Explore the Past to Improve the Future: How Airlines Can Benefit From Historical Data?

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Agenda

- Airline operations: current state

- Robust Maintenance Routing Problem (MRP)
  - Definition of the problem
  - How robustness is defined
  - How to model/evaluate robustness

- Comparative results for robust MRP
Impact of disruptions (US)

- Total profit (07): $5.6 Billion
  - < 2% profit margin

- Total delay costs (08): $41 Billion
  - 4.3 Billion hours delay
  - $19 Billion additional operating costs
  - $12 Billion passengers’ value of time
  - $10 Billion spill out to other industries

- Pollution: 7.1 Mio tons of carbon dioxide.
  - 0.2% of total US emission in 2008, solely additional flight time due to delays
Robust Maintenance Routing Problem

- Modify existing maintenance routing by:
  - Re-assigning aircraft to flights (rerouting only)
  - Retiming flights for same routes (retiming only)
  - First rerouting and then retiming

- Use different Objectives:
  - Minimize total propagated delay
    - Requires historical data to estimate delays
  - Maximize total slack
  - Maximize minimum slack

- Limit total retiming by constant upper bound
Measuring Robustness

Robustness of a solution depends on

- Metric defining robustness
- Model
  - Objective function
  - Way objective is modeled
  - Way the model is solved
- Evaluation
  - A priori and/or a posteriori evaluation
  - Used performance metrics to evaluate
- Data
  - Airline type (network structure, disruption management,...)
  - Historical data used in model
Evaluating a robust MRP

- According to initial a priori metric
  - Total slack
  - A priori estimations on delay propagation
  - Effects of retiming (lost connections/passengers)

- Evaluate on a posteriori statistics
  - Aircraft statistics
    - Propagated delay
    - 15 or 60-minutes on-time performance
  - Passenger statistics
    - Number of disrupted passengers
    - Number of canceled passengers
    - Total passenger delay
Used models

- **Myopic methods (no historical data)**
  - IT: maximize total slack (RR or RT)
  - MIT: maximize minimum slack (RR or RT)

- **Models using historical data**
  - RAMR: minimize propagated delay then maximize slack by rerouting only (H1 or H2)
  - RFSR: minimize propagated delay and total deviation from initial schedule (H1 or H2)

- **Ways to use historical data**
  - H1: min average propagated delay on historical data
  - H2: min propagation of average delays
Propagated Delay – Original Schedule

Propagated Delay [min]

Original

March 08

0 200 400 600 800 1000 1200 1400 1600

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

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Propagated Delay – Rerouting only

Titre du graphique

- Original
- IT_RR
- MIT_RR
- RAMR_H1
- RAMR_H2

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Propagated Delay – Retiming only

Titre du graphique

Propagated Delay [min]

Original
IT_RT
MIT_RT
RAMR_H1
RFSR_H1
RFSR_H2

March 08

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Propagated Delay – Rerouting and retiming

Titre du graphique

Propagated Delay [min]

March 08

Original
RFSR_H1
RAMR+RFSR_H1
RAMR+RFSR_H2
Observations so far

- Retiming allows for higher propagated delay reduction
- H1 lead to better results than H2
- Myopic rerouting barely improve the original schedule
- Myopic retiming models are not reducing propagated delay as much as other models
  - Knowing where to place the slack allows for further reducing slack
Number of disrupted passengers

Total Disrupted Passengers

- **Original**
- **IT_RT**
- **RAMR_H1**
- **RFSR_H1**
- **RAMR+RFSR_H1**

March 2008

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Conclusions (1)

- More robustness is useful, but has to be well defined
- Using historical data helps
  - BUT: most intuitive way is not most efficient
- Myopic solutions are not as efficient w.r.t. delay propagation
  - BUT: way better in terms of disrupted passengers
Conclusions (2)

Q: Which model is most appropriate?

A: It depends what metric(s) the airline wants to improve!
Thank you for your attention!

Any questions?