

# **Problem 3: AIR TRAFFIC FLOW MANAGEMENT REROUTING PROBLEM**

**Industry: Air transport**

**Industrial Representative: Alex Somto Alochukwu**

**Moderators: Aderemi Oluyinka Adewumi, University of KwaZulu  
Natal and Montaz Ali, University of the  
Witwatersrand**

**Student Moderator:**

## **Preamble:**

The air transportation industry has experienced rapid growth in recent times and the demand for airport and airspace usage increases exponentially as the number of users increase. Moreover, congestion problem abounds almost on a daily basis as a result of bad weather conditions and other unforeseen factors. This has a serious effect and impact on the Air Traffic Control System as well as the nation's economy due to the significant costs incurred by the airlines and passengers arising from the flight delays. Hence, the need for efficient and safe air traffic flow management that mitigates delays, congestion problems as well as minimize the cost of total delay.

Currently, The Central Airspace Management Unit (CAMU) is responsible for the management of air traffic flow and capacity management within South African airspace in collaboration with the South Africa Air Traffic and Navigation Services (ATNS), the sole commercial provider of air traffic, navigation and associated services and responsible for air traffic control in approximately 10% of the world's airspace.

To ensure safe and efficient traffic flow management, CAMU already have different ATFM techniques like Ground Stops, Ground delay Programmes and Airspace Flow Programmes as well as ATFM tools like Airport Flow Tool (AFT), Airspace Management Tool (AMT), Thales's ATFM solution (FLOWCAT) AND CAMU WEB etc. for traffic management decision making which can either be strategic, pre-tactical or tactical flow management decision. In particular, FLOWCAT developed by Thales with the support of Metron is a system that optimizes the use

of available airspace and airport resources by balancing load and capacity in order to reduce delays, alleviate congestion and streamline the workload of air traffic controllers.

One of the major challenges encountered by air traffic managers is the problem of finding good and optimal scheduling ATFM strategies that minimizes delay costs as well reducing the impact of congestion problems while satisfying the airport and en-route airspace capacity constraints. The problem statement and the expected modeling variation are presented below taking into consideration that the number of flights departing or arriving from a certain airport as well as the number of aircraft's traversing in a particular sector of the airspace are functions of several variables: the number of runways available, ATC capacity, airspace restrictions and restrictions as to which aircraft can follow an aircraft of a given class

## **Problem Statement:**

### **Input Data Sets and Parameters:**

- Given an airspace system, consisting of a set of airports, airways, and sectors, each with its own capacity for each time period,  $t$ , over a time horizon of  $T$  periods,
- Flights schedules through the airspace system during  $T$ .

### **Constraints:**

The constraints for the model formulation are classified into different category namely capacity, operational or connectivity and delay constraints. The bounds of the variables are also considered as part of constraints when formulating the model. The capacity constraints ensure that the capacity of the resources is not exceeded while the operational constraints ensure the smooth operation of flight while en route to its destination. The delay constraints ensure that the flight ensures that the maximum allowed time for flights are not exceeded. They include:

- The number of flights departing from or arriving at an airport at time period  $t$  does not exceed the departure and arrival capacity of airport for that time period.
- The number of flights in a sector at time period  $t$  does not exceed the sector capacity for that period.
- Connectivity between sectors or Connectivity between routes depending on the modeling choice.
- Flight arrives to its destination if it departs from its origin airport and vice versa; otherwise, the flight is canceled.
- Flight connectivity to take care of instances where flight's aircraft is scheduled to perform a subsequent flight within certain user specified time interval continued i.e flight continuation.
- Flight cancellation priority.
- Each flight is expected to arrive to its destination without exceeding the maximum acceptable duration of flight; otherwise the flight is canceled.
- Connectivity in time for all flights.

## Objective Function:

The global objective function, depending on the goal of the decision makers, can include different terms which can be combined using appropriate weights to form a single objective function to be optimized. In as much that the objective function comprises of different terms to be minimized, the main goal is to minimize the total delay costs in such a way that airborne delay should be more costly per unit of time than ground delay and delays assigned to flights should be in a "fairly" manner.

- ❖ Cost of delaying the flights.
- ❖ Total Cancellation Cost.
- ❖ Number of flights exceeding the maximum allowed number of time units delay for arrival to their destination without penalization.
- ❖ Cost of arriving at each sector at each time period,  $t$ , in the flight routes.
- ❖ Cost of using alternative flight routes.
- ❖ Cost of arriving at each sector at each time period,  $t$ , in the flight routes.

The basic ATFMP has been formulated and solved using exact methods (and extended to stochastic environment) considering cases of airport congestion and in some cases both airport and airspace congestion but not many of them considered rerouting as a control option. To include rerouting in the formulation, there are two known approaches to consider namely sector or path approach.

- **The Path Approach:** decides from onset which of the routes a flight chooses from available options of routes to reach its destination. To use this approach, the set of possible routes that a flight may fly needed to be defined and the formulation of the problem need to be of manageable size.
- **The Sector Approach:** decides at each sector in a flight's route, the next sector to enter a next. To use this approach, one needs to define the set of sectors that a flight can enter immediately after leaving a particular sector and another set of sectors that flight can enter immediately before entering a sector. This is defined for each sector in a flight's path.

## Problem:

- Can this problem be formulated as a Linear Integer Programming Model or Mixed Integer Programming Problem for the deterministic case using the approaches mentioned above? More precisely, how best can one formulate this problem to depict the current practice in South Africa?
- It has been shown that exact optimization methods cannot handle large instances. Hence, what is the best heuristic or meta-heuristic approach that can be applied to solve large instances of the Air Traffic Flow Management Rerouting Problem?
- Since we already know that the system is disrupted when there is fluctuating weather conditions, equipment outages and demand surges and these disruptions are highly unpredictable and cause significant capacity-demand imbalances, temporary and substantial reductions in airspace and airport capacity. The big question that arises is how

to extend the deterministic environment of this formulation to a probabilistic environment in order to account for the uncertainties that are inherent in the system.

### **Modelling Variation and Additional Opportunities:**

- There are cases where same runways are used for both arrivals and departures. Thus, the runway allocation is the determining factor of how the airport's capacity is allocated between the arrivals and the departure at a given time. This gives rise to trade-off between arrival and departure capacities. How can the model be extended to account for this variation
- One assumption of the models that considered the basic ATFMP is that "flight connectivity constraints needed to be satisfied a priori based on planned aircraft connections". But this is not always the case in practice due to the presence of hub and spoke networks which motivate the use of bank of flights. With respect to this, how can the formulated model be extended to account for Hub Connectivity with Multiple Connections and Banking of Flights Constraints.
- Interaction with Airlines: Airlines have the opportunity to propose modifications to ground delays that have already been assigned through a cancellation or substitution process. How can these interactions be analyzed and what additional constraints can be imposed on the model to cover airline requirements such as maximum ground holding and air delay that can be assigned to the flights of each airline and maximum number of flights for any airline that can be ground held or delayed in the air.
- Dynamic Updating of Decisions: In theory, ground and air delays are assigned simultaneously before a flight leaves but in practice, en-route delays are not issued until after the aircraft is in the air. How can this be addressed and also how can the previous solutions be updated in order to incorporate any new available information.