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FOR THE SAFETY OF AIR NAVIGATION

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EUROCONTROL EXPERIMENTAL CENTRE

# Study of the impact of ATFM uncertainty and smoothing performance on declared capacity (intermediate results)

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**Abstract :**
**Objective:** This note presents the intermediate results of a study launched in September 2005. The study aimed at assessing the relationship between ATFM smoothing performance, ATFM uncertainties and declared capacity.

The study was part of the yearly NCD “ATFCM Studies” work programme, in support of and funded by CFMU.

**Results:** It appears that the ATFM performance assessment grid currently used at strategic level fails to provide explanations of a number of observed results on the field.

At the present stage, no clear conclusion shall be taken for granted. However, it has been demonstrated by the analysis and throughout interviews with FMPs that FMPs / FMDs have developed methods of using the ATFM regulation process to fullfil a number of new operational objectives, which are not currently taken into account when evaluating the ATFM performance.

## DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

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| 0.1 | April 7th 2006 | First Draft | |
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# TABLE OF CONTENTS

# LIST OF TABLES AND FIGURES

# GLOSSARY

| | |
|---|---|
| ACC | Air Traffic Control Centre |
| AIRAC | Aeronautical Information, Regulation and Control |
| AO | Aircraft Operator |
| ATC | Air Traffic Control |
| ATCO | Air Traffic Controller |
| ATFM | Air Traffic Flow Management |
| ATM | Air Traffic Management |
| ATS | Air Traffic Services |
| ATSU | Air Traffic Service unit |
| CFMU | Central Flow Management Unit |
| CPR | Correlated Position Report |
| CTFM | Current Tactical Flight Model |
| CTOT | Calculated Take Off Time |
| EATMP | European Air Traffic Management Programme (former EATCHIP) |
| ECAC | European Civil Aviation Conference |
| EEC | EUROCONTROL Experimental Centre |
| EOBT | Estimated Off Block Time |
| ETA | Estimated Time of Arrival |
| ETFMS | Enhanced Tactical Flow Management System |
| ETO | Estimated Time Over |
| FMD | Flow Management Division (Flow Controller at CFMU) |
| FMP | Flow Management Position (ACC) |
| FPL | Filed Flight Plan |
| FTFM | Filed Tactical Flight Model |
| IFPS | Integrated Initial Flight Plan Processing System |
| PRC | Performance Review Commission |
| REA | Ready Message |
| RPL | Repetitive Flight Plan |
| RTFM | Regulated Tactical Flight Model (by ATFM Measures) |
| SAL | Slot Allocation List |
| TV | Traffic Volume |

# REFERENCES

EUROCONTROL / Performance Review Commission:
Performance Review Reports: n°1 (1998) to n°8 (2005).

EUROCONTROL
Tasking Support for ATFM – Impact of uncertainty and smoothing on declared capacity – Interim results (November 2005).

EUROCONTROL
Tasking Support for ATFM – Impact of uncertainty and smoothing on declared capacity – General framework (November 2005).

# 1 INTRODUCTION

## 1.1 Document rationale

This note was issued in the frame of the "Study of the impact of ATFM uncertainty and smoothing performance on declared capacity", a study launched by the EEC in September 2005. The present document gives the interim conclusions drawn at the end of year 2005. These were presented and discussed with CFMU representatives in February 2006.

The subject addressed herein is the relationship between **ATFM uncertainty**, **ATFM smoothing performance** and **Declared capacities.** The study team, working at the EEC, was given access to CFMU data records in order to provide for quantitative evidence of any statement exposed in this respect.

## 1.2 Context

At the time the study was launched, the question of the relationship between ATFM uncertainty, ATFM smoothing performance and Declared capacities had already drawn the attention of a number of people within the ATM community. Several statements supported by quantified arguments were indeed available at least at two different levels: (1) from ATM Performance Reviewers providing performance figures for European ATM strategy decision makers; (2) from on-field ATFM operational actors invited to express their opinion for the daily improvement of ATFM service supply.

A first task in the study consisted in consolidating the available arguments into a consistent explanatory theory of this relationship. The theory would then be further assessed against real statistical samples. In parallel, the ATFM performance was assessed through collecting the field perception (2), and comparing it to the high level perception (1), the expression of which within the EUROCONTROL Agency is entrusted to the Performance Review Commission and published in the Performance Review Reports.

This comparison led to the following statements: ATFM smoothing performance depends on a complex display of internal & external influential factors, leading to different – potentially contradictory – interpretations and performance assessment, depending on the different objectives and perspectives adopted by the ATM stakeholders.

The present document describes and comments the work findings, provides first conclusions about the statistical analysis, and draws a first set of hypotheses that might explain the discrepancies stated between the field and the high level perceptions about ATFM performance.

# 2 THE GLOBAL PICTURE: FIELD AND HIGH LEVEL PERCEPTIONS

The findings presented herein were obtained by carrying out reviews of the documentation available at the EUROCONTROL Agency. In particular, the Performance Review Reports where entire sections dedicated to ATFM smoothing performance as perceived by the EUROCONTROL Performance Review Commission could be found.

Interviews with FMPs and controllers were carried out in parallel so as to confront the high level against the field perceptions of ATFM performance.

## 2.1 High level perception: Performance Review Reports

**Theoretical model of the relationship between traffic uncertainties, ATFM smoothing performance and declared capacities**

In 1999, a first model of capacity loss attributable to ATFM smoothing performance is presented. (Ref. figure 17 "Protection against overloads" - PRR2) and commented as follows (source PRR2):

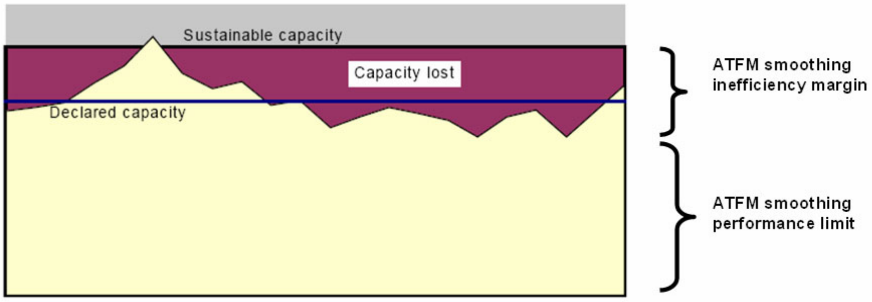



**Figure 1 - Model of capacity loss (PRR2)**

*"Traffic is regulated well in advance of the time of real operations. The result is a combination of bunching and empty space, which does not lead to an efficient and full use of available capacities (...) If traffic frequently exceeds that (declared) capacity, ACCs will reduce their declared capacity accordingly".*

It can therefore be inferred from the statements above that according to the PRC,

1°) ATFM uncertainties, ATFM smoothing performance and Declared capacities are closely interdependent;

2°) ATFM uncertainties are mainly born from the necessity to implement ATFM ground regulations long in advance (at a time, it can be further inferred, after which there is still room for many unpredictable events to occur and end in drifts from the ATFM plan output from the slot allocation process)[1];

3°) Uncertainties alter the ATFM smoothing performance – alterations observable in the form of "bunching and empty space"; which in turn has a negative impact on capacities – a certain amount of capacity is lost, absorbed into the buffer ACCs take after experiencing the negative effect of a "loose" Regulated Traffic smoothing.

1 And – as a corollary inferrence – from the impossibility to cancel the development of the regulation process until completion once a early deadline, long before the real time, is passed.

## The notion of "unnecessary regulations"

In PRR5, the PRC makes the following statements: *"Most ATFM delays occur with regulations being applied for low level of excess demand. "Ground delays" are not well adapted in such cases: random effects and tolerances result in poor ATFM performance (many unused slots, and yet some over-deliveries).*

In light of these statements, the notion of "unnecessary regulations" is introduced.

In PRR7, a statistical evidence of inefficient use of ground regulations is presented. Regulations are classified according to a specific criterion, the average delay per flight compared to the 10 minutes delay parameter allowed by the ATFM regulation adherence rule[2]. Two separated diagrams are drawn:

PRR 7, p. 23 - figure 31: Ground regulations generating less than 10 min. delay / flight.

PRR 7, p. 23 - figure 32: Ground regulations generating more than 10 min. delay / flight.

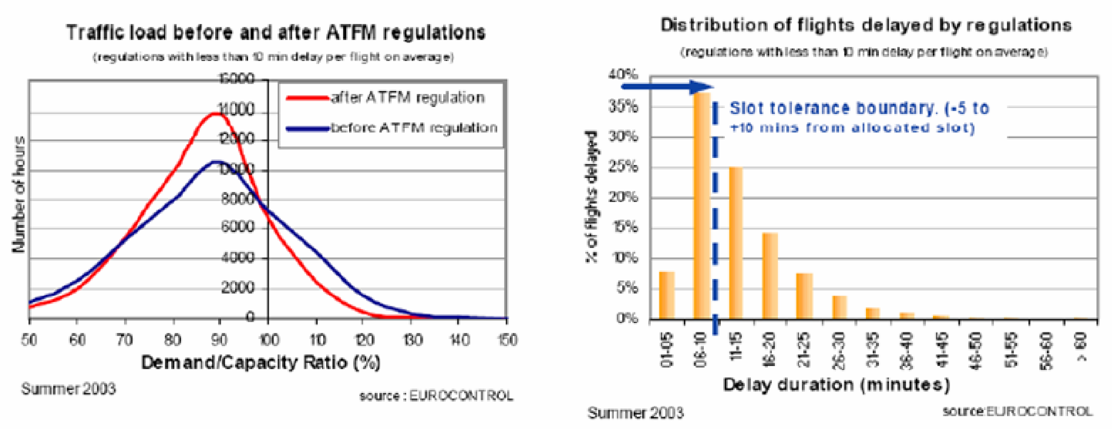



**Figure 2: Ground regulation generating less than 10 min. delay/flight (source PRR7 – Fig. 31)**

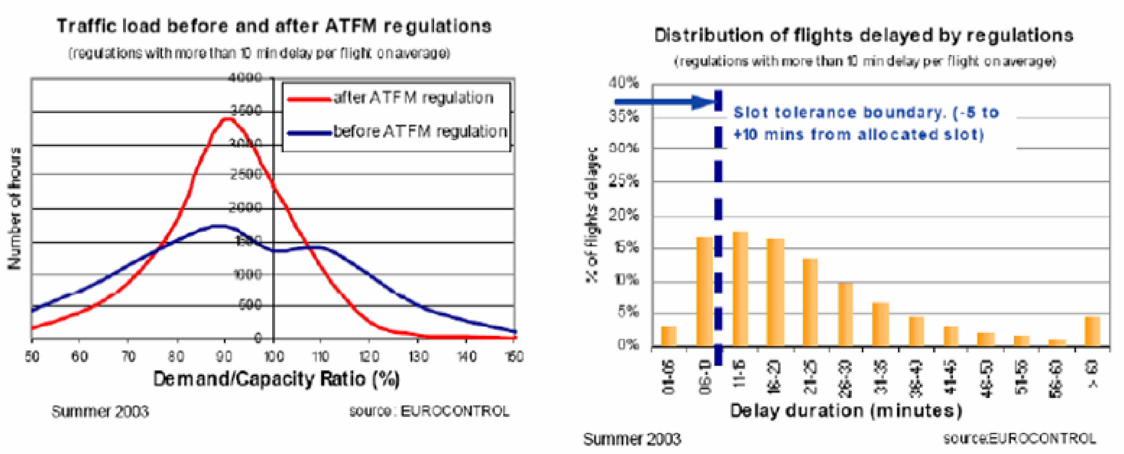



**Figure 3: Ground regulation generating more than 10 min. delay / flight (source PRR7 – Fig. 32)**

2 The ATFM slot regulation tolerance allows for the aircraft to take off with a 10 min. delay. This 10 minutes delay tolerance can indeed be taken as a direct uncertainty parameter enabling to distinguish between situations when ATFM uncertainties start or stop being negligible in the result of ATFM regulations.

The results concentrated on regulations with short average delays, are commented as follows: the implementation of a regulation "*does not have much impact on traffic flow, and yet generate unnecessary delays*"[3]. Whereas the results concentrated on regulations with significant delays show an impact no longer considered negligible: these are reckoned in that case as "effective".

Absolute ATFM effectiveness is characterised as follows; *"ideally, actually demand should not exceed capacity*". The success criterion should therefore be the following: "*the red line (the regulated hourly traffic distribution) should be at 0 for demand/ capacity>100%*".

In figures 31 and 32, PRR7, this criterion is indeed not met when demand/ capacity <110%, yet considered satisfactorily achieved when demand/ capacity >120%.

**ATFM efficiency limits and PRC recommendations**

In light of these statements, the PRC draws the following recommendations:

- To preserve the slot allocation mechanism when demand / capacity > 120%;
- Otherwise, to look for alternative ATFM solutions, particularly for the situations of demand / capacity < 110%, where the slot allocation mechanism shall no longer be applied.

## 2.2 Field perception

### ATFM regulation performance appears to globally satisfy its direct beneficiaries

Most interviewed FMPs expressed their general satisfaction with respect to the levels of services and performances of the ATFM ground regulation system.

French FMPs reported that the ATFM ground regulation mechanism delivers traffic according to rates with a very acceptable accuracy margin (seldom more than 3 flights). They reckon the ATFM ground regulation process as an efficient tool preventing traffic overload and in which they have strong confidence. Increased confidence has even allowed en-route and approach sectors ATC capacities to increase over the years.

### Flow rates rather than declared capacities are used in order to provide better adequacy of ATFM regulations effects with ATC needs

Declared capacity figures are communicated by FMPs to CFMU, which use them as the local ATC capacity references. These references will be used by FMD and FMP to analyse the traffic demand and to identify in which portion of airspace they must closely monitor the evolution of the demand and be ready to implement an ATFM regulation. Regulations, if their implementation is decided, are set using other parameters, namely "traffic volumes" and "flow rates".

3 See Figure 31 and PRR7 comment: "(..) (blue line) and (..) (Red line) are not very different in this case"

A key interest in using Traffic Volumes and Flow rates is the ability it offers to adjust the throughput of the different flows feeding a sector so as to obtain less complex traffic configurations within the sector and hence maintain its capacity at optimum level. Indeed basically increased complexity induces reduced capacity[4]. In order to play on this complexity, ATFM agents regulate separately each flow feeding the sector in such a way that the most complex flow crossings are avoided[5]. Working with separated flows is enabled by regulating “traffic volumes”[6] and associating “flow rates”, rather than “sectors” and their associated “capacities”.

A significant aspect of the impact of ATFM mechanisms on capacities hence relies on the intermediary process(es) through which FMPs locally translate the need to avoid situation of traffic exceeding ATCO capacity into regulation parameters: sets of {flow rates; traffic volumes}. Moreover in its most sophisticated form mastering this process requires thorough judgment on very ATC expert notions such as local Traffic complexity.

**ATFM regulation efficiency has undoubtedly an influence on capacity figures**

Capacities are evaluated based on local agents’ expertise and criteria depending on internal policies. Capacity figures are calculated essentially on account of physical (stable) constraints[7] plus empirical or statistical indications[8] of what an ‘acceptable’ workload for a controller on a specific Working Position could be. The figures are therefore imperfect approximates.

Declared capacity figures are modified based on progressive adjustments whenever a long run change into local operational conditions justify it, but also when increased confidence is gained towards the ATFM service.

In interviewing FMPs, it appears that the ability of the ATFM system to ensure that traffic loads will never exceed a limit regarded as "acceptable" for controller is an essential decision-making driver when regulation rates are set. In the long run, once the ATFM system has proven being efficient in preventing any traffic overload and hence has brought about controllers confidence, it may be possible for the ACC to show less restraint and re-adjust the capacity figures accordingly.

Therefore, capacity calculation also encompasses the perceived progresses achieved while working under the protective umbrella of the ATFM regulation system on a day to day basis. Therefore, declared ATC capacity could increase over the years if the real traffic, resulting from ATFM regulations, system matches as close as possible the declared ATC capacity. And the other way round if the real traffic overpasses repeatedly the ATC capacity.

4 Some FMPs reported that the consequence of increasing complexity was far from negligible in some cases; up to 25% of capacity loss could sometimes be recorded.

5 For example, within an en-route sector, climbing flights only may be regulated so that a larger number of cruising flights can be handled than with the perturbation of a sustained flow of climbing flights crossing each occupied FL one after the other.

6 e.g. traffic overflying a particular waypoint, a particular route, etc..

7 e.g. the route pattern in the sector.

8 e.g. the percentage of stable traffic within the sector.

**On-field opinion is that ATFM regulations reduce nominal uncertainties and provide safeguards against disruptions impacts**

At least two categories of uncertainties (and associated alterations) shall be distinguished: a nominal uncertainty that results from routine hazards and related to the stochastic nature of air transport; and uncertainties due to disruptions that result from sudden unanticipated changes in ATC operations conditions.

In practice, the former induces uncertainties on traffic loads contained into identified margins, making the resulting ATFM indicators, if not perfectly accurate, at least relevant for decision making. To the contrary, the latter may suddenly make the ATFM indicators evolution no longer consistent with the decisions so far made.

A consideration, often expressed to explain the impact of ATFM regulations on nominal uncertainties on field, rests on the following statement: Since ATFM regulations impose additional restrictions on departure times[9], the regulation process augments traffic flows predictability and hence reduces the margins applicable on nominal uncertainties.

Field operators reported that, even when the planned demand excesses is close to nil, the decision can be made to implement a ATFM regulation only to make sure that the uncertainty margin is better controlled and hence that actual loads will remain consistent with the prediction, whereas without it, a greater doubt (and higher strain) could persist.

**Field expectations towards the ATFM service go beyond reduction of hourly demand excesses: Tackling the bunching threat**

Fixing a certain level of capacity for one hour, in itself, provides no guaranty that the traffic flow will be evenly spread throughout the hour. During an hour period, there could be an accumulation of aircraft over a period followed or preceded by periods with very little traffic. This effect is called the bunching effect.

Avoiding bunching peaks within the regulated hours was also a concern expressed by some FMPs declaring to apply ATFM regulations with this very objective in mind. This local and short duration effect is considered most “unpleasant” especially when ATCO are already working at the limits of the hourly sector capacity and hence hardly accept to handle a number of flights unevenly distributed within the hour.

This requirement has much to deal with the maximum smoothing accuracy level achievable on field with the ATFM ground regulation mechanism.

One interviewed FMP expressed concerns on insufficient success rate of the slot regulation solution when applied on those particular peaks characterised by their short duration (typically 20 minutes). This FMP reported that, at some locations, ground regulations were most often successful, whereas at some others, the success was not systematic. In that case, some reactionary corrections (based on more dynamic flow control tools, such as airborne FL re-distributions), were implemented after the ground regulation solution (nominally preferred because not ATC workload consuming) was recognised to have not been successful.

9 the regulations restrict departure times variations down to a 15 minutes tolerance whilst the tolerance applicable on non-regulated traffic is 30 minutes.

## 2.3 Conclusions of the chapter

Different perceptions and approaches to ATFM ground regulation efficiency, the impact of uncertainties and their result on capacities coexist. These differences in perceptions and approaches lead to controversial appreciation of ATFM ground regulations performance (field versus high level view) and to different opinions on how the ATFM ground regulation tool shall be used and operated. While the PRC recommends not to use the ATFM ground regulation solution for low hourly demand excesses, on-field operators could provide (different) justifications as to why they continue to apply ground regulations in such cases.

In a methodologic viewpoint, high level reports provide for a self consistent set of evidence in support of PRC recommendations. Demonstrations are granted on globalised statements, centred on the notion of demand / capacity ratio; while field arguments are based on illustrative cases reflecting a variety of distinct regulations typologies and accounting for a larger number of operational factors.

Therefore, in order to better understand the sources of discrepancy between the different viewpoints, the theoretical material found in the PRRs was assessed in the light of the reported local typicality of a number of regulation cases. The first data analysis was therefore conducted by making the distinction *a priori* between each regulation case found in the sample under study. The first results of this case-by-case analysis are presented in the next chapter.

# 3 FIRST FIGURES: CASE-BY-CASE ANALYSIS

## 3.1 The approach

The findings were obtained by analysing CFMU data records of about 1000 regulation cases applied on 18 different traffic volumes during 3 AIRAC cycles spread over the 06 June 2005 – 31 August 2005 period.

The database was analysed using a method aimed to characterise each regulation case according to the ATFM smoothing performance assessment guidances found in the PRRs. Shortly summarised, the method is based on tracing the predicted instantaneous evolutions of hourly Traffic deliveries considering a number of key modification events (e.g. the activation of a regulation), then on characterising the curbs so obtained using the ground regulation effectiveness indicators specified in the PRR.

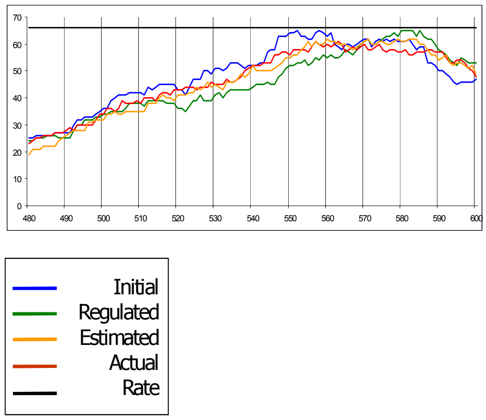



**Figure 4 : Example of representation of a regulation case**

This method is presented in Annex 1.

The first analysis mainly aimed at assessing to which extent the PRR statements and subsequent recommendations could be validated:

The PRR criteria set up to dissociate the conditions of ATFM ground regulation effectiveness from those of ineffectiveness (cf. chapter 2.1: **ATFM efficiency limits and PRC recommendations**) served to characterise each regulation case of the studied sample:
Particular focus in this respect was put on the following PRR key criterion: the **demand/capacity ratio** that if <110% qualifies ineffective (thus inappropriate) regulations and if >120% qualifies effective (thus appropriate) regulations.

For each regulation case, the different hourly traffic delivery prediction curbs traced back from the raw data sample were qualified against the maximum (hourly traffic delivery/ flow rate) ratio observable over the regulated period – less than 110%, between 110% and 120%, more than 120%.

The effectiveness of the regulation was then assessed against the evolution of this ratio from one curb to the other. If this ratio failed to remain close to 100% but tended to fluctuate between 100% and 110% to maximum 120% on the actual traffic curb after the uncertainties on the actual execution of the flights played their foreseen alteration role, the PRR conclusion was considered endorsed in the very case, if not, the case was qualified differently.

### 3.2 First results

The sample so qualified was classified into seven distinct recurrent classes of cases referenced as followed:

(a) **Regular cases** that can be directly referenced vis-à-vis PRR ground regulation efficiency criteria:

- **endorsing cases** where PRR-defined appropriate demand/capacity conditions led to effective regulation results;
- **invalidating cases** where PRR-defined inappropriate demand/capacity conditions led to effective regulation results;
- **contradictory cases** where PRR-defined appropriate demand/capacity conditions led for the same regulation to effective results on a particular day and vice-versa on another;
- **borderline cases** where PRR-defined appropriate demand / capacity conditions are unspecific and unsystematic effectiveness is recorded.

**(b) Singular cases** that cannot be directly referenced vis-à-vis PRR ground regulation efficiency criteria:

- **major failures** including cases where in spite of PRR defined appropriate demand / capacity conditions, the ground regulation mechanism fails to correct the demand excess;
- **no demand excess** including cases where a regulation was put despite the absence of hourly demand excess;
- **retroactive corrections** including cases where actual records are improved contrary to the assertion made that actual traffic uncertainties alter ATFM performance records.

Illustrative examples can be found for each class of regulation cases in Annex 2.

### 3.3 First conclusions

The results of the analysis tend to prove that the ATFM regulation mechanism can behave in a variety of manners, which lie far beyond those covered by the PRR. More generally it appears that no generic assertion equivalent to that drawn from the PRRs could reconcile all the observed behaviour classes into a single consistent one. Instead a quite heterogeneous set of sub-classes could be distinguished, among which an equivalent number of ATFM regulation cases that would strengthen or weaken the PRR arguments, (regular cases) but also a significant number of singular cases, where direct reference to the PRR statements could hardly apply.

The typology so obtained tends to endorse the facts that:

- As the PRR states it, the hourly demand / capacity ratio could be considered a relevant performance indicator when measuring the effectiveness of ATFM activities. But this indicator might not be the single one applicable.

- As ATFM end users declare that they may follow different objectives (smoothing the incoming flows reducing uncertainties, etc..) when employing the slot allocation process, the ATFM performance should reflect the objectives pursued by the end users. Some ATFM regulation cases show that a case could provide a good performance for a given end user objective and perform poorly for the others.

- As the ATFM ground regulation tool offers a great spectrum of options for customised configuration by its users (choice of traffic volume, activation time, applicable rate, etc) and as it is the lastest available protection against too heavy traffic pressure in most places in Europe, the ATFM ground regulation performance may depend equally on what the intrinsic performance limitations of the slot allocation solution are as on how people happen to use it in potentially difficult contexts. This could explain some cases where the ATFM performances were poor on a particular day whereas the slot allocation process seemed to work efficiently on another day in similar traffic conditions.

# 4 NEW STATEMENTS

In light of the previous results, a series of complementary data studies was carried out, from which a number of complementary leads and propositions has been drawn and presented below.

## 4.1 Some complementary leads

New propositions and leads were considered in order to apprehend the ATFM ground regulation performance in a more segmented perspective. These include to consider separately (a) the different users objectives, (b) the ATFM service offer & the use of capacity resources, (c) the regulation request specification & the departure slot mechanism.

### 4.1.1 Different user objectives: predictability, protection against overloads, capacity increase

From interviewing FMPs, it appeared that there potentially existed other motivations on field for using the ATFM regulation solution apart from the dissolution of hourly demand excesses. The diversity of expressed intents is summarised in the Table below.

Three classes of objectives pursued by FMPs could be distinguished. The first two are direct results of ATFM ground regulation use, the last is an indirect, long term induced effect.

| Three classes of Objectives | User expectation against which ATFM regulations performance is perceived on field |
|---|---|
| Reduce uncertainty | Helps to make appropriate decisions<br>- Improvement of flows predictability<br>- Better awareness of situational disruption |
| Improve smoothing of the incoming flows | Provides solutions to overloads<br>- Solution to capacity shortage<br>- Solution to traffic bunching<br>- Solution to complex flights clustering |
| Augment capacity offer | Positive reverse effect<br>- Increase of capacity in providing confidence to end users. |

It is relevant here to notice that only the second class of objectives directly refers to the smoothing performance of the ATFM ground regulation solution, and only the first expectation in this class (solution to capacity shortage) relies on hourly flows counts measurements.

The last class of objective – that draws the link between the ATFM service performance and the capacity offer, has been regularly identified as an underpinning objective that ATFM service users on field keep in mind; though an indirect, longer term one that becomes measurable after months of accumulated experience of using the ATFM ground regulations system in a particular area.

Determining whether or not the ATFM ground regulation provides genuine added value against each of these objectives requires separated performance measurements, using, in addition to the hourly demand / capacity ratio, more specific sets of metrics per item.

### 4.1.2 The ATFM service offer & the use of capacity resources: Flows versus loads

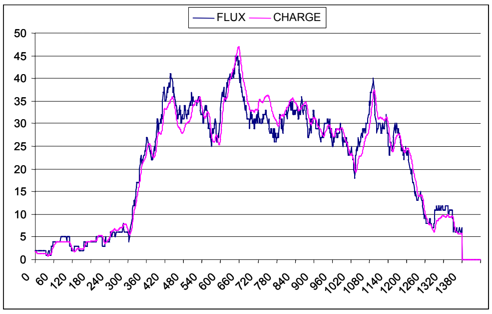
The primary purpose of ATFM service users in each ACC is to avoid situations of unbearable ATCO workload. The external constraint is to limit the burden imposed on airspace users induced by the restrictions implemented to meet this objective. Capacities directly relate to workload.

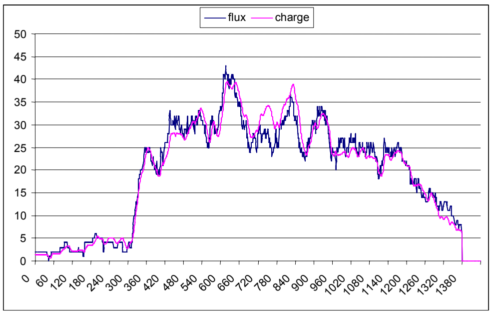
An indicator widely adopted on field to measure this workload rests on flight occupancy counts or sectors loads, characterising a number of aircraft consuming the attention of ATCO in a specific unit of time. On the other hand the ATFM activity rests on the notion of traffic delivery throughput. Local ATFM service users specify a particular request on traffic deliveries throughput in order to meet a specific load requirement. The ATFM services in turn implement the necessary actions in order to meet the requested traffic delivery throughput.

Now as illustrated in the diagrams besides the comparison of the flow throughput and sector loads evolutions indicate that:

1) Flow evolutions provide a good indicator of loads evolutions, but are exceptionally overoptimistic;

2) Loads counts evolutions are smoother than flow counts evolutions.




In the strictest sense, the ability of balancing demand against capacity constraints shall be best measured by considering loads rather than flows.

However, adopting loads rather than flows in the assessment of ATFM ground regulation performance would remain inappropriate since it is outside of ATFM ground regulation mandate. However the ATFM smoothing performance can be considered a good but an approximate of how ATC capacities are used – either wasted or saturated.

### 4.1.3 Departure slot mechanism versus regulation request specification

The ATFM ground regulations mechanism can be split into two distinct processes, which in turn encompass a set of differentiable sub-processes:

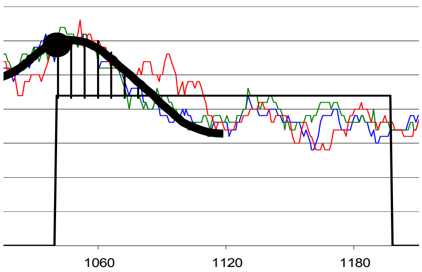
1) The regulation request specification: the process by which ground regulation requests are decided and specified, characterised by a request time and a set of (Traffic Volume, Flow Rate, Regulation start time, Regulation end time);

2) The slot allocation mechanism: the construction of the slot allocation plan, its communication to airspace users and its real-time execution.

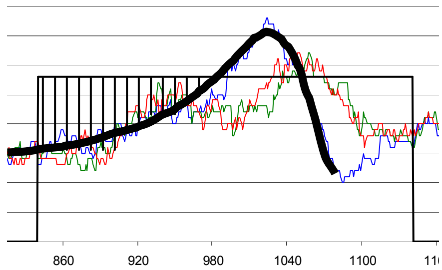
Both processes are normally consecutive – the latter following the former, but are sometimes intertwined with a new regulation request specification process being launched taking account of the output of a previously launched departure slot process.

Especially, it appeared while tracing back some poor ATFM regulation performance cases that the causes of the weak performance could sometimes be attributed to the specification processes. Examples of recurrent observed “failure patterns” are presented below.

***« Too late »***




***« Too early »***

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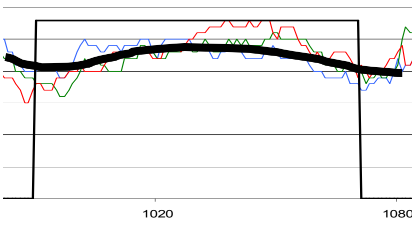


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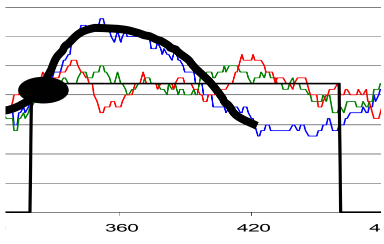


Reasons for poor performance here were to be investigated using additional information (e.g. regulation request time, activation time, etc) not available while analysing traffic and capacity figures only but recorded at the CFMU in heavy databases where all the relevant ATFM events, including regulation requests tracks, are archived.

Regarding the measurement of ATFM ground regulation (smoothing) performance, the main point is the following: the effectiveness of the ATFM ground regulation solution is questioned here on account of potential “flaws” in the regulation request specification – possibly due to contextual constraints outside from ATFM scope of action, rather than on account of the smoothing performance of the slot allocation mechanism itself.

Therefore such cases can hardly constitute conclusive evidence of a poor performance of the slot allocation mechanism itself; neither can they constitute endorsing cases for stopping or continuing to use it. These are separated issues.

### 4.2 Conclusion of the chapter

The relationship between (1) ATFM uncertainties, (2) ATFM smoothing performance (the ground regulation performance in general), and (3) Declared capacities may potentially rest on principles more complex than a direct cause-effect function.

This complexity may originate from sundry reasons and causes: firstly from the non-direct relationship between ATFM performance and capacity figures, secondly from the heterogeneity of objectives from operators using the ATFM ground regulation process, and thirdly from the variety of failure sources that might exist within the ground regulation mechanism. This leads to approach the question of ATFM regulation performances and its relationship with uncertainties and capacities, recognising:

(a) the different (distinguished) actual objectives that are pursued by the end users of the ATFM ground regulation service i.e. ATC;

(b) the causes of inefficiencies distinguishing the quality of the regulation request specification from the slot allocation mechanism response on field;

(c) the intermediary processes that separate the daily ATFM service provision from the daily management of the available capacity.

# 5 CONCLUSION: A SEGMENTED ATFM GROUND REGULATION PERFORMANCE ASSESSMENT?

The question of the relationship between ATFM smoothing performance, ATFM uncertainties and declared capacity taken in its current European form is certainly a complex one. It appears also that the ATFM performance assessment grid currently used at strategic level fails to provide explanations of a number of observed results on the field.

At the present stage, no clear conclusion shall be taken for granted. However, it has been demonstrated by the analysis and throughout interviews with FMPs that FMPs / FMDs have developed methods of using the ATFM regulation process to fullfil a number of new operational objectives, which are not currently taken into account when evaluating the ATFM performance.

The original and basic mission of restoring acceptable hourly demand / capacity balance for both the ATCO and the Airspace User is maintained but it is complemented, into operation, by different and distinguishable new objectives. Some ATFM service users may look for increased traffic predictability, others for decreased sector complexity, or others for the elimination of bunching peaks. All these constitute direct or indirect levers for achieving a better demand / capacity balance.

Regarding the question currently at stake, assessing whether these different direct objectives are properly met by using the ATFM ground regulation system is a first step and requires that a new set of performance metrics be considered. Assessing the current limits of the ATFM system in meeting these objectives and whether these have a negative effect on capacities is a second step that needs to be further analysed in light of these findings.

More specifically this new approach to the problem is based on:

(a) a segmented assessment of the different (distinguished) objectives pursued by the ATFM ground regulation service end users;

(b) an evaluation of the causes of ATFM inefficiencies distinguishing the quality of the regulation request specification from the slot allocation mechanism performance;

(c) and the identification of the intermediary processes that separate daily ATFM service provision from the daily management of the available capacity.

The existence of a genuine added value for each so-defined segment of service shall be assessed and in turn be mitigated with considerations of the cost to Airspace Users.

Developing a more segmented ATFM ground regulation performance grid means specifying a richer matrix of assessment metrics. Provided that there potentially exist thousands of ways of drawing statistics from ATFM data records[10], the definition of such a matrix remains a difficult task, yet certainly worth completing.

Such new ATFM performance metrics would indeed offer a key new insight on the actual contribution of the ground regulation system in helping ACCs to perserve safety but also to minimise the burden imposed to Airspace Users. Moreover the recognition in the performance assessment results of other sources of effectiveness (e.g. the conditions in which regulation requests are specified), distinct from the properly achievable capabilities of the slot allocation mechanism itself (when all the unavoidable alteration factors born from the stochastic nature of Air Transport are integrated), shall bring more specific indications of the operational conditions where the ground regulation solution itself can by no practical means longer provide a satisfactory result.

10 Today it is still unclear whether it is more relevant to measure 10, 15, 20, 30 or 60 minutes counts, area occupancy or traffic entry counts, Instantaneous demand fluctuations or average hourly trends, etc…

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# ANNEX 1

## TRAFFIC DATA ANALYSIS - METHODOLOGY

The method applied in 2005 for the analysis of CFMU traffic data records is based on:

- The selection of an **appropriate sample of regulation cases**;
- A **traffic data structuring model** indicating which specific data to be extracted from the raw CFMU database in order to isolate relevant data subsets for each regulation case;
- A **standard ATFM data observation template** applicable to all regulation cases, and a **case categorisation model**;
- Complementary case analysis methods applied on the most singular cases.

### 1. Selection of appropriate study cases

Our "airports list" includes airports where the ground regulation tool is frequently used. These are the following:

- **London Gatwick**: EGKKARR traffic volume (Gatwick arrivals);
- **London Heathrow**: EGLLBN traffic volume (Heathrow inbound flow through LAM waypoint);
- **Amsterdam Schiphol**: EHAMARR, EHARTIP, EHRIVER, EHSUGOL (Schiphol arrivals);
- **Madrid Barajas**: LECMARR, LEMDARR (Madrid Barajas arrivals);
- **Paris CDG**: LFPGARR1, LFFTE2, LFFTPPG, LFP3A, OMAKO1 (Paris CDG arrivals).

At these airports (and in Terminal Airspaces surrounding the airport physical location), initial demand is regularly above the capacities, because of its concentration during specific periods of the day (peak hours). ATFM regulations are regularly implemented to prevent such overloads.

Our "En Route list" includes a centre where regulations are nominally requested (capacities are nominally close to the demand) and another centre, where the impact of upstream regulations on the studied regulations is low, which allows to isolate the "network effect" on the studied regulations. These are the following:

- **Reims LFEE** (cases of nominal traffic regulations): LFEUF4 (all traffic through LFEUF sector) and LFEUHL4 (non stable traffic through LFEUH sector);
- **Bordeaux LFBX** (cases where the impact of the "network effect", on studied regulations, is low): LFBX1, LFBX2, LFBX3. These traffic volumes are occasionally regulated.

The analysis of these 18 "airports" and "En Route" traffic volumes was performed on 3 AIRAC cycles spread over the 6 June 2005 – 31 August 2005 period, representing about 1000 regulation cases, in total.

## 2. Traffic data structuring model

The traffic data structuring model is granted on the identification of a number of key events in a regulation life cycle that nominally trigger ATFM information updates. Different traffic pictures are drawn before and after slot issuance, just after flights take-off time, then at flights entry time into the regulated traffic volume. Two types of uncertainties (ground vs. airborne uncertainty) were therefore distinguished.

For each regulation case, four sets of distinct data aimed to build four different instantaneous TV entry counts (initial, estimated, regulated and actual TV entry counts) were extracted and compared to the requested flow rates.

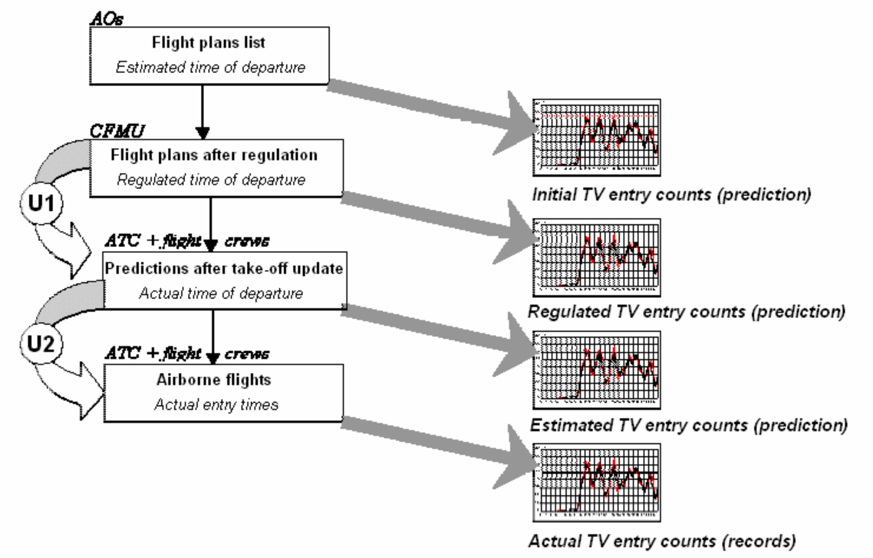



**Figure 5: Proposed analytical model**

Initial, Regulated, Estimated and Actual TV entry counts reflect predictions at different anticipation levels:

- **Initial:** Flight plans list (before regulation).

The "initial" TV entry curve reflects the status of the demand before activation of the regulation plan. It is computed with the latest flight plan version, sent by each AO to the CFMU/IFPS. The data is extracted from the All-FT files – FTFM profile (field n°64 and field n°65).

- **Regulated:** Flight plans list (after regulation).

The "regulated" TV entry curve reflects the status of the demand after activation of the regulation plan. It is computed with the latest ATFM slot (CTOT) issued to the AO, by the ground regulation system. The data is extracted from the All-FT files – RTFM profile (field n°66 and field n°67).

Note:

In order to optimise the regulation process, ETFMS integrates dynamic events such as deviations between actual and planned profiles (through the processing of Radar Data – CPRs) into the slot allocation process. As a consequence, slots that are not frozen yet (before EOBT – 30 minutes, on average) can be improved (in the frame of the true revision process).

The “regulated” vision, available from the reading of RTFM profiles, is not strictly reflecting the traffic load situation that is output from the regulation process, after activation and/or update of the regulation, but is rather an approximate of the latest regulated planned demand situation. Since the slots are frozen at different times (function of the EOBT of each aircraft), one slot that is already frozen, can indeed be reallocated[11] to another aircraft still on the ground, which hence benefits from the true revision process.

- **Estimated:** Flight plans list (after take-off update).

The “estimated” TV entry curve reflects the status of the demand after activation of the regulation plan, and updated with the actual take off times. This view enables to isolate the impact of the departure time uncertainty alone on the result of the ATFM ground regulation. This is a virtual view that might at no time have been observed on the field where traffic departing from remote airports, still airborne, can be mixed with still on-ground traffic departing from closer sources.

- **Actual**: Flown profiles (Real-time execution of the flight plans).

The “actual” TV entry curve integrates the actual entry time of the flights in the regulated TV. It is computed with the Radar Data sent by ACCs to CFMU/ETFMS. The data is extracted from the All-FT files – CTFM profile (field n°68 and field n°69).

U1 and U2 reflect two different types of uncertainties inherent to the real-time execution of flights:

- **U1: Pre-departing TV entry counts uncertainty.**

  U1 reflects the ground uncertainty vis-à-vis the actual off-block time and the taxi time. It is important to note that a great proportion of the uncertainty results from the tolerance applicable on departure times. For regulated flights, the ATFM slot tolerance window is -5 minutes +10 minutes around the allocated CTOT. For non regulated flights, the tolerance applicable is EOBT + 30 minutes.
- **U2: Airborne TV entry counts uncertainty**

  U2 reflects the uncertainty on the actual TV entry time for airborne flights resulting of errors on flight segments time estimates (between 2 waypoints).

Uncertainties U1, U2 are evaluated through the comparison respectively of:

- The regulated and the estimated TV entry counts;
- The estimated and the actual TV entry counts.

The traffic smoothing target is evaluated against one or several flow rates applicable on a studied regulated traffic volume.

## 3. Standard observation template & case categorisation model

Following the rationale of the problem at stake – controversial appreciations of ATFM ground regulations performance – field (local) versus high level view, our approach consisted in building a standard observation template for all cases, according to the evaluation guidance found in the PRRs.

11 For instance, this happens when the system detects deviations between actual and predicted TV entry records (predicted profiles are updated if the CPR shows a time, vertical or a lateral deviation).

In a regular situation, it consisted in the following:

- **Hourly flight counts evolutions** are traced, for initial, regulated and actual statuses (see analytical model presented above);
- **A comparison of the observed morphology of curves** is performed.

  NB: Because of the issue concerning the building of the "regulated" curve (see § 2 above), the focus, while comparing curves is not put on the "regulated" vision, but rather on the observation of "initial" and "actual" curves morphologies.
- The studied regulation case is **classified**, **according to the evaluation guidance found in the PRRs** (demand / capacity ratio criterion < 110% (ineffective regulations) and > 120% (effective regulations): endorsing, invalidating, contradictory and borderline categories. These are the "regular" categories.

In applying such template, we found however that some cases could not be referenced vis-à-vis PRR ground regulation efficiency criteria. We therefore proposed the creation of three additional categories (singular categories) gathering cases of "Major failures[12]", "No demand excess[13]", and "Retroactive corrections[14]"; and conduct complementary analyses for that cases.

## 4. Complementary assessment for the singular categories

The finding of singular cases led us to assume that additional factors, complementing the PRRs criteria, might indeed be taken into account on-field for the using of the ground regulation service and measurement of its performance in general.

For these cases, the standard observation template was modified as follows:

- **Distinct flight counts parameters has been considered:** hourly, 20 minutes, 1 minute parameters (see figure 6 below);
- **The regulation request specification** have been traced back: the process (times of activation) by which ground regulation requests are firstly activated, modified, cancelled, vis-à-vis the regulation start and end periods.

Below is an example of a specific method applied on a singular case where a poor ATFM smoothing performance was recorded as a mix of unsolved hourly over delivery (but actually due to a too short regulation activation time further corrected), unsolved bunching peaks as a result of a well known phenomenon of traffic accumulation at the end of the regulated period.

12 Indicate cases where in spite of PRR defined appropriate demand / capacity conditions, the ground regulation mechanism fails to correct the demand excess.

13 Include cases where a regulation was put despite the absence of hourly demand excess.

14 Include cases where actual records are improved contrary to the assertion made that actual traffic uncertainties alter ATFM performance records.

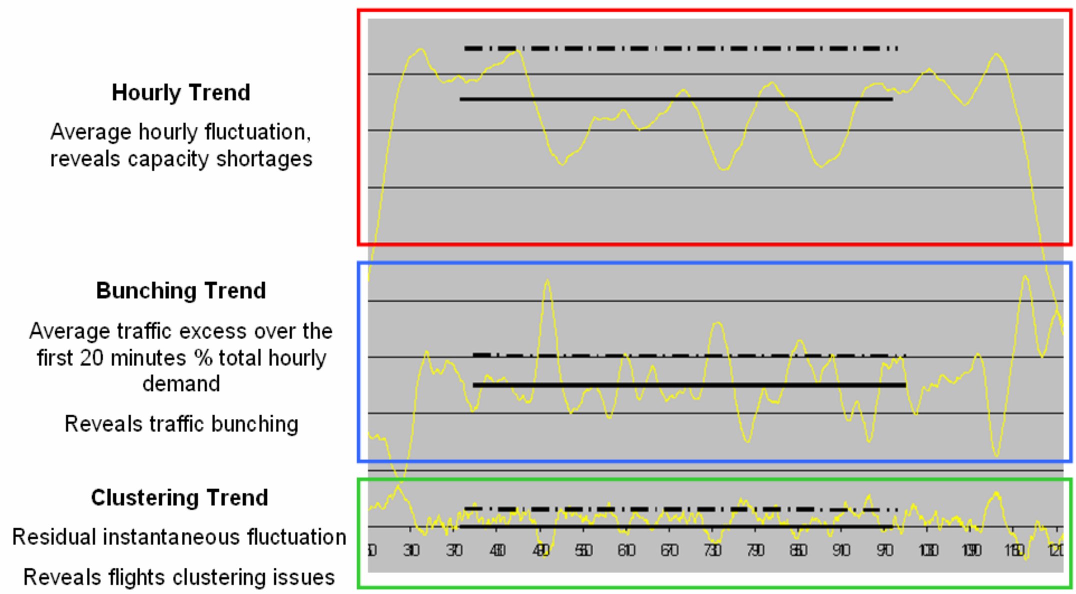


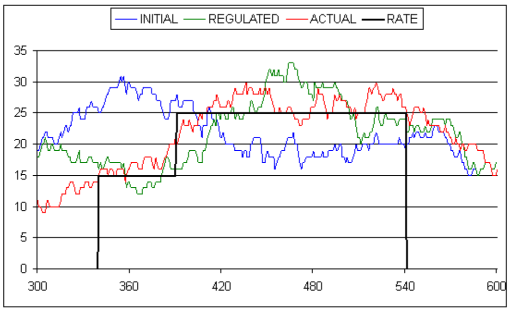

**Figure 6: Complementary assessment**

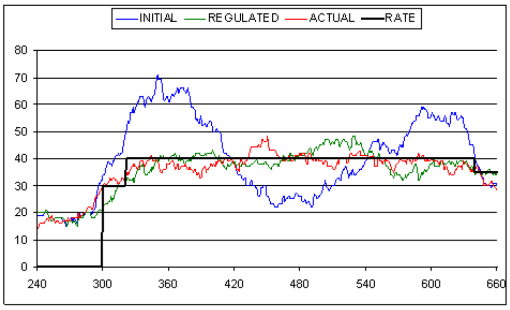
Distinct smoothing purposes (capacity shortage solution, traffic bunching solution, complex flights clustering solution) in the figure above were related to distinct fluctuation speeds (hourly trends, 20 minutes trends, instantaneous trends). The hourly curb was therefore decomposed into three sub-curves where capacity shortage issues could be decorrelated from bunching issues; themselves decorrelated from the instantaneous fluctuation of inter flights entry times; thus enabling a separated analysis of different issues and the respective contribution of the ATFM regulation.

# ANNEX 2

## EXAMPLES OF REGULAR CASES

### Endorsing cases: favourable demand / capacity conditions leading to effectiveness



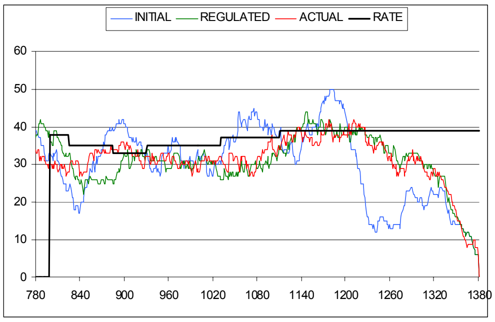



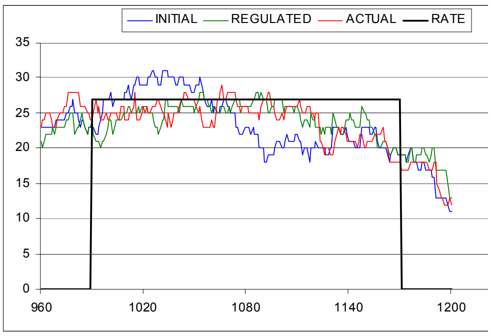

In the examples besides, demand was significantly exceeding the requested flow rate. (PRR favourable ground regulations applicability conditions)

The ground regulation provided for an effective, observable correction of the global demand distribution, in the respect of the requested flow rates.

However residual fluctuations below and above the flow rate threshold, of reduced magnitude (<120%), are recorded in the actual distribution. Yet these residual fluctuations, are recorded both in the regulated curb and in the actual curb, and are equivalent in magnitude and length. These are cases compliant with PRR recommendations and conclusions.

### Invalidating cases: unfavourable demand / capacity conditions leading to effectiveness



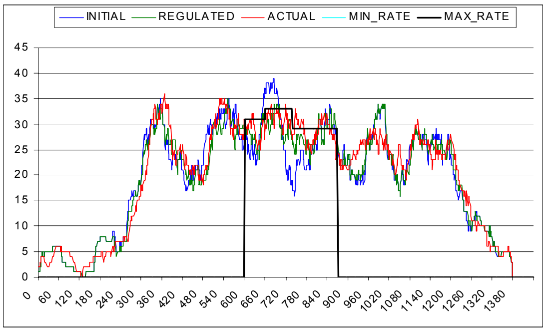

Besides are two cases where the demand was not strictly significantly exceeding capacity (demand/rate < 110%) in the lower case, (demand/rate ~ 110-15% < 120%) in the upper case. (PRR disfavourable ground regulations applicability conditions)

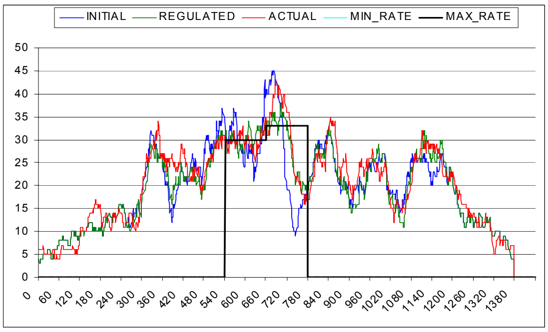
The slight correction of the demand distribution was effectively recorded in actual traffic entries all along the regulation period.

The observable correction on the regulation plan (regulated curb) is accurately reproduced on the actual record, plus or minus 1 to 2 flights per hour.

These examples show better accuracy performance records than those suggested in the PRR (both are here lower than 10% of the flow rate but closer in absolute terms to 2 units).

**Contradictory cases: favourable demand / capacity conditions leading to ineffectiveness and vice-versa**



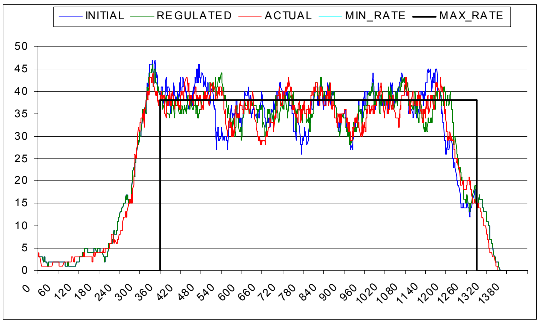



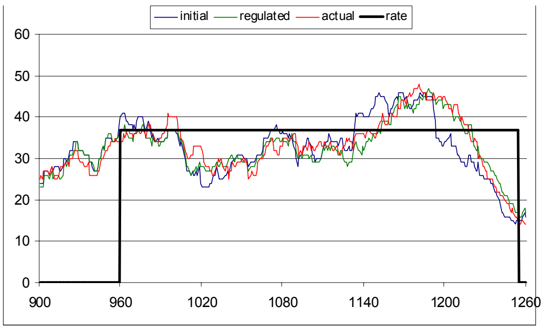

Besides are two records of two regulation cases implemented on two different days but on the same traffic volume, with no capacity variation.

Demand was once not significantly exceeding capacity, upper case (demand/rate < 110%) (PRR disfavourable ground regulations applicability con-ditions), once significantly, lower case (demand/rate>120%), (PRR favourable ground regulations applicability con-ditions).

Yet the correction of the demand profile provided by the regulation is in the upper case effective, in the lower, ineffective.

**Borderline cases: demand / capacity fluctuates between 110% and 120%**



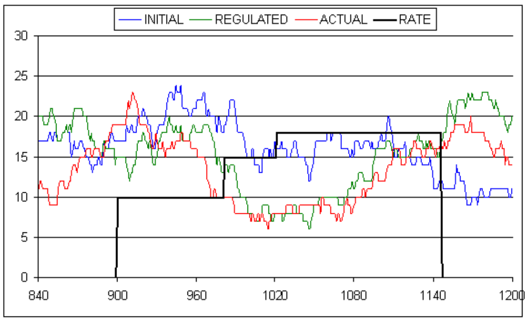

In the examples besides, demand was not significantly exceeding the requested flow rate yet in the upper case, was punctually but continuously threatening to, in the lower case, was once but for a sustained period, both fluctuating between a 110-120% excess.

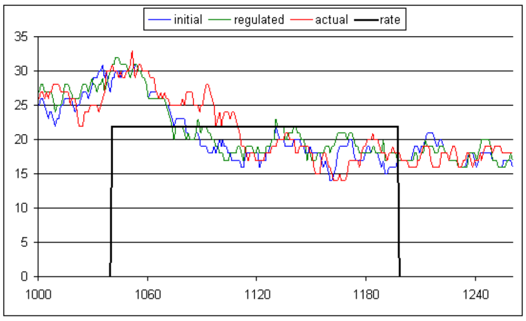
The regulation could sometimes provide for an effective correction of the demand curb other times not. However the flaws in the actual curb accurately reproduce flaws already recorded in the regulation curb.

These cases are at the borderline of PRR conclusions, where the demand/capacity excess fluctuates between 110% and 120%. No clear demonstration that the regulation ineffectiveness rests upon traffic uncertainties can be drawn here.

## EXAMPLES OF SINGULAR CASES

### Favourable demand / capacity conditions leading to major failures



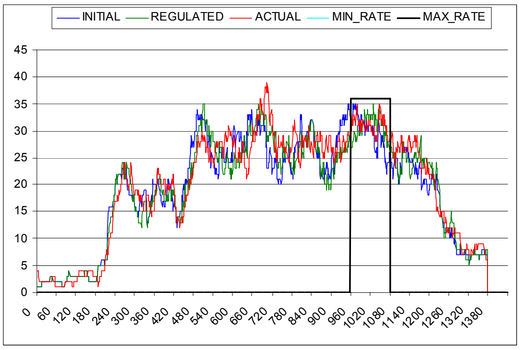

The sample under study also provided for singular cases.

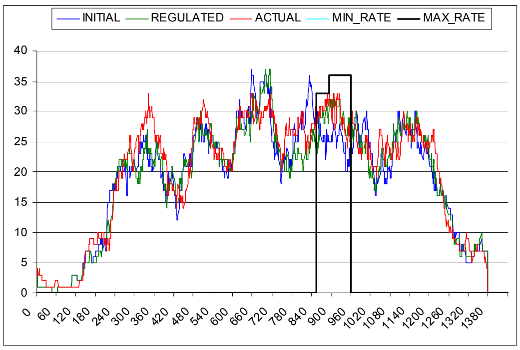
Besides are two illustrations of a first class of those. The demand was significantly exceeding capacity (demand/rate>120%).

However the regulation mechanism failed to correct the demand profile below the requested flow rate.

Significant over deliveries and unused capacity were recorded. According to the recorded traffic entries shapes, this failure can hardly be attributed to traffic uncertainties but is apparently representative of another category of failure source attributable to the condition of implementation of the regulation.

### Singular cases: the regulation request is not granted on an hourly demand/capacity ratio criterion



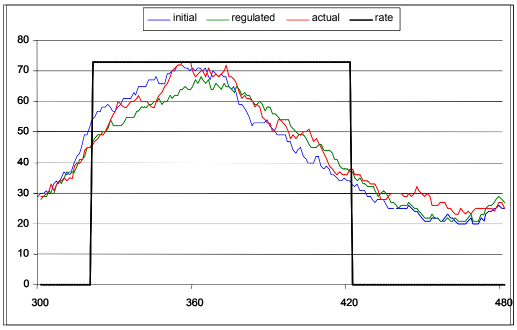



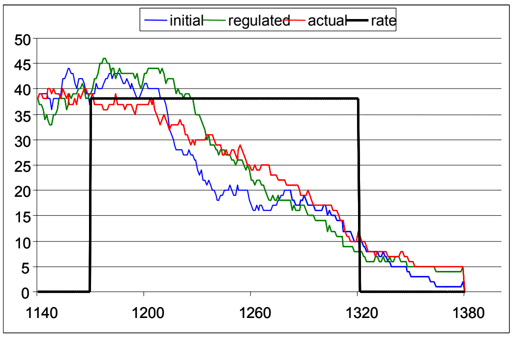

Besides are two examples of a singular class of regulations, where no hourly demand excess is recorded into the regulated period. Instead the regulation start time shortly succeeds to a very punctual demand peak.

A result of the regulation can however be observed: the punctual hourly demand peak shortly preceding the regulation period is no longer recorded in the actual curb.

The analytic grid used herein does not provide for a clear indication of the ATFM regulation requestor intent. However it appears that this morphology is representative of a very particular issue, unrevealed by hourly counts: the presence of bunching peaks into the demand curb.

**Singular cases: actual curb is well shaped in spite of a failing regulation plan**




Besides are two examples of a singular class of regulations, where the regulated curb indicates a much less satisfactory result than the actual curb. In the upper case, capacity loss, in the lower case, overloads.

These flaws however are no longer recorded in the actual traffic entry curb.

The morphologies exhibited besides are apparently representative of now effective new ATFM improvement processes that still provide for improvements much closer to the real time (for instance at the departure airport with the slot improvement process). The counterpart however is an instability of the regulated curb that may continue to evolve very close to planned flights departures time.