Lightning Impacts on Flight Operations

Matthias Steiner
NCAR Research Applications Laboratory
msteiner@ucar.edu

With contributions from
Wiebke Deierling, Kyoko Ikeda (NCAR)
and Randy Bass (FAA)
The Problem in a Nutshell

Hazard – Lightning

Concern – Personnel Safety

Impact – Operational Efficiency

Mitigation – Ramp Closure

When Thunder Roars, Go Indoors!

Seek shelter in a substantial building or hard-topped vehicle.

www.lightningsafety.noaa.gov
Ramp Closure Impacts on Air Traffic

- **Ramp Closure Impacts**
  - gate pushback delay (no service)
  - taxi-out queuing (backlog)
  - taxi-in delay (gate availability)
  - delayed deplaning of passengers
  - delayed turn-around times

- **Airport Balance**
  - aircraft landing, but no departures
  - potential for gridlock
  - impact ripple effects into national airspace system
**Annual Impact Statistics**

- **Direct Impacts**
  - gate pushback delays are substantial (on average several tens of minutes per affected flight)
  - dependent on weather, demand, & airport complexity

- **Indirect Impacts**
  - taxi-out queuing delays as part of backlog recovery (on average 5 – 15 minutes)
  - taxi-in delays caused by unavailable gates (on average 5 – 20 minutes)
  - ripple effects beyond airport

- **Other Lessons**
  - weather alone is not good proxy for measuring traffic impacts

---

### Average delays, taxi times & range of uncertainty for several major airports

<table>
<thead>
<tr>
<th>Airport</th>
<th>Metric</th>
<th>Ramp Closures min – max</th>
<th>No Closures min – max</th>
<th>Average Impact Minutes/Flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATL</td>
<td>Gateway Departure Delay</td>
<td>59.11 – 83.48</td>
<td>9.27 – 10.07</td>
<td>61.6</td>
</tr>
<tr>
<td></td>
<td>Taxi Out</td>
<td>29.37 – 35.20</td>
<td>17.91 – 18.06</td>
<td>14.3</td>
</tr>
<tr>
<td></td>
<td>Gateway Arrival Delay</td>
<td>36.41 – 45.02</td>
<td>5.58 – 6.31</td>
<td>34.8</td>
</tr>
<tr>
<td></td>
<td>Taxi In</td>
<td>13.14 – 21.68</td>
<td>8.98 – 9.02</td>
<td>8.4</td>
</tr>
<tr>
<td>DEN</td>
<td>Gateway Departure Delay</td>
<td>44.95 – 77.28</td>
<td>12.86 – 13.76</td>
<td>47.8</td>
</tr>
<tr>
<td></td>
<td>Taxi Out</td>
<td>21.47 – 25.75</td>
<td>14.72 – 14.87</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Gateway Arrival Delay</td>
<td>25.31 – 41.63</td>
<td>6.93 – 7.76</td>
<td>26.1</td>
</tr>
<tr>
<td></td>
<td>Taxi In</td>
<td>11.78 – 24.92</td>
<td>8.62 – 8.69</td>
<td>9.7</td>
</tr>
<tr>
<td>EWR</td>
<td>Gateway Departure Delay</td>
<td>60.11 – 70.17</td>
<td>14.96 – 15.79</td>
<td>49.8</td>
</tr>
<tr>
<td></td>
<td>Taxi Out</td>
<td>24.46 – 44.98</td>
<td>20.22 – 20.36</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td>Gateway Arrival Delay</td>
<td>36.18 – 65.89</td>
<td>11.81 – 12.63</td>
<td>38.8</td>
</tr>
<tr>
<td></td>
<td>Taxi In</td>
<td>11.26 – 14.74</td>
<td>8.56 – 8.61</td>
<td>4.4</td>
</tr>
<tr>
<td>IAD</td>
<td>Gateway Departure Delay</td>
<td>61.17 – 98.20</td>
<td>12.47 – 13.20</td>
<td>66.9</td>
</tr>
<tr>
<td></td>
<td>Taxi Out</td>
<td>15.87 – 32.47</td>
<td>16.55 – 16.76</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Gateway Arrival Delay</td>
<td>37.29 – 63.52</td>
<td>6.26 – 6.69</td>
<td>43.9</td>
</tr>
<tr>
<td></td>
<td>Taxi In</td>
<td>11.59 – 24.54</td>
<td>6.71 – 6.75</td>
<td>11.3</td>
</tr>
<tr>
<td>IAH</td>
<td>Gateway Departure Delay</td>
<td>35.23 – 55.28</td>
<td>10.47 – 11.10</td>
<td>34.5</td>
</tr>
<tr>
<td></td>
<td>Taxi Out</td>
<td>21.45 – 28.82</td>
<td>15.51 – 15.64</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>Gateway Arrival Delay</td>
<td>16.23 – 24.42</td>
<td>4.05 – 4.40</td>
<td>16.1</td>
</tr>
<tr>
<td></td>
<td>Taxi In</td>
<td>9.34 – 13.36</td>
<td>7.38 – 7.42</td>
<td>4.0</td>
</tr>
<tr>
<td>MCO</td>
<td>Gateway Departure Delay</td>
<td>42.65 – 70.06</td>
<td>9.08 – 10.19</td>
<td>46.7</td>
</tr>
<tr>
<td></td>
<td>Gateway Arrival Delay</td>
<td>17.65 – 29.20</td>
<td>4.46 – 5.16</td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td>Taxi In</td>
<td>13.52 – 22.70</td>
<td>7.43 – 7.60</td>
<td>10.6</td>
</tr>
<tr>
<td>MIA</td>
<td>Gateway Departure Delay</td>
<td>25.99 – 45.70</td>
<td>8.39 – 9.14</td>
<td>27.1</td>
</tr>
<tr>
<td></td>
<td>Taxi Out</td>
<td>22.22 – 23.56</td>
<td>16.17 – 16.46</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>Gateway Arrival Delay</td>
<td>11.07 – 17.01</td>
<td>2.59 – 3.22</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td>Taxi In</td>
<td>9.68 – 15.17</td>
<td>7.82 – 7.91</td>
<td>4.6</td>
</tr>
<tr>
<td>ORD</td>
<td>Gateway Departure Delay</td>
<td>70.61 – 104.01</td>
<td>15.06 – 16.02</td>
<td>71.8</td>
</tr>
<tr>
<td></td>
<td>Taxi Out</td>
<td>21.50 – 30.57</td>
<td>16.15 – 16.41</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>Gateway Arrival Delay</td>
<td>48.79 – 71.77</td>
<td>8.85 – 9.90</td>
<td>50.9</td>
</tr>
<tr>
<td></td>
<td>Taxi In</td>
<td>18.78 – 42.91</td>
<td>9.32 – 9.43</td>
<td>21.5</td>
</tr>
</tbody>
</table>

Uncertainty related to procedures & lightning data is substantial
Ramp Closure Decisions

**Today’s Approach**
- reactive based on lightning within critical distance
- reset waiting period with each lightning strike
- commercial decision support

**Dilemma**
- balancing safety & efficiency
- definition & quantification of risk
- risk tolerance

---

**Challenge – Uncertainties Everywhere**
- balancing safety & efficiency
- definition & quantification of risk
- risk tolerance

**Challenge – Personnel Safety & Minimal Downtime**

**Lightning Information**
- detection efficiency (sensor & network)
- classification uncertainty (in-cloud & cloud-to-ground)
  - location accuracy
  - network evolution
  - choice of network

**Procedures**
- safety rules (distance & time)
- efficiency (minimal downtime)
- decision support tools
- centralized versus distributed guidance
- automated or human centric

**Human Cognition & Behavior**
- trust in approach
- implementation of procedures (communication & timeliness)
  - watching other stakeholders
  - operational distractions

---

**Where is Sweet Spot?**

---

**Challenge – Uncertainties Everywhere**
Uncertainties with Lightning Networks

• **Measurement**
  - sensor (partial measure of spectrum)
  - network (station density & placement)
  - detection efficiency

• **Processing**
  - classification (IC & CG; stroke & flash)
  - spatial extent & location accuracy
  - data transmission & dissemination

• **Other Factors**
  - multiple national networks
  - regional total lightning networks
  - notable differences in detection efficiency & location accuracy
  - evolution of networks & algorithms

• **Implications**
  - missed lightning threats yield no ramp closures => people at risk of getting hurt
  - unnecessary ramp closures (closed too long or no closure needed due to false alarm) => inefficient operations
  - uncertainties cause confusion, potential safety risks & inefficiencies
Effectiveness of Ramp Closure Implementation

- **Procedures**
  - reflecting varied degrees of risk tolerance
  - increased pressures for operational efficiency
  - tight rules may not necessarily yield smaller impacts
  - source of lightning matters

- **Human Cognition & Behavior**
  - effectiveness of implementing established procedures varies by operator, time of impact, supervisor, etc.
  - sometimes closing ramp early, but most often late, & occasionally ignoring lightning altogether
  - watching other operators using different rules causes confusion & distrust

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Closures (#)</th>
<th>Duration (min)</th>
<th>Hits (min)</th>
<th>False Alarms (min)</th>
<th>Misses (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Actual</td>
<td>37</td>
<td>1357</td>
<td>1201</td>
<td>156</td>
<td>1937</td>
</tr>
<tr>
<td>2 Actual</td>
<td>96</td>
<td>2791</td>
<td>1799</td>
<td>922</td>
<td>366</td>
</tr>
<tr>
<td>3 Actual</td>
<td>22</td>
<td>1091</td>
<td>891</td>
<td>300</td>
<td>713</td>
</tr>
</tbody>
</table>

Ramp closures for June, July & August at one Core30 airport

- Actual = recorded ramp closures
- Nominal = perfect implementation of procedures
Summary

• **Lightning Impacts on Aviation**
  - personnel safety concerns necessitate ramp closures
  - lightning-induced ramp closures cause substantial impacts on aviation
  - impacts quantifiable for both departures & arrivals
  - some impacts may be avoidable => need to focus on that

• **Uncertainties in Lightning Data**
  - detection efficiency, location & classification accuracy affect safety decisions
  - understand & quantify uncertainty => yields buffers for decision support
  - lightning networks are evolving => beneficial for reducing uncertainty

• **Challenges from User Perspective**
  - balancing safety concerns with operational efficiency => appropriate procedures
  - trust in safety procedures & sources of lightning data (human cognition & behavior)
  - weather is “nuisance” distracting from focus on operations

• **Acknowledgements**
  - Thank you to airport & airline partners in this research
  - Thank you to Drs. Paul Krehbiel & Bill Rison for access to LMA lightning data
  - Thank you to Earth Networks, Vaisala, and WSI for use of their respective lightning data

This research is in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.