Improved Flexibility and Equity for Airspace Users During Demand-capacity Imbalance
An introduction to the User Driven Prioritisation Process (UDPP)

Nadine PILON, EUROCONTROL
Sergio RUIZ, Politech. University of Catalunya
Lorenzo CASTELLI, University of Trieste
Andrew Cook, University of Westminster
Andrada Bujor, ALG
Problem statement

In order to maintain safety, the **European** Network ATFM Function at Airports or En-Route impose delays or other measures on certain flights before departure

→ limitations on AUs operations

- For ATFM, all flights are equal
- For AUs, every flight is unique
- Reasons:
  - Passenger experience
  - Limitations: Airport/Crew/Aircraft
  - Schedule Integrity

- Reduce cost of delay
- Prioritise important flights
- Transparency
- Flexibility

```
DELAYED
DELAYED
DELAYED
```

Equity
Cost of Delay for Airspace Users?

No way to Act on Delay -> Act on Cost of the Delay

Cost of delay (example on 1 flight)

Non-linear cost structure due to:
- PAX flow: Transit, VIP, Rotations, …
- Resources Mgt: CREW constraints, pilots constraints, Maintenance, Curfew …..

Slope = punctuality policy

First max delay target (Margin of manoeuvre 1)

2nd max delay target (Margin of manoeuvre 2)

Each flight has its own particular complex cost structure (not easy to manage)
AU goal: Decrease the Cost of the delay in a hotspot, taking into account the knock-on effect in the along-day schedule
Principles of the UDPP concept

- **Flexibility**: AUs are able to protect most important flights
- **Equity**: no negative impact on other AUs
- **Stable coordination**: high rate of acceptance of requests, coordinated with ATM actors
• EUR 4900— the average cost saved per single ATFM slot swap
• EUR 7-8 million per year saving currently
• 500 M€ estimated over 20 years
• Deployment in 2017

Benefits

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Airspace Users</th>
<th>Network Manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>More opportunities to swap</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Reduced workload</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Reduced cost of delay</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Higher acceptance of swap requests</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

Swap Requests

- Prefer not to say: 7; 14%
- < 1000 euros: 4; 8%
- 1000-5000 euros: 7; 14%
- 5001-10000 euros: 3; 6%
- > 10000 euros: 3; 6%
- Don't know: 26; 52%
UDPP overview

Two prioritisation methods have been validated in SESAR for current operations:

- **Enhanced ATFM slot-swapping**: more flexible rules and a swap identification tool deployed by NM in 2017
- **UDPP departure**: AUs can change the priority order of flights in the pre-departure sequence: *DFlex at Paris-Charles de Gaulle*

New innovative prioritisation approaches are elaborated with AUs to allow **AUs’ pro-active repositioning for important flights involved** in any Capacity Constrained Situation (Departure – En-route – Arrival), and to share AUs’ input in the Network CDM, in a future Trajectory-Based Operations environment:

- Fleet Delay Apportionment
- Selective Flight Protection
- Enhanced Selective Flight Protection
**UDPP Concept : Selective Flight Protection**

- **Neutral impact for flights between Baseline 8 and Original Schedule 8**
- **Positive impact for all the others**

**Ration by Effort principle**

**Original Schedule**

```
1 2 3 4 5 6 7 8 9 X
```

**Hotspot (baseline delay)**

```
1 2 3 4 5 6 7 8 9 X
```

**First Suspend…**

```
2 3 4 5 6 7 8 9 X 1
```

**Suspend 1**

**Positive impact for all others flights**

**… then Protect**

```
2 3 4 8 5 6 7 9 X 1
```

**Protect 8**
Definitions and terminology

Operating Index (OI) measures the imbalance severity: demand vs. capacity ratio for the hotspot

\[ OI = 100 \frac{D}{C} \]

Capacity Constraint Situation
Decrease Capa from 30 -> 25
From 0500 to 1520

Over-capacity Stressed period

Recovery period

Back to normal capacity
Equity in Selective Flight Protection

The new assigned delay is equitable because no one is worse off.
Equity in suspension – protection

Since $NI < PI$, many protections can be neutralised by one suspension.

1 Flight suspension & 4 Flight protections

Condition of equity: \( MFP \times NI \leq PI \) → Win-win or win-neutral situation
Selective Flight Protection mechanism

- The UDPP Selective Flight Protection (SFP) values are represented by **Operating Credits (OC)**
- The **Operating Index (OI)** provides a means to indicate the severity of a hotspot
- The OI value determines the **Maximum number of Flights that can be Protected (MFP)** in the hotspot in exchange for a suspended flight:

\[
MFP = \frac{100}{OI - 100}
\]

SFP rules for prioritising a flight:
1. Suspend lower priority flights to liberate the 100 OCs of those flights (effort must be done always first).
2. Move the available credits to flights that are to be protected by raising the OC for these flights to the OI level
3. Protected flights must have new positions in the sequence which are always after or equal to the original scheduled times of the suspended flights

\[
Cr_{HI} = 100 \times S - [OI - 100] \times P
\]
Enhancements for the SFP method

- **AUs asked for enhancement** of the SFP to extend the validity of the credits to other hotspots, so the non-used leftover credits in a hotspot are not lost.

- Specially relevant for the **Low Volume User in Constraint (LVUCs)**, as they usually have fewer chances to take advantage of the flexibility provided by UDPP.

- E.g., LVUC with 1 flights in a hotspot (never can protect that flight).
- E.g.: LVUC with 3 flights Hotspot with OI=125 ➔ MFP = 4
  - 1 suspension (Cr =+100), 2 protections (Cr =-2x25) ➔ Cr =50 (leftover credits).

New method ESFP aims at addressing these needs.
Enhanced Selective Flight Protection

Assign different value for the credits according to the different levels of delay in each hotspot (equivalent factor)

Hotspot
Demand > Capacity

Baseline Delay assigned to the flights in the hotspot

AUs suspend flights and receive credits

AUs use credits to protect flights

Leftover credits are saved

Credits are weighted through an Equivalent Factor

Hotspot
Demand > Capacity

Baseline Delay assigned to the flights in the hotspot

AUs suspend flights and receive credits

AUs use credits to protect flights

Leftover credits are saved

Leftover credits can be accumulated only by AUs with low number of flights affected by the hotspot (Low Volume Users in Constraint)
**Enhanced Selective Flight Protection**

Duration of hotspot H1: $\omega_{H1}$

**Traffic Demand**

LVUC’s credits in H1: $Cr_{H1} = 100 \times S - \left[ OI - 100 \right] \times P$

Duration of hotspot H2: $\omega_{H2}$

LVUC’s credits in H2: $Cr_{H2} = 100 \times S_{H2} - \left[ OI_{H2} - 100 \right] \times P_{H2} + \frac{Cr_{H1} \times \frac{\omega_{H1}}{\omega_{H2}}}{H1 \ leftover \ credits}$

Equivalence Factor
**ESFP example**

<table>
<thead>
<tr>
<th>Hotspot</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$C$</td>
</tr>
<tr>
<td>H1</td>
<td>20</td>
</tr>
<tr>
<td>H2</td>
<td>20</td>
</tr>
</tbody>
</table>

An LVUC in hotspot H1 **suspects** one flight ($S_{H1}=1$) $\Rightarrow$ +100 OCs. It **protects** only another one ($P_{H1} = 1$) $\Rightarrow$ -35 OCs

\[
Cr_{H1} = 100 \times 1 - (135 - 100) \times 1 = 65
\]

$\Rightarrow$ Still could protect \(\frac{65}{(135-100)} = 4\) flights

\[
Cr_{H2} = 65 \times \frac{300}{250} = 78
\]

$\Rightarrow$ Now could protect \(\frac{78}{(115-100)} = 5\) flights

Hotspot duration determines the number of credits carried to other hotspot, while severity (OI) determines how many flights can be protected.
Example (with realistic traffic data)

**Hotspot 1**
- OI = 128
- Suspended flight: OA1 318 (+100 OC)
- Protected flight: OA1 1714 (-28 OC)

<table>
<thead>
<tr>
<th>AU name</th>
<th>Total flights</th>
<th>Baseline delay</th>
<th>Assigned delay</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUB</td>
<td>52</td>
<td>1388</td>
<td>1294</td>
<td>94</td>
</tr>
<tr>
<td>LC1</td>
<td>8</td>
<td>250</td>
<td>241</td>
<td>9</td>
</tr>
<tr>
<td>LC2</td>
<td>12</td>
<td>461</td>
<td>446</td>
<td>15</td>
</tr>
<tr>
<td>OA1</td>
<td>6</td>
<td>227</td>
<td>373</td>
<td>-146</td>
</tr>
<tr>
<td>OA2</td>
<td>2</td>
<td>32</td>
<td>29</td>
<td>3</td>
</tr>
<tr>
<td>OA3</td>
<td>2</td>
<td>59</td>
<td>59</td>
<td>0</td>
</tr>
<tr>
<td>OA4</td>
<td>1</td>
<td>33</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>OA5</td>
<td>3</td>
<td>94</td>
<td>91</td>
<td>3</td>
</tr>
<tr>
<td>OA6</td>
<td>4</td>
<td>113</td>
<td>101</td>
<td>12</td>
</tr>
<tr>
<td>OA7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OA8</td>
<td>6</td>
<td>208</td>
<td>201</td>
<td>7</td>
</tr>
</tbody>
</table>

98 2865 2865 0

**Hotspot 2**
- OI = 132
- Protected flights: OA1 318, 192, 1714 (-32 OC x 3 = -96 OC)

<table>
<thead>
<tr>
<th>AU name</th>
<th>Total flights</th>
<th>Baseline delay</th>
<th>Assigned delay</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUB</td>
<td>39</td>
<td>463</td>
<td>481</td>
<td>-18</td>
</tr>
<tr>
<td>LC1</td>
<td>6</td>
<td>112</td>
<td>127</td>
<td>-15</td>
</tr>
<tr>
<td>LC2</td>
<td>9</td>
<td>196</td>
<td>215</td>
<td>-19</td>
</tr>
<tr>
<td>OA1</td>
<td>4</td>
<td>74</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>OA2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>OA3</td>
<td>1</td>
<td>32</td>
<td>37</td>
<td>-5</td>
</tr>
<tr>
<td>OA4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OA5</td>
<td>2</td>
<td>35</td>
<td>40</td>
<td>-5</td>
</tr>
<tr>
<td>OA6</td>
<td>2</td>
<td>13</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>OA7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OA8</td>
<td>5</td>
<td>88</td>
<td>98</td>
<td>-10</td>
</tr>
</tbody>
</table>

69 1014 1016 -2

**Hotspot 3**
- OI = 136
- Protected flight: OA1 1714 (-36 OC)

<table>
<thead>
<tr>
<th>AU name</th>
<th>Total flights</th>
<th>Baseline delay</th>
<th>Assigned delay</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUB</td>
<td>22</td>
<td>166</td>
<td>172</td>
<td>-6</td>
</tr>
<tr>
<td>LC1</td>
<td>4</td>
<td>41</td>
<td>45</td>
<td>-4</td>
</tr>
<tr>
<td>LC2</td>
<td>7</td>
<td>80</td>
<td>82</td>
<td>-2</td>
</tr>
<tr>
<td>OA1</td>
<td>3</td>
<td>17</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>OA2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OA3</td>
<td>1</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>OA4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OA5</td>
<td>1</td>
<td>12</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>OA6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OA7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OA8</td>
<td>3</td>
<td>36</td>
<td>36</td>
<td>0</td>
</tr>
</tbody>
</table>

41 367 367 0

Hotspot 1
72 Leftover credits

Hotspot 2
117 credits from H1 (equivalent to the 72 credits in H1)
21 Leftover credits

Hotspot 3
43 credits from H2 (equivalent to the 21 credits in H2)
5 Leftover credits
Positive or almost neutral general impact on the delay distribution

- OA1 is the Airspace Users suspending and protecting flights
- Very low negative impact on some AUs only (equitable)
- The LVUC use credits among different hotspots and benefited from flexibility

AUs found the impact negligible compared to the number of flights operated, and valued positively the benefits of the extra flexibility given by ESFP
Conclusions

• **UDPP** bring flexibility to Airspace Users to reduce their cost of delay
• **UDPP** concept comprises several mechanisms at different levels of E-OCVM maturity: V3+ maturity for ESS and D-Flex; early V2 maturity for FDA and SFP; **V1 maturity** for ESFP
• **There is still a lot of work to do:**
  • Continued **validation** of assumptions and performance, introducing uncertainty and improving the mechanisms
  • Integrate **prioritisation with other AUs’ processes and tools** (pax reaccommodation, ..) to inform decision about costs reduction
  • Integrate UDPP into the other stakeholders’s processes for an improved **Collaborative Decision Making in the ATM Network**
• **AUs expressed their interest for further UDPP development**
• Thanks for the contributions to the achievements:

... and Frankfurt, Munich, Heathrow and Paris-CdGaulle Airports
Any Questions?

nadine.pilon@eurocontl.int
sergio.ruiz.navarro@upc.edu