Strategic Flight Cancellation under Ground Delay Program Uncertainty

Christine Taylor
Shin-Lai (Alex) Tien
Erik Vargo
Craig Wanke

The MITRE Corporation
McLean, VA

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17-21 June, 2019
Motivation: Strategic Planning from an FOC Perspective

Strategically Cancel Flights

Significant AAR reduction for a sustained period
Likely Low Rate GDP
Confidence: High

Early Cancellation allows for best resource management and minimal passenger disruption

<table>
<thead>
<tr>
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<tbody>
<tr>
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<tr>
<td>ABC890</td>
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Motivation: Strategic Planning from an FOC Perspective

Strategically Cancel Flights

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<tr>
<td>ABC890</td>
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Moderate to Significant AAR reduction
Potential GDP
Confidence: Medium

Risk unnecessary disruption

FOC Dispatcher

Wait and See
Motivation: Strategic Planning from an FOC Perspective

Strategically Cancel Flights

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Wait and See

Risk unnecessary disruption

Significant AAR reduction for a sustained period
Likely Low Rate GDP
Confidence: High
No Notice Cancellations
Large Delays
Crew Time Outs
Newsworthy Passenger Disruptions

Strategically Cancel Flights

Risk unnecessary disruption

Significant AAR reduction for a sustained period
Likely Low Rate GDP
Confidence: Medium
No Notice Cancellations
Large Delays
Crew Time Outs
Newsworthy Passenger Disruptions

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Motivation: Strategic Planning from an FOC Perspective

Which (if any) flights should be cancelled now?

- Strategically cancel a few flights
- Look for opportunities to recover
- Wait and See
- Strategically cancel later flights

GDP: Time/Rates Probability: 25%
GDP: Time/Rates Probability: 35%
GDP: Time/Rates Probability: 40%
Adaptive Planning Framework

Recommended action given current forecast

Adaptive strategy to optimize performance under predicted future scenarios

Balancing Cost and Risk
• Earlier decisions are less costly than later decisions
• Later decisions are made under greater certainty
• Some decisions are not available later
• Some decisions can be changed (at a cost); others cannot
Generating Forecast Tree

Ensemble Weather Forecast

- Probabilistic AAR Forecast Translation
- Learned Forecast Similarity
- AAR Scenario Tree
- GDP Scenario Prediction
- GDP Emulator

Forecast Horizon

100 Ensemble Members

Current decision node

Now \rightarrow Time

- Scen. 1, prob.
- Scen. 2, prob.
- Scen. 3, prob.
- Scen. 4, prob.
- Scen. 5, prob.
Strategic Flight Cancellation Problem

Current decision node

Time

Now

Future decision points

Recommended action given current forecast

Adaptive strategy to optimize performance under predicted future scenarios

GDP 1, prob.

Cost 1

GDP 2, prob.

Cost 2

GDP 3, prob.

Cost 3

GDP 4, prob.

Cost 4

GDP 5, prob.

Cost 5

Plan Objective

Cancellation Costs

Legacy Narrowbodies: Regional Jets

4.7:1

Early Decision Penalty/Reward

Flights Cancel

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Delay Costs

Assignment costs represent passenger delay

Flights Cancel

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<tr>
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</table>
Case Study
LGA GDP 13 November 2018

Single Decision Point (SDP)
- GDP 1, prob.
- GDP 2, prob.
- GDP 3, prob.
- GDP 4, prob.
- GDP 5, prob.

Cost 1
Cost 2
Cost 3
Cost 4
Cost 5

Min. Expected Cost

Adaptive Planning Framework (APF)
- GDP 1, prob.
- GDP 2, prob.
- GDP 3, prob.
- GDP 4, prob.
- GDP 5, prob.

Cost 1
Cost 2
Cost 3
Cost 4
Cost 5

Min. Expected Cost
Case Study
LGA GDP 13 November 2018

Time GDP is Issued

Actual GDP

Forecast Issued

22Z

Forecast Issued

Forecast Issued

Optimize SDP Strategy

Optimize SDP Strategy

Optimize SDP Strategy

Optimize SDP Strategy

Optimize SDP Strategy Assuming Prior Actions

Optimize SDP Strategy Assuming Prior Actions

Optimize SDP Strategy Assuming Prior Actions

Optimize SDP Strategy Assuming Prior Actions

Optimize APF Strategy

Optimize APF Strategy

Optimize APF Strategy

Optimize APF Strategy

Optimize APF Strategy Assuming Prior Actions

Optimize APF Strategy Assuming Prior Actions

Optimize APF Strategy Assuming Prior Actions

Optimize APF Strategy Assuming Prior Actions

Forecast Issued

Forecast Issued

Forecast Issued

Forecast Issued
13 Nov Forecasted GDPs: Prior-day planning (22Z)

<table>
<thead>
<tr>
<th>Scen</th>
<th>Prob</th>
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<tbody>
<tr>
<td>S1</td>
<td>33%</td>
</tr>
<tr>
<td>S2</td>
<td>4%</td>
</tr>
<tr>
<td>S3</td>
<td>16%</td>
</tr>
<tr>
<td>S4</td>
<td>21%</td>
</tr>
<tr>
<td>S5</td>
<td>7%</td>
</tr>
<tr>
<td>S6</td>
<td>7%</td>
</tr>
<tr>
<td>S7</td>
<td>12%</td>
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GDP = 61%

GDP Hourly Rate

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<th>GDP</th>
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<tbody>
<tr>
<td>30</td>
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<td>36</td>
<td></td>
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<tr>
<td>38</td>
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Individual Scenario Optimization

## Scenario 1

- **No Action**
- **Swap Only**
- **Cancellation and Swap**

Cost

- # swap = 157
- # swap = 136
- \# Cx = 22

# flights = 169
Adaptive Planning Framework vs. Single Decision Point Solutions at 22Z

**SDP Solution at 22Z**
Cost = $46,331

- S1: 33%
- S2: 4%
- S3: 16%
- S4: 21%
- S5: 7%
- S6: 7%
- S7: 12%

**APF Solutions at 22Z**
Cost = $36,913

- S1: 33%
- S2: 4%
- S3: 16%
- S4: 21%
- S5: 7%
- S6: 7%
- S7: 12%
### 13 Nov Forecasted GDPs: Prior-day planning (02Z)

#### Timeline (Z)

<table>
<thead>
<tr>
<th>Scen</th>
<th>Prob</th>
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<tbody>
<tr>
<td>S1</td>
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<tr>
<td>S2</td>
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<tr>
<td>S3</td>
<td>4%</td>
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<td>S4</td>
<td>2%</td>
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<td>S5</td>
<td>2%</td>
</tr>
<tr>
<td>S6</td>
<td>11%</td>
</tr>
<tr>
<td>S7</td>
<td>1%</td>
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**GDP = 85%**

#### GDP Hourly Rate

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Adaptive Planning Framework vs. Single Decision Point Solutions at 02Z

SDP Solution at 02Z
Cost = $38,842

SDP Solution at 02Z assuming 22Z actions
Cost = $48,884

APF Solutions at 02Z
Cost = $38,543
13 Nov Forecasted GDPs: Day-of Planning (09Z)

GDP Hourly Rate

GDP = 37%
Adaptive Planning Framework vs. Single Decision Point Solutions at 09Z

SDP Solution at 09Z
Cost = $37,608

09Z
- S1: 11% 132
- S2: 1% 89
- S3: 1% 148
- S4: 4% 148
- S5: 10% 148
- S6: 11% 148
- S7: 62%

APF Solutions at 09Z
Cost = $29,247

09Z 12Z 15Z
- S1: 11% 127
- S2: 1% 89
- S3: 1% 141
- S4: 4% 142
- S5: 10% 142
- S6: 11% 142
- S7: 62%

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APF vs SDP solutions @ 09Z with prior actions

SDP Solution at 02Z assuming 22Z decisions
Cost = $36,838

02Z  09Z
22Z
S1: 11%   5
S2: 1%  29
S3: 1%
S4: 4%   11
S5: 10%  12
S6: 11%  12
S7: 62%

APF Solutions at 09Z assuming 02Z decisions
Cost = $34,624

02Z  09Z  12Z  15Z
0  3  7  0
9  10  16  S1: 11%   4
9  7  0  S3: 1%
9  16  S4: 4%   15
9  16  S5: 10%  12
9  16  S6: 11%  12
9  16  S7: 62%
### Incurred verses Projected Cost

#### Incurred Cost & Projected Cost By Scenario and Decision Method

<table>
<thead>
<tr>
<th>Decision Point</th>
<th>D1_22Z</th>
<th>D2_02Z</th>
<th>D3_09Z</th>
<th>D4_11Z</th>
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Conclusions

- **APF permits explicit optimization of future decisions, highlighting actions that should be taken now**
  - Aligns decisions with information uncertainty
  - Directly captures risk of inaction with cost of inappropriate response

- **Key to successful adaptive planning is representing the forecast tree**
  - Similarity must reflect appropriate features of forecast evolution
  - Scenarios should span the space of planning outcomes

- **What does a validation plan look like?**
  - Beyond forecast tree representation (and accurately capturing costs), how do we validate probabilistic planning decisions?