

Reducing Traffic bunching through a more Flexible Air Traffic Flow Management

Extended abstract for ATM-2001

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Summary

Traffic bunching in congested sectors is a serious threat to the efficiency, but also to the safety of the European Air Traffic Management (ATM) system. Bunching occurs when packets of aircraft arrive at the same, unexpected time, in a congested area. The European Air Traffic Flow Management (ATFM) system has been built with the principle objective to prevent Air Traffic Control sectors from being delivered more traffic than they can safely handle, and therefore principally aims at annihilating the bunching effect. The very simple model we have developed and describe in the present paper shows that the intrinsic tolerance of the ATFM mechanisms, such as, for example, allowing for a take off 5 minutes before or up to 10 minutes after the calculated time, leads to built-in bunching in ATFM-regulated, and therefore congested areas. Our model also shows how some specific operational behaviours, characterising specific operations such as hub operations for example, result in traffic bunching, *actually amplified* by the ATFM mechanisms. The model is then used in order to introduce adaptive Flow Management measures, which, applied after the flights have taken off, could alleviate the generation of traffic bunching.

1. Introduction

The European Air Traffic Flow Management system primarily aims at protecting Air Traffic Control positions from being overwhelmed with traffic. It is based on centralising the demand for traffic in the European airspace, and processing it in order to smoothen traffic peaks where demand exceeds capacity. The current system relies on a calculated take off time which, taking into account the predicted trajectory of the aircraft, makes sure that congested areas are protected from overload, and that the available capacity is used in the most efficient manner.

Although the principles of the European ATFM system have shown their overall efficiency in the last 5 years, its very foundations, which rely upon static calculations made on Flight plans and frozen until the actual departure of the aircraft, seem to bear inherent sub-efficiency.

Indeed, imposing constraints on Take Off Times can be a heavy burden for airports and airlines operators, having other optimisation objectives in mind; for example, isn't the hub philosophy, which aims at concentrating arrivals and departures in banks, at the opposite of what ATFM tries to do? Statistics have, thus, shown that a significant number of major airports in Europe have high non compliance rates with ATFM departure slots (the average non compliance rate in Europe is of 23% flights outside the tolerance window, with peaks up to 34 or 35% at some major hubs)¹...

Other sources of uncertainty in the system can lie in the tolerance of the ATFM system itself (the slot tolerance window is of 15 minutes), or of unexpected events affecting the actual trajectory of aircraft (e.g. aircraft receiving a 45 minutes delay, and trying to compensate that delay by speeding up).

The impact of these inefficiencies is a high uncertainty on the actual time of entry of ATFM regulated traffic into a congested area, resulting in overloads followed or preceded by under-usage of available capacity. Such overloads, which can have a severe impact on the ability of controllers to do their tasks safely, have a direct result, which is an under-declaration of the potential capacity in order to protect the sectors from safety critical situations. They also, mechanically, lead to worsened under-usage of available capacity.

The present paper tries to examine the effect of minor,

¹ ATFM/IFPS Operations Statistical analyses, November 2000, CFMU report

or not so minor, stretches to the ATFM rules, on the traffic deliveries into a congested area. It then shows how new Flow Management measures could alleviate that effect.

2. The bunching effect in Air Traffic Flow Management

A preoccupying risk in leaving some loose end to ATFM rules is certainly the birth of uncontrolled peaks within the traffic deliveries at entry in a congested area. This phenomenon is well known in the operational world as the “traffic bunching” effect, which is often denounced to explain controllers’ mistrust towards the ATFM service.

As a matter of fact, the presence of traffic peaks in the system is quite natural. The European system of prevention against congestion is currently quasi exclusively based on a centralised ground delay planning process, rather isolated from actual operations. With a significant notice, at least three hours before planned departure, AO’s are requested to file their flight plans at the Central Flow Management Unit. The flight plans database is input in a planning system, the TACT-CASA, which, in case demand exceeds available capacity, runs a smoothing process. It consists in modifying the planned departure of filed Flight Plans for each flight in the restriction in order to smooth over time the demand within the limits of available capacity. This process results in a “departure slots allocations plan” which is the principal product output from the ATFM system. Allocated departure slots are transmitted at least a couple of hours before planned departure to concerned AO’s, which are requested to re-organise their flight operations accordingly. The ATFM instruction per regulated flight is roughly the following: respect of the deposited flight plan with updated departure time as allocated by the CFMU planning system.

The operational application of the ATFM plan is thus confided to AO’s, with respect to a pre-defined series of “ATFM rules” but with little control from the CFMU on the process. In such a context, the current system can hardly grant a strict application of the emitted plan thus a perfect control of the resolution of congestion issues. At least, in average, can the system grant that the hourly capacity is not exceeded. However like any “remote-controlled” system, it must deal with intrinsic noise, which is precisely at the origin of these famous “bunching peaks”.

Still, in any system of any kind, dealing with a certain level of noise is actually unavoidable. The important point is to manage to confine this noise within “acceptable limits”. It is crucial in terms of quality of

service. Now the peaks, which inherit the “traffic bunching” appellation are precisely the ones presenting amplified, disturbing magnitude, operationally felt as threatening and therefore overwhelming the “acceptable” noise limits the system of prevention against congestion should tolerate. The bunching phenomenon is thus a sort of symptom of punctual deterioration of the ATFM service.

As far as ATFM is concerned, the argument traditionally exposed to grant a certain minimisation of this “operational” noise relies on the so-called “compensation effect”. It essentially deals with the fortunate juxtaposition of all isolated operational drifts from the ATFM plan, leading to a different but all so suitable traffic distribution as the planned one. Whether the bunching effect is effectively ‘confined’ in acceptable limits due to the natural trend of all drifts to compensate each other is one major question raised herein.

As a consequence, while analysing potential impact of stretches to ATFM plans and rules, a great deal of attention has been devoted to the “bunching phenomenon” playing against the “compensation effect”. The very motivation here is to better apprehend what could be the operational mechanisms leading to traffic bunching peaks, possible orders of magnitude, frequency... For this purpose, a light model based on Excel routines has been developed providing a quantitative dimension to the analysis. Tests on a series of operational events potentially generating bunching have been run using it. The results further presented are part of the most meaningful simulation output, whose interpretation explains, to a major extent, what may motivate the introduction of new operational practices aimed at correcting such problematic distortions.

3. The model

The model is aimed at exploring among operational situations typically perceived as disturbing, potential sources of bunching on a regulated traffic. It is based on a rather simple principle: provided a regulation plan issued at the CFMU, each AO, each airport involved, either strictly adhere to ATFM instructions of the plan or slightly (or significantly) derives from it. All isolated drifts are modelled and their cumulated effect on the ATFM plan is visualised.

In order to concentrate on “operational noise” exclusively i.e. the one due to non-strict application of the ATFM plan, regardless of other sources of noise within the ATFM planning system itself., the model ignores algorithmic finesses of the departure slots

planning process, which in the model is reduced to its simplest expression: perfect smoothing of the demand in adherence to the declared capacity.

Provided a baseline regulation plan, the model calculates the actual amount of traffic at entry in a congested sector, as a result of the accumulation of all distortions from the regulation plan issued by the CFMU (e.g. delayed flow at airport, en-route recovery of a delay for a certain part of the flow...).

Distortions from regulation plans are dependent on the particular behaviour airports and AO's show in regulated situations (whether they have difficulties to adhere to the plan, whether they tend to compensate en-route the imposed delays on-ground...). Such behaviours are modelled and input in the simulation. These are the source-elements of the operational noise visualised in the simulation output.

The results are given in percentages since the whole interest here lies in is the magnitude of the peaks that can be generated compared to a target noise tolerance, which may be situated around a + 10% overtaking limit.

• The baseline regulation plan

The slot allocation model is intentionally reduced to its simplest expression, since issues related to the slot allocation by itself are not considered. Departure slots are calculated only to estimate the resulting delay per flight since the delay imposed to flights is the main element, which condition aircraft as well as airport operators' behaviours in regulated situations (the worse the delay, the more perturbations, the more resistance to regulation, the worse the adherence to the plan? ...).

The slot allocation model is simply based on a stretching of the periods of traffic transit in proportion to the demand excess. 30% demand excess on a given period leads to a 30% stretching of the same period, stretched period along which flights are regularly spaced. It leads to an increase (roughly linear) of the average delay per flight as time goes on.

The regulation scenario has been modelled considering the following context:

- One sector
- three flows feeding the sector whose proportion with regard the traffic entering the sector evolves with time. The sector is alternatively fed in majority either with the first (mid-grey) or with the second (dark grey) or with the third flow (light grey).

- 4 hours regulation simulation:
 - 2 hours with 33% of demand excess
 - 1 hour with 10 % demand excess
 - 1 hour with 33% excess

Below are roughly summed up the input and output of the regulation model taken as baseline. The first diagram (figure 1) represents the demand/capacity ratio before regulation, the second one (figure 2) after regulation, associated with the distribution of traffic per flow. The three-colour code below is used in all diagrams of the article to identify each of the three flows considered for the simulations.

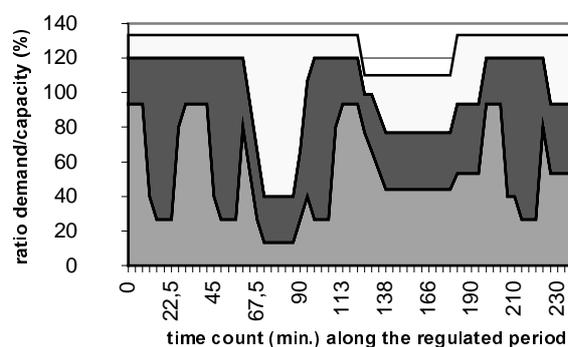


Figure 1 - regulation context: demand over capacity, distribution of the demand per airport

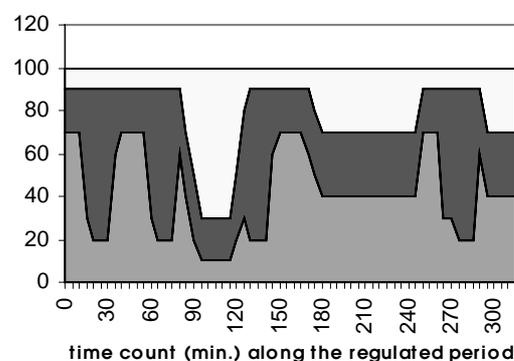


Figure 2 - regulation context: regulated traffic over capacity, distribution of the traffic per airport

The only viewable effect of the regulation is a smoothing of the initial demand rate at 100% of the capacity and a stretching of the period of traffic transit (from 240 min. to 306 min.). The resulting distribution of the delay goes from 0 to 66 minutes.

• Simulating “operational behaviours”

The simulation of “operational behaviours” is at the core of the model. It is indeed through it that the bunching phenomenon is generated. It characterises

the way the ATFM slot plan is respected in operations by the various operators involved in the process (airports and AO's).

Among typical “operational behaviours” in regulated situations one can quote the example of airports managing regulated flight departures with a strict respect of the planned ATFM instructions, in opposition to airports operating with slight spreading of departures outside from the ATFM tolerance, giving the priority to the platform movements optimisation. These are two opposite variants of “operational behaviours”, not to mention some airlines’ policy to try and recover, when airborne, any ATFM delay imposed on ground...

Such “operational behaviours”, observable in reality, are all causes of modifications from what was initially planned by the ATFM system at entry to a regulated sector.

To better apprehend their impact, simulations have been run inputting various “Operational behaviours” in the model. The regulated traffic has been divided into a certain number of groups, called “traffic populations”. Flights belonging to the same “traffic population” react to equivalent delay constraint and belong to the same flow. Typically, one traffic population corresponds to a certain proportion of the traffic belonging to one of the three flows with a certain “category of ATFM delay” impacting it (less than 1 min delay, 1 to 5 min delay, 6 to 10 min delay...).

Each “Operational behaviour” of each “traffic population” has been modelled regarding its direct impact on the distribution of traffic actually entering the congested sector. It essentially means that each “operational behaviour” is translated into a relative distribution of traffic around the Time of Entry at the regulated zone, as initially allocated by the Central Flow Management Unit.

Such distributions are modelled using juxtapositions of statistical normal laws, the parameterisation of which reflects the “operational behaviour” of each traffic population. To be able to better reflect reality, statistical results about actual adherence to ATFM slots provided by the CFMU were examined prior to the simulation. Below is an example of such distributions (figure 3), its morphology roughly

corresponds to a classical distribution of the departures around the CTOT (Calculated Take-Off Time, allocated by the CFMU) for a traffic impacted with an ATFM delay, in an airport with no capacity problems. Airport operators are able indeed to make the majority of flights depart as soon as allowed by the CFMU in the CTOT tolerance-window [CTOT-5min; CTOT+10min.]. Indeed the main peak of traffic is stated at CTOT-5 minutes.

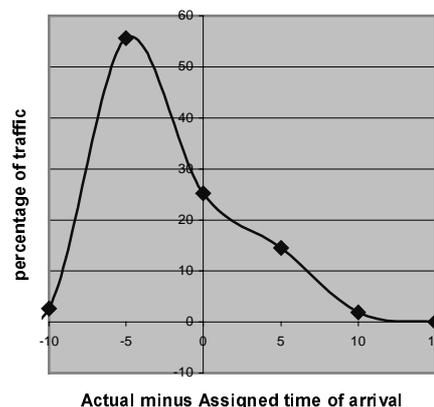


Figure 3 - traffic dispersion around allocated time of arrival in the congested zone

This model enables to simulate the impact of airport operations, (respect of departure slots), as well as aircraft in-flight operations (ATFM delay recovery, accentuation...) on the actual evolution of the ATFM plan in operations.

In order to study the effect of the conjunction of different “operational behaviours” at entry in a congested sector, various traffic populations are defined, each is assigned with a specific “operational behaviour” i.e. a specific traffic spreading effect around what was initially planned by the CFMU. All these spreading effects are combined in the initial regulation plan leading to a new distribution of the traffic, which is the result of all operational events encountered from the emission of the slot allocation plan to the arrival of the traffic at the congested zone (see figure 4).

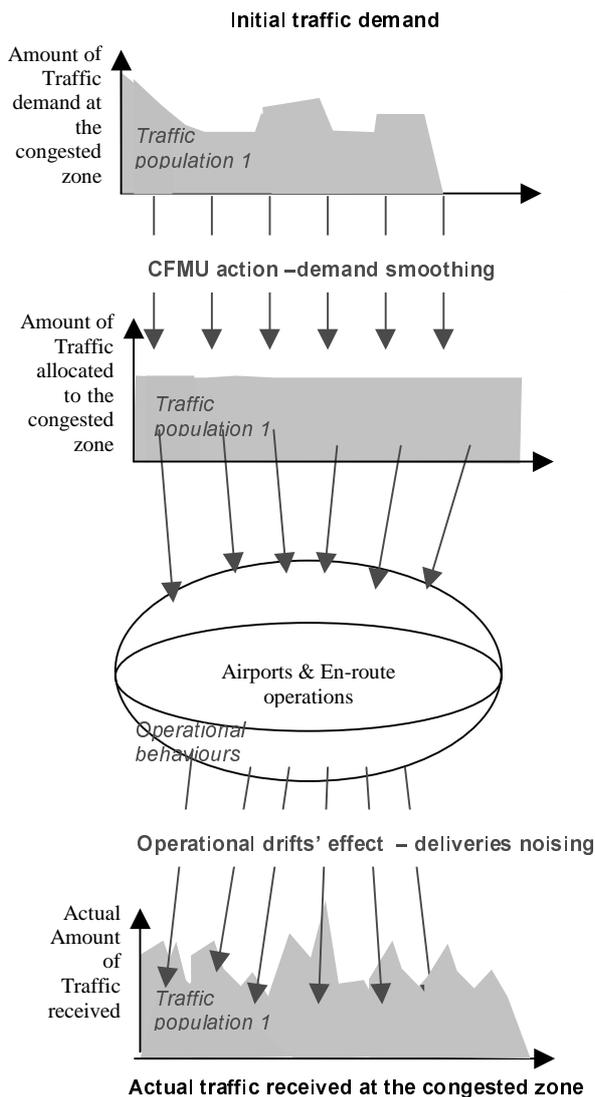


Figure 4 – schematised simulation model

4. Illustrative scenarios

Although the model is quite simple, meaningful results have been obtained from the simulations. It has notably highlighted some major characteristics of the operational conditions increasing the risk of bunching.

The sample of scenarios presented herein has been selected for its pertinence with regards to these conditions. Tests have been run both inside and outside of the field of ATFM tolerances.

• Remaining within ATFM tolerances

The current ATFM system does not totally ignore that

the operational world has to deal with many proper constraints, which can make it hardly possible to adhere to strict ATFM instructions. To answer to that issue and provide a reasonable level of operational manageability, a certain margin around the allocated Take-Off Time [-5min. ; +10min] is tolerated.

The consequence is the emergence of a sort of “institutional” noise impacting actual results of ATFM measures. To what extent this noise may threaten the stability of the traffic deliveries is the first question we examined.

As a matter of fact, simulations tend to show that there may be some characteristic situations, where such a “institutional” noise could reach important levels of magnitude, leading to significant bunching peaks.

While playing on different types of “allowed” “operational behaviours”, clear variations in the morphology of the results (traffic actually received over available capacity) appeared. It seems that if the “operational behaviour” for each flow is maintained constant (or at least slightly evolves) along time, the generated noise remains confined within acceptable limits (see figure 5). In other terms, although the plan is not strictly followed but applied with deviations constantly of the same nature for every population of traffic, little deterioration of the delivery rate at entry to the regulated sector is stated. The order of entry of the traffic at the regulated sector is not exactly what was initially planned but the delivery rate is preserved. The compensation effect is here plainly stated.

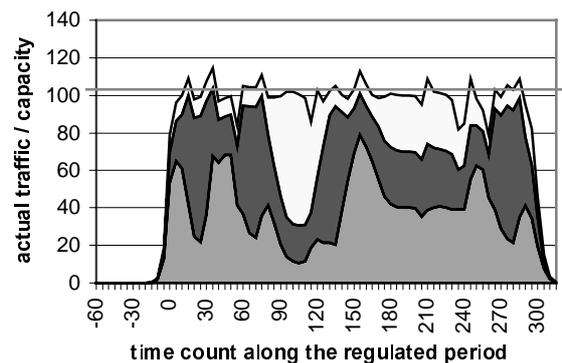


Figure 5 - "institutional" noise in a regular situation

But it is while introducing irregularities in the “behaviour” of a flow along time (simulation of a sudden change) that significant instability is stated (bunching peaks appear). Such is the case for the

scenario whose results are viewable in the following diagram (see figure 6). A sudden change in the way the traffic was launched in one airport was simulated and two significant peaks appeared. This scenario may be assimilated to a situation, where take-offs are stopped for a few minutes still without leading to infringements to ATFM rules, which is not uncommon actually.

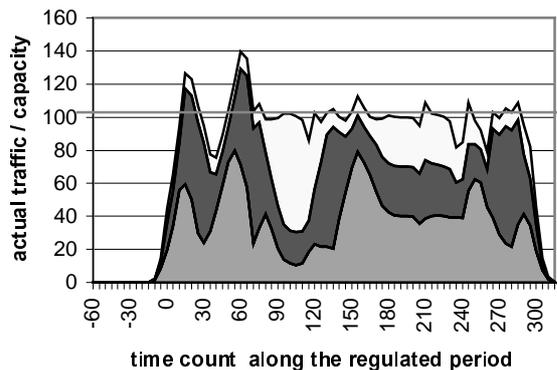


Figure 6 - "institutional noise" generated by a rupture within airport operations

The two major over-delivery peaks reach a maximum magnitude of 40%, which lead in 17 and 22 % traffic excess for 15 minutes periods.

N.B.: Over-deliveries are preferably examined on the basis of 15 minutes periods since it certainly better reflects the issue at stake. Indeed the interest of the study is to try and evaluate ATC trouble due to the bunching phenomenon. And it appears that an over-delivery is all the more perturbing for a controller as it lasts and as traffic keeps on accumulating on the control position. Thus is the maximum instantaneous delivery rate less meaningful in terms of congestion than the accumulation of traffic occurring in a 15 minutes period, which approximately represents the average time of transit of traffic in a sector.

This example is a typical case of what can be obtained when a sudden rupture into operations is simulated, while maintaining operations into the "institutional limits" allowed by the ATFM. It roughly shows, first, that significant peaks can appear although the rules are respected, second, that however the peak periods do not last. The trouble due to the bunching effect is thus present but minimised, thanks to the ATFM intervention on operations, which in average guarantees that potential over-delivery periods if not impossible are significantly shortened.

- **Deviations from ATFM instructions**

Statistics at high airports showing up to 30 % or more

average deviations from ATFM instructions are not unusual. Some are certainly merely avoidable since the operational world must deal with a lot of constraints outside of the ATFM ones. In that context, the way the traffic actually received in a congested sector is impacted is worth examining.

According to results obtained from simulations, the risk of bunching and its severity increases in situations where ATFM instructions are infringed. It sounds logical but the important result is certainly that scenarios showing significant bunching do not necessarily correspond to "extravagant" situations. Indeed easily conceivable operational situations such as a drift of departures during a short period of no more than several minutes can dramatically damage the quality of the ATFM delivery smoothing. Below are presented two illustrative results where rather "common" situations have been simulated. Peaks, up to 20 or 40 % of excess of traffic over capacity, have been recorded.

The first one (figure 7) is a test on a maintained delay of a flow of ~10 minutes, which may be generated by the airport (departure delay), exacerbated by en-route high counter-wind effect.

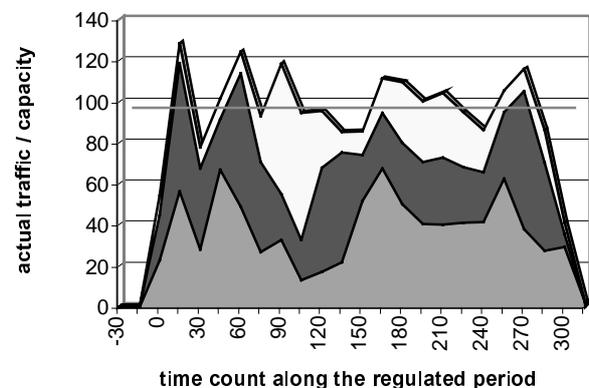


Figure 7 - traffic bunching generated by a constant delay of a single flow

The second example (see figure 8) deals with a sudden change of operational configurations, resulting for instance from an airport freezing its operations for a while (20 minutes). Only one peak is recorded but of a significant magnitude (up to 38% excess during a 15 min. period).

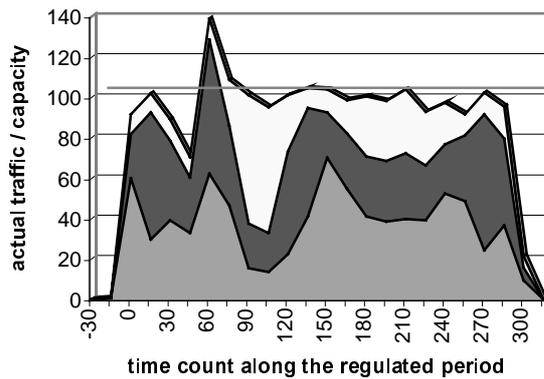


Figure 8 - traffic bunching generated by a sudden airport delay

Actually, the significant result obtained from the sample of scenarios tested with various natures of infringement is that non-adherence to ATFM rules does not necessarily bring about significant bunching effect. In the extreme, perfect maintenance of the delivery rate is even possible if the deviation from ATFM rules, even if significant, is constant during time and the same for any traffic population. It appeared indeed in the study when the same dispersion was applied for each of the three flows considered in the simulation, regardless of the width of the dispersion window. Below is presented (figure 9) the common dispersion input in the model, same dispersion applied for the three flows. The ATFM tolerance window [CTOT-5min.; CTOT+10min.] is visibly infringed, (30% of the traffic is outside from the tolerance window). However (see figure 10), the smoothing is theoretically perfect for the compensation is total. The only change is a more gradual transit of the block of traffic considered. This looks quite natural since the “compensation effect” can plainly act as a regulator completing the ATFM action.

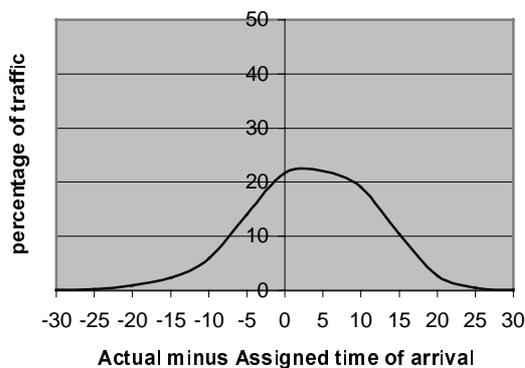


Figure 9 - example of regular "operational behaviour" infringement

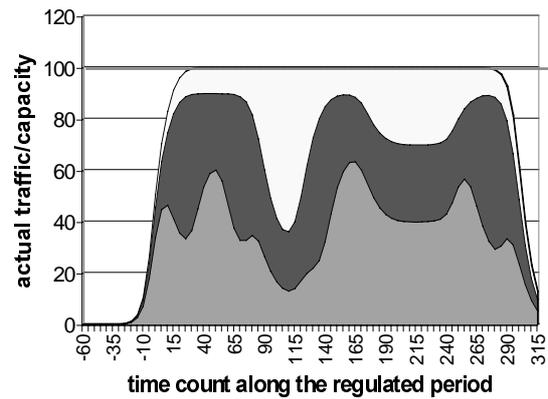


Figure 10 – A theoretical illustration of the compensation effect

Now if the infringement is based on a rupture within operations (see figure 8) or if the drift is isolated (see figure 7), then bunching appears with an impact with increased severity compared to when the ATFM tolerances are not infringed.

5. the hub effect: exacerbated risk of bunch

What certainly best characterises the hub effect is the organised concentration of traffic it generates, which exactly opposes to the ATFM demand-smoothing mission. As far as the bunching phenomenon is concerned, it means that traffic bunching is not issued from random and unfortunate but rationalised mechanisms of traffic re-concentrations.

This is exactly how the hub effect has been modelled herein, provided this principle of re-concentration. Hub-and-spoke traffic is voluntarily organised into interconnected groups of flights. The ATFM interfering as a traffic smoother tends to de-group and disorganise it. Still each flight participating to a hub-and-spoke network, if impacted by an ATFM delay, risks a disconnection from the hub network, which has a significant commercial cost for it impacts the whole connected flights network. It is therefore important for the Hub traffic to try and counter-balance the delay the ATFM imposes on its operations. Therefore for the simulation, it was supposed that any time a hub traffic is impacted with an ATFM delay, it voluntarily attempts to recover it via en-route accelerations (delay recovery of up to 10% of the deposited flight duration) or an advanced departure at airport. This to be able to respect correspondences with inter-connected flights. The delay recovery is nonetheless limited, due to operational constraints impeding to recover more than several minutes delay in-flight for instance. However the sensitivity of the regulated traffic delivery rate to

such policies is very significant. The result represented below (figure 9) is a good illustration. The flow represented at the lower level in the diagram (mid-grey) is the one on which the hub effect has been simulated re-concentrations of traffic are neat. Two major bunching peaks have been recorded, of a severe magnitude (up to 60 %) and of a significant length (45 min. of more than 20% excess). The bunching risk is indeed exacerbated for the re-concentration is voluntary.

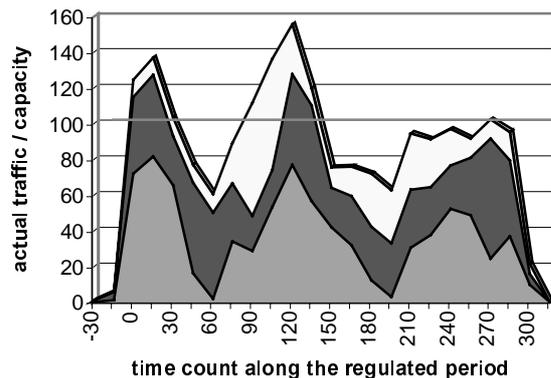


Figure 11 - the hub effect on traffic bunching

6. Learning from simulations results

According to the simulations results, significant traffic bunching can be recorded during operations. But the important point is that it does not occur exclusively in situations of significant crises but in rather usual daily operational context. Indeed, a punctual rupture within airport operations or natural trends to en-route deviations are all potential sources of significant bunching. It should also be stated even in a context where the “institutional” ATFM tolerance is respected.

Bunching appears therefore as a “nominal” threat to the stability of the traffic deliveries, against which the ATFM system looks quite weak.

How this “operational noise” could be effectively controlled is certainly a challenging question. Nonetheless the simulations’ results may provide some clues to start drawing the shape of potential palliative solutions.

Indeed, first, it appears that the efficiency of ATFM seems dramatically weakened by the current trend in the Air Transport domain to concentrate (hub phenomenon). The problem seems to lie on the opposition of interests defended by each one into the daily organisation of flows. Some tend to concentrate the traffic while others tend to smooth it. A consolidated pre-entente between operating worlds (AO’s, ATC and ATFM) shall then be required to

find better trade-offs and break the chaining of isolated counter-acting measures, certainly costing and sub-efficient, be it for AO’s, airports or ATFM.

Second, simulations tend to show that the bunching effect has “a certain liking” for situations of ruptures in the operating configurations in an airport or within a particular flow. In the majority of simulated cases, the compensation effect can merely counter-balance operational ruptures. Such sources of bunching are certainly too local, sudden and leaving too short notice for the re-calculation of a whole regulation plan. The solution should rather be more “locally adaptable” and very “reactive”.

7. Reducing the ATFM noise: introducing preventive and corrective techniques

As previously stated ATFM constraints tend to be overridden by real-time airports and aircraft operators’ constraints. Nonetheless, the impact on the Air Traffic Control is far from negligible, because of traffic bunching. Since the ATFM service is currently fully dependent on the way the ATFM plan is respected by AO’s and Airports during real-time operations, it is fully weakened by a huge amount of perturbations it can hardly control, impacting the way the ATFM service is provided to the ATC.

In that situation, increasing the integration of proper Airports, Aircraft Operators and ATC daily constraints within ATFM planning shall prevent potential drifts due to operational constraints ignored by the ATFM. Some examples of direct integration of all sides’ constraints, in simplified flow management situations, already exist and show interesting results. For instance an airport and a close Air Traffic Centre can agree in real-time to co-ordinate the regulation of a flow (they apply minimum departure intervals). The airport, when requested by the centre and when possible, simply sends the traffic to the centre at the requested delivery rate. The advantage, for both, is the control or at least the integration of both airport and ATC constraints in the management of the flow. Moreover, since the airport and the congested sectors are close, perturbations on the traffic from the airport to the requesting sector have no time to appear. Such a technique, already marginally applied, significantly stabilises the traffic deliveries to a congested sector

From a more global viewpoint, the reinforcement of pre-tactical discussions for the consolidation (validation and stabilisation) of daily ATFM plans goes indeed in that direction.

Now, an additional way to solve the problem could be for the ATFM system to dispose of proper means to

correct or re-adjust the status of traffic flows in function of actual drifts from the ATFM plan. The ATFM could indeed dispose of proper recourses against traffic bunching forming during real-time operations. “Real-time anti-bunching recourses”, could thus become significant ATFM assets to lower the dependence of the ATFM service upon AO’s and airports “operational behaviours”, hardly controllable. And yet as stated in the present analysis, such “anti-bunching” means should be “locally adaptable” and very “reactive” solutions. Solutions, which certainly exist in the real world, lying at ATC disposal but not directly dedicated to Traffic Flow management purposes.

Techniques used for the structuring and organisation of arrival flows are certainly most adapted. Such techniques could be used en-route, for the readjustment of the times of arrival at a congested point, enabling to de-bunch problematic en-route delivery configurations via measures applied on upstream flows. Provided a risk of bunching identified in a sector, these techniques should enable up-stream controllers to “work” on the traffic for the bunching peaks to be smoothed.

The techniques would roughly consist in slightly re-routing or delaying some airborne flights; speed control (en-route absorption of a delay to adhere to a certain “Required Time of Arrival at a congested sector”), path stretching (en-route absorption of a delay via lengthened portions of route), airborne re-routing (modification of the trajectory of an flight to avoid the congested area), or flight level capping (maintain of the flight in a lower less congested level).

To better understand how these corrective actions could impact the bunching effect, simulations have been run on our model. The simulations are no more than basic illustrations of what is meant here with “real-time anti-bunching actions”. A correct analysis of their impact would actually involve more sophisticated models integrating a wide series of operational factors not considered in the model. Indeed possibilities of delaying or re-routing flights depend on control work complexity, traffic configuration... Still manipulations with the model (e.g. figure 9) helped visualising how a situation of bunching could be addressed by slightly delaying certain flights. Provided a bunching scenario, several measures have been tested tuning the delay of a given percentage of traffic on each flow with the objective to remove the traffic from bunching peaks. Certain limits, while manipulating the flows and simulating “real-time anti-bunching actions” have nonetheless been considered (e.g. maximum delay per flight of no

more than several minutes). Below is presented the result obtained while working on the bunching scenario presented in Figure 8 (simulation of a sudden airport delay). The bunching peak has been effectively smoothed. Two flows (in dark-grey and mid-grey in the diagram) have been manipulated. The bunching peak was roughly characterised as follows: a 20% over-delivery lasting 15 minutes. The manipulation corresponds for both flows to a re-sequencing of the traffic delivered during the second half of the first hour of the regulated period. Such distributions imply to delay the concerned traffic from 1 to 5 minutes and therefore to apply a certain “airborne” anti-bunching technique to absorb this requested delay. The interesting result is that it was possible to effectively recover a correct noise level (not exceeding 5%) with reasonable actions on flows. The corrective action implies the manipulation of 30% of the traffic expected for half an hour (statistically corresponding to no more than about ten flights) with a maximum delay of 5 minutes.

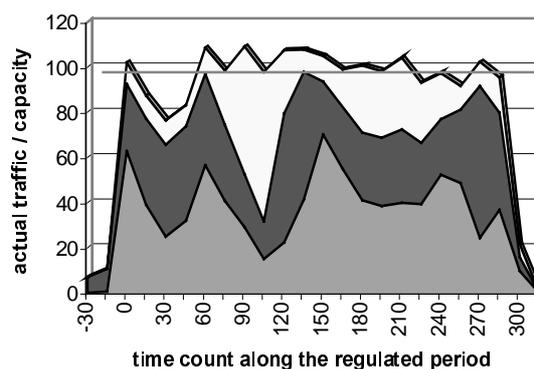


Figure 12 - the effect of airborne flow management techniques on traffic bunching

This exercise enabled to check whether at first glance the corrective work would be important or not. And it appeared that reduced effort was required to recover correct instantaneous delivery rates. Actually the first CFMU demand smoothing, though not sufficient, enabled to maintain a manageable amount of airborne traffic, which left enough place en-route for corrective last real-time smoothing refinements.

8. Conclusion

The current ATFM system is based today on the respect of the planned slot allocation. But, is the planned operational rhythm easy to maintain? The operating world permanently risks to move outside of what is planned and even little “sand grains” can generate important drifts. Simulations examining whether the ATFM system is armed against these

“sand grains” effect tend to show its limitation.

The risk is currently well known by Air Traffic controllers. And their current solution to face this nominal problem is an under-declaration of the available capacity to the CFMU, in order to preserve a certain capacity buffer against uncontrolled peaks of traffic.

If this “operational noise” could be better controlled i.e. anticipated and counter-balanced with actions complementary to the current ATFM measures, this may naturally get controllers to handle traffic demand more efficiently with greater confidence on the respect of their actual capacity.

The action of the CFMU is clearly positive, since it enables, at least (in the worse situations) to reduce and confine risks of overloads to punctual bunching peaks at entry in a congested sector. It sounds now profitable to complete the action with real-time corrective measures as proposed in the article. This requires to enriching the mechanism of prevention against congestion with real-time anti-bunching measures, the action-field of which lies between ATFM and ATC (now called “traffic synchronisation”).

The suggested enhancement certainly demands increased collaborative involvement of all ATM actors towards the problem of prevention against congestion within the European flow network taken in a whole. But in a context where real-time operational dynamics is high and ATC capacity a scarce resource, palliating to traffic bunching problems when they appear rather than maintaining permanent protections “in case of”, freezing a certain part of ATC capacity may be better adapted to current Air Traffic Management needs.

9. References

Independent Study for the Improvement of ATFM,
September 2000

*Future ATFM Measures (FAM), Project Management
Plan and Questionnaire to Airlines*, EEC, 2001

Adherence to ATFM Slots in 2000, DOP 11, CFMU

Author Biographies

Stéphanie Stoltz is a consultant of SOFREAVIA working for the Performance, Flow and Economics (PFE) business area of the Eurocontrol Experimental Centre.

Graduate engineer from l'Ecole Nationale Supérieure de l'Aéronautique et de l'espace (SUPAERO), she has been working since 1999 in the field of air traffic management. She previously spent a few months working for the Planning department of an airline operator. She has contributed in 2000 to the ATFM Improvement Study, mandated by the Performance Review Commission, and then joined Eurocontrol to go further in the definition of new flow management concepts.

Patrick Ky is a graduate engineer from Ecole Polytechnique (Paris) and Ecole Nationale de l'Aviation Civile in Toulouse. He also holds a post-graduate degree in Public Economics from the Université des Sciences Sociales in Toulouse, and a Master of Science in Transportation from the Massachusetts Institute of Technology (MIT).

Patrick began his career by doing software development on the French ATFM system. He then was appointed Head of Division for the French Technical Service for Air Navigation, in charge of the development of ATFM, AIS and National Archive systems. In that position, he was the technical co-ordinator for the French participation to the implementation of the Central Flow Management Unit.

He then joined a consulting company where he began as a consultant in very diverse fields such as airlines economics, ATC systems architecture, airspace organisation, etc... He was later on appointed Head of the ATM consulting division, where he managed an international team of about 60 consultants.

Patrick joined Eurocontrol in 2000, where he is currently Head of the Performance, Flow Management, Economics and Efficiency business area at the Experimental Centre.