Evaluation of Departure Pushback Time Assignment Considering Uncertainty Using Real Operational Data

9 th SESAR Innovation Days

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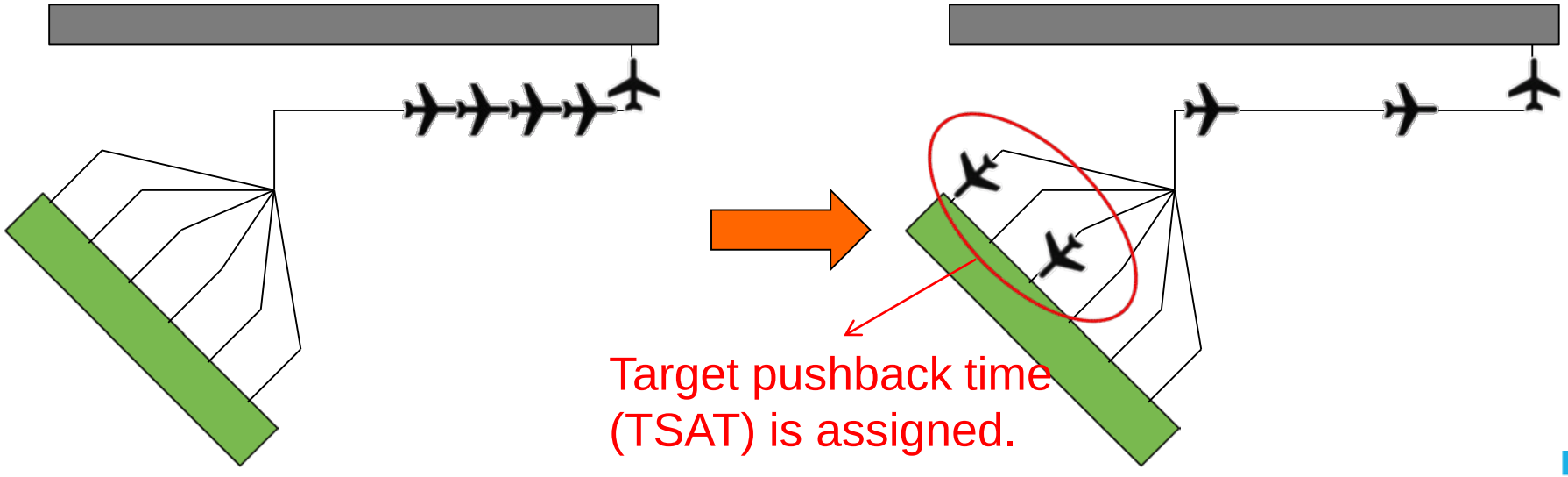
Background (1)

- Aviation growth causes airport congestions.
  - Both departure and arrival aircraft wait in long queues.
    - ➔ This research focuses on controlling departure aircraft.
- Pushback time control management (called TSAT operation: Target Start-up Approval Time) is promising.
  - Benefit
    - Reduce taxi-out time by waiting at the spot ➔ save fuel
  - Disadvantage
    - Take-off delay (throughput loss) due to too late pushback time assigned



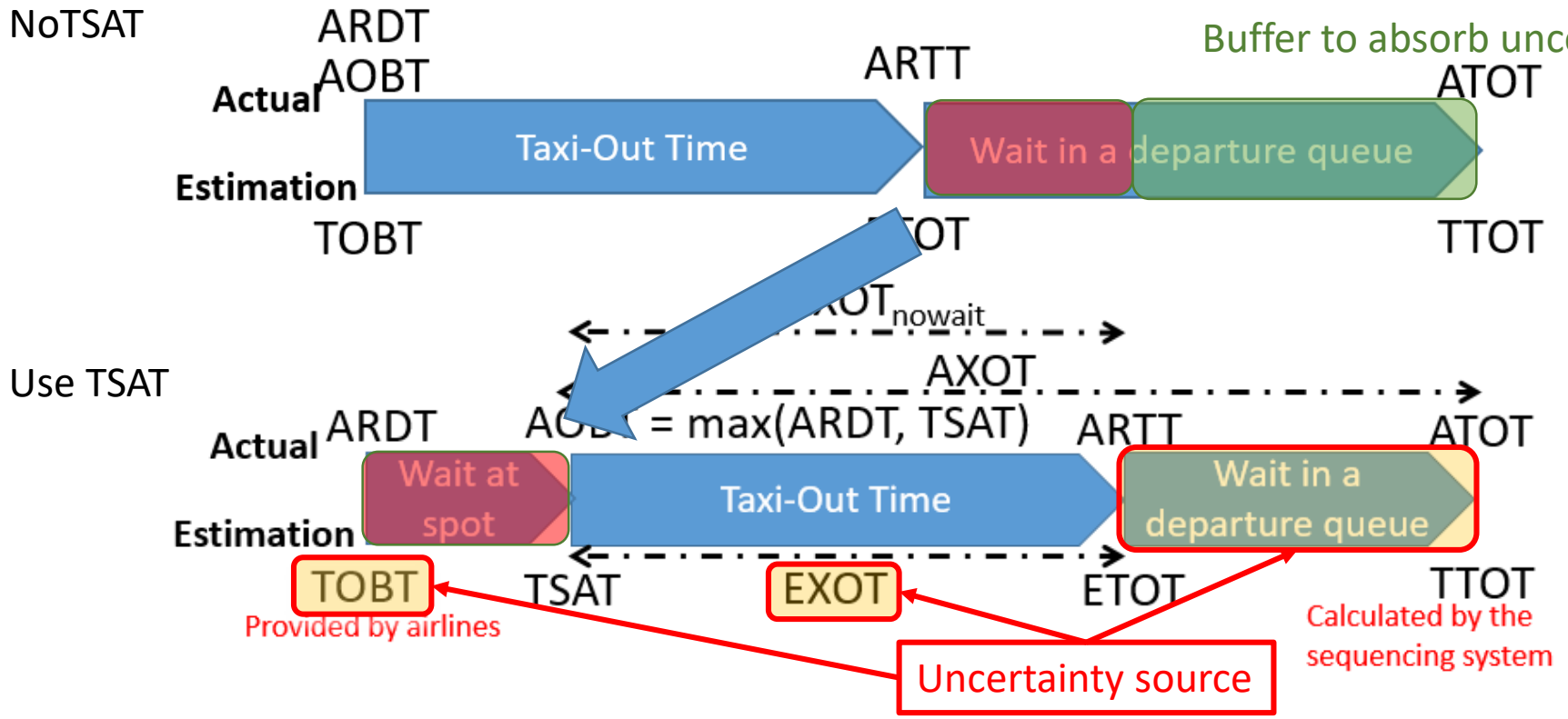
Background (2)

- Take-off delay (throughput loss) using TSAT is caused by departure uncertainty.
  - No take-off delay occurs if everything is known in advance.
  - TOBT (Target Off-Block Time: estimated time of aircraft ready for pushback) is the biggest uncertainty factor
- There are few researches to investigate the actual departure uncertainty.

➔ Therefore, this research will

- Investigate the actual departure uncertainty using real operational data at a mid-size French airport.
  - One month data in 2018 is available.
  - A single runway is used for departure only.
  - TSAT operation is already introduced.
- Compare several pushback time assignment algorithms and evaluate TSAT performance using “real” departure uncertainty environment.

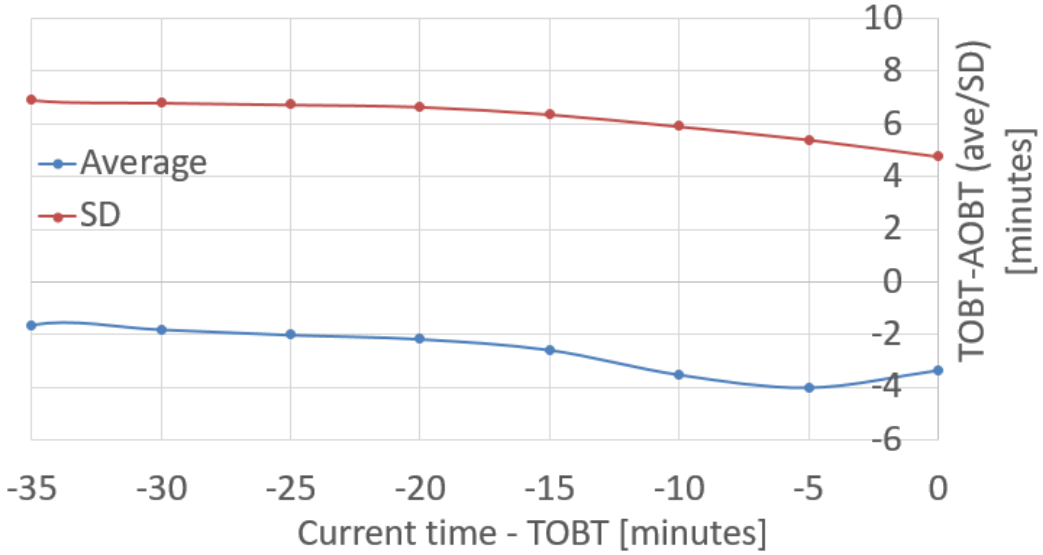
General TSAT assignment

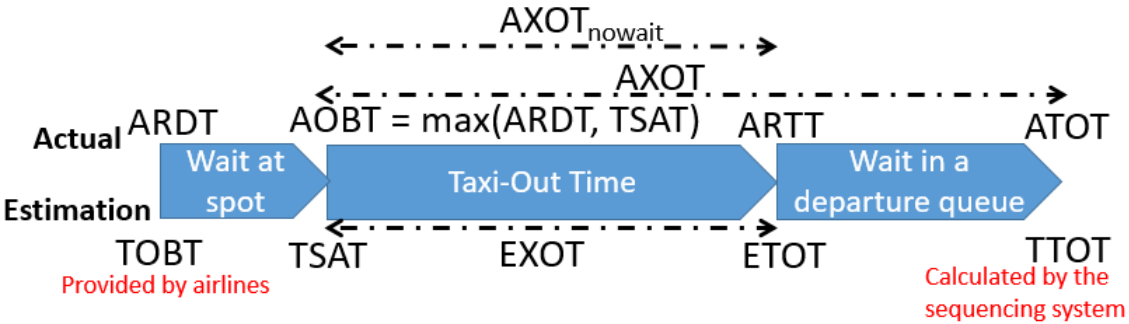


- Ready time for pushback
  - ARDT (Actual Ready Time)
  - TOBT (Target Off-Block Time)
- Pushback start
  - AOBT (Actual Off-Block Time)
  - TSAT

- Earliest possible take-off time
  - ARTT (Actual Ready for Take-off Time)
  - ETOT (Estimated Take-off Time)
- Take-off time
  - ATOT (Actual Take-off Time)
  - TTOT (Target Take-off Time)

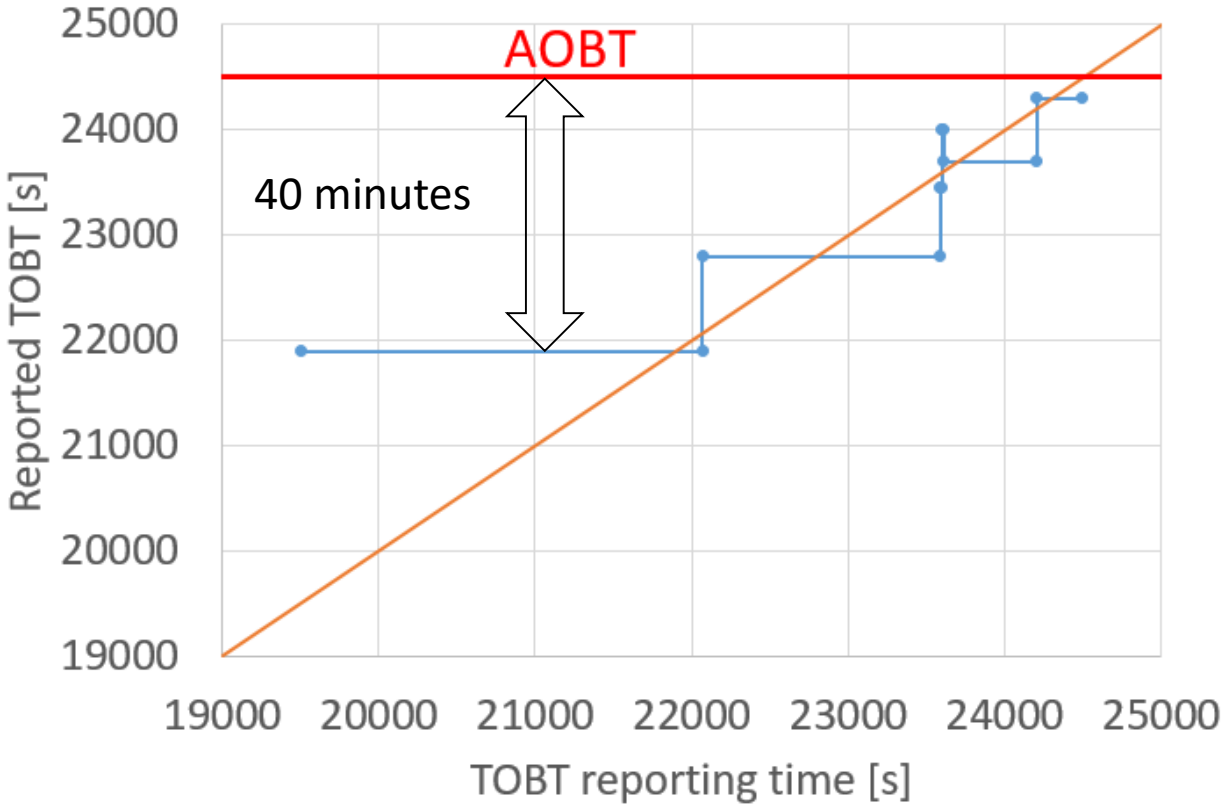
TOBT accuracy





- TOBT can be updated anytime.
  - TOBT accuracy is expected to become better as time progresses.
- According to the result,
  - TOBT accuracy is about 5 minutes of SD just before pushback.
  - TOBT-AOBT is always negative.
    - TOBT tends to be set earlier than actual.

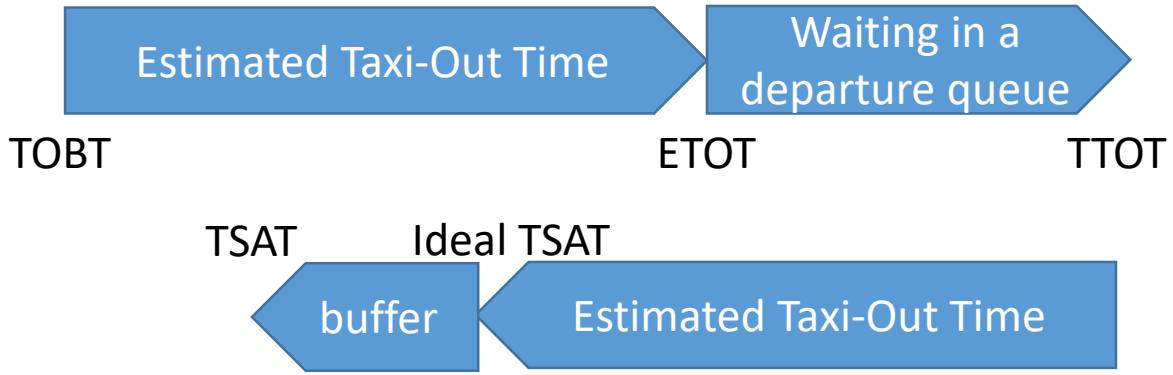
Example of TOBT update history



- Some aircraft do not update TOBT even if the aircraft cannot leave the gate around TOBT.
  - These aircraft are also considered in the simulation by using the TOBT update history.

Two methods for TSAT assignment (1)

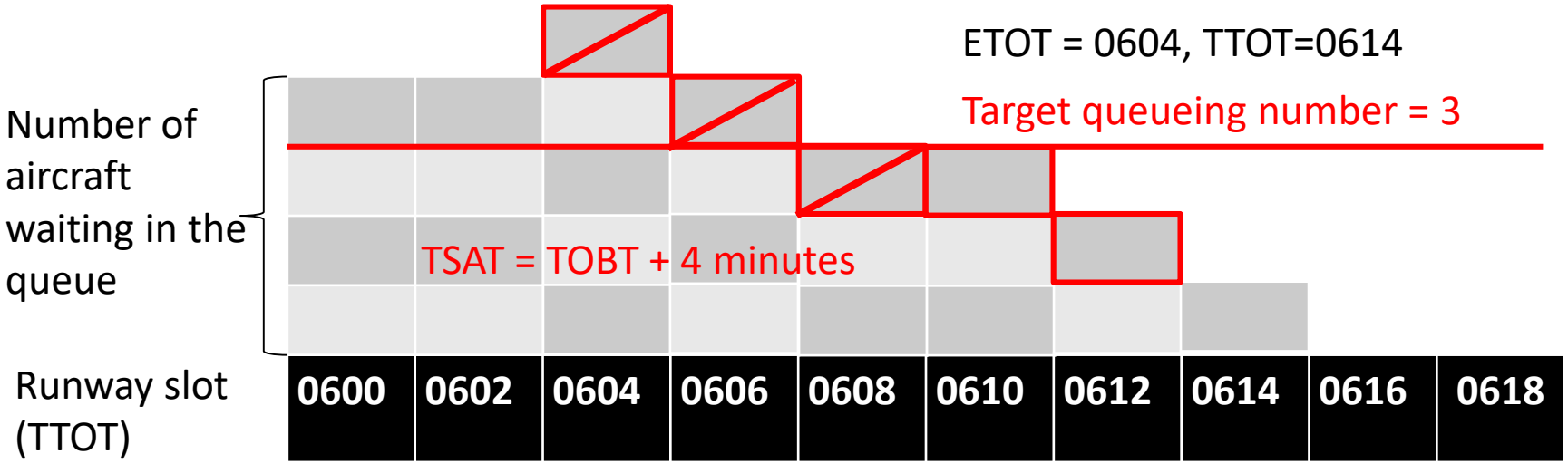
- Constant buffer method



  - The buffer (= TTOT-ETOT = wait in a departure queue) is set constant when TSAT is assigned.
  - Most existing TSAT assignment systems use this method.

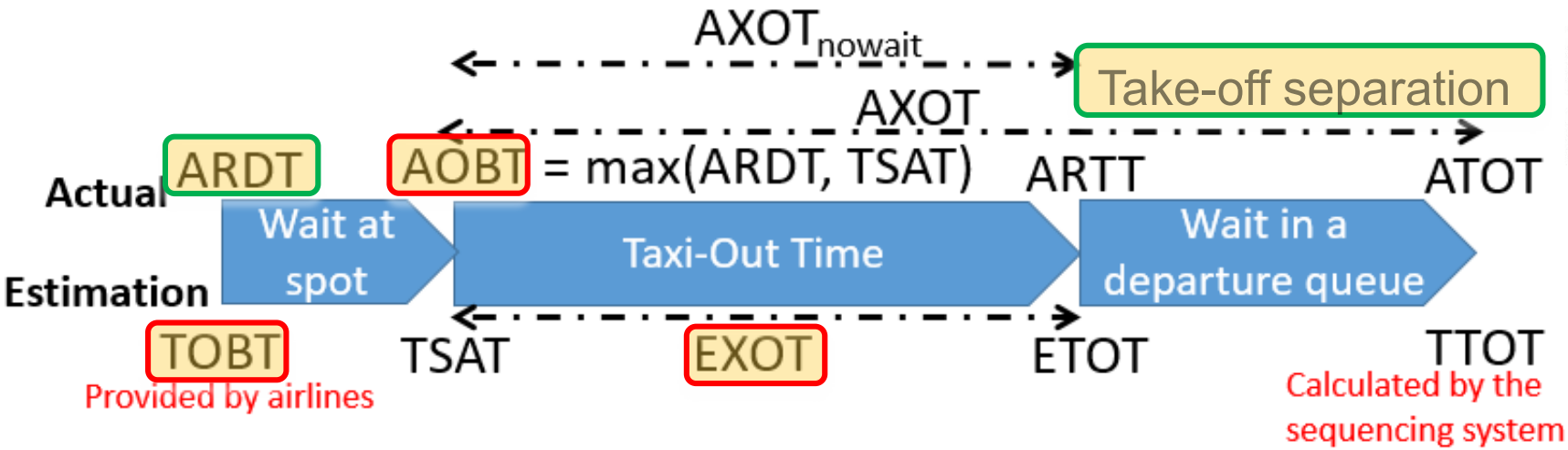
Two methods for TSAT assignment (2)

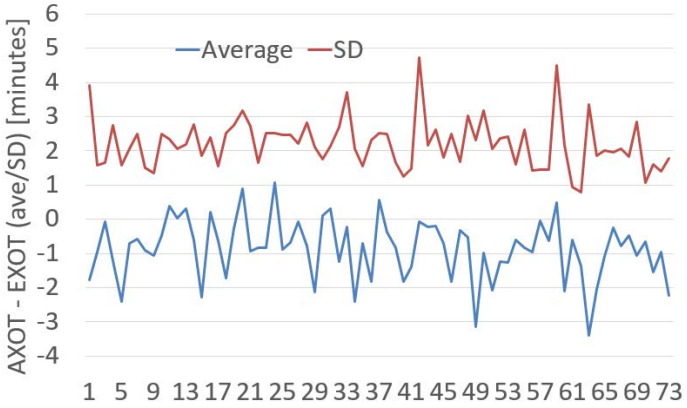
- Constant queueing number method



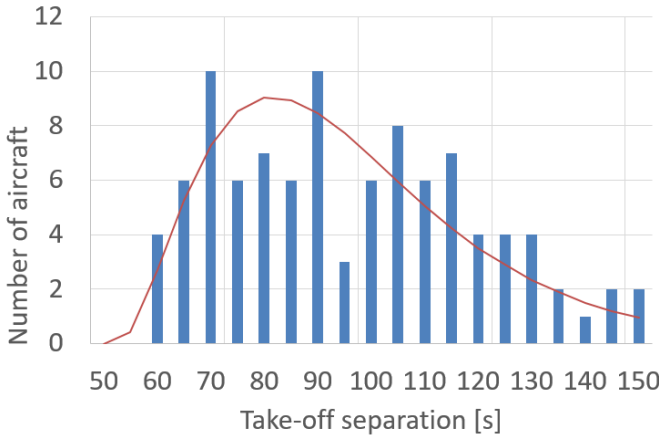
  - Keep the target queueing number in each time slot.
  - Previous research confirmed that this method outperforms the constant buffer method.
    - Later slides shows both results.

Simulation model for evaluation





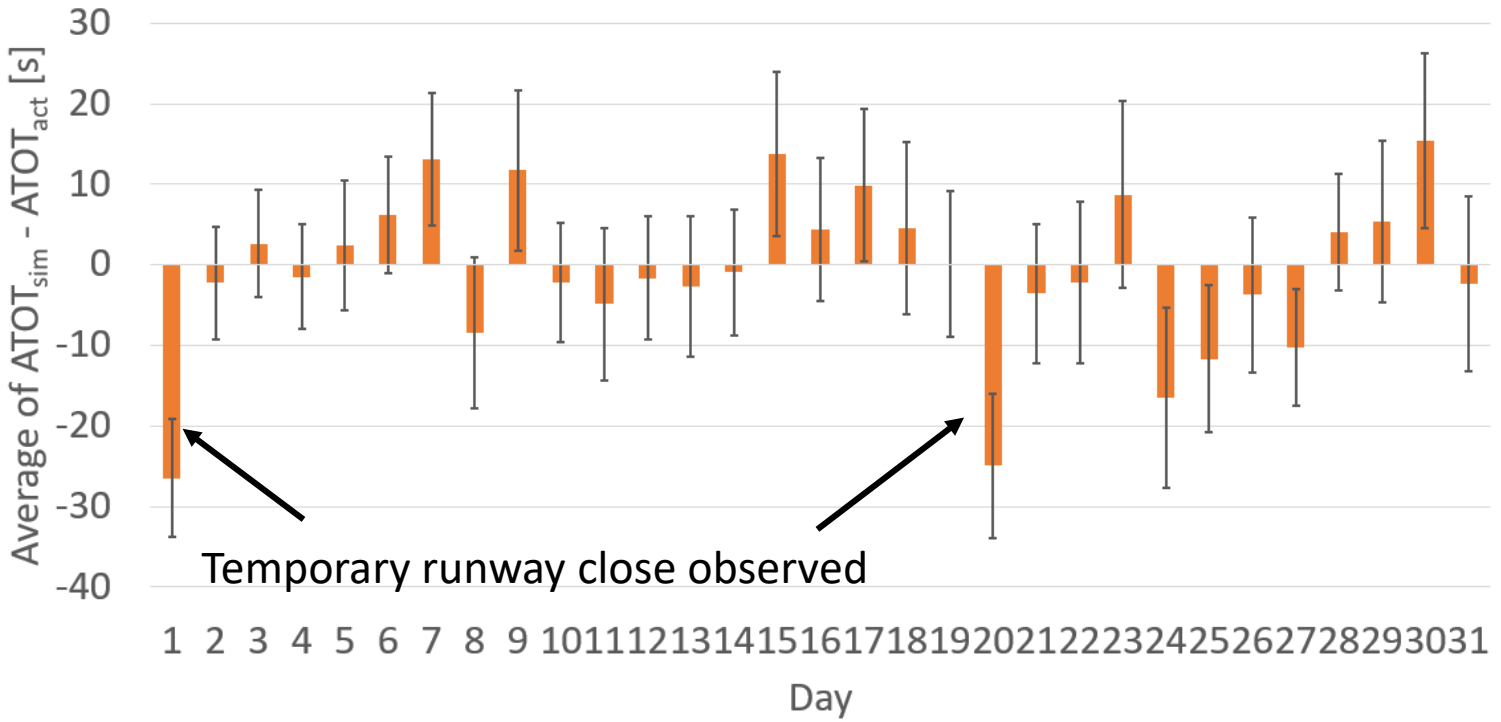
EXOT accuracy

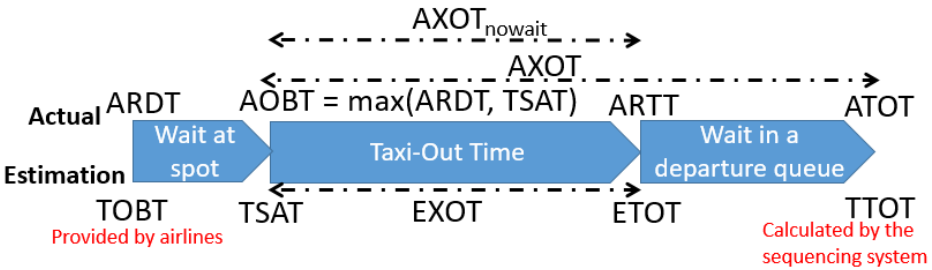


Distribution of take-off separation

- To simulate the realistic airport operation for evaluation of TSAT assignment algorithm, the actual value is used as much as possible.
  - The actual traffic demand is used.
  - Actual TOBT history is used to assign TSAT.
  - If TSAT is not assigned in actual operation, ARDT = AOBT.
  - The actual take-off separation is used, if the actual separation is [50, 120] s.
- Other unknown parameters follow random distribution based on data.
  - ARDT is estimated using TOBT.
  - $AXOT_{nowait}$ is estimated using EXOT.

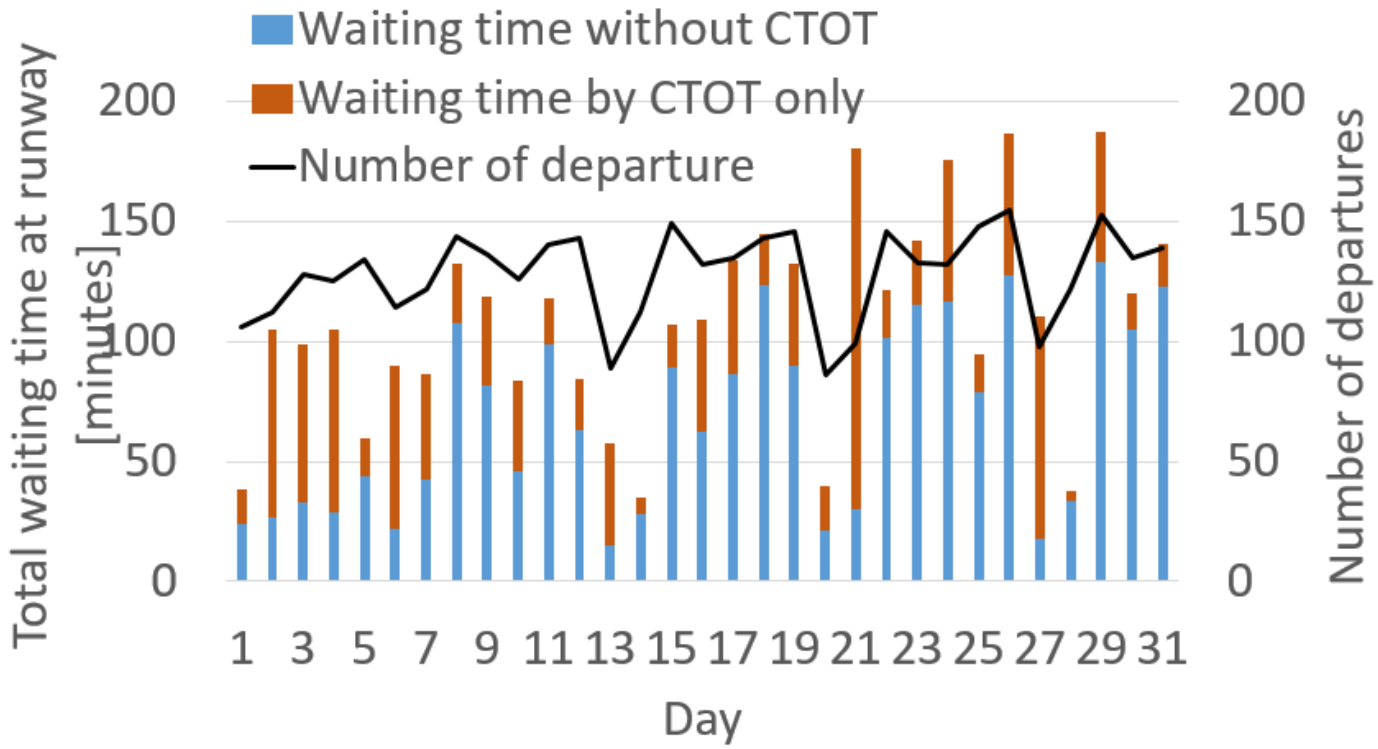
Simulation accuracy





- Simulation is conducted assuming AOBT$_{sim}$ = AOBT$_{act}$.
  - ATOT$_{sim}$ is expected to be the same as ATOT$_{act}$.
  - Average of 100 times simulation.
  - Simulation seems to model the airport traffic reasonably.

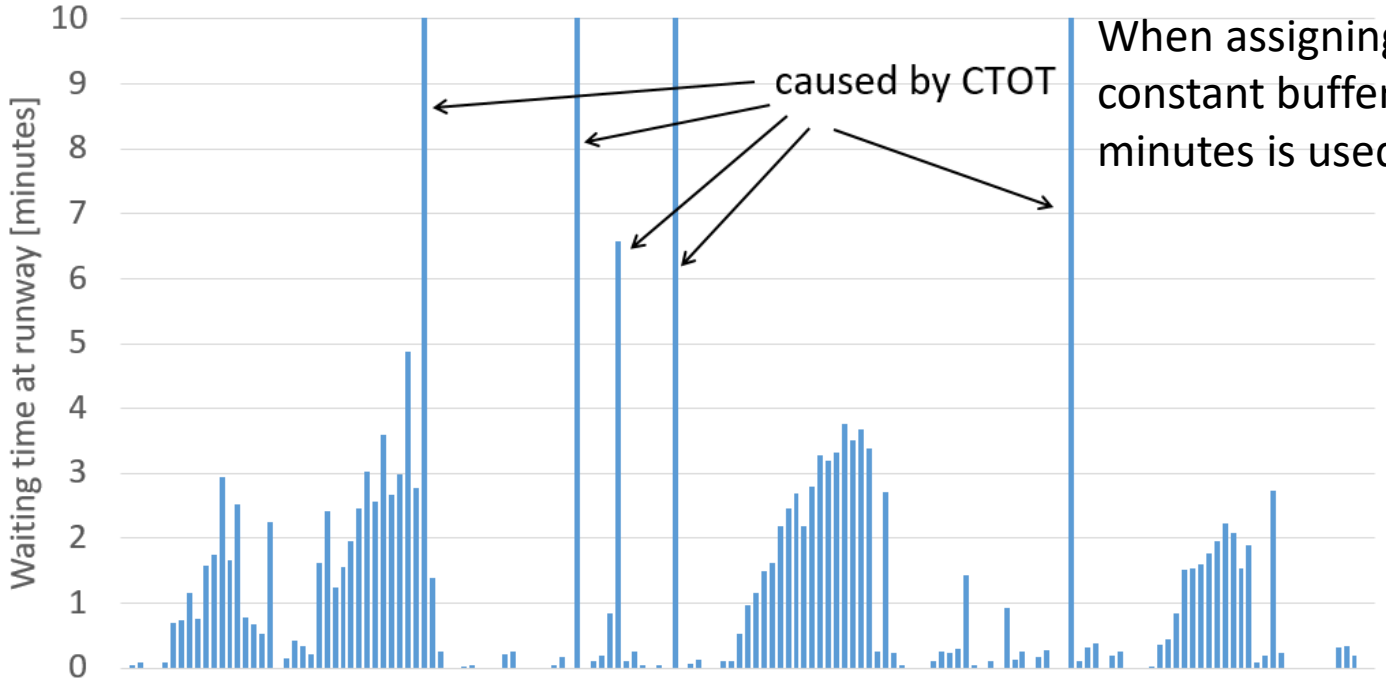
Waiting time in a departure queue



- Waiting time is caused by
  - Congestion at the runway
  - CTOT

- CTOT: Controlled Take-Off Time
  - The aircraft has to take-off after CTOT due to ATC requirement.
- Larger waiting time is observed with larger traffic.
- Waiting time caused by CTOT is about 40% of total waiting time.
- Waiting time per aircraft is at most about 1 minute.

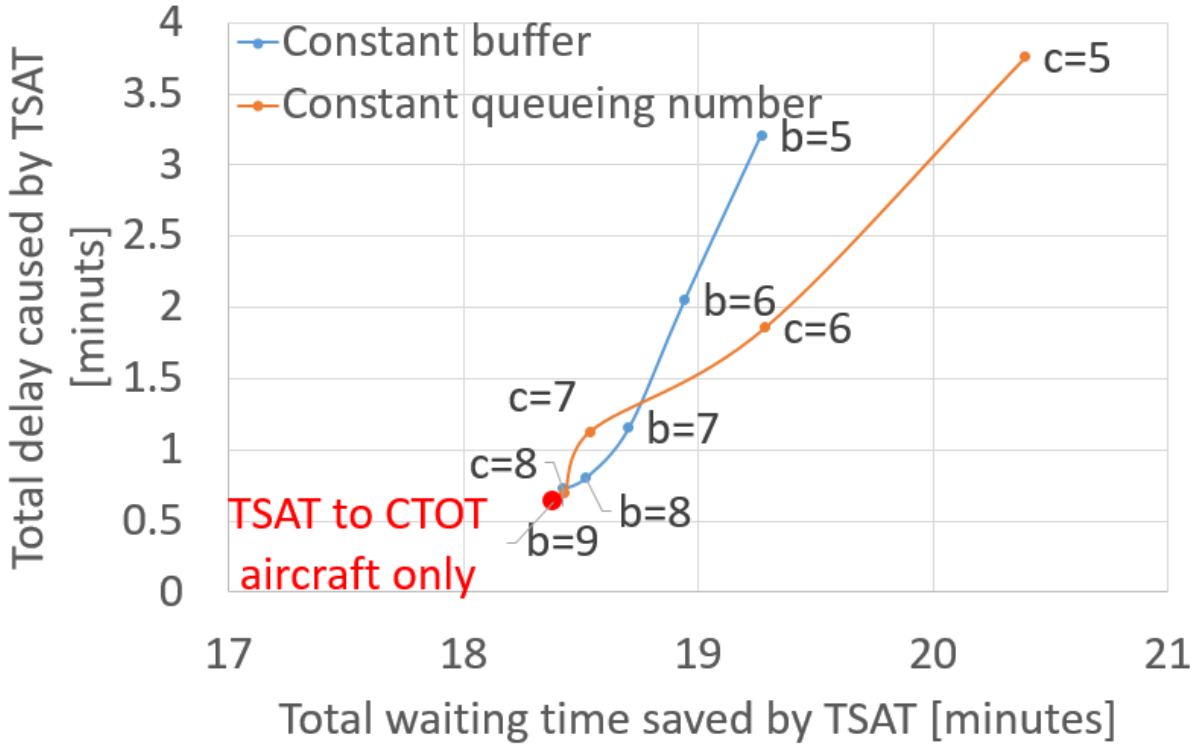
Waiting time on Day 29



When assigning TSAT, constant buffer of 5 minutes is used.

- The maximum waiting time caused by runway congestion is less than 5 minutes.
  - TOBT accuracy is 5-7 minutes of SD.
- TSAT is not expected to work at this airport.

Waiting time saved and delay caused by TSAT

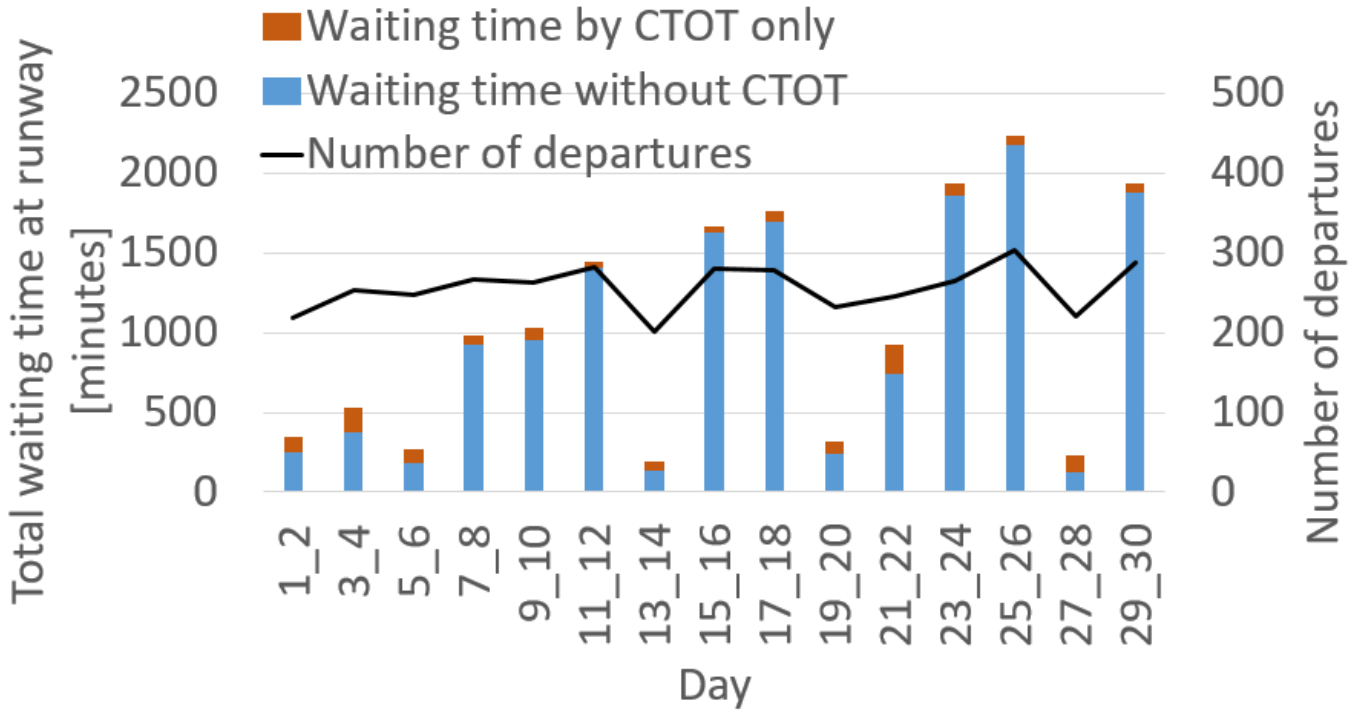


- As for CTOT aircraft, 18 minutes waiting time is saved while 0.6 minutes delay is caused.
- As for other aircraft, waiting time saved is nearly equal to delay caused by TSAT.
  - TSAT does not work well.

Heavy traffic simulation

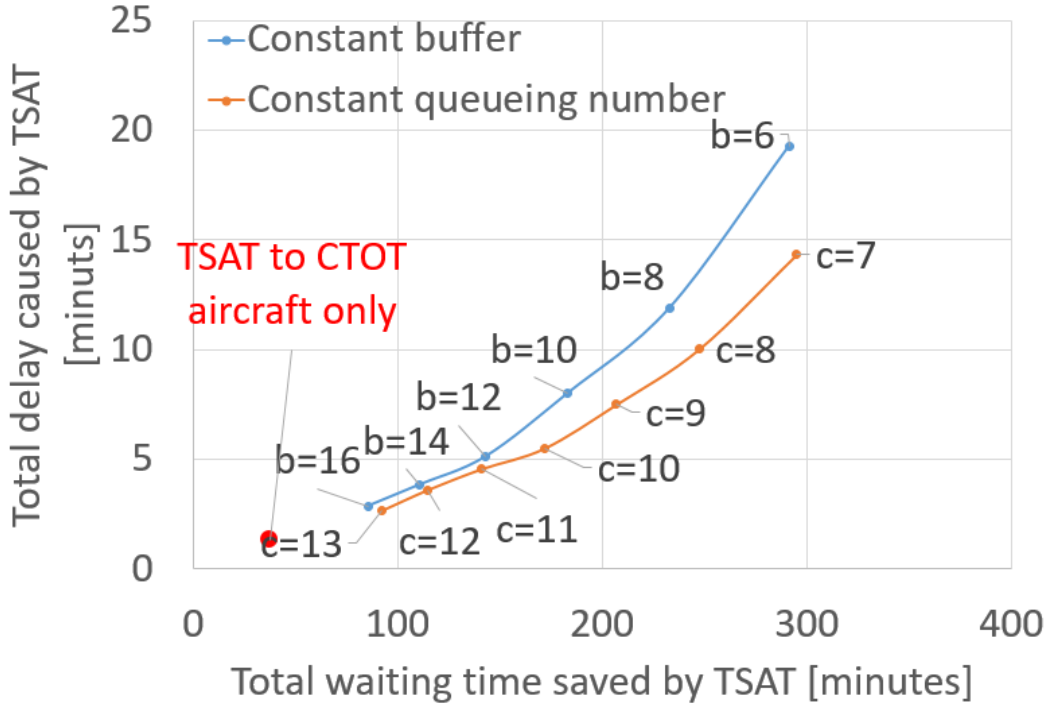
- Single day traffic is not heavy enough to use TSAT at this airport.
- Double day traffic is assumed.
  - 2 days traffic are merged on a single day.
    - No effect (e.g. gate congestion) is considered due to double traffic.
  - Heavy traffic situation can be easily simulated.
    - TOBT/CTOT history can be used.

Waiting time in a departure queue assuming double traffic



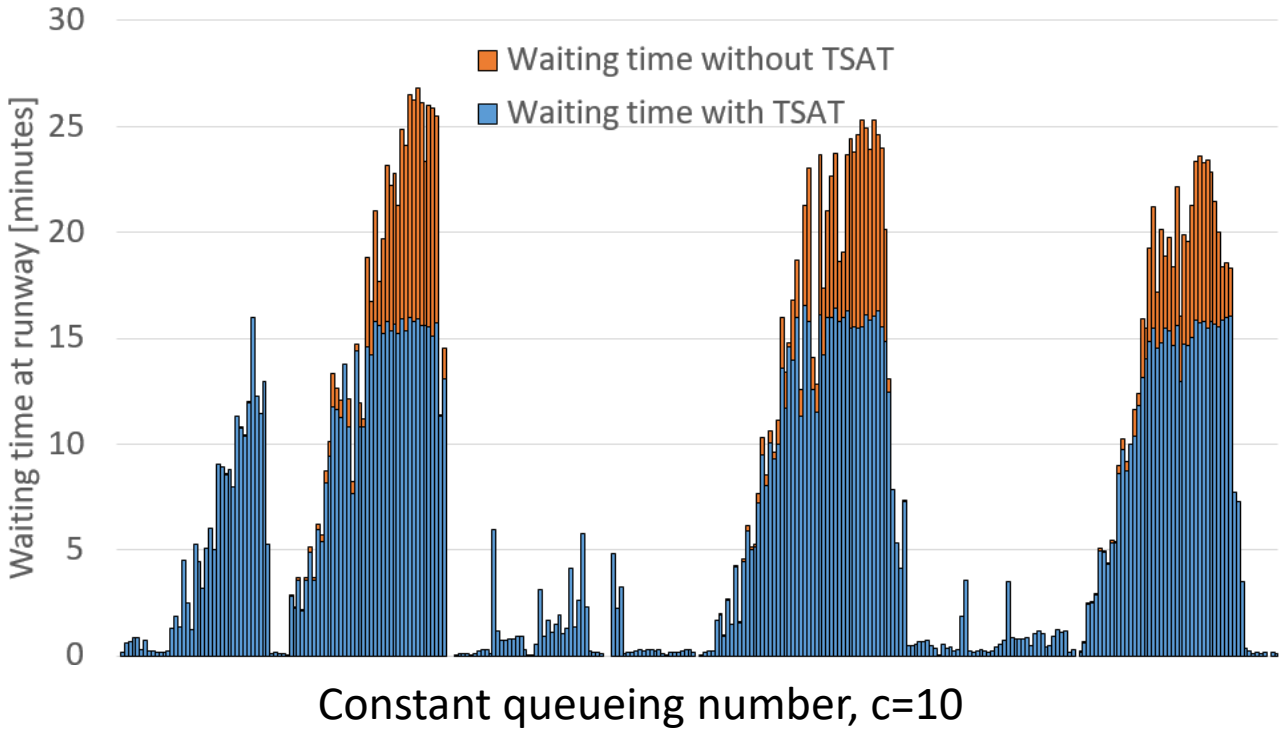
- On a single day, waiting time is about 100 minutes.
- Assuming double traffic, minimum about 200 minutes (1.06 min/aircraft), maximum about 2200 minutes (7.39 min/aircraft).

Waiting time saved and delay caused by TSAT (double traffic)



- Much larger waiting time saved is observed due to double traffic.
- As expected, the constant queueing number method outperforms the constant buffer method.

Waiting time on Day 25 and 26



- Overall, waiting time more than 15 minutes is saved by TSAT.
  - SD of TOBT accuracy is 5-7 minutes, so the result is expected.

Summary

- TOBT accuracy is investigated using real operational data.
  - SD of TOBT accuracy is at least 5 minutes.
- Two TSAT assignment algorithms are evaluated with the simulation model developed with data.
  - Constant queueing number method outperforms constant buffer method.
- Traffic at the considered airport is too small, and the use of TSAT is not beneficial.
  - Assuming double traffic, TSAT will potentially work.
- Further TOBT accuracy improvement will be necessary in the future.