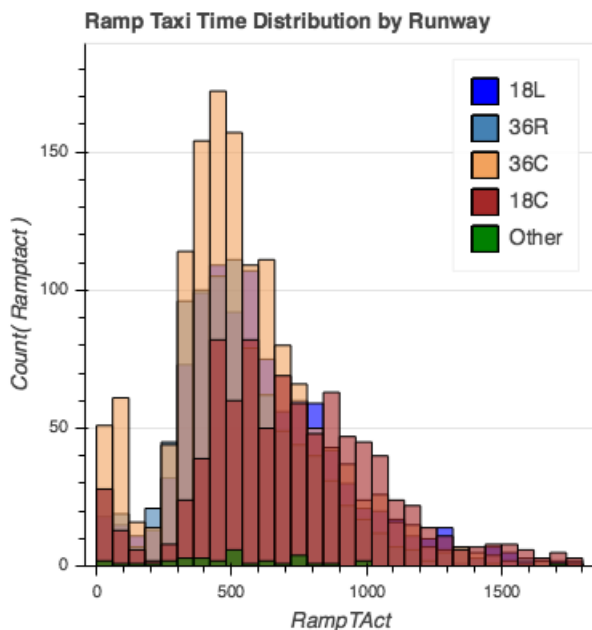


- Departures: 90th percentile value of taxi-out speeds for all departures going to each runway
- Arrivals: 90th percentile value of taxi-in speeds for all arrivals from each runway

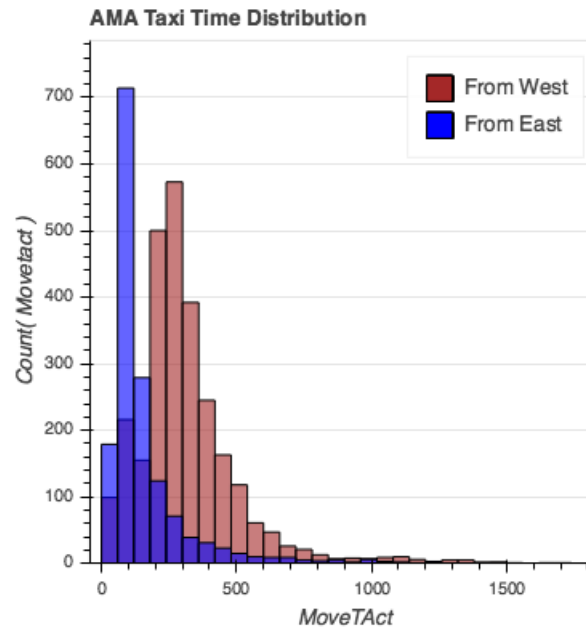
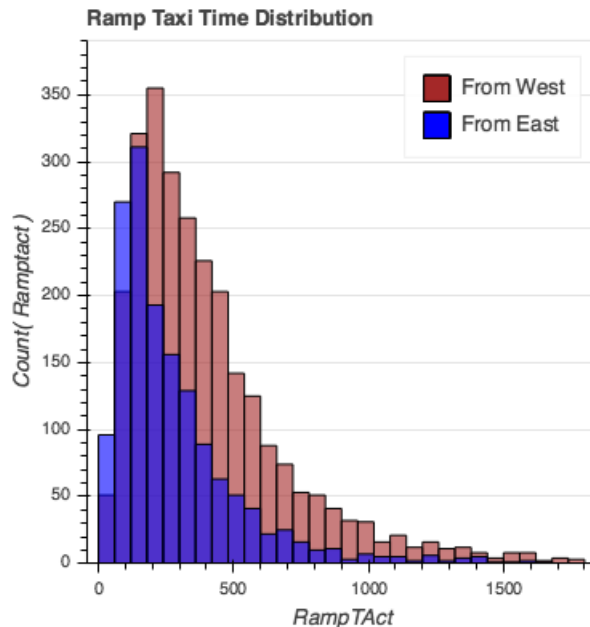
Departure Runway	Taxi Speed (in knots)	
	AMA	Ramp
18C	10.2	8.3
18L	16.4	8.9
36C	14.0	8.4
36R	13.4	7.9
Default	13.6	8.3

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

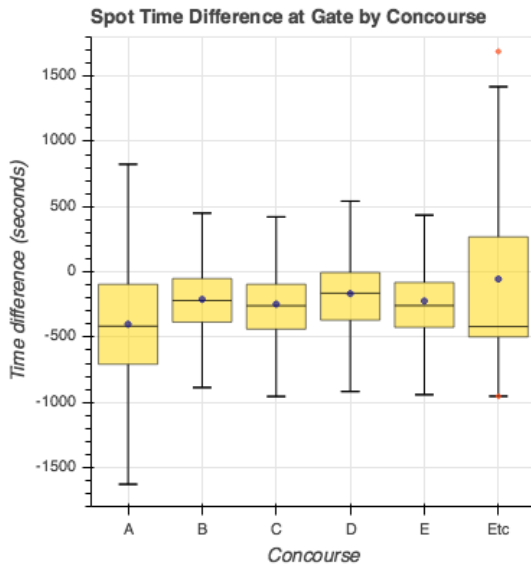


- Taxi-in time histograms
 - Shorter taxi times both in the Ramp and AMA, compared to departures
 - Longer taxi-in time from West due to longer taxi distance

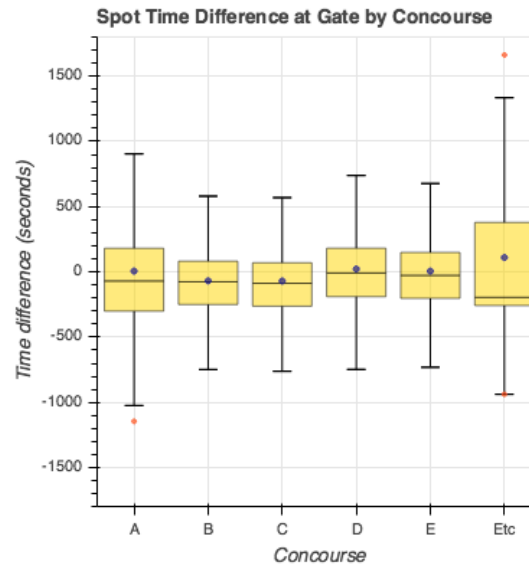


- Box plots for spot time difference at gate by concourse
 - Show ramp taxi-out time prediction accuracy
 - $(\text{Actual spot time}) - (\text{Undelayed spot time estimate})_{@pushback}$
 - Run 1: longer ramp taxi times predicted
 - Negative values on y-axis for most flights

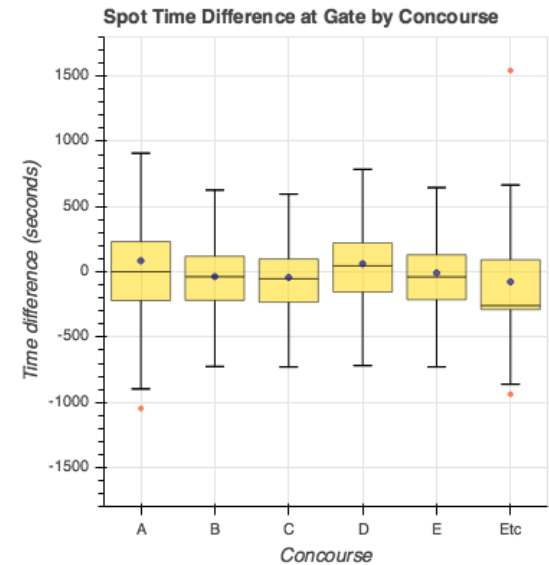
R1: Baseline



R2: Various speeds

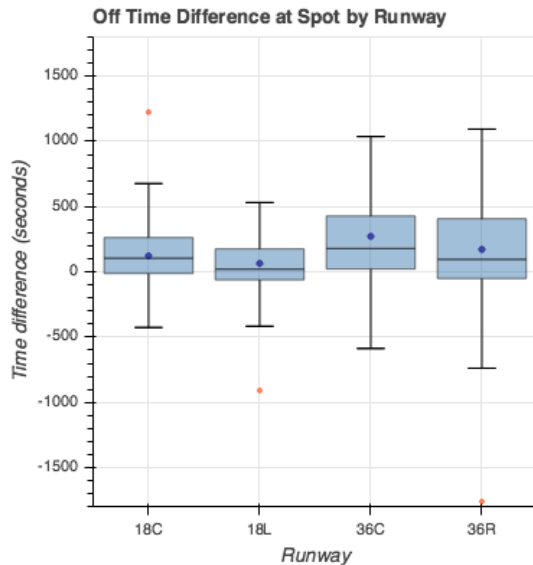


R3: Constant speed

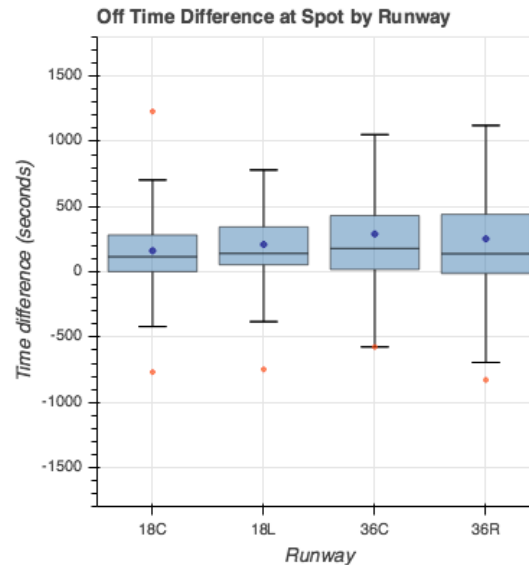


- Box plots for takeoff time difference at spot by runway
 - Show AMA taxi-out time prediction accuracy
 - $(\text{Actual off time}) - (\text{Undelayed off time estimate})_{@spot}$
 - Positive mean values are expected because runway separations are accumulated in actual off times.

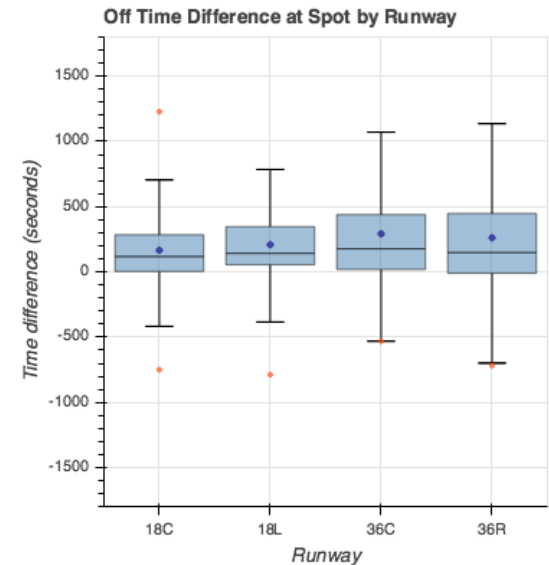
R1: Baseline



R2: Various speeds

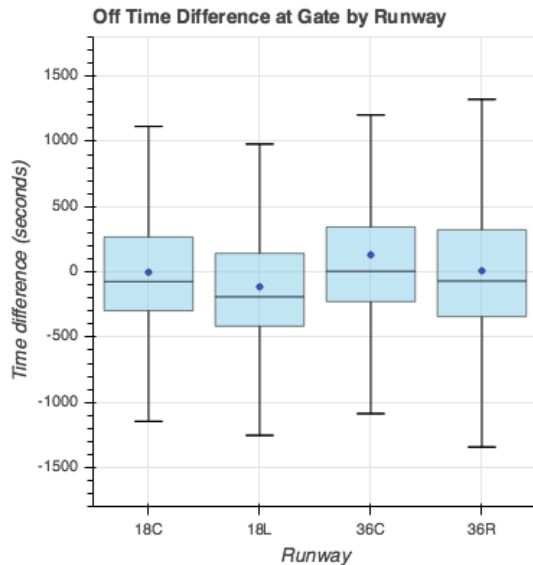


R3: Constant speed

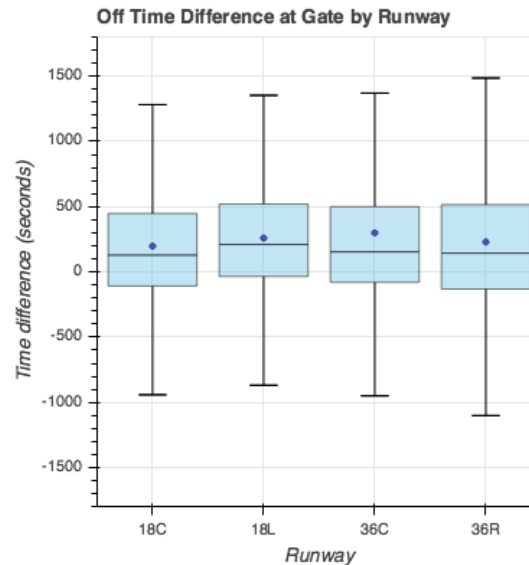


- Box plots for takeoff time difference at gate by runway
 - Show total taxi-out time prediction accuracy
 - $(\text{Actual off time}) - (\text{Undelayed off time estimate})_{\text{@pushback}}$
 - No significant difference by departure runway

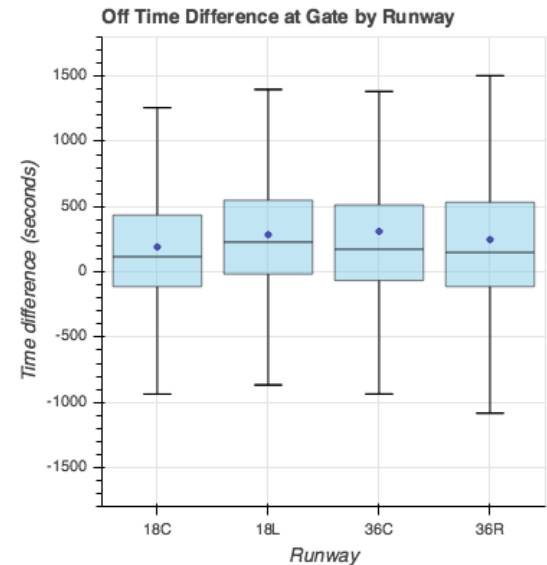
R1: Baseline



R2: Various speeds

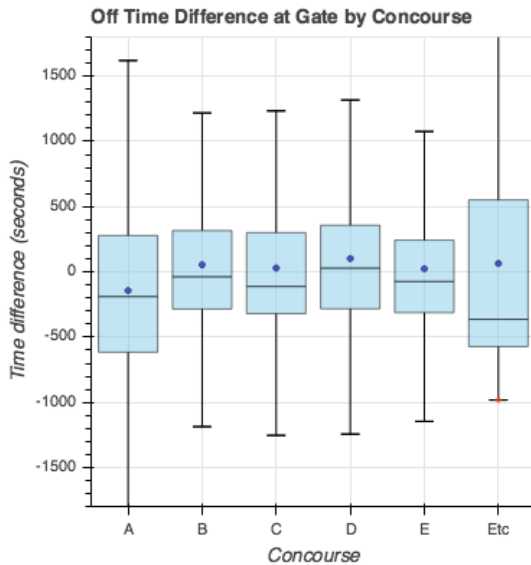


R3: Constant speed

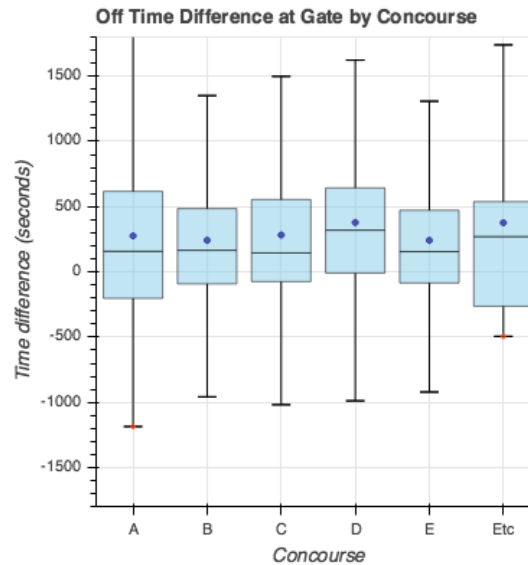


- Box plots for takeoff time difference at gate by concourse
 - Show total taxi-out time prediction accuracy
 - $(\text{Actual off time}) - (\text{Undelayed off time estimate})_{@pushback}$
 - Large variations observed in Concourse A and Etc.

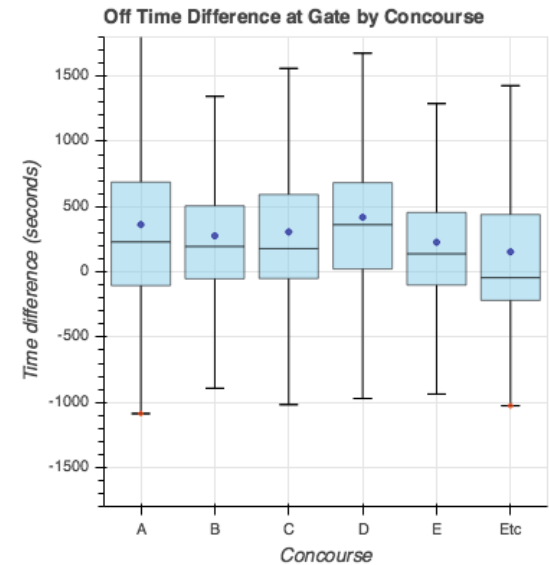
R1: Baseline



R2: Various speeds

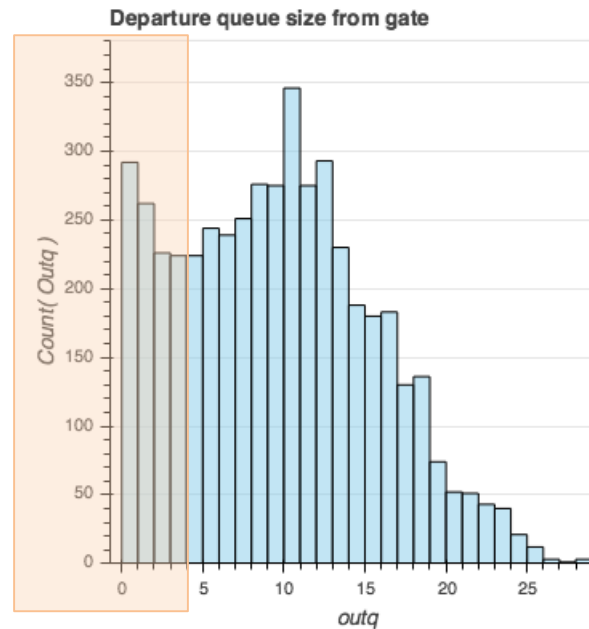


R3: Constant speed



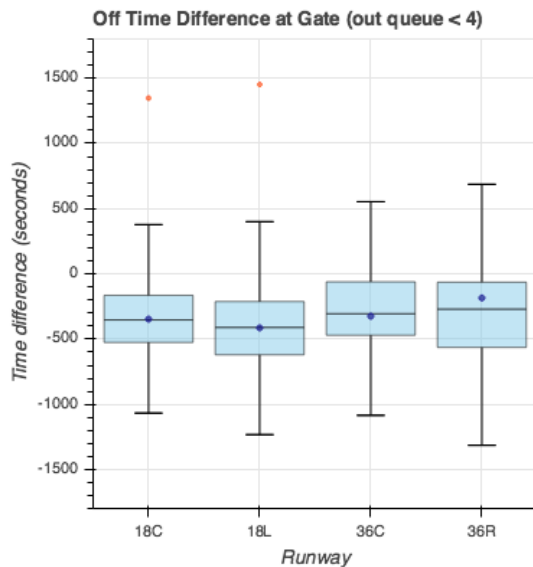
- Departure queue size histogram from test dataset
 - Count the number of departures going to the same runway on the surface when a flight pushes back from its gate
 - Queue size less than 4 aircraft is assumed to be in unimpeded taxi conditions.
 - Enable to better compare actual and undelayed OFF times

Queue size < 4:
~17%

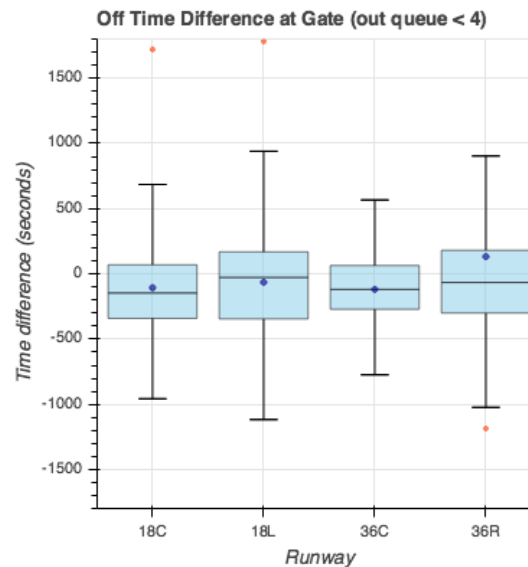


- Box plots for takeoff time difference at gate by runway
 - Departures only in queue size < 4 (from gate to runway)
 - Longer taxi-out times predicted in Run 1 (baseline)

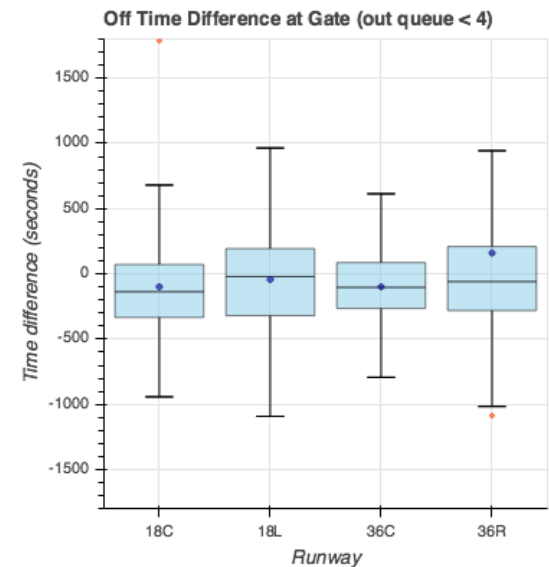
R1: Baseline



R2: Various speeds

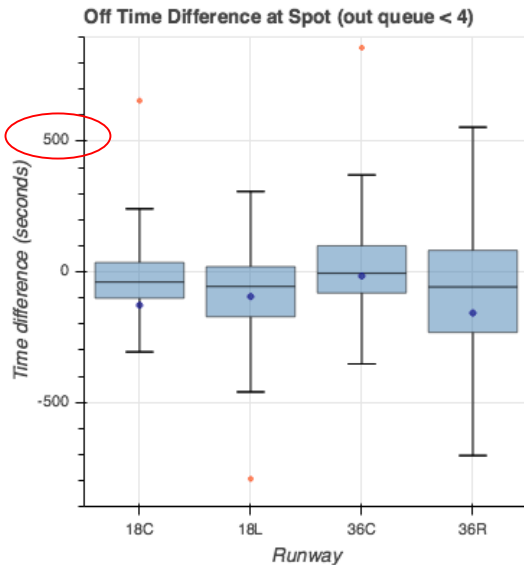


R3: Constant speed

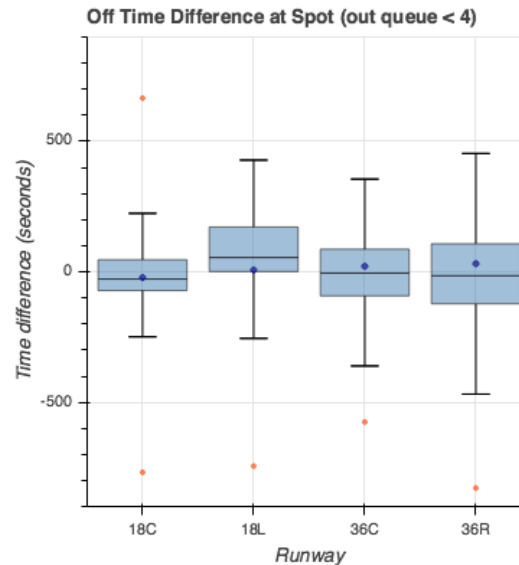


- Box plots for takeoff time difference at spot by runway
 - Departures only in queue size < 4 (from gate to runway)
 - Better prediction accuracy in Run 2 and 3 for Runway 36R

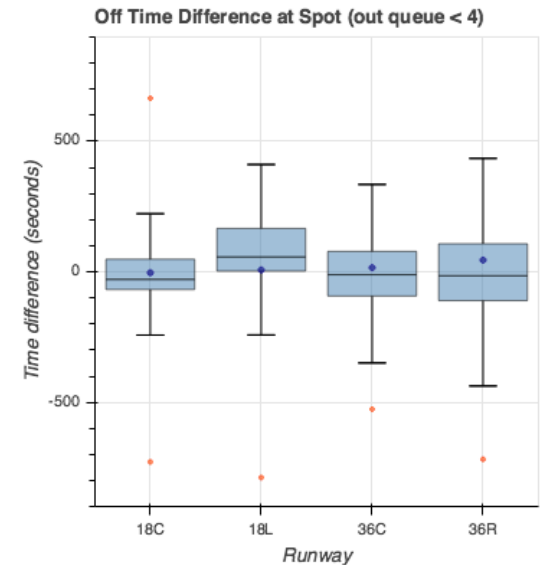
R1: Baseline



R2: Various speeds

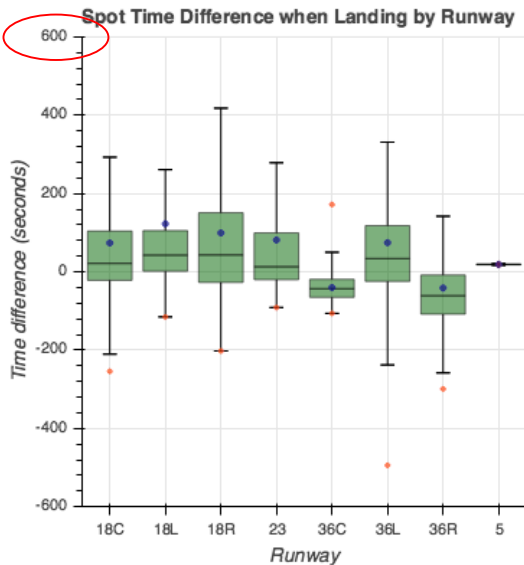


R3: Constant speed

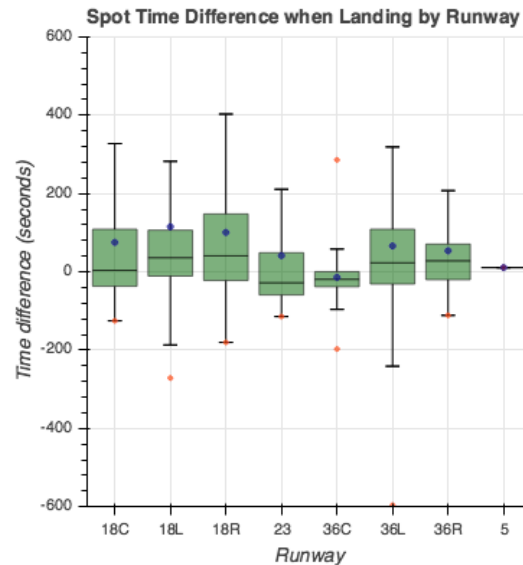


- Box plots for spot time difference when landing, grouped by runway
 - Show AMA taxi-in time prediction accuracy
 - $(\text{Actual spot time}) - (\text{Undelayed spot time estimate})_{\text{@landing}}$
 - Better prediction performance for arrivals than departures

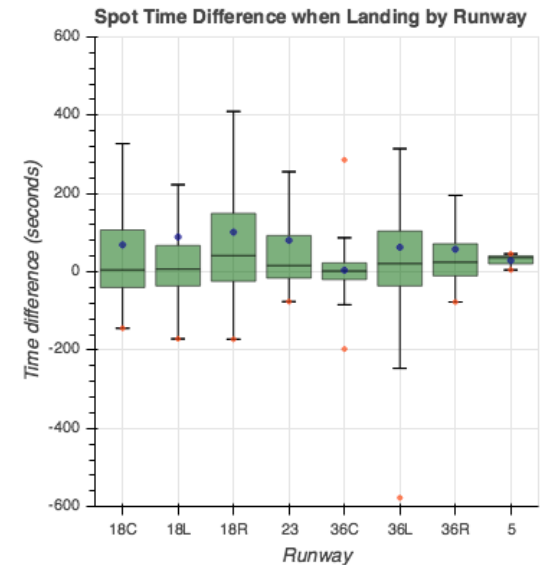
R1: Baseline



R2: Various speeds

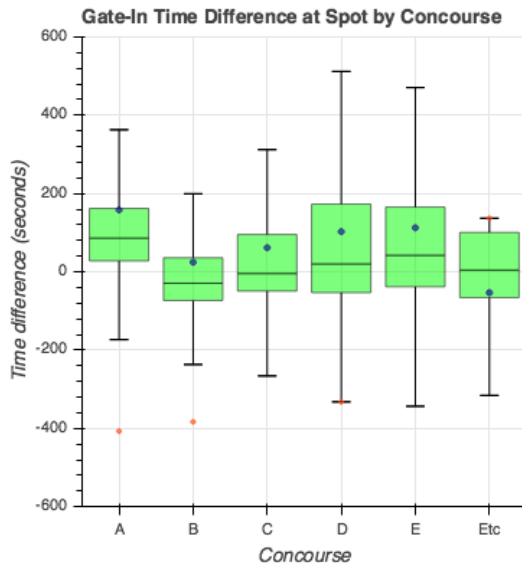


R3: Constant speed

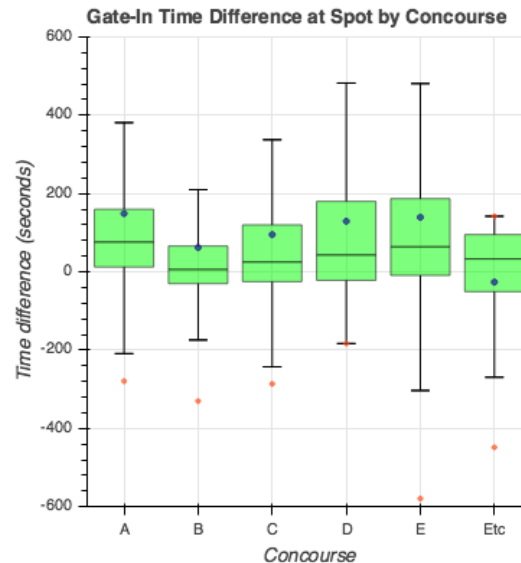


- Box plots for gate-in time difference at spot by concourse
 - Show ramp taxi-in time prediction accuracy
 - $(\text{Actual gate-in time}) - (\text{Undelayed gate-in time estimate})_{@spot}$
 - No significant difference between three runs
 - Relatively poor performance for Concourse A

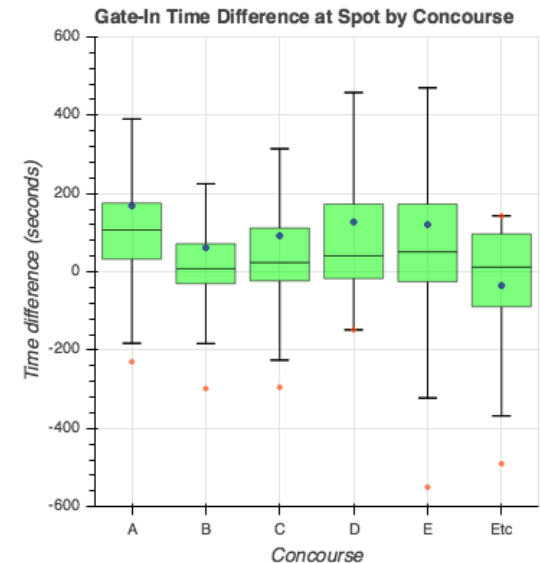
R1: Baseline



R2: Various speeds

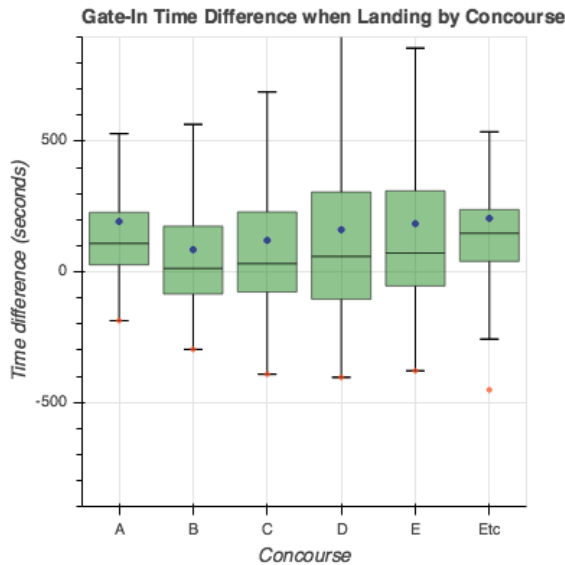


R3: Constant speed

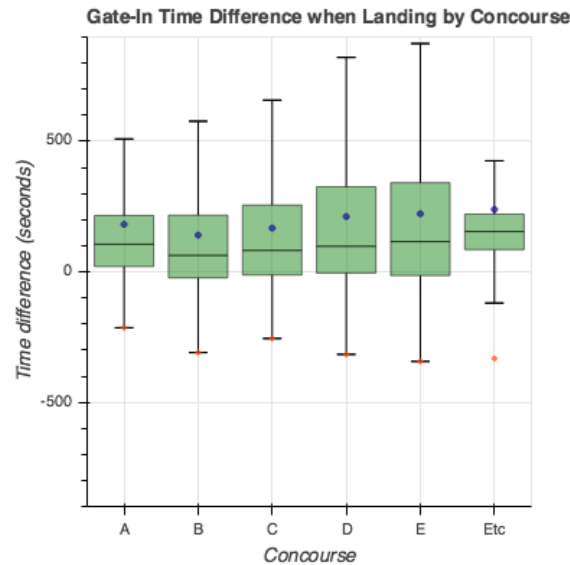


- Box plots for gate-in time difference when landing, grouped by concourse
 - Show total taxi-in time prediction accuracy
 - $(\text{Actual gate-in time}) - (\text{Undelayed gate-in time estimate})_{@landing}$

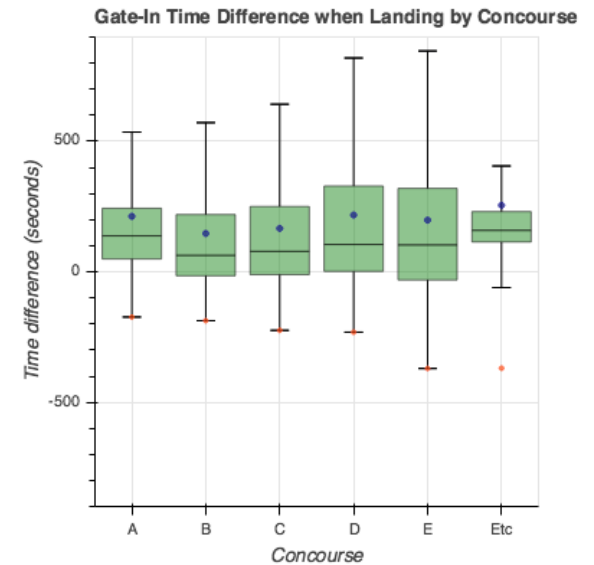
R1: Baseline



R2: Various speeds

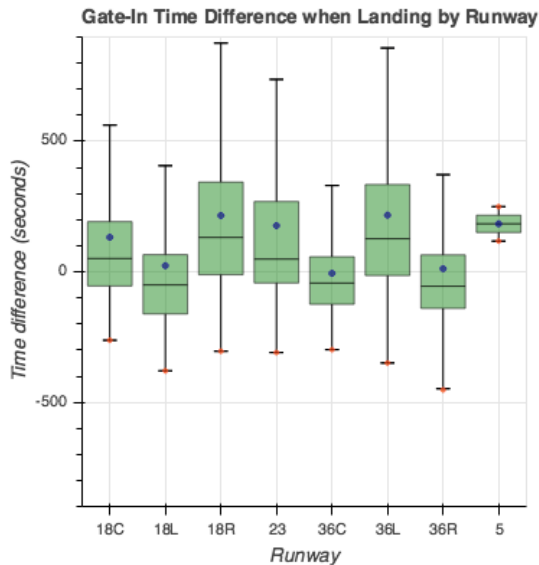


R3: Constant speed

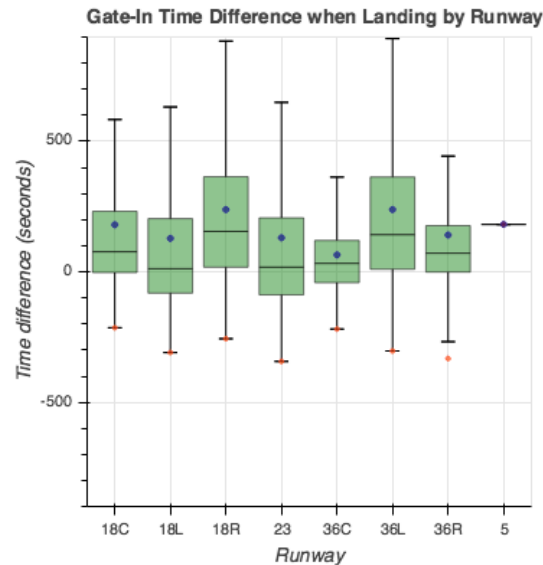


- Box plots for gate-in time difference when landing, grouped by runway
 - Show total taxi-in time prediction accuracy
 - $(\text{Actual gate-in time}) - (\text{Undelayed gate-in time estimate})_{@landing}$

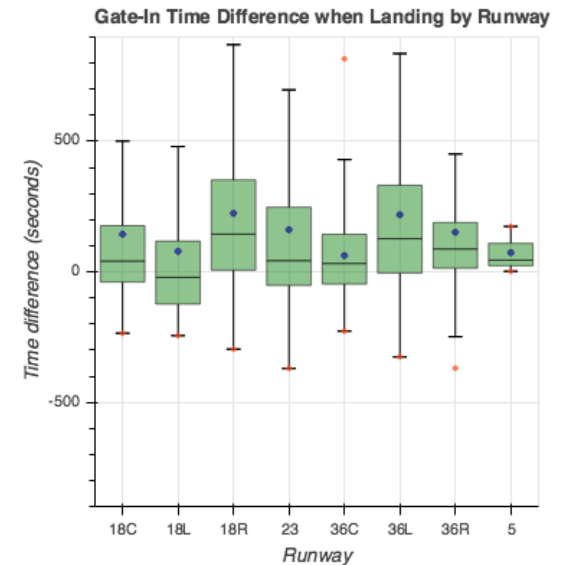
R1: Baseline



R2: Various speeds



R3: Constant speed



STBO ToolBar

TM Actions Create

NEW 3 OPEN ORD 1940

Timeline: Parking Gate

Arrival

Departure

Flight Status

Scheduled... Arrive... In...

Enroute... In... Term... Arr...

Enroute... Scheduled... Enroute... Arr...

Term... On... In...

In... In...

All

Actual sequence for Rwy 36C:
..., AAL1840, JIA5049, JIA5326, ...

Current time: 22:24:12

Estimated sequence for Rwy 36C:
..., AAL1840, JIA5049, JIA5326, ...

Timeline: Runway 18C/36C 18R/36L

Runway

18C/36C

18R/36L

JIA5230 E3

DAL826 BOBZY A3

SKW1377 BOBZY A10

AAL1809 ESTRR C13

AAL749 BOBZY C12

AAL1954 C13

JIA5455 E10

JIA5441 E27

SWA1543 A8

JIA5250 E14A

PDT4940 E38B

PDT4895 E36

JIA5278 E2

JIA5180 KRTR UNK

AAL733 ESTRR B16

JIA5271 BOBZY E6

AAL868 WEAZL UNK

PDT4976 ROBABY E38A

JIA5258 BOBZY E25

AAL1908 JOJJO D3

AAL470 ESTRR B5

JIA5037 BOBZY E22

JIA5429 JOJJO E32

XOJ1717 JOJJO UNK

GNQ7348 UNK

AAL463 C15

JIA5256 E32

JIA5143 E16

PDT4796 ROBABY E14A

JIA5326 PITTY E3

JIA5049 JOJJO E20

AAL1840 KRTR C4

EDV3492 JOJJO A5

AAL9940 ESTRR E10

AAL589 BOBZY D1

AAL1799 BOBZY B3

AAL673 ESTRR C3

AAL509 JOJJO C15

AAL765 JOJJO C2

JIA5101 E20

RWY 18C/36C 22:24:11

RWY 18R/36L

JIA5264 JOJJO E5

JIA5424 KRTR E16

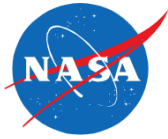
AAL721 BOBZY B6

AAL1804 B6

AAL732 C7

Dest	Origin	Flight Status	AC Type	Rwy	Gate	Gate Time	Spot	Spot Time
Z	CLT	Scheduled_Out	CRJ	E36C	E14/23:38 A8	E14/23:30	S125	E14/23:33
T	ILN	In_Ramp	B763	36R	14/21:28 UNK	E14/22:27	SC_1	14/21:32
T	MGM	Scheduled_In	D328	E36L	E14/22:09 UNK	E14/22:19	GA_2	E14/22:18
						14/23:50	S13	E14/23:55
						4/21:28	S27E	14/21:22
						4/21:55	S27E	14/21:22
						4/20:57	S27E	14/20:57
						14/23:18	S9W	E14/23:11
						14/22:06	S24	14/22:23
						14/21:23	E20	14/21:24
						14/22:01	E21	14/21:42
						14/20:05	E30	14/19:50
						14/20:54	E16	14/20:33
						14/20:36	E27	14/20:17
						14/21:09	E22	14/21:25
						14/20:36	E18	14/20:29
						14/21:09	HC_1	14/20:29
						14/20:52	E9	14/20:36
						14/20:52	E9	14/20:48

< STBO Client Timeline and Map >



- 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)