Modeling Deicing Operations in Departure Scheduling using Fast Time Simulation

Zhifan Zhu, Vashali Hosagrahara, KBRWylie/SGT Inc
Yoon Jung, Hanbong Lee, NASA Ames Research Center
Yeonju Eun, Daekeun Jeon, Korea Aerospace Research Institute

38th Digital Avionics Systems Conference
San Diego, California, USA, Sep 8-12, 2019
Deicing operation is a procedure to remove frost, ice, slush, or snow from aircraft, and to apply anti-icing fluid to aircraft surface if needed.

Courtesy of James Lee for the image at https://www.flickr.com/photos/ronaldlee/4266798167, shared under the license: https://creativecommons.org/licenses/by/2.0/legalcode
**Incheon International Airport** requires deicing operations in winter season

- 2015-16 winter season analysis showed multiple deicing days
- Dec 3rd, 2015 had 190 deicing operations, ~40% of departures
Motivation

- Deicing operations impact on airport operations
  - Extra workload to controllers
  - Extra aircraft time on ground
  - Extra uncertainty to surface traffic management

- Insufficient study in managing deicing operations as off-nominal use case
  - Not considered as part of departure scheduling problem
  - No individual aircraft based decision support tool existing today
Research Objectives

• Understand how deicing operations affect surface traffic movement
• Evaluate deicing service resource management strategies
• Investigate scheduling of deicing aircraft to improve efficiency of surface operations
Outline

• Deicing Operations at Incheon International Airport (ICN)
• Approach
• Deicing Model and Departure Scheduler
• Simulation Environment
• Results and Analysis
• Summary and Future Work
ICN Deicing Operations

ICN layout

Runways

<table>
<thead>
<tr>
<th></th>
<th>Arrival</th>
<th>Departure</th>
</tr>
</thead>
<tbody>
<tr>
<td>North flow</td>
<td>33R, 34, (33L)</td>
<td>33L, 34</td>
</tr>
<tr>
<td>South flow</td>
<td>15L, 16, (15R)</td>
<td>15R, 16</td>
</tr>
</tbody>
</table>

Deicing zones

<table>
<thead>
<tr>
<th>Wingspan Category</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>A South</td>
<td>2</td>
<td></td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>A North</td>
<td>10</td>
<td></td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>M South</td>
<td></td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>M North</td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D South</td>
<td>4</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>D North</td>
<td>4</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>T Center</td>
<td>4</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ICN Deicing Control Procedure

1. Pilot contacts Deicing Position (DP) at Ramp for deicing request

2. DP assigns a deicing zone to the aircraft

3. Pilot calls when ready and obtains pushback clearance

4. Aircraft leaves gate and taxies to the assigned zone

5. Aircraft arrives at the Zone and gets a pad assignment from DP

6. Aircraft taxies to the pad and deicing service starts

7. Pilot contacts ATC for pre-departure clearance during deicing

8. Pilot contacts Ramp to taxi out of deicing zone after deicing
• Develop a deicing model at ICN and integrate it with a departure runway scheduler
• Create a deicing day traffic scenario
• Conduct fast time simulations and analyze the results

* SOSS: Surface Operations Simulation and Scheduler
Deicing Model

- Deicing request decision (for simulation only)
- Deicing zone assignment
- Deicing zone time
Deicing Request

- Deicing request decision – at gate when aircraft ready to pushback
- Use a uniform distribution sampling
- A single parameter -- deicing request rate, e.g. 40%
Deicing Zone Assignment Heuristic

- A priority zone list based on departure gate, runway and ac type

  Zone List: First → Second → Last → Gate Hold

  Overflow

- Zone load condition = assignment / capacity
  example: 4 assignments to a zone of having two wingspan category E pads → load condition = 200% for E

- Overflow: if the front zone’s loading condition >= a prescribed threshold, move onto the next zone on the list

- Gate hold: if all zones are overloaded, hold aircraft at gate

- Example: from a terminal gate to runway 33L
Zone Time

Normal distribution based on 2015-16 winter data

- zone in and zone out (grouped by aircraft wingspan categories)
- bad data points filtered out

<table>
<thead>
<tr>
<th>Category</th>
<th>Samples (%)</th>
<th>μ (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>29.8%</td>
<td>21.01</td>
</tr>
<tr>
<td>D</td>
<td>5.3%</td>
<td>20.58</td>
</tr>
<tr>
<td>E</td>
<td>56.6%</td>
<td>25.19</td>
</tr>
<tr>
<td>F</td>
<td>8.2%</td>
<td>24.98</td>
</tr>
<tr>
<td>All</td>
<td>100%</td>
<td>23.67 (σ =11.0)</td>
</tr>
</tbody>
</table>
• Schedules runway time using aircraft group priorities and unimpeded surface transit time

• Groups aircraft in priorities
  – Arrival
  – Departure in taxiing
  – Departure ready at deicing zone to runway
  – Departure ready at gate to runway

• Schedules departure gate pushback and zone exit time
  – Gate/zone to runway: target off time – unimpeded transit time
  – Gate to deicing zone: once zone assignment made
Traffic Scenarios

- Data source from the Dec 3, 2015 operations

<table>
<thead>
<tr>
<th>Departures</th>
<th>33L</th>
<th>34</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Deicing</td>
<td>171</td>
<td>69</td>
<td>240</td>
</tr>
<tr>
<td>Deicing</td>
<td>118</td>
<td>67</td>
<td>185</td>
</tr>
<tr>
<td>Total</td>
<td>289</td>
<td>136</td>
<td>425</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arrivals</th>
<th>33L</th>
<th>33R</th>
<th>34</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>34</td>
<td>286</td>
<td>110</td>
<td>430</td>
</tr>
</tbody>
</table>

- Two simulation scenarios were created:
  - The 24-hour scenario was used for simulation validation
  - The 5-hour scenario from 08:00 to 13:00 local time was used for the study in Monte Carlo runs
Simulation Validation

- Validation scenario: the 24-hour from Dec 3\textsuperscript{rd}, 2015 (north flow)
- Departures push @AOBT (actual off-block time) of the operations
- Arrivals land @ON\_Time (actual wheels on time) of the operations
- Deicing zone/pad assignments and deice times match the actual operations
- SOSS configuration adjusted for best possible match up to actual operations
Simulation Setup

- Traffic scenario: the 5-hour traffic scenario from Dec 3rd 2015 operations

<table>
<thead>
<tr>
<th></th>
<th>33L</th>
<th>34</th>
<th>33R</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Departure</td>
<td>73</td>
<td>65</td>
<td>138</td>
<td></td>
</tr>
</tbody>
</table>

- Deicing model configurations
  - Deicing rate – **40%**
  - Deicing zone assignment heuristic (three zone lists)
    - Terminal to 33L : [A South, A North]
    - Cargo to 33L : [D South, D North, A South]
    - Terminal and Cargo to 34 : [M South, M North]
  - **Three** deicing zone load thresholds: [100%, 150%, 200%]
Analysis Metrics

- Zone assignment
- Zone queue size
- Deicing aircraft taxi out times
- Deicing gate hold *
- Runway and zone throughputs *

* Analysis can be found in paper
The model used the first-choice zones for majority of the requests.

At 100% threshold, the first-choice zone capacity meets the 80-85% deicing request.

In actual operations, zone assignments are spread out.

### Zone Assignment

<table>
<thead>
<tr>
<th></th>
<th>33L</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% threshold</td>
<td>71% (19%)</td>
<td>85% (15%)</td>
</tr>
<tr>
<td>150% threshold</td>
<td>84% (4%)</td>
<td>98% (2%)</td>
</tr>
<tr>
<td>200% threshold</td>
<td>88% (2%)</td>
<td>100% (2%)</td>
</tr>
</tbody>
</table>

**Actual Operations**

<table>
<thead>
<tr>
<th></th>
<th>M South</th>
<th>A South</th>
<th>A North</th>
<th>M North</th>
<th>98%</th>
<th>6%</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% threshold</td>
<td>24%</td>
<td>28%</td>
<td>38%</td>
<td>2%</td>
<td>28%</td>
<td>6%</td>
</tr>
<tr>
<td>150% threshold</td>
<td>24%</td>
<td>28%</td>
<td>38%</td>
<td>2%</td>
<td>28%</td>
<td>6%</td>
</tr>
<tr>
<td>200% threshold</td>
<td>24%</td>
<td>28%</td>
<td>38%</td>
<td>2%</td>
<td>28%</td>
<td>6%</td>
</tr>
</tbody>
</table>
Overloading the deicing zones increases the queue sizes → potentially add extra waiting time in the queues
Taxi Out Times of Deicing Aircraft

Measurements:

- Gate out
- Zone in
- Zone out
- Wheels off

- Zone time

- Gate to Zone
- Zone to Off

- Taxi Out
Mean Taxi Out Times of Deicing Aircraft

- Comparable gate to zone times among simulations
- Shorter zone to wheels-off times when more first-choice zones were used
Taxi Out Time STD of Deicing Aircraft

- No clear trend of overall taxi out time predictability change
- Gate to zone and zone to wheels-off predictabilities went in opposite directions as more first-choice zones assigned
- Better zone to wheels-off predictabilities suggest runway schedule of deicing aircraft from zone
A deicing model was developed for ICN and integrated with departure scheduling in fast time simulations

- Heuristic zone assignment to balance the deicing zone load and taxi and waiting times
- Traffic scenario and deicing demand derived from a heavy deicing day operation
- Monte Carlo simulations conducted using three zone load conditions
The simulations showed

- Increasing deicing zone load resulted in
  - reduced zone to runway taxi time and improved predictability
  - decreased gate to zone taxi time predictability
- Comparable overall taxi out times in different zone load conditions
- Potential benefit to have deicing support in departure scheduling for the off-nominal operation condition
Future Work

• Improve the deicing model to include dynamic zone capacity
  – Number of deicing trucks
  – Fatigue factor over time
• Include airline deicing operator contract constraint in zone assignment algorithm (ICN specific)
• Consider runway capacity reduction in deicing days
• Evaluate the benefit of integrating the deicing model in ICN departure management system
The End

Questions

e-mail: zhifan.zhu@nasa.gov