Delay assignment optimization strategies at pre-tactical and tactical levels

A. Montlaur and L. Delgado

Dr Luis Delgado
Senior Research Fellow
University of Westminster
Universitat Politècnica de Catalunya
Overview

- Background
- Optimization models
  - System overview
  - Stakeholders
  - General ground holding problem formulation
  - Cost functions
- Scenario
- Results
  - Tactical
  - Pre-tactical
- Conclusions and further work
Background
Background

Tactical traffic management

Pre-tactical traffic management

Diagram showing the relationship between tactical and pre-tactical traffic management.
Background

Tactical traffic management

Extended region

E-AMAN
Background

- **RBS**
- **Minimising passenger delay**
- **Minimising delay considering turn-around**

![Diagram of slots and demand](chart)

<table>
<thead>
<tr>
<th>Demand</th>
<th>Slots available</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>S1</td>
</tr>
<tr>
<td>F2</td>
<td>S2</td>
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<tr>
<td>F3</td>
<td>S3</td>
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<td>...</td>
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<td>Fm</td>
<td>Sn</td>
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<thead>
<tr>
<th>Optimisation assignment 1</th>
<th>Optimisation assignment 2</th>
<th>Optimisation assignment j</th>
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<tbody>
<tr>
<td>Metric 1</td>
<td>V₁₁</td>
<td>V₁₂</td>
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<tr>
<td></td>
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<td>V₁ₐ</td>
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<tr>
<td>Metric 2</td>
<td>V₂₁</td>
<td>V₂₂</td>
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<td>Metric i</td>
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Optimization models

- System overview
System overview

- Optimisation phases

  - Slot window between 10 to 15 minutes
  - Delay realised on-ground at origin

  • Slot window between 1 to 3 minutes
  • Re-optimised every time a flight enters the outer radius
  • Maximum 35 minutes of delay assigned

- Pre-tactical optimisation

  - Origin

- Tactical uncertainty

  - Tactical optimisation

  - E-AMAN

  - Destination

- 50 km

- 500 km
Optimization models
- Stakeholders
Stakeholders

- Airlines
  - Flight centric metrics

- Passengers
  - Passenger centric metrics

- Importance of optimization function focus
Optimization models
- General ground holding problem formulation
General GHP formulation

- Deterministic Ground Holding Problem (GHP)
- Constraints applied at destination
  - outer or inner radius

General GHP formulation

- Set of intervals
- Set of flights
- Inputs defined
  - Capacity at each time interval
  - Scheduled time of arrival for each flight
- Decision variables
  - If a flight is assigned to arrive at a given time interval
    (starting at the earliest possible arrival time for that flight)
- Problem formulation
  - Assign flights to intervals minimizing cost
    (all flights must be assigned, capacity not overpassed)

Optimization models
- Cost functions
Cost functions

• Four costs models considered ($c_{ft}$)
  - GHP Flight: Delay per flight minimised

\[ c_{ft} = \text{Arrival time} - \text{Scheduled arrival time} \]

Arrival delay
Cost functions

• Four costs models considered ($c_{ft}$)
  – GHP PAX: Delay per passenger minimised

$$c_{ft} = \text{Number of passengers arriving} \times \text{Arrival delay}$$
Cost functions

- Four costs models considered ($c_{ft}$)
  - GHP Reac: Delay per flight considering reactionary departure delay

$$c_{ft} = \text{Arrival delay} + 1.8 \times \text{Subsequent departure delay}$$

- Arrival time
- Latest arrival time not generate departure delay
Cost functions

- Four costs models considered ($c_{ft}$)
  - GHP Reac Pax: Delay per passengers considering reactionary departure delay

\[
c_{ft} = \text{Passenger arrival delay} \times \text{Number of passengers arriving} + 1.8 \times \text{Subsequent passenger departing delayed} \times \text{Number of passengers departing} \times \text{Subsequent departure delay}
\]
Cost functions

- Four costs models considered ($c_{ft}$)
  - GHP Flight: Delay per flight minimised
  - GHP PAX: Delay per passenger minimised
  - GHP Reac: Delay per flight considering reactionary departure delay
  - GHP Reac Pax: Delay per passengers considering reactionary departure delay
Scenario and model uncertainty
## Scenario definition and uncertainty

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• Between 5:00 and 11:00 GMT  
• Cancelled flight considered pre-tactically but not tactically  
• Flights within inner radius excluded | Once |

Demand Data Repository 2 (DDR2)
### Scenario definition and uncertainty

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| Turnaround|           |                                                                              |       |

#### Top 10 AC types

![Bar chart showing the number of flights per aircraft type]

#### A320 turn around times

![Graph showing the proportion of turnaround time]

**Legend:**
- **Burr probability distribution**
- **Real data**
# Scenario definition and uncertainty

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• AC types top 10 used  
• AC categories otherwise  
• Burr and Weibull distribution fitting  
• $MTT(f) = \text{Max}(\text{rand}(0.1,0.4),\text{STT}(f))$ | Once |
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<tr>
<td>Passenger</td>
<td></td>
<td>• Triangular distribution between 60-95% centered at 85%</td>
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<tr>
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<td></td>
<td></td>
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<tr>
<td>Capacity</td>
<td>80 acc/h nominal · 40 acc/h regulated from 6:00 to 8:00 GMT</td>
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![Graph showing arrival demand at CDG, 12 Sept 2014](image)
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<tr>
<td></td>
<td></td>
<td>• 40 acc/h regulated from 6:00 to 8:00 GMT</td>
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<tr>
<td>Radii</td>
<td></td>
<td>• Outer 500 km (270 NM)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Inner 50 km (27 NM)</td>
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<td>• Inner 50 km (27 NM)</td>
<td></td>
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<tr>
<td><strong>Optimisation window</strong></td>
<td></td>
<td>• 15’ pre-tactical (20 acc/15’ nominal, 10 acc/15’ regulated)</td>
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<tr>
<td></td>
<td></td>
<td>• 3’ tactical (4 acc/3’ nominal, 2 acc/3’ regulated)</td>
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<tr>
<td>Tactical noise</td>
<td>• Difference scheduled actual</td>
<td>Monte Carlo 50</td>
</tr>
<tr>
<td></td>
<td>• Burr distribution</td>
<td>times</td>
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</tbody>
</table>

**Diagram Notes:**
- **Tactical optimisation**
- **E-AMAN**
- **Tactical uncertainty**
- **Origin**
- **Destination**
- **50 km**
- **500 km**
Results
Results

• Per flight and per passenger
  – Mean arrival delay
  – Mean tactical delay, i.e., delay generated at the E-AMAN
  – Mean reactionary delay
  – Mean total delay (arrival and reactionary)
  – Number of flights with reactionary delay
  – Maximum reactionary delay
Tactical results

![Graph showing tactical delay per flight and per passenger (PAX)]
Pre-Tactical results

Arrival and Reactionary Total Delay per Flight

Arrival and Reactionary Total Delay per PAX
Pre-Tactical results

Number of flights with Reactionary Delay

- GHP Reac PAX–RBS
- GHP Reac–RBS
- GHP PAX–RBS
- GHP flight–RBS
- RBS–RBS

Maximum Reactionary Delay

- GHP Reac PAX–RBS
- GHP Reac–RBS
- GHP PAX–RBS
- GHP flight–RBS
- RBS–RBS

Number of flights [55 - 75]
Delay [min] [60 - 140]
Pre-Tactical results
Pre-Tactical results
Conclusions and further work
Conclusions

• Flight and passenger centric metrics might lead to different results

• Four optimization functions considered
  – Arrival delay for flight
  – Arrival delay for passengers
  – Total delay for flight
  – Total delay for passengers
Conclusions

- Tactical management and delay is required to adjust arrivals
  - All strategies represent benefit with respect to RBS, benefit very small and there are not different between strategies
  - At the E-AMAN scope a more sophisticated strategy rather than RBS is not justified
  - E-AMAN allows to manage delay more efficiently leading to benefits in terms of fuel consumption, reduction of holdings, etc.
Conclusions

• Pre-tactical management (ATFM delay)
  – Other strategies rather than RBS might lead to better results for flights and passengers
  – If optimisation only focus on arrival delay, counter-productive effects might be generated
  – Minimising total delay considering turnaround the best strategies
  – Passenger centric might lead to higher reactionary delays and less fair delay assignment
Further work

• Passenger delay values are preliminary
  – Values highly correlated with aircraft size
  – Need to incorporate itineraries with connections
  – We expect to find strategies that will benefit passengers without impacting flight metrics significantly

• Propagation of delay should consider other sources of delay

• Cost of delay incorporated
Thank you