Abstract

Airspace congestion is a worrying feature of the European Air Traffic Management system. It’s of paramount importance to work out an effective regulatory policy in order to protect en-route airspace from overflow, this is likely to affect more delays to aircraft, regrettably for airspace users (since airspace is a bounded resource and users are many). Anyway, the relevant cost to be minimized is total delay.

This paper recalls key elements of Air Traffic Flow Management, depicts the main problems and discusses the strategy and challenges to take up so as to improve air traffic performance.

Introduction

Aircraft filed under Instrument Flight Rules require complete control services: Terminal control at aerodrome level, Approach control in climbing and descent and En-route control during the cruise stage.

In the sequel, we are interested in the upper airspace (above 195 Flight Level), which is liable for en-route control, all involved aircraft are mandatory of IFR group.

Why regulation?

For all practical purposes, en-route control is done by teams of controllers; each team is responsible of a center constituted of elementary sectors of a geographical region.

Each team of controllers shares workload by collapsing elementary sectors so as to form groupings; a lot of configurations (called opening schemes) are possible.

Controllers are able to handle traffic safety if its load is reasonable; the number of aircraft entering an activated grouping shall not exceed a threshold (called capacity and expressed in aircraft per hour), which depends on its geometry and routes layout.

Consequently, airspace is to be protected from congestion. Different measures can be applied within this framework, for instance affecting regulation delays to aircraft take-off times, re-routing aircraft in real time, collaborative decision making and adapting opening schemes to the observed traffic.

Capacity

By analogy, capacity can be defined to an Air Control Center as the number of aircraft the team of controllers can manage safely.

It is worthwhile noticing that the later definition is quite consistent despite its obvious (but deceptive) dependency on the team size, it is neither the sum of sectors capacities nor sensitive to the way the center is split into small sectors.

In fact, if we add more controllers to a center team, each controller will handle smaller area and thus will have less monitoring and conflict workloads, but unfortunately more coordination workload. This compensation shows that airspace congestion can’t be avoided simply by recruiting controllers! There is a workload barrier; center capacity is to be understood in this sense.

Several approximate values are used in practice:

• Nominal saturated capacity gotten by combining sectors capacities so as to have all sectors saturated.
• Nominal zero delay capacity is so defined when the first sector reaches saturation.
• Observed capacity, determined from current traffic data.
• New capacity values can be assessed using COCA software (Complexity and Capacity) developed by NAS.

Some Air Navigation Services Providers declare ACC capacities to CFMU in order to be used for ATFM processing, others declare openings schemes with the corresponding capacities. Anyway, the CFMU uses the best values known to it into the process.

In a nutshell, this stage is performed by a deterministic algorithm (Computer Assisted Slot Allocation), which affects delay to aircraft at take-off so as to insure en-route capacity constraints while respecting an equity principle.
of « the first planned is the first served ».

**Safety rules**

En-route controllers are responsible of the application of safety rules in operational conditions, which consists in aircraft separating vertically (by 2000 feet below Flight Level 290 and 1000 feet above it), horizontally (by 5 nautical miles or even more at collapsed sectors borderlines) and laterally.

Each activated en-route grouping is managed by two controllers, one is Executive in contact with pilots via Data Link, the other is Planner keeping an eye on strips board and negotiating flight parameters with adjacent groupings in order to make the traffic less complex.

Strips are printed half an hour before aircraft entrance to the center, and become activated when neighbor center controllers phone to update flight parameters.

These tactical measures avoid clusters or simultaneous conflicts that may occur theoretically at any moment due to uncertain delays aircraft have.

It follows that we shall insure steady control workload during a broad period without care for the small fluctuations of traffic intensity.

Current traffic data show that en-route capacity constraints are not satisfied all the times. In over delivery periods, leaving aside conflict workload, monitoring and coordination workloads increase. Controllers may change aircraft routes or flight levels so as to make their job easier and more effective.

**ATFM process**

We distinguish three different levels:

**Strategic planning**

This phase hits the high spots several months before the day of operation by analyzing flight demand evolution, potential problems and finding a way of making the air traffic safe, orderly and effective.

Resulting annual capacity plan is the only thing related to airspace congestion.

**Pre-tactical planning**

Aircraft submit flight plans to the IFPU (of Brussels if departure airport is in northern Europe, or of Brétigny-sur-Orge in France otherwise), which corrects syntax errors (i.e. mistakes in names of beacons) and route errors (i.e. some flight segments are not authorized because of restrictions published by ANSPs of European states).

Twenty four hours before the day of operation, these flight plans are sent to the CFMU (Brussels) for slot allocation. Almost 80% (or even more) of the day traffic load is concerned.

**Tactical planning**

Late flight demands are sent to the CFMU for slot allocation, traffic loads begin to reach capacity limits, and the dynamical shift of regulation process starts.

Some flight plans (up to 5%) contain route errors but even so are accepted by IFPU if the aircraft are already in the airspace (it is the case of aircraft coming from outside Eurocontrol region and submitting late and erroneous flight plans).

Update strips are sent to concerned en-route control centers, and the teams of controllers deal with the current traffic insofar as possible.

Controllers are used to ask for changes in routes or flight levels in order to avoid conflicts and simplify their task.

**Concrete example**

The following data belongs to Lonon's region (EGTT), which contains five ACCs: northern EGTTNACC, eastern EGPTTEACC, southern EGTTSACC, western EGTTWACC and central center EGTTACC, we'll pay more attention to the later.

Data concerns the period from Thursday June 10th to Sunday June 13th 2004 (Airac cycle 406).

In all the subsequent figures, the curves plotted in black and red represent respectively flight demand before and after regulation (filed traffic FTFM and regulated traffic RTFM), while the blue curve describes current traffic (CTFM) evolution.

**ACC case**

First, let's take a good look at a center
In the figures 1.1 and 1.4, the black and red curves are almost identical, this means that the flight demand don't contravene capacity constraints. However, regulation is behind the slight differences between these curves in figures 1.2 and 1.3.

Current traffic curve shows higher peak values than what is forecasted in most of times, so can we speak about over-delivery?

In reality, over-delivery is to be understood with respect to controllers workload, realized traffic values ought to be compared to capacity rather than regulated traffic values.

**Increasing traffic volume**

One can amplify regulated traffic average (or peak) value over a period of the day to reach capacity limit, then the difference between realized and regulated traffic curves contains information about over-delivery that would result if traffic demand was higher enough.

This idea sounds fair but it's false, air traffic is rather too complicated to be modeled in a linear way: in fact, if a center is non congested, it can cope with more traffic, neighbor centers controllers may reroute aircraft through it in order to alleviate their workloads. The supplementary traffic resulting from such plausible collaboration disappears near capacity.
level.

**Rerouting aircraft**

Rerouting aircraft for congestion purposes is not a theoretical hypothesis.

Traffic analysis shows that some aircraft have crossed the center EGTTCACC unlike what is mentioned in flight plans.

By analogy, a part of flight demand seems to be cancelled, but maybe the corresponding aircraft were rerouted!

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**Figure 2. Unnormal traffic in EGTTCACC from June 10th to 13th 2004**

Cancellation or not, how the supplementary traffic of the blue curve can be explained?

One can say, because we are dealing with British Isles, Jet Stream (fast air current flowing from west to east) is the responsible of traffic variability, physical routes may be shift from a center to another due to meteorological reasons.

However, after sorting aircraft according to departure and arrival airports, aircraft related to Canada (whose airports codes are of the form (CY**)), the USA (K***) and Central America (M***) have no connexion with our case. The main concerned flights are between the UK and other European Countries (E*** or L***).

Thus, it's deliberate controllers reroute aircraft regardless meteorological situation, probably due to traffic handling difficulties.

**Uncertainties on EOT**

Normal traffic, constituted of all aircraft having crossed EGTCCACC according to already submitted flight plans, shows small oscillations of current traffic curve around the one of regulated traffic.

Delays aircraft have weak mean value and small standard deviation (except during the night, where capacity problems are absent),

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That's why uncertainties affecting aircraft Estimated Off Block times have a reduced effect on traffic load in the congested periods.
General overview

This remark holds also for others centers in London region where rerouting is negligible. As depicted in Figure 3, the northern and eastern centers show considerable harmony between traffic types, while the western one reveals small oscillations.

The remaining center is the most crossed, it has a realized traffic at a level slightly below what is forecasted.

Despite the compliance of flight demands above EGTTACC with its capacity constraint (because the red curve is not a peak limited version of the black one), the high values of traffic make controllers reroute some aircraft via the central center EGTTACC, mainly those flying nearby.

Opening schemes

The last traffic load is important, certainly, but is there any congestion?

Each grouping configuration (opening scheme) gives a capacity value to the center, these values are of the same size.

When the CASA algorithm allocates slots, it yields a traffic that cope with center capacity.
but not necessarily with the configuration constraints if it is not known to it. Overflow may result at groupings level even if it's all right at center level.

Controllers are used to change their configuration according to their number and the observed traffic.

The configuration filed for EGTTCACC on Thursday June 10\textsuperscript{th} 2004 can't be applied as it is because of the obvious unbalance of workload, see the figure 4 (30 mn counting).

![Figure 4. Traffic volume and sectors configuration of EGTTWACC](image)

### Discussion

#### Questions

1. Should slot allocation be performed with center capacity or capacities of groupings?

2. Should slot allocation remain deterministic or become stochastic to absorb EOB uncertainties?

3. What measures are able to protect airspace from congestion if flight demand continues its increase?

#### Author's beliefs

1. With center capacity, the traffic resulting from slot allocation may not be suitable for the filed opening scheme. However real-time change of the configuration is possible to follow traffic behavior.

Therefore, this solution would be better than the second one, which may result in great amount of total delay to aircraft if the traffic demand is far from the filed configuration.

2. It's not fair to accuse CASA of ignoring uncertainties since they have reduced effect and don't induce congestion, moreover safety rules that controllers apply avoid disastrous situations. Any stochastic procedure will give more total delay since it takes some margin with respect to undesirable events (weighted with its probability of occurring).

3. It's a wide open question. Controllers often choose a configuration with no information about the distribution of traffic, so there is a gap of capacity between ACC and groupings levels.

Airspace congestion requires better opening scheme optimization, which is possible if separation of collapsed sectors becomes more flexible.

Rerouting aircraft via less congested areas can be proposed in the pre-tactical phase, as controllers can ask for it as a tactical measure. However this solution is not welcome in European ATM.

As far as the increasing number of flight demands, when traffic volumes becomes beyond airspace capacity, we have to let a part of the traffic out of control (like over the oceans), long-range aircraft for instance may be separated from the rest by devoting the highest flight levels to highways.

### Conclusion

Although air traffic centers are close one to another, airspace congestion does not affect them in the same manner; some pre-tactical and tactical measures can be elaborated so as to insure reasonable workloads for en-route controllers.

As for the future, with saturation of airspace resources in long-term, congestion problem cannot be overcome unless airspace structure is re organized.
References


Biography

Nabil Belouardy holds an engineering degree from Ecole Polytechnique (France) in 2001, and a Msc (DEA) in automatic control and signal processing from University of Paris XI. After a short mission into THALES laboratories, he joined ENST Paris for PhD studies, his research is supervised by Patrick Bellot and Vu Dong at Eurocontrol Experiment Center.