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Arrival Flow Control by Local Cherry Picking

an "in vivo" experiment in ATM

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***Abstract*—In the past arrival regulations have been used at Vienna airport almost on a daily basis to resolve short term congestion.**

With the aim to reduce arrival delays and improve management of traffic flows, Austro Control and Eurocontrol's Central Flow Management Unit (CFMU) have performed a trial in close cooperation with two airlines home-based in Vienna. The trial was supported by a number of Flow Management Positions (FMP) in the region and took place between the 4th and 30th October, 2010. The trial implied the application of a newly developed Air Traffic Flow and Capacity Management (ATFCM) technique called "local cherry picking" to manage short period congestion (in arrival peaks of up to 40 min).

Instead of applying an arrival regulation systematically, Vienna FMP and CFMU tried to spread the traffic in a Collaborative Decision Making (CDM) manner through direct contacts with FMPs, Tower (TWR) units and flight operations departments of the airlines concerned. The trial was highly successful as delay was reduced considerably compared to the normal flow management process and overall workload was not increased for the participants (specifically the air traffic controllers)

The successful conclusions drawn from the trial have led Austro Control to implement the concept as a normal operating procedure for Vienna starting January 17, 2011. The Vienna trial has demonstrated that the method of "local cherry picking" may be used to reduce arrival delays and resolve short term congestion at other European airports that have similar structural problems.

Keywords—air traffic management; air traffic control; tactical flow management; arrival capacity; airport operations; flow regulation; air traffic system, air traffic network; airport capacity

I. INTRODUCTION

Over long periods of time, the airport of Vienna/Austria (ICAO-Code: LOWW) has experienced short term congestion problems, which resulted in regular (almost daily) arrival flow regulations and thereby created delays for airlines. After a thorough analysis of airspace structure and procedures, as well as operational interaction between the airport operator and ATC, a key contributor of this problem has been identified in the mismatch between the number of airport slots issued at LOWW and declared ATC capacity. A further study of the actual operational situation following a predicted excess demand has been made in conjunction with the air traffic controllers, which showed that short peak excess demand can better be handled in terms of workload if the peak is not regulated. Instead, the emphasis would be on ensuring that the traffic delivered to the Approach Air Traffic Controllers be at the acceptable levels [1]. This had been confirmed by Eurocontrol's CFMU. A trial was thus envisioned between Austro Control and Eurocontrol to actually avoid regulations in clearly defined conditions of short peaks. In order to pass the required operational safety assessments and make the concept usable as a future standard procedure, a mechanism had to be devised to cope with extreme excess load in a non regulated peak. With additional holding capacity in ACC airspace not being an option, another concept has been developed which is based on a practice that has previously (but slightly differently) been applied by ENAV in Italy [2]. As a working title, the concept has been called "Local Cherry Picking" as it is based upon the principle of local flow control of selected flights by means of TMA entry times. To ensure the effective management of the network impact it thereby requires close cooperation of the Vienna FMP with neighboring FIRs as well as airlines operating short haul flights (up to one hour flying time) into Vienna. The concept, its motivation and the trial results shall be presented in the following paragraphs.

II. PROBLEM SITUATION

In the last years, Vienna Airport has experienced a fairly difficult situation of arrival delays which has multiple reasons. One major challenge is the hub function of Vienna for Austrian Airlines as the main Austrian carrier operating a hub-and-spoke network with short-haul feeder flights from Austrian and nearby foreign airports, connecting to a medium-haul network which focuses on Eastern Europe and a smaller intercontinental network including flights to North America and the Far East. This hub function has created a daily demand curve which is far from an even spread but shows three strong peaks in the morning hours (7:20-8:40 local), afternoons (12:30-13:30 local) and early evenings (17:30-19:00 local), plus occasionally two smaller peaks in between. The indicated times do not refer to the peak duration, but the period of most frequent occurrence. In order to indicate the order of magnitude of delay produced by a regulated peak, one can say that a regulation of

the relatively short morning peak usually produced about 300-600 delay minutes, obviously depending on the demand.

Obviously, it is paramount for airlines operating hub-and-spoke networks that punctuality within these peaks is maintained to the highest degree possible as this strongly affects connectivity between feeder and receiver flights. On the other hand, peak demand reaching capacity limits is a considerable workload issue for the affected ATC facility, which in our case is Vienna approach [3].

Initial motivation for a regulation avoidance trial was given by statements from Vienna Approach controllers who mentioned that their perceived workload is at times higher in a regulated morning peak where they work for up to 2,5h at the capacity limit, which is the result of a "forced demand spread" by means of flow regulations given through departure slot times at the airport of origin [4]. In rare cases where no regulation was applied but arrival demand grew unexpectedly above the declared capacity limit they claimed to be able to work through a fairly short (usually about 30min) high workload period whilst processing the entire peak within that time span. It was stressed by many controllers that this would, indeed, be the favorable scenario as it includes a more predictable end of the high workload period as opposed to the extended duration of working at the APP capacity limit when arrival regulations were applied.

It cannot be stressed enough, however, that this observation was strictly limited to short peaks of about one hour or less. In any longer excess demand scenario, arrival regulations were and still are seen as the right remedy to contribute to a manageable controller workload.

This general observation was quickly backed by Eurocontrol's CFMU unit which stressed that the "natural spread" of arrival traffic due to airspeed/wind and other external influences usually eases the actual demand situation as compared to the predicted demand which is shown to ATC supervisors and flow controllers through the so-called CFMU Human-Machine-Interface for FMP (CIFLO) [5]. With this information being used by FMPs as a source for decision-making in their flow management, it can often be observed that the upcoming demand situation looks more critical than it eventually turns out to be. This was subsequently analyzed for Vienna and proven by recurrent observation.

All of the above led Austro Control and Eurocontrol experts to the idea of conducting an operational trial to see if short-term arrival peaks (which had yet to be defined precisely) at Vienna airport and the excess demand could be managed through the cherry picking procedure and deliver to the approach controller the traffic they can handle. Such a procedure would knowingly exceed capacity limits declared in the arrival regulations and rely on both natural traffic spread as well as high ATCO performance for rapid resolution of the situation. Keeping in mind that the workload issues of operating beyond declared capacity limits obviously requires a thorough safety assessment, it was soon clear that a safety net procedure would have to be devised to ensure the safe handling of excess load, esp. if it grows beyond safely workable levels [6]. A previous candidate for such a safety net was the establishment of additional holding capacity in ACC airspace (standard holdings are performed within APP airspace in Vienna). It soon became clear, however, that this was no practicable solution as the staffing requirements for such additional holdings would have made the procedure a purely "theoretical" one.

Thus, other solutions were considered, one of which was presented by ENAV at a Eurocontrol Airport Delay Reduction Task Force (DRTF) [7], which aimed at a local (and tactical) method to avoid arrival regulations in Rome-Fiumicino by delaying individual short-haul inbound flights to Rome and thus pushing the demand below the regulation trigger value. The departure delays would thus only affect a few flights and - by predefinition- not exceed 15min per delayed flights while all other arrivals would benefit from a non-flow-regulated environment. This obviously brings about issues of equity, which will be briefly discussed in the summary of this paper. Moreover, it should be clear that airline acceptance and involvement is essential to the feasibility of such a concept.

After further discussions between Austro Control, Eurocontrol and a first contact with the local hub carrier it was decided to go ahead and develop a similar procedure for Vienna based on the ENAV approach and to be used as a safety net for the planned regulation avoidance trial. The details of this "Local Cherry Picking" methodology and its application in a real-world trial will be described in this paper.

III. THE EFFECT OF A STANDARD ARRIVAL REGULATION AND POTENTIALS FOR DELAY SAVINGS

Under standard flow management procedures, any predicted excess arrival demand beyond the declared capacity value (40/h in Vienna under normal conditions, lower values by APP supervisor decision under low-visibility, strong wind or other limitations) leads to arrival regulations being imposed on inbound traffic to Vienna by Vienna FMP via CFMU unless it can be resolved either pre-tactically (e.g. by means of re-routings) or tactically by the approach supervisor's assessment that the excess demand can be handled safely due to full staffing, benign weather, etc. [8][9]. Vienna, like many other airports in Europe, thereby faces the problem of having a seasonal airport slot allocation which hardly considers ATC capacity but looks at airport slot distribution from a pure airport operator's point of view. This leads to the phenomenon of regular excess demand during three main peaks (morning, afternoon, evening) whereas the morning and the evening peaks often seem to have the strongest traffic [10]. Keeping in mind that Vienna serves as a hub for at least two large airlines, it is noteworthy that from an airline operator's point of view an inbound delay during a peak hour (which usually serves as an inbound-outbound node) can be very detrimental to the overall schedule stability [11]. Moreover, schedule disruptions caused by the morning peak can trigger ripple effects throughout the day and are therefore a highly critical issue for the overall network [12]. In order to get an idea about the order of magnitude of these arrival delays for Vienna it shall be noted that 329.555 min of delay were created at LOWWARR in 2010 (142.908 of which where weather related and can therefore not be regarded as a capacity issue) which accounted for more than 20 % of the overall delay production in the Austrian Flight Information Region (FIR). A selective look at the usually short

morning peak between 0620 UTC and 0740 UTC shows that recurrent arrival regulations create 300-600 minutes of delay depending on the actual demand. Comparable situations usually occur in the afternoon peaks around 1320 and 1600 UTC.

These numbers clearly show the potential of an arrival delay reduction and its criticality for the overall ATM system which was the motivation for the procedural trial described in this paper.

A structural analysis of the peak arrival traffic patterns by Eurocontrol's CFMU in connection with controller statements on perceived workload have led to the following conclusions:

- If the demand is larger than 70 flights within 2 hours, a regulation is fully justified, as the demand shall literally be reduced.
- If the demand is smaller, it is rather the goal to spread the traffic evenly than to reduce it.
- This leads to a delay which is much too high compared to the effective goal of the regulation.

Based on this analysis it was concluded that the goal of the regulation trial was to reduce the delay by applying a different procedure than a normal regulation in such situations which led to the concept of "local cherry picking".

IV. THE CONCEPT OF CHERRY PICKING

With the aim to reduce delay produced by ARR regulations at LOWW and improve management of traffic flows, Austro Control and Eurocontrol's CFMU agreed to perform a trial in close cooperation with two airlines having their home base in Vienna and operating a hub-and-spoke from there. The trial was supported by the following FMPs from the region: Belgrade, Bratislava, Budapest, Ljubljana, Milan, Munich, Padova, Prague, Warsaw and Zagreb.

It consisted of applying the cherry picking technique to reduce the use of ARR regulations to manage short period (peaks of up to 40 min) congestion at LOWW. It should be stressed that ARR regulation were still to be used to manage congestions of longer duration. However, unlike previous standard operations, no pre-tactical arrival regulations were in force during the trial period [13]. Thus, from 4th and the 30th of October 2010 no ARR regulation was applied for regular short term peaks.

The so-called target load (actual demand) was selected to be 46/h (i.e. deviating from the declared capacity of 40/h) which in case of excess demand should be trimmed by means of cherry picking of flights from nearby airports (max. one hour flying time to LOWW). A graphical representation of the airports included (which obviously had to be part of the participating airline's inbound schedule during the peak hours) is shown in Figure 1.

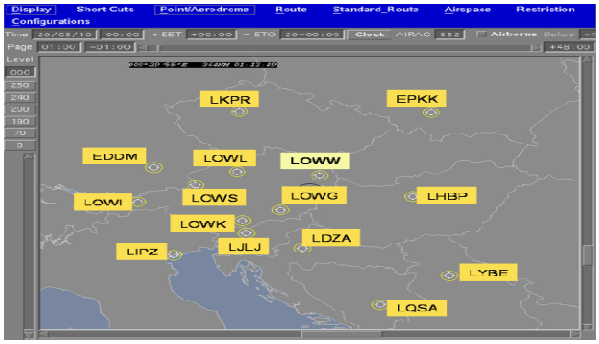


Figure 1: airports around LOWW considered for local cherry picking

The procedure expected short term traffic peaks in the following periods: 06.00 - 08.00 and 15.30 - 17.30 and occasionally 13.00 - 15.00 (all times UTC).

As a first "gate", the procedures applicability had to be verified by checking the following prerequisites:

- APP unit is fully staffed
- normal runway operations are in effect (e.g. one runway for DEPs, one for ARRs)
- no weather issues are observed of forecast (poor visibility, strong winds, CBs, etc)
- expected traffic load is not higher than a maximum of two peaks (entry hour/20minutes) or maximum load during two hours is equal or less than 70 flights

For all other overload situations in LOWW ARR, a regulation was considered to be fully justified and should therefore be applied as usually, e.g. with the standard rate of 40/h during normal operations or with a reduced rate if the actual situation requires it.

Having completed this prerequisite check about two hours before the expected peak start, Vienna FMP would then select as many flights as possible from a flight list of the two participating carriers for potential "cherry picking" and define the minimum amount of flights that should be actually shifted to another time.

In this procedure, the actual selection of individual flights is based upon a list of candidate flights, which has been agreed before applying the procedure with the participating airlines based on their seasonal schedule. Apart from their requirement to feature the pre-defined airports of origin (which yield the proper flying time) these flights have to be accepted by the airlines as candidates for cherry-picking, which is a question of connect criticality and potentially other airline-internal considerations. From an ATC point of view, every flight on the list is therefore an equally valid candidate for cherry-picking and the final selection only depends on their scheduled arrival time relative to the critical arrival demand window and their potential to relax the demand situation through a slight shift in departure times. If necessary according to the aforementioned decision rules and demand thresholds, it is then the manual task of the local FMP to select flights from this list in order to artificially push the demand below 46/h. The number of flights

selected then simply depends on the predicted demand "overflow" beyond 46/h.

If the demand stayed below 46/h, no cherry picking had to be performed as the trimming procedure only aimed at the aforementioned target load of 46. In its cherry picking selection process, Vienna FMP would not consider flights which were affected by non-Austrian regulations. It would also check if flights affected only by Austrian regulations could actually be considered for cherry picking. With qualifying flights, FMP would check the expected entry times of the selected flights and decide by how many minutes each flight shall be shifted. Vienna FMP would then contact the flight operations of the two participating airlines (and their subsidiaries/affiliates) and agree with them candidate flights for cherry picking. The actual flow management of the selected flights would then start one hour before the expected peak:

In case of domestic flights Vienna FMP would request the respective TWR unit within the Austrian FIR to shift the selected flight with destination LOWW to a later or, where possible, to an earlier departure time and include a "required time over" (RTO) for the entry point of the Vienna TMA into the ATC clearance.

For non-domestic flights FMP would send an e-mail to Eurocontrol's CFMU with the list of the selected flights. This list had to include call-sign, entry point and RTO, which need to comply with the required entry time for TMA Vienna (time over various TMA entry fixes, whichever applied for the individual routing). This list would also be e-mailed to the participating airlines. CFMU then contacted all regional FMPs concerned and requested them to ask relevant TWRs to shift flights to a later departure time and include the RTO for the entry point of the TMA Vienna in the ATC clearance.

For feedback and post-operations analysis CFMU recorded actual time of the trial start, flights that have been "cherry picked" and the delay given as well as any other relevant information related to the trial. Moreover, a daily feedback form had to be filled out by CFMU staff, FMPs concerned, AOs, APP Vienna and Vienna FMP.

From the beginning of the trial it was planned to thoroughly analyse the results after trial completion (especially the differences between regulated and non-regulated peaks), and - subject to positive findings - to fine-tune the procedure and prepare it for operational deployment.

V. RESULTS OF THE TRIAL

The trial - as described in previous paragraphs - was carried out between the 4th and the 30th of October 2010. It was originally planned to apply the procedure for a two-week period only (October 4th to October 17th), yet conditions regarding the prerequisites for execution of the trial were not given in sufficient quantity to reach solid conclusions about the procedure's effectiveness. This was due to some bad weather days (with low visibility) as well as a number of exceptionally good weather conditions (and wind directions) between October 4th to October 17th which enabled Vienna APP to fully lift the arrival capacity limit of 40/h by applying the only runway configuration that - from a flow management point of view- does not imply any capacity limitation, which is the simultaneous use of RWY11 and RWY16 for arrivals. Hence it was decided to extend the duration of the trial to which all parties involved gave their agreements.

Finally, the trial period of approximately four weeks yielded a total of 81 arrival peaks which had to be dealt with. For 20 of these peaks, the trial procedure could be applied following a check of all prerequisites which had to be fulfilled. Figure 2 shows in more detail why the remaining 61 peaks could not be tackled by the trial.

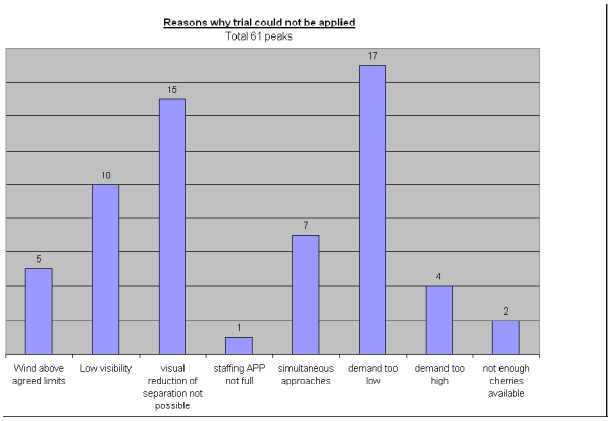


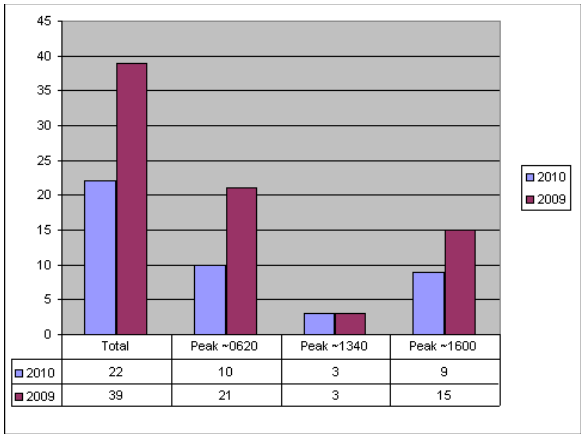
Figure 2: reasons for trial non-application

The positive application rate of about 25% may at first seem to be fairly low. However, it should be remembered that the underlying concept of the entire trial was based on the assumption that only very short peaks (see previous definition) can be successfully addressed with the procedure. Hence, it was clear from the start that only a fraction of all arrival peaks would qualify. Considering all aforementioned parameters that have to be fulfilled in order to apply the procedure, capturing one fourth of all peaks is a fairly high yield that certainly exceeded most of the participants' expectations. Of the 20 peaks where the regulation avoidance concept was applied, only six required a cherry picking procedure to trim the hourly demand to be within the range of 46/h. This number was unanimously seen as a success by the participants, as it was small enough to prove that cherry picking is a "fall back" procedure to avoid overloads whilst also avoiding regulations, but it is not a permanent necessity in the regulation avoidance concept. On the other hand, six peaks which required the cherry picking procedure was a number large enough to test the functionality of the cherry picking, its effectiveness and the underlying communication concept between FMPs, airlines and CFMU.

The real "litmus test" of the regulation avoidance concept, however, was to see if, and to what extent, it actually reduces delay. For this analysis, the same time period in the previous year (October 4th to October 30th, 2009) was taken as a basis of comparison, where obviously, no such trial had been applied. It was thereby happily noted that the overall traffic levels had increased since 2009, which makes the comparison a conservative one regarding the effectiveness of the trial. Thus,

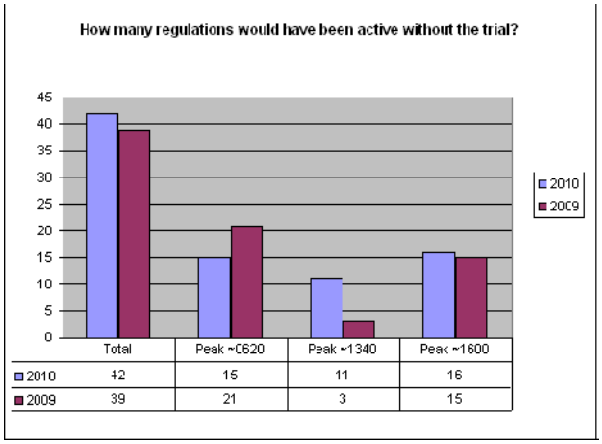
in 2010 the overall arrival demand in Vienna APP was 10.289 flights compared to 9.793 in 2009, which equals a growth of 5.1%. Moreover, the weather induced delays - which, by definition, were not addressed by the trial - had increased by 30.4 % from 6.362 min in 2009 to 8.299 min in 2010. This simple fact, which was outside the participants' realm of influence, also makes the entire analysis of the trial's operational success highly conservative. Thus, the entire delay production by Vienna APP within the two comparative periods could be reduced by an impressive 32.5% from 22.700 min in 2009 to 15.333 min in 2010. Taking the weather delay out of this scope the trial's delay reduction even amounts to 56.9%.

In addition to the pure delay impact, an analysis was carried out to see how many regulations would have been imposed without the trial following standard FMP procedures and the usual capacity limit of 40/h. This shows that 20 out of 42 regulations under standard procedures could be avoided. The exact distribution over the three daily "main traffic peaks" in Vienna during the trial and a year before is shown in Figure 3 as well as the "what-if" scenario assuming standard procedures also for 2010 in Figure 4.



	Total	Peak ~0620	Peak ~1340	Peak ~1600
2010	22	10	3	9
2009	39	21	3	15

Figure 3: number of regulations per peak



	Total	Peak ~0620	Peak ~1340	Peak ~1600
2010	42	15	11	16
2009	39	21	3	15

Figure 4: number of regulations under standard ATFCM procedures

Another interesting analysis is the direct comparison of two structurally similar peaks on successive days, one of which could be addressed with the regulation avoidance procedure whilst the other had to be dealt with through a conventional flow regulation (see Figure 5). The comparison was made based on the produced delay, whilst - for the sake of a balanced analysis - not only ATFM delay was considered (in which case the regulation avoidance case would have a zero delay, by definition) but also delay in tactical holdings which had to be flown prior to landing in Vienna.

	PEAK 06:20					
Date	Trial yes	Trial no	Comments	Regul. & Rate	Holding	Enroute Holding
WED Oct 20	x		• Demand in 2 hours: 66 (48+18) • **Cherry picking of 3 flights.**		Approx. 20 A/C, 2-3 holdings	
THU Oct 21		x	• Demand in 2 hours: 64 (44+20) • Cross winds, showers of rain.	40/60	Approx. 10 A/C, 1-2 holdings	

Figure 5: comparison of two peaks with/without cherry picking

Thus, starting with the conventional situation on October 21st, a total of 29 flights out of 44 were affected by the regulation (i.e. received a slot time for their departure to Vienna). These delayed flights had an average delay of 14,4 min and the total delay produced in holdings inbound Vienna was 80 min which yields a total delay for this regulation scenario of 498 minutes. The total number of aircraft in holding was about 10 flying 1-2 circuits.

The previous day fulfilled all requirements for the trial but saw a slightly higher demand which exceeded the target load value so that "local cherry picking" had to be applied. Three flights were "cherry picked" to trim the load accordingly which gave these flights 6, 7, and 11 min of delay, respectively. All other flights could fly to Vienna without any departure slot time. The traffic situation in the Terminal Area resulted in about 20 aircraft having to enter a holding pattern of 2-3 circuits each which caused a total holding delay of 240 min. Together with the delays of the three flights, the total delay produced was thus 265 min, which equals an impressive 47% delay reduction compared to the conventional scenario.

Finally, an analysis was performed as to how exactly the required entry times (termed "ETO - estimated time over" in this context, although "RTO - required time over" would be more adequate but the acronym is no element of official FMP nomenclature today) were fulfilled. The list of all cherry pickings is shown below in Figure 6 and shows that the ATO/ETO difference usually stayed within a few minutes. Some early arrivals, however, were detected (marked amber and red) which show a slight lack of RTO adherence. The overall results, however, were such that sufficient RTO compliance was considered practicable by all parties.

Date	Peak	FPL Callsign	ADEP	Delay	Point	ETO	ATO	ATOT	Remarks
13.10.2010	~ 16:00	722Q	LHBP	8 Min	PESAT	16:55	17:01	+ 9 Min	**Results not reliable.** Trial cancelled at 16:35. (blocked RWY)
		24MN	LOWS	6 Min	BARUG	16:52	16:59	+ 8 Min	
14.10.2010	~ 16:00	722Q	LHBP	7 Min	PESAT	16:54	16:58	- 11 Min	
		58KL	LOWL	9 Min	MASUR	16:56	16:51	+ 11 Min	
15.10.2010	~ 06:20	894Z	EDDM	14 Min	MASUR	07:12	07:13	+ 13 Min	
		97CD	LOWG	12 Min	NIGSI	07:10	07:14	+ 12 Min	
		16VG	LOWI	10 Min	BARUG	07:15	07:15	+ 8 Min	
20.10.2010	~ 06:20	97CD	LOWG	8 Min	NIGSI	07:08	07:08	+ 6 Min	
		92MN	LOWS	7 Min	BARUG	07:11	07:08	+ 7 Min	
		18PY	LIMC	11 Min	NIGSI	07:14	07:26	+/- 0 Min	
26.10.2010	~ 16:00	14PY	LIMC	13 Min	NIGSI	16:46	16:47	+ 5 Min	
		78CD	LOWG	14 Min	NIGSI	16:49	16:44	+ 6 Min	
		94HB	LOWK	15 Min	NIGSI	16:50	16:49	+ 13 Min	
27:10:2010	~ 16:00	722Q	LHBP	8 Min	PESAT	16:54	16:49	- 1 Min	
		24MN	LOWS	8 Min	BARUG	16:52	16:49	+/- 0 Min	**Results not reliable.** Trial cancelled at 15:45 (simultaneous APPs)
		58KL	LOWL	4 Min	MASUR	16:46	16:45	+ 6 Min	
		78CD	LOWG	13 Min	NIGSI	16:48	16:37	+ 1 Min	
ADEPs: LOWG (4); LOWS (3); LHBP (3); LOWL (2); LIMC (2); LOWK (1); LOWI (1); EDDM (1)									
A/Os:									

Figure 6: listing of ETO compliance during cherry picking

To summarize, the regulation avoidance concept with target values above the declared capacity limit as well as a "cherry picking" procedure for tactical load trimming proved to be feasible and successful in its practical application. It was feasible because the seemingly complex information flow was quickly established and professionally pursued as well as respected by the large number of parties involved. Moreover, it was successful because it reduced the delay situation in short-peak scenarios in the order of 50% compared to the conventional regulation procedure.

It has to be stressed that a critical element of the methodology presented here is the issue of equity. It can be argued that those airlines (usually local hub carriers) that commit to a participation in the concept by offering flights that can be selected in the cherry picking process encounter an unfair burden compared to all other airlines that also benefit from an environment without ATFCM regulations. However, the Eurocontrol/Austro Control team that developed the concept argued that this "sacrifice" is fully compensated by the hub carriers' disproportionate benefit of ATFCM regulation avoidance as their share of flights in peak hours (as well as their schedule sensitivity during these critical periods) is higher than that of an airline offering just a small number of flight to the airport. This argument finally convinced the local hub carriers but it cannot be denied that some strikingly odd situations may occur where the hub carrier flies a route in parallel to a competitor where the former gets penalized and the latter flies unrestricted. Cases like this should by all means be avoided in the cherry picking process, if possible and the future will tell if this impedes the general acceptance of the procedure.

Finally, the overall success of the trial led Austro Control to the decision to implement the concept as a normal operating procedure for Vienna starting January 17. The full safety assessment had obviously already been carried out prior to the trial phase in 2010 so that this quick transition into operations was possible. The procedure is now officially called "CARA" (Collaborative Arrival Regulation Avoidance) and may stand as an approach that could be interesting for several airports in Europe and throughout the world.

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