Airline disruption recovery
ROADEF Challenge 2009

Niklaus Eggenberg and Matteo Salani

TRANSP-OR laboratory, École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Model The global structure is a Column Generation scheme based on the constraint specific networks presented in Eggenberg et al. (2008)[1]. We denote F the set of flights to be covered, P the set of available planes, S the set of *final states*, which describes the type of aircraft, the location, time and maximal allowed resource consumption expected at the end of the recovery problem for the ARP. T is the length of considered period, which corresponds to the recovery period for the ARP. A route r is defined by the covered flights in the route, the reached final state and the plane the route is assigned to. Let Ω be the set of all feasible routes r, x_r the binary variable being 1 if route r is chosen in the solution and 0 otherwise, and c_r the cost of route r. We also define the time-space intervals $l = (a,t)$ as the time period $[t, t+1)$ at airport $a \in A$, where t is the length of the time intervals to consider (typically 60 minutes). We denote L the set of all time-space intervals (there are $\mid A \mid \times \lceil \frac{T}{t} \rceil$ such intervals in total). The departure and arrival capacities for an airport a during period $[t, t+1)$ are given by $q_l^{\texttt{Dep}}$ and $q_l^{\texttt{Arr}}$ with $l = (a,t)$.

Finally, consider the following set of binary coefficients :

b_r^f 1 if route r covers flight $f \in F$, 0 otherwise ;

b_r^s 1 if route r reaches the final state $s \in S$, 0 otherwise ;

b_r^p 1 if route r is assigned to plane $p \in P$, 0 otherwise ;

$b_r^{\texttt{Dep},l}$ 1 if there is a flight in route r departing within time-space interval $l \in L$, 0 otherwise ;

$b_r^{\texttt{Arr},l}$ 1 if there is a flight in route r arriving within time-space interval $l \in L$, 0 otherwise.

Finally, we add binary slack variables y_f, $\forall f \in F$ for flight cancellation : y_f is 1 if flight f is canceled, and the associated flight cancellation cost is c_f. With this notation, the Master Problem (MP) is the following integer linear program :

$$\min z_{MP} = \sum_{r\in\Omega} c_r x_r + \sum_{f\in F} c_f y_f$$

$$\sum_{r\in\Omega} b_r^f x_r + y_f = 1 \forall f \in F$$
$$\sum_{r\in\Omega} b_r^s x_r = 1 \forall s \in S$$
$$\sum_{r\in\Omega} b_r^p x_r \le 1 \forall p \in P$$
$$\sum_{r\in\Omega} b_r^{\texttt{Dep},l} x_r \le q_l^{\texttt{Dep}} \forall l \in L$$
$$\sum_{r\in\Omega} b_r^{\texttt{Arr},l} x_r \le q_l^{\texttt{Arr}} \forall l \in L$$
$$x_r \in \{0,1\} \forall r \in \Omega$$
$$y_f \in \{0,1\} \forall f \in F$$

The objective obj is to minimize total costs. Constraints covering ensure each flight is either covered by a route $r \in \Omega$ or canceled. Constraints airport ensure each final state is

[1] Eggenberg, N., Salani, M. and Bierlaire, M. (2008a). Constraint specific recovery networks for solving airline recovery problems, Technical Report TRANSP-OR 080828, EPFL, Switzerland.

reached by a plane and constraints plane ensure each aircraft is assigned to at most one route. Finally, constraints departure and arrival ensure the departure and arrival capacities of the airports are satisfied, and constraints xint and yint ensure integrality of the variables.

In the Column Generation process, the pricing problem aims at finding new feasible columns improving the current (partial) solution. The pricing is solved as a Resource-Constrained Elementary Shortest Path Problem (RCESPP) on the constraint specific networks.

Passenger recovery Model obj-yint optimizes resource utilization, i.e. aircrafts, and tries to minimize the number of canceled flights. Once this problem is solved we build the complete connection network of available flights. Each flight is represented as a node and each arc represents a possible connection for passengers between two flights, dummy node $\{0\}$ represents generic passenger source and arcs between flights to the dummy node represent final connection for passengers. The capacity of the flights in terms of number of passengers are associated to outgoing arcs.

For each itinerary we solve a flow problem on the connection network where the origin, the destination and the available time for the passenger are taken into account to slightly modifying the network as follows : the capacity of arcs $\{0\} - f$ is set to 0 for all flights not departing from itinerary's origin. The same happens for final arcs for itinerary's destination.

When the passengers are routed on a flight, the aircraft's capacity covering the flight is updated accordingly. Itineraries are considered in a greedy way : those with highest cancellation cost are rerouted first.

Computational Results In this section we present some computational results for the ROADEF Challenge 2009 B data set.

Instance	Total Cost	Instance	Total Cost
B01	45332180.70	B06	58083111.10
B02	65932350.15*	B07	88709573.80*
B03	47399606.25	B08	61334494.65
B04	46958301.10	B09	61334690.40
B05	96062882.85	B10	117368359.35

Tab. 1. Recovery cost for instances B01-B10.

For instance $B02$ and $B07$ our algorithm was not able to automatically reroute aircraft $BAE200\#116$ to its maintenance airport. In practical implementation of a recovery algorithm this can be easily done in a post-processing phase.