Hub operations: delay recovery based on cost optimisation
- dynamic cost indexing and waiting for passengers strategies

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Overview

• Background and objectives
• Model description
• Datasets
• Case of study
• Results
• Conclusions and next steps
Background and objectives
Background and objectives

Dynamic cost indexing

outbound arrival delay

CI_{\text{max}} CI_{\text{min}}

EI BT_0\rightarrow MCT\rightarrow\text{connecting buffer}\rightarrow\text{departing delay}\rightarrow EOB T_0

Wait for passengers

MCT \rightarrow \text{missed connection}
Background and objectives
Background and objectives

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<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td>10h00</td>
</tr>
<tr>
<td>2</td>
<td>10h03</td>
</tr>
<tr>
<td>4</td>
<td>10h09</td>
</tr>
<tr>
<td>5</td>
<td>10h12</td>
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AMAN (EPTI – 1h)
Slots available
negotiation
delay

AOC

DCI

WFP

Delay

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Background and objectives

• Model operations at a hub allowing two strategies
  – Dynamic cost indexing (DCI)
  – Wait-for-passengers (WFP)

• Analyse effect of these strategies considering
  – Delay and uncertainty at different phases
  – DCI for inbound and outbound flights at TOC
  – E-AMAN with slot negotiation capabilities
Model description
Model description

- Agent Based Model
Costs computation

Fuel costs

Non-pax costs

Maintenance

Crew

Delay costs

Pax costs

Hard

Soft

Provision

Compensation

Transfer

Primary

Rotary
Cost computation

Fuel costs

Delay costs

Non-pax costs

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Maintenance

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Costs computation

Fuel costs

- Based on BADA 4
  (4th degree polynomial fitting)
  - Ac model
  - Considering FP length
  - Flight level based on historical analysis
  - Reference speed for the aircraft from BADA
  - Mmin and Mmax (load factor 1.3g)
  - Estimation of reference weight considering specific range consumption
Cost are estimated following a normal probability distribution as a function of MTOW.

- Maintenance
  - At gate
  - Taxi
  - En-route
  - Arrival

- Crew
Costs computation

- Based on departure or connection delay
- Consider ticket and airline type

<table>
<thead>
<tr>
<th>AO (ticket)</th>
<th>Cost applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSC (flexible)</td>
<td>Average of high &amp; base</td>
</tr>
<tr>
<td>FSC (inflexible)</td>
<td>Base</td>
</tr>
<tr>
<td>REG, LCC, CHT</td>
<td>Average of low &amp; base</td>
</tr>
</tbody>
</table>

Delay costs

Pax costs

Hard

Soft

Provision

Compensation

Transfer

Primary

Rotary

Based on departure or connection delay
Consider ticket and airline type
Costs computation

- Based on arrival delay
- Based on Reg. 261 (distance and delay)
- Only percentage of passengers claim

Delay costs

Pax costs

- Hard
- Soft

Provision

Compensation

Transfer

Primary

Rotary
Costs computation

- Based on ticket type
- Consider airline and alliances

Delay costs

Pax costs

Hard

Soft

Provision

Compensation

Transfer

Primary

Rotary
Based on arrival delay
Consider propagation of delay from outbound with 30 minutes buffer
Metrics

• 140 indicators per flight (e.g. selected speed)
• 22 performance indicators (e.g. flight departure delay)
  – Delay (flight and passenger)
  – Costs
  – Efficiency
• Aggregators (e.g. average, count, percentile 90)
• Restrictors (e.g. all flights, only FSC)
• Total of 381 metrics
• 50 simulations per scenario
Datasets
Datasets

- **Traffic data**
  - Flight schedules from PRI SME
  - Flight trajectory and phases based on so6 data file
  - Nominal speed from BADA (adjusted for short flights)
  - Passenger itineraries from anonymised airport data
  - Taxi time estimations
  - Average ground speed to estimate wind

676 flights (336 inbound, 340 outbounds)

61,446 pax itineraries (11,570 connecting (18.9%))
Datasets

• Taxi times estimation
  – Planning stage
  – Execution stage
Datasets

- Taxi times estimation
  - CFMU
  - Schedules and planned flight plans
  - Reported at post-operation

![Diagram showing taxi times estimation process]

- Estimated Taxi out
- Flight plan take-off time
- EOBT

- Taxi in + buffer
- Flight plan landing time
- EIBT

- Average CFMU taxi in error
Datasets

- **Buffers**
  - Schedules
  - Minimum turn around time

Arrival buffer

Turnaround buffer
Datasets

- Average cruise wind estimation
Datasets

- Difference between cruise DCI and speed variation

(a) Full trajectory modified

(b) FL maintained

Cost index variation effect

Estimated from Airbus Performance Engineering Program
Datasets

- Uncertainties

Analysis of a year of traffic to-from the hub (AIRAC 1313-1413)

Normal distribution around reported values
Datasets

- Delay
  - CODA data
  - Select 25 and 75 quartile to define low, medium and high delay days
  - Outbound flights delay reduced considering reactionary delay (codes 91-96)
  - Consider release of delay information to AOC

Burr distribution fitting
Case of study
Case of study

- Strategies
  - Baseline
    - Flights with delay > 15 minutes → 10% probability recover up to remaining 5 minutes
    - Outbound → wait-for-passengers if inbound recovering and waiting time required < 20 minutes
  - Optimised
    - Delay recovered and wait-for-passenger based on estimated cost
Case of study

• Parameters
  – Delay
    • Nominal
    • High
  – Fuel
    • Nominal (0.5 EUR/kg)
    • High (0.8 EUR/kg)
  – Passenger compensation uptake
    • Nominal (11%)
    • High (50%)
Results
Results

• Number of missed connections at the hub

Reduction between 14.4% and 17.5%
Results

- Gate-to-gate trip time (min)

Increases by around 1.1%
Results

• Gate-to-gate trip time (min)

- Decreases by around 0.6-0.8%
- Increases by around 0.4%
Results

- Wait for passengers performances

- Increases by around 30 acc 3% to 12% of all outbound
  Increases by around 7 mins
Results

• DCI performances at TOC

- Increases more when delay is high
  Impact of fuel

- Decreases
  Effect of fuel cost
Results

- AMAN performances

Average delay (min)
Fuel is saved
More on high fuel

Average extra fuel consumption (kg)
More delay is generated
Fuel is saved
More on high fuel
Conclusions
Conclusions

• Hub operations modelled considering
  – Dynamic cost indexing
  – Wait-for-passengers rules
  – E-AMAN with collaborative decision making to select slots
  – Passengers’ gate-to-gate times
  – Costs: fuel, delay, passengers (hard and soft)

• Collaborative strategy computation

• Passenger-centric metrics
Conclusions

• Dynamic cost indexing
  – High number of flights decide to apply speed variations
  – Increment in speed is small (around 4%)
  – Sensitive to fuel cost
  • Higher fuel cost reduces flights increasing speed by 30-35%
    and selected speed by 5-7%
  – Delay recovered is small and adsorbed by E-AMAN

• Wait-for-passengers
  – Number of flights waiting increases from around 10 to around 45
  – Average waiting time increases from around 7 min to 13-14 min
Conclusions

• E-AMAN
  – Trade delay for fuel: consideration of connections at that point
  – Higher fuel cost leads to more delay and more fuel saving
  • Voluntary selection of later slot
  – Sensitive to original delay
Conclusions

• Costs
  – Airline costs reduced by around 0.7%

• Delay
  – Gate-to-gate time increased by around 1.1%
  – Tradeoff between type of passengers
  – Reduction of missed connections (14.4-17.5%)
  – Waiting time for passengers at airport decreases (around 1.6%)
  – Sensitive to passenger claiming ratio (missed connections reduced by 8.5-15%)
Next steps
Next steps

- Airport selection

![Map of Europe with airport locations]

**AIRAC 1313 to AIRAC 1413**
Next steps

- Airport selection
- Analysis expected and actual costs
Next steps

- Airport selection
- Analysis expected and actual costs
- Sensitivity and stability go the solutions to input variables
- E-AMAN radius
- Feedback to inbound flights when outbound are modified
- Differentiation of airline behaviours
- Learning techniques
Thank you