EN-024

A Simulation Study on a Method of Departure Taxi Scheduling at Haneda Airport

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Outlines

- Background and objectives
  - Characteristics of Haneda airport

- Traffic management algorithm

- Results of fast-time simulation experiment
  - Reduction of taxiing and queuing time
  - Guarantee of takeoff time

- Discussion

- Conclusion
Backgrounds

- **Corresponding R&D vision**
  - ICAO ASBU (Aviation Systems Block Upgrades)
    - Module 80: Airport CDM (Collaborative Decision Making)
    - Module 15: AMAN/DMAN (Arrival/Departure Manager)
  - Corresponding R&D reports in Europe and the United States says…
    - Airport CDM is effective for improving efficiency and punctuality of airport operation
  - **CARATS** (JAPAN: Collaborative Actions for Renovation of Air Traffic Systems)
    - Bottlenecks at congested airports and airspaces in the Greater Tokyo Metropolitan area, etc. must be eliminated
Aims of the study

To examine a traffic management method suitable for Haneda airport
  – Departure taxi scheduling

Expected performance

1. Reduction of taxiing time
   - Especially for departure

2. Transparency in takeoff time planning and execution (guarantee of takeoff time)
About Haneda airport (1/2)

- The most congested airport in Japan
  - Over 1,000 movements per day
  - Origin and destination of major air traffic flow in Japan
- Mainly used for domestic airways
About Haneda airport (2/2)

Complex layout and operation

- 4 runways (2 pairs of parallel runways)
- 3 or 4 runways constantly active
- Interference between runways occurs frequently
- Gates: densely located around terminal buildings
Interference between runways

Example of southerly wind configuration

Departure flight path
Arrival flight path (considering go-around)
Simulated surface traffic flow (simulator developed by ENRI)
Location of congestion at Haneda

- Almost limited in the area before departure runway
  - Relevant to apply taxi scheduling (queue management)

Mapping of taxiing time with speed less than 10 [km/h] (excl. pushback)

Departures (504 flights)
Simplified congestion model

Focusing on takeoff queues
- Dynamics of congestion will be determined by…
  - Takeoff capacity of runway system
  - Number of departures reaching takeoff queue
- Takeoff capacity drops temporarily due to interference with arrival flow

Gates → Apron/Taxiway
FIXED taxi times w.r.t gate-runway pair
Takeoff queues
Final approach
Runway system
Runway capacity constraint model

Based on Gilbo’s capacity model

- Count (#dep., #arr.) observations in 5 minute time window, rejecting (0,0) as exception
- Evaluate the proportion of each (#dep., #arr.) in total observations

<table>
<thead>
<tr>
<th>#dep.</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>#arr.</td>
<td></td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>21.0%</td>
<td>11.6%</td>
<td>5.7%</td>
<td>1.2%</td>
</tr>
<tr>
<td>1</td>
<td>18.3%</td>
<td>17.1%</td>
<td>13.0%</td>
<td>5.4%</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>3.9%</td>
<td>1.5%</td>
<td>1.0%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Capacity constraint assumption

$\#\text{dep}[/5\text{min}] \leq 3 - \#\text{arr}[/5\text{min}]$
Departure scheduling algorithm 1/2

- Taxi time table
- Queue prediction
- Block-out time assignment
- Takeoff time window assignment
- Final approach
- Arrivals
- Runway capacity model
- Runway system

- Gates
- Apron/ Taxiway
- Takeoff queues
- Departures
  - Predicted flow
  - Actual flow
### Departure Scheduling Algorithm 2/2

**a) Predicted Interfering Landing Number per 5 Minutes**

- One arrival within 5-minute window

**b) Predicted Takeoff Demand per 5 Minutes**

- One departure within 5-minute window

**c) Takeoff Time Window Assignment**

Block-out time assignment

Queue prediction

Takeoff time window assignment

- Departure scheduling algorithm 2/2
Baseline scenario

Derived from observation of actual operation
- Block-out/ -in time and gate
- Takeoff / landing time and runway

Hourly traffic volume

Through the day
Dep.: 504 flights
Arr.: 525 flights
Modified scenario

94 departures were assigned block-out delay

- Sum of delay: 249 min.
- Many for congested period in the evening

![Graph showing the number of departures with delayed block-out over time (JST)]
Simulation result

Baseline scenario

Modified scenario

Queue reduction in congested period (19:30 JST)
**Reduction of taxiing time**

**How to measure**

- Comparing taxiing/queuing time between the simulation result of baseline and modified scenario

<table>
<thead>
<tr>
<th>Baseline Scenario</th>
<th>DEP003</th>
<th>DEP002</th>
<th>DEP001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxiing time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Queuing time</td>
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**Performance index 1.**

- Time
Reduction of taxiing time

Significant reduction in the evening

– Through the day: total 2.12% (133 min.) reduction for departure taxiing time
 Guarantee of takeoff time

How to measure

– Punctuality: takeoff within the assigned takeoff time window

Performance index 2.

Takeoff Assigned window

Too early

Takeoff Assigned window

On time

Takeoff Assigned window

Too late
Performance index 2.

**Guarantee of takeoff time**

- 63.3% of departures took off within assigned time window

<table>
<thead>
<tr>
<th>Difference b/w planned and resulting takeoff time [min]</th>
<th>Too early</th>
<th>On time</th>
<th>Too late</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>92 acft.</td>
<td>319 acft.</td>
<td>93 acft.</td>
</tr>
<tr>
<td></td>
<td>(18.2%)</td>
<td>(63.3%)</td>
<td>(18.5%)</td>
</tr>
</tbody>
</table>
Discussion

18.2% took off slightly earlier than assigned window (up to 4 min., mostly within 2 minutes)
  – Due to rough assumption on runway capacity
    Sometimes #dep. + #arr. > 3

18.5% took off later than assigned window
  – In some cases, large deviation from assigned window
    Though, takeoff times are same as baseline results
  – Due to unmodeled congestion factor
    Congestion at aprons

These may be solved by detailed modeling
Conclusions

Traffic management method suitable for Haneda airport
  – Departure taxi scheduling

Good performance obtained
  – Reduction in departure taxi time: 2.12%
  – Guarantee on takeoff time: 63.3%

Problems to be solved
  – More precise forecast of runway capacity
  – Taxi time prediction method considering apron congestion
Acknowledgement

The authors express special thanks to the Japanese Civil Aviation Bureau (JCAB) of the Ministry of Land, Infrastructure, Transport and Tourism (MLITT) for providing the source data.

and especially…

Thank you for your attention!

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Motivation

- CARATS says…
  - “Bottlenecks at congested airports and airspaces in the Greater Tokyo Metropolitan area, etc. must be eliminated”

- Many literatures report effectiveness of Airport CDM
  - How will Airport CDM work at Haneda airport?

Our research topics

- Technical arguments on traffic management at Haneda airport
  - Post-operation data processing
  - Surface traffic flow analysis
    - Identification of congested area
    - Queue analysis
  - Airport surface movement simulator
  - Traffic management methods
  - Evaluation methods for traffic management
Traffic management algorithm 1/2

Arrivals assumed as independent movement
- Landing time assumed as fixed
  → enabling takeoff capacity prospect

Time management for departures
- Predict takeoff demand at runway from initial planning of departing gate
- Detect excess demand compared to the prospect of takeoff capacity
- Assign wait at gate for excess demand
Congestion at apron

- Departure’s taxiing route is blocked by arrivals