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

Ryota Mori (ENRI)
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

Target pushback time (TSAT) is 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

NoTSAT

Use TSAT

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

Uncertainty source

• 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)

Buffer to absorb uncertainty

Provided by airlines

Calculated by the sequencing system

Wait at spot

- ARDT
- TOBT

Wait in a departure queue

- ARTT
- ETOT
- TTOT

Estimated Taxi-Out Time

- TOBT

Actual Taxi-Out Time

- AOBT = max(ARDT, TSAT)

- TSAT

- EXOT

- ETOT

- TTOT

Wait in a departure queue

- ARTT
- ATOT
- TTOT

Actual Ready Time

- ARDT

Actual Off-Block Time

- AOBT

Actual Take-off Time

- ATOT

Target Take-off Time

- TTOT

Target Off-Block Time

- TOBT

Target Ready Time

- TSAT

Buffer to absorb uncertainty

Engage
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

- 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\text{\_nowait} is estimated using EXOT.

### Take-off separation

- \( \text{AXOT} = \max(\text{ARDT}, \text{TSAT}) \)
- \( \text{ARTT} \)
- \( \text{ATOT} \)
- \( \text{AXOT\text{\_nowait}} \)
- \( \text{TXT} \)
- \( \text{Wait in a departure queue} \)

### Estimation

- Actual TOBT
- \( \text{AOBT} \)
- Wait at spot
- \( \text{AXOT\text{\_nowait}} \)
- \( \text{EXOT\text{\_nowait}} \)

### Diagram

- Distribution of take-off separation
- EXOT accuracy
- AXOT - EXOT (ave/SD) [minutes]

### Graphs

- Average
- SD

- Number of aircraft
  - 50
  - 60
  - 70
  - 80
  - 90
  - 100
  - 110
  - 120
  - 130
  - 140
  - 150
Simulation accuracy

- Simulation is conducted assuming $\text{AOBT}_{\text{sim}} = \text{AOBT}_{\text{act}}$.
  - $\text{ATOT}_{\text{sim}}$ is expected to be the same as $\text{ATOT}_{\text{act}}$.
  - 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

- 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.

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