Challenge ROADEF 2009
Disruption Management for Commercial Aviation, A Mixed Integer Programming Approach

Sophie Dickson[1], Olivia Smith[1] and Wenkai Li[2]

[1] Department of Mathematics and Statistics, The University of Melbourne
s.dickson@ms.unimelb.edu.au
[2] Faculty of Information Technology, Monash University

This abstract describes a solution approach to the problem posed in the **ROADEF 2009 Challenge : Disruption Management for Commercial Aviation**. For details of the challenge see `http ://challenge.roadef.org/2009`.

The **ROADEF Challenge 2009** deals with the airline recovery problem. The objective is to find the optimal passenger and aircraft routing given a set of disruptions, existing passenger itineraries and operating constraints.

The operating constraints considered include airport capacity constraints (limits on the number of departures and arrivals per hour), the minimum turn time for each aircraft (or transit time for multi-leg flights), the maximum flight range for each aircraft, any maintenance requirements (at a specific location and time), aircraft capacity, minimum connection time for transiting passengers, maximum passenger delay and the required aircraft location at the end of the recovery period.

The disruptions considered in the challenge include airport capacity disruptions such as reduced departure and arrival capacity or closure, aircraft unavailability (the timing and duration of an aircraft unavailability due to unserviceability or fault), flight cancellations and flight delays.

For more detail on the constraints and disruptions, the reader is referred to the full problem description at `http ://challenge.roadef.org/2009/challenge_en.pdf`.

A 2 stage process was developed to address this problem. The first stage seeks to re-route aircraft, retime and/or cancel flights so as to minimise the disruption experienced by passengers on their existing itineraries. This is achieved through the use of a Mixed Integer Linear Program (MILP) connection network, with flights represented by nodes and connection variables for both passengers and aircraft. A continuous delay variable also exists for each flight to allow it to be retimed.

A second phase then reoptimises passenger itineraries based on the flight schedule determined in phase one. A multi-commodity network flow model is used, with each passenger itinerary a separate commodity, flowing through arcs representing each cabin class in each flight. The objective is then to maximise the value of the itineraries flowing through the flight network, within the given flight capacity and passenger demand.

There are a wide range of potential scenarios for the airline disruption problem, and each scenario presents its own challenges with resepect to solvability of the MIP. As a result, some aspects of the model are adjusted according to the size of the problem (e.g. the number of flights, the duration of the recovery period, the number of passenger itineraries).

The key to keeping the MILP at a manageable size is to limit the number of binary variables. Flight connections and departure/arrival slot variables represent a significant proportion of binary variables in the model. The following parameters are used to limit their number

- *MAX_FLIGHT_DELAY* restricts how long we are prepared to delay a flight. Any flight that does not depart within *MAX_FLIGHT_DELAY* of its original scheduled time of departure, must be cancelled. This parameter limits the number of binary variables required for the airport capacity constraints because the longer a flight is able to be delayed, the more possible airport slots it can depart/arrive in.
- *MAX_GROUND_TIME* dictates where flight connections representing aircraft flow are able to be created. If flight j is scheduled to depart within *MAX_GROUND_TIME* of the scheduled arrival time of flight i, then our solution approach will create a connection variable between these two flights, otherwise it will not.
- *MAX_SLACK_SHIFT* also dictates where flight connections representing aircraft flow are able to be created. For regular routing you would normally only expect to create a connection between flights i and j if flight i arrives at least MTT[3] before j is scheduled to depart. However, in the disrupted environment, the best option may be to delay a flight until an aircraft becomes available. *MAX_SLACK_SHIFT* determines how long you would be prepared to delay flight j to wait for the aircraft from flight i to become available.
- *MAX_SLOTS* limits the number of airport departure/arrival slots considered for each flight.
- *MAX_SUCCESSORS* limits the number of possible successors for a given flight. Note that this excludes the original successor of that flight, which is always included.

These parameters are adjusted dynamically according to the size of the input problem, for example, problems with a large number of flights are given a lower value of *MAX_GROUND_TIME* so as to reduce the number of connections.

For larger problems, the paramaters mentioned are set to very restricting levels in order to ensure the Xpress-MP solver can find a feasible solution within the time allowed. Extra variables and hence routing possibilities are then added by iteratively extending these parameters, while the integer solution found in the previous iteration is loaded to ensure a feasible solution is always available.

The model and solution approached outlined were implemented in Xpress Mosel Version 2.0.0 and run in Xpress-IVE Version 1.18.01 on a PC with an Intel(R) Core(TM)2 Duo processor and 2GB of RAM running Windows XP Professional SP2 (32 bits). Results were obtained on the provided problem sets. All of these results were set to run for 600s, however the way the time is allocated between Phase I and II sometimes means there is leftover time, whether or not an optimal solution was found in the first phase.

[3] Minumum Turn Time