Stochastic Air Traffic Flow Management

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Motivation

Published flights schedules are subject to disturbance events such as:

- Bad weather
- Mechanical failure

These events causes modifications to the flight schedules such as:

- Delay
- Rerouting
- Diversion
- Cancellations

in the states of Eurocontrol area:

- Flights faced a total of 9.3 million delay minutes in 2017.
- Delays increased by 58.1% in the period August 2017- July 2018 compared to the same period in the previous year.

Modifying schedules is a complex task and is not necessarily based on optimal configurations and options, which may lead to some negative impacts on the airspace stakeholders.

Initial Models

The following shows parts of the objective function that minimizes the network costs

Deterministic Version

$$\min C = \sum_{f\in\mathcal{F}}\sum_{z_f\in\mathcal{Z}_f}\left(\sum_{t\in\mathcal{T}^{f,z_f}_{dest_f}} c^f_{arr}(t)\left(w^{f,z_f}_{dest_f,t}-w^{f,z_f}_{dest_f,t-1}\right)+\sum_{t\in\mathcal{T}^{f,z_f}_{origin_f}} c^f_{dep}(t)\left(w^{f,z_f}_{origin_f,t}-w^{f,z_f}_{origin_f,t-1}\right)\right)$$
$$+\sum_{f\in\mathcal{F}}\sum_{z_f\in\mathcal{Z}_f/\{z^s_f\}} C^{f,z_f}_{reroute}\times\left(w^{f,z_f}_{origin_f,\mathcal{T}}\right)+\sum_{f\in\mathcal{F}}\sum_{k=dest_f k\in\mathcal{K},\left(f,z_f,f',z_{f'}\right)\in\mathcal{R},} C^f_{R\ airport}\times R^{z_f,z_{f'}}_{k,f,f'}$$
$$+\sum_{f\in\mathcal{F}}\sum_{j\in p^{z_f}_{f},\left(f,z_f,f',z_{f'}\right)\in\mathcal{R},} C^f_{R\ sector}\times R^{z_f,z_{f'}}_{j,f,f'}$$

Stochastic Version

$$\min TC = TC_{Delay}+TC_{Cancellation}+TC_{Reroute}+TC_{Diversion}$$

$$TC_{Delay} = GD^A+AD^A+AD^B+GD^C+AD^C+AD^D$$

$$TC_{Cancellation} = \sum_{f\in\mathcal{F}} C^f_{cancel}\times\left(1-\sum_{e\in\theta_T} p^e_T\sum_{z\in\mathcal{Z}_f} w^{f,z,e}_{origin_f,\mathcal{T}}\right)$$

$$TC_{Reroute} = \sum_{e\in\theta_T} p^e_T\sum_{f\in\mathcal{F}}\sum_{z\in\mathcal{Z}_f/z^s} C^{f,z}_{reroute}\times\sum_{k\in\ dest_f\cup dest^{Alt}_f} w^{f,z,e}_{k,T}$$

$$TC_{Diversion} = \sum_{e\in\theta_T} p^e_T\sum_{f\in\mathcal{F}}\sum_{z\in\mathcal{Z}_f} C^{f,z}_{Alt}\times\left(w^{f,z,e}_{dest^{Alt}_f,\mathcal{T}}\right)$$

Objectives

The goal is to provide a decision support system for Air Traffic Flow Management

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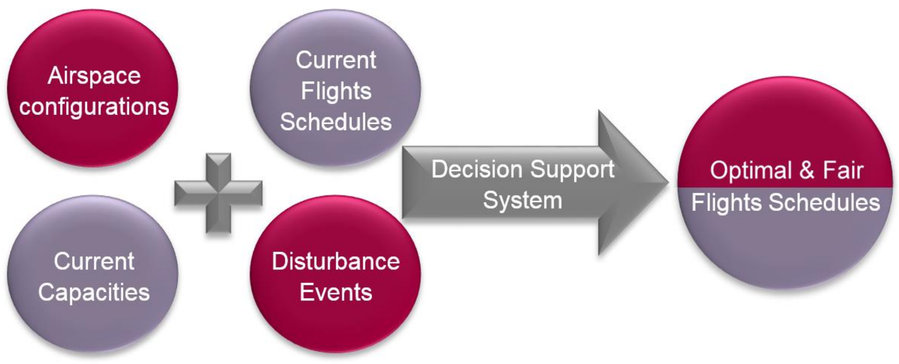
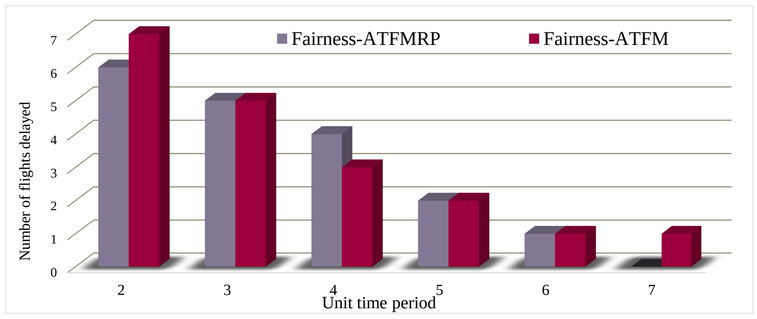


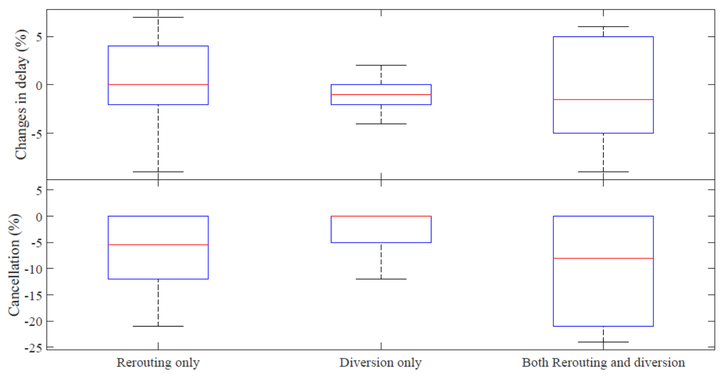
This system will help in developing mitigation plans in case of disruptions:

- Which flight(s) (if any) should be held in the ground or held in the air, for how long, and what are the new departure and/or arrival times?
- Which flight(s) (if any) should be canceled?
- Which flight(s) (if any) should be rerouted to avoid disturbance events and which alternative route is the most feasible?
- Which flight(s) (if any) should be diverted to a different landing airport?

Preliminary Results



The above figure illustrates the usefulness of including rerouting in the air traffic flow management (ATFM) model under fairness.

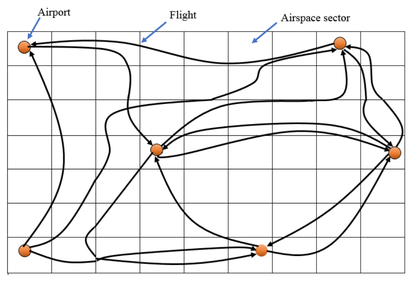


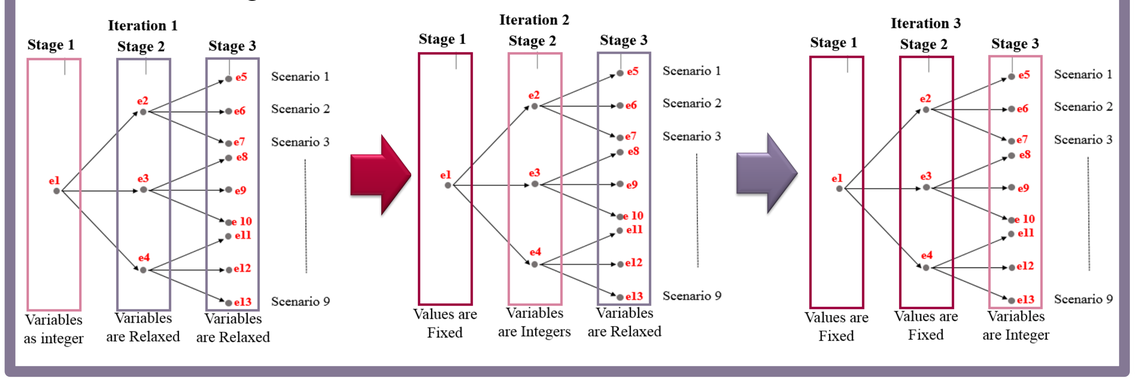
The above figure illustrates the impact of the different decisions of the ATFM on the flight cancellation and delays.

Approaches

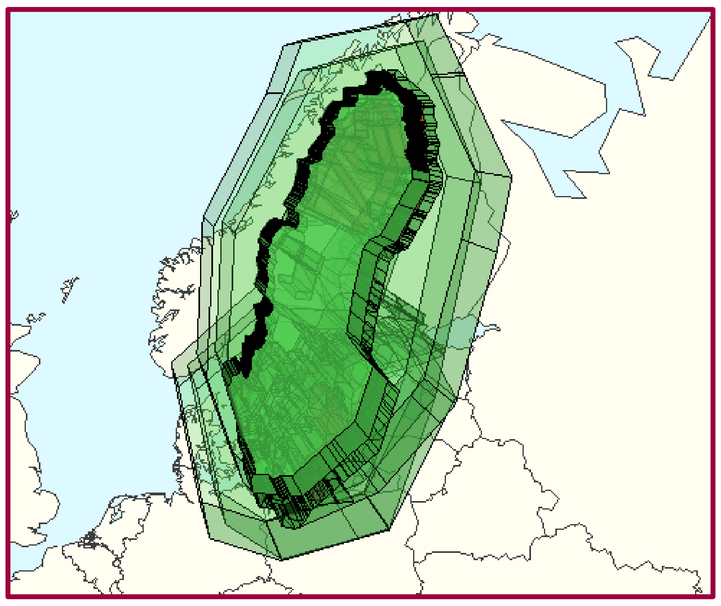
The Decision Support System is based on a **stochastic binary optimization model.** The Stochastic aspects are considered in the form of Scenario trees.

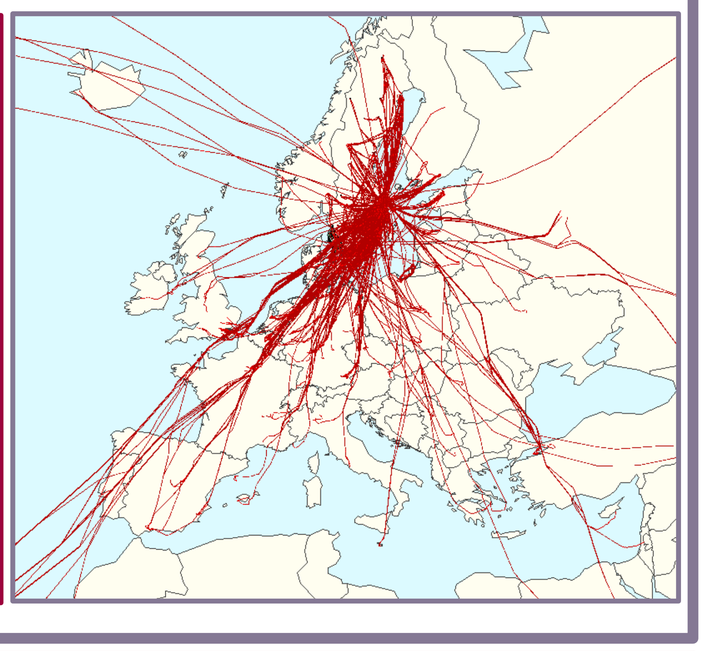
This model is solved using Fix and Relax Heuristics for large-size instances.





Case Study





Challenges

- The dataset contains some sensitive data that needs to be filtered
- The dataset contains some corrupted data that needs to be processed
- Flights networks cover the entire world which increases the complexity
- Limited data are available to define stochastic scenarios

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