Minimizing the Cost of Delay for Airspace Users

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Overview

- The problem
- The UDPP* concept
- The validation exercise:
  - Exercise plan
  - Results
  - Conclusions

* User-driven prioritization process
The Problem
To maintain safety, the European air traffic flow management (ATFM) function can impose ground delay on some flights.

For ATFM, all flights are equal and are given delays in accordance with the first planned first served principle.

But for airspace users, all flights are unique.

Problem Statement
Cost of Delay for Airspace Users

- Example delay-cost profile:

- Profile is not linear because:
  - PAX: connections, goodwill,…
  - Resource management: crew constraints, maintenance, airport curfews

- Each flight has a unique delay-cost profile
Current Situation

- Today there is already some limited prioritization of flights by airspace users:
  - En-route swapping between 2 flights (Europe)
  - Swapping flights in the pre-departure sequence at Paris Charles-de Gaulle airport (Europe)
  - Ground Delay Program (USA)
  - Airspace Flow Program (USA)

- In Europe, the prioritization measures are tactical – reacting to capacity constrained situations (hotspots)
The UDPP Concept
Conceived for situations where demand exceeds capacity (‘hotspot’) for arrivals or departures.

**FDA**
- ‘Fleet delay apportionment’
- Assign a numerical value to denote priority of a flight. Assign when building the schedule or during a hotspot.
- Works by relative priority between your flights in the hotspot.
- Possible values: {1,2,3,4,5,6,7,8,9,Ba}

**SFP**
- ‘Selective Flight Protection’
- Normal operations:
  - Every flight starts with 100 operating credits (OC)
  - Every airport starts with operating index (OI) = 100
- OI = \((\text{demand} / \text{capacity}) \times 100\)
- 3 actions allowed:
  - Prioritize (OC=OI)
  - Accept ‘baseline delay’ (OC=100)
  - Suspend (OC=0)

FDA and SFP can be used together, separately, or not at all.
The UDPP Concept

- First you have to give before you get (‘ration by effort’)
- UDPP acts on the schedule. Arrivals example:

- Equity is important – don’t penalize other airspace users
Expected Benefits

- Improvements over what’s possible today:
  - Strategic – more time to plan and act
  - Can prioritize the whole affected fleet at once
  - Prioritization can be done during seasonal planning
  - Airspace users are rewarded if cancellations are necessary

- Some expected performance impacts:
  - Reduced costs of delay for airspace users
  - Fewer missed PAX connections
  - No negative impact on runway capacity
Exercise Planning
Platform and Prototype
### Participation

- 4 teams of 2 airspace users (mostly dispatchers):

<table>
<thead>
<tr>
<th>Position Name</th>
<th>Airspace User</th>
<th>Type of Operation</th>
<th>Suggested Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub1</td>
<td>EEE</td>
<td>Short / medium haul operations</td>
<td>Protect single rotations (suspend multiple rotations / low load factors)</td>
</tr>
<tr>
<td>Hub2</td>
<td>LLL</td>
<td>Long haul</td>
<td>Protect A380 operations and 747 flights (commercially important and protects airport)</td>
</tr>
<tr>
<td>Hub3</td>
<td>XXX</td>
<td>Short haul operations primarily connecting to/from CDG hub with remote regional outstations</td>
<td>Protect single rotations where possible due limited rerouting options</td>
</tr>
<tr>
<td>Low Cost</td>
<td>HHH</td>
<td>Point-to-point</td>
<td>Ensure the following day starts on time without impact and aircraft are in place. Suspend flights (will be cancelled) to deliver this protection.</td>
</tr>
<tr>
<td>Other Airlines</td>
<td>OA</td>
<td>N/a - the reference position</td>
<td>N/a - the reference position</td>
</tr>
</tbody>
</table>
Scenarios and Runs

- 6 solution scenarios: 2 different capacity constraints x 3 different concept solutions (FDA, SFP, FDA+SFP)
- 2 reference scenarios: 1 for low visibility, 1 for de-icing
- Only 1 run per scenario

<table>
<thead>
<tr>
<th>Capacity Constraint</th>
<th>Start</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Visibility</td>
<td>No capacity constraint</td>
<td>Capacity constraint: 0730-1130</td>
<td>Capacity constraint: 0730-1130</td>
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<tr>
<td></td>
<td>69 mov/hr</td>
<td>39 mov/hr</td>
<td>30 mov/hr</td>
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<tr>
<td></td>
<td>OI = 100</td>
<td>OI = 150</td>
<td>OI = 194</td>
</tr>
<tr>
<td>De-Icing</td>
<td>No capacity constraint</td>
<td>Capacity constraint: 1545-1900</td>
<td>Not played</td>
</tr>
<tr>
<td></td>
<td>69 mov/hr</td>
<td>21 mov/hr</td>
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<tr>
<td></td>
<td>OI = 100</td>
<td>OI = 191</td>
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</tbody>
</table>
Results
The impact of a given FDA priority on a flight’s delay:

- The higher the priority, the larger the delay reduction.
- Mid-range values (4, 5, 6, 7) were not popular.

*Scenario: FDA only, low visibility*
SFP Usage

- Protected and ‘UDPP-suspended’ flights:

  - EEE could have prioritized one more flight but didn’t → wasted credit
  - UDPP-suspended flights are heavily penalized

(Scenario: SFP only, low visibility)
Volatility / Stability

- FDA and SFP cause volatility in total delay for all airspace users
- SFP adds more delay to the user, but reduces delay from others
Punctuality

- Definition: $|\text{AOBT}-\text{SOBT}| < 3$ minutes
- SFP significantly improved punctuality, but FDA did not
Cost of Delay

- Decoupling of cost and delay for airspace user XXX
- No smooth downwards trend – suggestive of an inefficient minimization process
Equity – How Non-Participants Were Affected

- Airspace users that didn’t use UDPP were impacted by the UDPP actions of others
- For FDA only and FDA+SFP scenarios, 70% flights received no extra delay or a reduction in delay
- SFP only produced the least negative impact on non-participants.

(OA flights only, low visibility)
Conclusions
Conclusions

- **Benefits:**
  - UDPP provides cost savings for airspace users
  - SFP improves punctuality, but FDA does not

- **Equity:**
  - UDPP actions affect those that don’t use UDPP
  - Generally, impacts are small – the order of a few minutes
  - Flights can be impacted by either an increase or decrease of delay

- **Algorithms**
  - Total and individual flight delays are subject to some volatility → this risks undermining the concept
  - Hard to minimize delay cost with FDA ‘by hand’ → automation needed?
Conclusions: Future Work

- Improve the algorithm to reduce volatility and inequity
- Improve the cost model

Assess UDPP in a more realistic operational environment:
- Add airport processes and constraints
- Add normal and abnormal network perturbations
- Let airspace users reroute or level cap, for example
- Let several airports use UDPP simultaneously

Measure the impacts on other actors:
- Airports – stand allocation, runway throughput
- Wider network – congestion created by UDPP
Latest developments…

Algorithm redesigned, which now works by assigning slots (more like the USA’s GDP).

A ‘margin of manoeuvre’ for each flight will show by how much a flight can be prioritized or delayed further.

Next exercise in Autumn 2018, with a focus on integrating UDPP within airport processes, and a rudimentary network.
Questions?

On this day in…

1939 – a Dixie Clipper completes 1st commercial plane flight from US to Europe

1965 – USAF Capt Joseph Henry Engle reaches 85,530 m in X-15

2007 – Apple’s iPhone released
Backup Slides
### FDA (proportion of “Delay x Priority”)

<table>
<thead>
<tr>
<th>Original</th>
<th>A1</th>
<th>A2</th>
<th>C1</th>
<th>B1</th>
<th>A3</th>
<th>C2</th>
<th>B2</th>
<th>B3</th>
<th>A4</th>
<th>B4</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
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<tbody>
<tr>
<td>FSFS Seq.</td>
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<td>A2</td>
<td>C1</td>
<td>B1</td>
<td>A3</td>
<td>C2</td>
<td>B2</td>
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<td>X1</td>
<td>X2</td>
<td>X3</td>
<td>X4</td>
<td>X5</td>
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<td>Baseline Delay</td>
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<td>4</td>
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<td>Priority</td>
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<td>CoefPrio</td>
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<td>A3 delay</td>
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<td>A4 delay</td>
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**CoefPrio** = \( \frac{\text{Sum(Dly)}}{\text{Sum(Dly*Prio)}} = \frac{8}{((9x4) + (4x1))} = \frac{8}{40} \\
A3 delay = \text{Prio*Dly} * \text{CoefPrio} = 36 * \frac{8}{40} = 7.2 \\
A4 delay = \text{Prio*Dly} * \text{CoefPrio} = 4 * \frac{8}{40} = 0.8**
Selective Flight Protection

Hotspot

OI = 140

Suspend

Protect

Protect

Suspend

Prohibited Area to respect equity

Operating Credits

Time

Left-over credits

100

120

80

60

20

100

200

300
UDPP Prioritization

- Airport where UDPP applied
  - Movements per hour
  - Standard deviation of the distribution of actual vs planned taxi-in duration
- Other airports
  - Movements per hour
  - Stand allocation
- Airspace users (AU)
  - Total delay per AU
  - Delay (for UDPP users)
  - Delay (for non-UDPP users)
  - Indirect costs (affects all flights)
  - Direct costs (affects specific flights)
  - Punctuality (for UDPP users)
  - Punctuality (for non-UDPP users)
- En route ATM / NM
  - Delays after prioritization are in line with expectations and needs
  - Total network en route delay
  - ATCO workload in TMA

- Runway throughput
- Stand allocation
- Airport capacity
- Predictability
- Equity
- AU cost-efficiency
- Punctuality
- Flexibility
- Airspace capacity
- Safety

Note: the claims made in this benefit mechanism are subject to validation

<table>
<thead>
<tr>
<th>Concept</th>
<th>Impact Area</th>
<th>Indicators</th>
<th>Positive / negative impacts</th>
<th>Key Performance Area</th>
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