

Airport CDM Network Impact Assessment

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Abstract-The Airport CDM (Collaborative Decision Making) project aims to improve the overall efficiency of operations at an airport, with a particular focus on the aircraft turn-round procedures. One of the main outputs of the CDM process will be a very accurate Target Take Off Time which will not only enhance ground planning but can be used to improve en route planning as well.

Munich Airport is the first airport to be considered fully Airport CDM compliant and has demonstrated the local benefits such as a reduction in average taxi times and an improvement in CFMU CTOT conformance.

However, one of the aims of the Airport CDM project is to supply the CFMU with accurate Target Take Off Times in order that the CFMU can use them to more accurately plan the management of the whole of the European airspace.

The aim of this study was to measure what the affect would be on the network if more airports were to implement Airport CDM and provide the CFMU with accurate Target Take Off Times via DPI messages.

The study conclude that,

Munich Airport currently has the most accurate take off estimate of the 42 airports considered in the study and this accuracy was used as the baseline for those airports in order to evaluate the impact on sector capacities within the European area.

The results show a potential sector capacity increase within the European area of up to 4% which equates to between 1-2 aircraft per sector.

The impact of Airport CDM on delays has highlighted a room for improvement of between 33%-50%.

The positive results recorded in this study show that the expected benefits of Airport CDM implementation could extend from the local airport environment to the Network.

Keywords: Airport; CDM; Air Traffic Management; Delays; Capacity.

I. INTRODUCTION

A. Airport cdm background

The objective of the Airport CDM (Collaborative Decision Making) project is to improve the overall efficiency of operations at an airport, with a particular focus on the aircraft turn-round procedures. This is achieved by enhancing the decision-making process by the sharing of up-to-date relevant information and by taking into account the preferences, available resources, and the requirements of those who are involved at the airport (such as Aircraft Operators, Air Traffic Control, handling agents, and the airport management). One of the main outputs of the CDM process will be a very accurate Target Take Off Time (TTOT) which will not only enhance ground planning but can be used to improve en route planning as well.

The Airport CDM project forms part of the work of the EATM Airport Operations Programme (APR) and since 2001 EUROCONTROL has been actively working with many of the major European Airports to develop and implement the Airport CDM concept.

Implementation of Airport CDM is now at different stages depending on the airports concerned, however, in summer 2007 Munich Airport became the most advanced CDM airport when they successfully started exchanging Departure Planning Information (DPI) messages with the CFMU. These DPI messages contain the accurate TTOT which is based on the Target Start Up Time (TSAT) and a Variable Taxi Time (VTT).

Munich Airport has demonstrated the local benefits of Airport CDM e.g. since Airport CDM was introduced average taxi times have decreased, the partners use the TSAT to allocate ground resources and CFMU CTOT conformance has improved.

These benefits and others were expected and it is foreseen that other airports implementing Airport CDM will benefit in the same way. However, one of the aims of the Airport CDM project is to supply the CFMU with accurate TTOTs in order that the CFMU can use them to more accurately plan the management of the whole of the European airspace or in other words, the risk of over delivery to an en-route or TMA sector is

reduced, and should lead to a declaration of sector capacity closer to the theoretical maximum capacity of the sector. The aim of this study is to try to measure what the affect will be on the network if the main airports that currently experience the most delay were to implement Airport CDM and provide the CFMU with accurate TTOTs via DPI messages.

B. Objective

The objective of the study is an assessment of the impact in the en route declared capacity due to the improvement in take off predictability and more accurate data available after implementing Airport CDM in a relevant number of airports.

C. Scope

The baseline scenario was based on an ECAC wide assessment of the situation using the current airport and en-route capacities and the current traffic. It was decided that the area that would be most likely to show a benefit would be the core area inside the ECAC and this included the busiest zones: Belgium (EB), Germany (ED), Maastricht (EDY), United Kingdom (EG), Holland (EH), Luxemburg (ELL), Spain (LE), France (LF), Italy (LI), Austria (LO), Swiss (LS), shown in the following figure.



Figure 1: Core Area used in the Study

Simulations were run with updated airport TTOTs taking into account the improvement provided by a wider implementation of Airport CDM. It was assumed that the Airport CDM improvement as shown from CDM as currently implemented in Munich would benefit the same proportion to other CDM airports in the future. This increased predictability was used to derive:

- The variation in sector capacities resulting from the impact on the traffic structure.
- The potential gain in declared sector capacity.

The assessment covered one week of traffic (including a week end) and considered 42 relevant airports.

II. APPROACH

A. General view

Airport CDM has been fully implemented in the Munich Airport since summer 2007.

For the benefit of the study it was assumed that 42 (including Munich) of the most delay constrained airports would implement in the near future

Two scenarios were defined:

- CDM1 was the scenario that happened when only 1 airport(Munich EDDM) was considered as CDM compliant
- CDM35 is a hypothetical scenario “what could happening” in the same conditions as CDM1 but in the case where 42 airports would be Airport CDM compliant

B. Used DATA and methods

In order to perform a high quality study the most accurate data and validated methodologies and tools were chosen. These are presented in the following

- CFMU data: ALL_FT files for 21-27.07.2007 AIRAC297

The traffic sample used was from the 21st-27th of July 2007, and the AIRAC cycle was AIRAC 297.

The main reasons for choosing this period as the reference one was, that at the time, the CDM was implemented in Munich Airport and the time period was a normal summer one in terms of traffic load. For the similar reasons, the same period has been chosen by several other projects in establishing the baseline.

For the defined period, CFMU data in ALL_FT format was collected. ALL_FT is a CFMU data format containing historical traffic recordings of all flights crossing the ECAC area. The following modifications were made to the recordings,

- Modified CFMU data for the CDM35 scenario. See the chapter IV.A for a complete description of the CDM35 traffic generation.
- Take Off Time Deviation (TOT_Dev) is defined as the difference ATOT-ETOT or ATOT-CTOT if CTOT is defined.

For the CDM project purposes, the relevant value to be studied is the TOT_Dev value.

The traffic related to Munich Airport was considered and the ATOT-ETOT deviation was evaluated for both CDM Airports and non CDM Airports.

The Gauss distribution is the most suitable model for the above mentioned deviation.

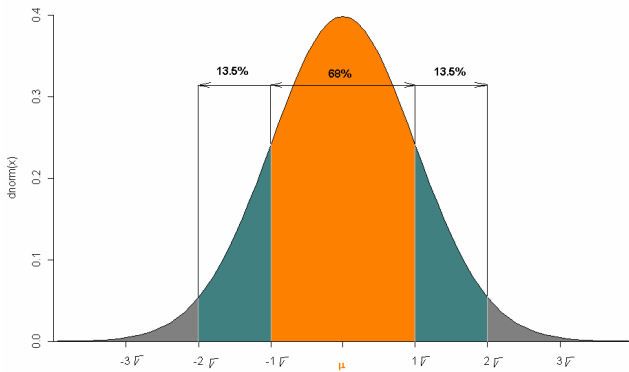


Figure 2: Gaussian distribution. General View

μ is the Gaussian distribution mean value

σ is the Gaussian distribution deviation

The meaning of these values is that about 68% of values drawn from a normal distribution are within one standard deviation $\sigma > 0$ away from the mean μ ; about 95% of the values are within two standard deviations.

Two scenarios were defined: CDM1 and CDM35

CDM1 scenario is the 2007 recorded situation. Only Munich Airport with Airport CDM fully implemented.

CDM35 scenario is taking into account 42 Airports (see list below) as being fully Airport CDM compliant like Munich is today.

In order to build the CDM35 scenario the Munich recorded distribution is applied for the ATOT-ETOT value for all the listed airports

TABLE I. AIRPORTS CONSIDERED TO BE AIRPORT CDM COMPLIANT

EDDF	Frankfurt
EDDH	Hamburg
EDDL	Dusseldorf
EDDM	Munich
EFHK	Helsinki
EGKK	London Gatwick
EGLC	London City
EGLL	London Heathrow
EGSS	London Stansted
EHAM	Amsterdam Schiphol
EKCH	Copenhagen Kastrup
ENGM	Oslo Gardemoen
EPWA	Warsaw / Okecie
ESSA	Stockholm Arlanda
LEBL	Barcelona
LEIB	Ibiza
LEMD	Madrid Barajas

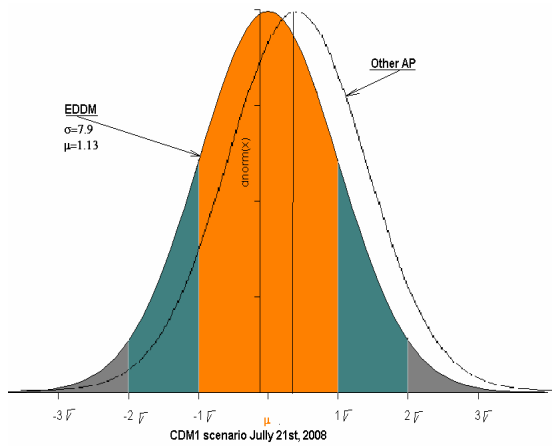
LETO	Madrid Torrejon
LEPA	Palma de Mallorca
LETO	Madrid Torrejon
LFLB	Chambery Aix bains
LFLP	Annecy
LFMD	Cannes Mandelieu
LFML	Marseilles
LFMN	Nice Cote Azur
LFPG	Paris CDG
LFPO	Paris Orly
LGAT	Athens
LGAV	Athens /Elftherios Venizelos
LGIR	Nikos / Kazantzakis
LGRP	Rhodes Diagoras
LIMC	Milan Malpensa
LIML	Milan Linate
LIPD	Villafranca
LIRA	Roma Ciampino
LIRF	Roma Fiumicino
LKPR	Prague Ruzyne
LOWW	Vienna
LPPT	Lisbon
LSGG	Geneva
LSZH	Zurich
LTAI	Antalya
LTBA	Istanbul Ataturk

C. Tools Used

- NEVAC fast time simulator.
- See <http://www.eurocontrol.int/nevac>
- NEVAC is an ATFCM fast time simulation platform developed by EUROCONTROL Experimental Centre (EEC) and broadly adopted and used by the ATFCM community.
- COCA methodologies and tools. See chapter V.A for a complete COCA description.

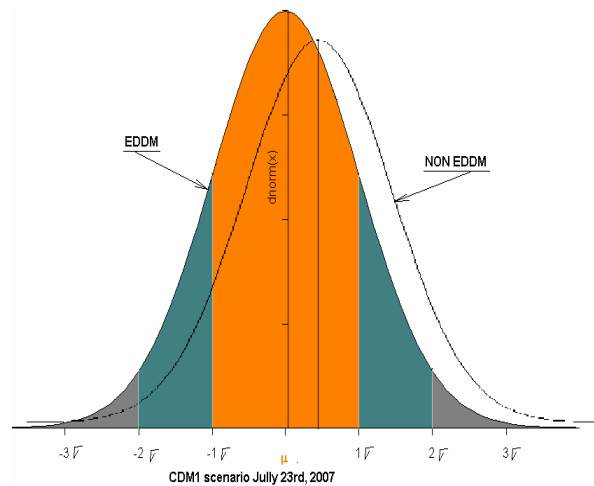
III. ANALYSIS OF MUNICH CHARACTERISTICS

Munich Airport being the first CDM fully compliant Airport was considered to be the Best In Class (BIC) and the other 42 airports in the CDM35 scenario were assumed to be performing in a similar manner.



21.07.2007	MUNICH	NON MUNICH
Deviation	7,92	11,61
Mean	1,13	2,97
Paris CDG	LFPG	NON LFPG
Deviation	11,04	11,57
Mean	2,95	2,97
Zurich	ZURICH	NON ZURICH
Deviation	10,35	11,57
Mean	2,96	2,97
Bruxelles	EBBR	NON EBBR
Deviation	7,70	11,57
Mean	2,96	2,97

Figure 3: July 21st



23.07.2007	MUNICH	NON MUNICH
Deviation	7,1	11,4
Mean	-0,1	2,9
Paris CDG	LFPG	NON LFPG
Deviation	10,5	11,4
Mean	4,3	2,9
Zurich	ZURICH	NON ZURICH
Deviation	10,7	11,4
Mean	2,9	2,9
Bruxelles	EBBR	NON EBBR
Deviation	9,2	11,4
Mean	2,8	2,9

Figure 4: July 23rd

A. Conclusions

Munich Airport:

- a mean value in the (-0.3;1) interval has been recorded
- a standard deviation of about 7 minutes
- For all the other Airports:
- a mean value bigger than 2 has been observed
- the standard deviation is more than 11 minutes

IV. SCENARIO DEFINITION

A. Traffic generation

Munich CDM1 observed mean values and deviation values of the ATOT-ETOT (or CTOT if defined) are applied for all flights taking off from a CDM35 airports. That means, for each of these flights, a new random value is attached for the ATOT-

ETOT in respect to the Munich observed Gaussian distribution of the ATOT-ETOT.

According to the new ATOT-ETOT value, for each flight, the new ATOT value is computed and the new 4D trajectory is shifted forward or backward in time with the ATOT-ETOT value.

In the picture below, the flight is departing from Manchester (EGCC) airport which is a CDM35 airport. The new ATOT-ETOT value is “-2” and keeping a constant ETOT a new ATOT is computed.

A	B	C	D	E	F	G	H	I	J	K	L	
1	ADEP	ADES	ETOT	CTOT	ETOT/CTOT	MINUTES	ATOT	ATOT-CTOT/ETOT	CDM NEW diff	NON CDM new diff	IS CDM 2010	IS NOT CDM 2010
2	EDW	EGCN	1145	1145	0.994	1134	-11	FALSE	-11	FALSE	TRUE	Dev
3	EGPF	EGSS	1625	1649	0.985	1630	-19	FALSE	-20	FALSE	TRUE	Mea
4	EGCC	EDDV	1020	1020	1.000	618	-2	FALSE	-2	FALSE	TRUE	Max
5	EDDF	EDBB	1035	1035	1.000	647	-8	FALSE	-8	FALSE	TRUE	Com
6	LIEE	LIML	910	910	1.000	505	-5	FALSE	-5	FALSE	TRUE	Com
7	LEMD	LFPO	1625	1625	1.000	1020	-5	FALSE	-5	FALSE	TRUE	Dev
8	EGNH	EGNH	1110	1110	1.000	679	9	FALSE	9	FALSE	TRUE	Mea
9	OMAA	LFPG	1015	1015	1.000	617	2	FALSE	2	FALSE	TRUE	Max

Figure 5: Simulated CDM ATOT

After the new ATOT computation, the whole 4D profile is shifted backward or forward as it is figured in the picture below.

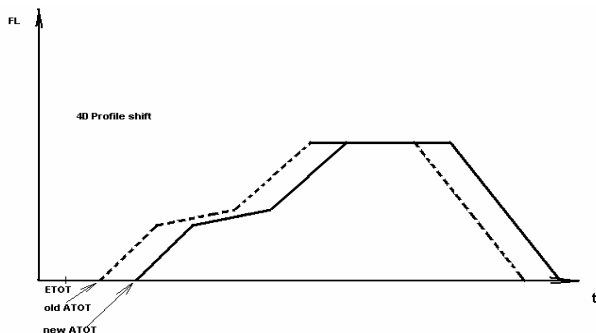


Figure 6: Flight profile. Shift mechanism

V. NETWORK IMPACT ANALYSIS

A. Impact of complexity on Capacity

Following the Airport CDM implementation, a new traffic distribution is expected and due to that, the sectors declared capacity should be impacted.

EUROCONTROL Experimental Centre (EEC) has developed a methodology to study the complexity changes and impact under the COCA (Complexity and Capacity) project. COCA project was launched by the EEC at the end of the year 2000. Its main objective is to describe the relationship between capacity and complexity by means of accurate performance metrics. This objective is addressed in two ways:

- Identifying and evaluating factors that constitute and capture complexity in air traffic control;

- Validating and testing complexity factors and highlighting those linked with controller workload.

The three terms “complexity”, “capacity” and “workload” are highly linked. Sector capacity is not just a function of the number of aircraft in a sector, it is also directly influenced by the interactions between the aircraft: the greater the number of interactions, the higher the complexity. Simply put, complexity drives controller workload, and workload limits capacity. Hence, there is a need to understand what factors or circumstances make the controllers’ work more complex and cause an increase in workload.

To gain a better understanding of the relationship between complexity, workload and capacity the COCA project’s specific objectives are to:

- Analyse the concept of ATM complexity at macroscopic and microscopic levels to include elements such as route segments, airspace volumes, traffic flows, converging/crossing points, etc. at various levels (sector, centre or state);
- Provide relevant complexity indicators and capacity evaluators for specific complexity studies and other studies: ATFM, Airspace design, ATFM Performance and Efficiency, Economical studies for ATM, etc.

COCA project built an elaborated complexity toolbox named COCA Light Analyzer (COLA), and performed several macroscopic studies, the results of which were validated by operational experts.

COCA methodology and COLA toolbox have been validated by several projects and the COCA outputs are highly appreciated by users. It is the reason COCA have been undertaken in some major European projects.

B. Results

The aim of the complexity study is to identify potential changes, problems or gains related to changes in complexity.

Since COCA for the Airport CDM complexity study has been performed on the ECAC wide level results could be “diluted” taking into account the fact that the core area is the most related to the CDM airports. Results could be refined in the next steps by performing a COCA complexity analysis on the CDM core area level.

There are no major changes in terms of capacity gains due to complexity changes brought by the Airport CDM project. The overall gain due to capacity changes is about 0.3% which is in the results tolerance window. The next steps may highlight some changes by reducing the reference area to the European core area.

C. Impact of predictability on capacity

1) Airport CDM benefit drivers

The benefits drivers from Airport CDM can be categorised in two main types:

1. Improvement in the process efficiency due to Airport CDM leading to timely and accurate information. The expected result is an improvement in punctuality.
2. Improvement in predictability due to the Airport CDM procedures based on the timely sharing and updating of information. The expected result is an improvement in the following processes downstream.

The first benefit (process efficiency) will improve the capability to avoid delays due to the processes itself and to reduce or eliminate initial delays (i.e. reactionary delays), and will improve the resources allocation process. This benefit mechanism is related to the resources management and decision making in real time. This effect is not addressed in the study.

The second benefit (predictability) will improve the resources planning and the confidence on the planning evolution during the execution phase.

The simulation is based on the last TTOT provided by Airport CDM, but timely information is not considered in this analysis. The possibilities on reorganisation of the airspace or the staff are also not addressed in the study; it addressed the predictability benefit mechanism only.

2) Key elements

The key elements influencing the capacity are:

- Capacity overload uncertainty: the actual traffic flow differs from the planned movements. The uncertainty between the planned traffic and the actual traffic introduces uncertainty in the planning phase, directly affecting the efficiency.
- Declared capacity: capacity considered in the planning phase.
- Maximum capacity (theoretical): maximum number of flights that can be handled in a sector at the same time under normal conditions of work..

3) Used methodology

In order to highlight the effect of the better predictability on the airspace occupancy the saturation of sectors was considered.

Sector saturation is the ratio demand over capacity

$$\Sigma = \frac{Demand}{Capacity}$$

Only sectors having the saturation bigger than 0.9 were considered.

For CDM1, 515 sectors present saturation greater than 0.9, and for CDM35 351 sectors present saturation greater than 0.9. Figure bellow shows the differences between CDM1 and CDM35 saturation maps in Germany only. In a similar way, some improvements are expected on the CDM Core area level too.

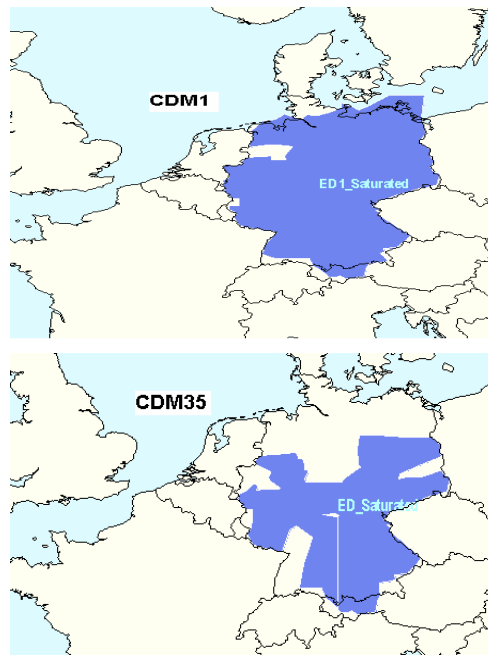


Figure 7: CDM1 vs CDM35 saturation of sectors

- In CDM1 the traffic forecast shows (in blue) all sectors whose traffic load is 90% or greater than sector declared capacity
- In CDM35, an improved traffic forecast due to the improved predictability obtained with extended Airport CDM, shows how some of the initially predicted overloaded sectors will actually operate under their maximum declared capacity and need no protection
- As a conclusion from the above, a further benefit can be obtained by reducing the size of the protection capacity buffer of sectors due to the improved predictability. Therefore the declared capacity could be increased.

The picture bellow illustrates the results from the simulation, a screenshot of the NEVAC fast time simulator:

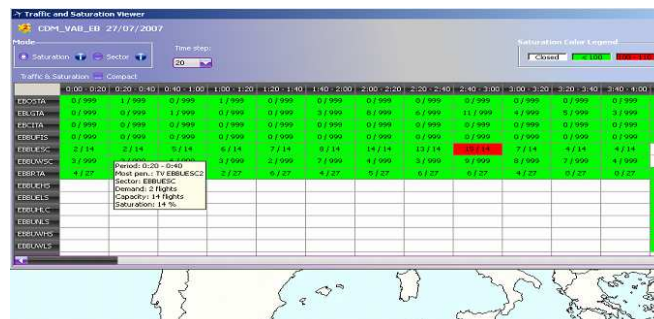


Figure 8: Saturation. NEVAC snapshot

As previously stated, the assessment is based on the comparison between the current situation and the simulated situation after implementing Airport CDM at 42 relevant airports.

Previously in this study, it was noted that there is a significant improvement in the TTOT predictability after implementing Airport CDM.. The focus now is on how a better TTOT can improve the en-route predictability, and it is proposed an approach to use it for reducing the buffers used in the declared capacity maintaining the confidence.

The first step is establishing the reference for the theoretical capacity. The assumption is to define R% as a capacity overload risk.

By obtaining the R% percentile from the actual traffic load for the congested traffic volumes the reference for the theoretical capacity was established, as shown for the 1APT CDM in Figure 9.

From the simulation data for the 42 CDM airports, we can obtain the equivalent figure and compare the overcapacity risk S% referred to the theoretical capacity reference established in the paragraph above. S is smaller than R due to the improved predictability (standard deviation), in other words there is less risk for capacity overload.

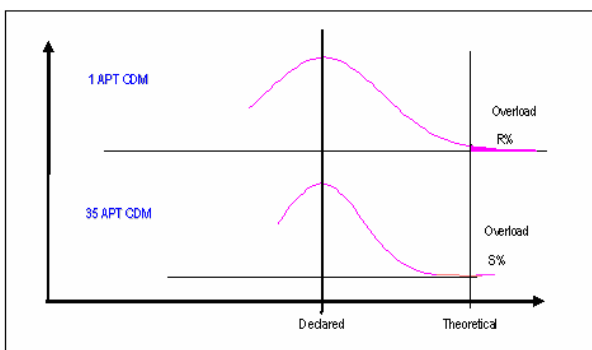


Figure 9: CDM1 vs CDM35 Saturations

The benefit in terms of capacity could be obtained just maintaining the capacity overload risk R% for the new 42 airports situation, taking into account the same current theoretical capacity. Then the declared capacity can be increased by X as much as matching the R% risk. The figure Figure 10 shows this process.

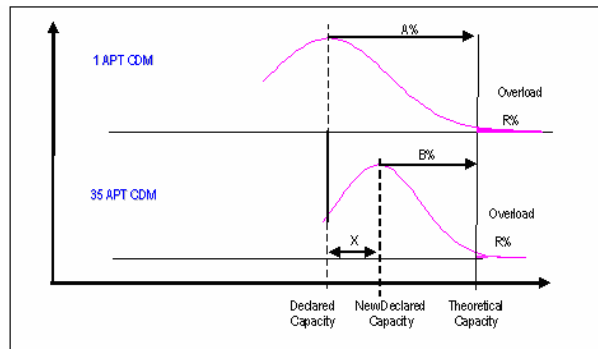


Figure 10: Increase declared capacity mechanism

4) Results dissemination

The analysis is based on the traffic flow in the congested traffic volumes, for two scenarios: real data from the days 23rd, 24th and 25 of July 2007 and simulated data including 42 CDM airports for the same period.

All the calculations have been performed directly on the data obtained from the simulation (without any statistical curve approximation).

The following graph shows the three days aggregated data for those traffic volumes where saturation (traffic flow referred to the declared capacity) is greater than 90%. All the traffic volumes also have been aggregated in order to obtain the required amount of data for a statistical analysis. The X axis represents the traffic load referred to the declared capacity (i.e. 120 means that the traffic flow exceeds the declared capacity by 20%). The Y axis represents the probability of saturation.

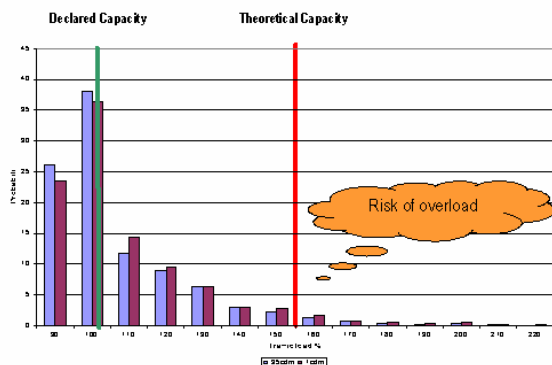


Figure 11: Declared and Theoretical Capacity. Key Elements

Figure 11 above, shows how the results from 42 CDM airports are less spread out compared to the current situation. Also we can note that the results for both cases are concentrated around the declared capacity (100), but slightly displaced to the left side for the 42 CDM airports. This effect in the average is not relevant here due to the data considered in the analysis is the last departing time recorded from the airport.

The maximum traffic acceptable corresponds to the theoretical capacity, the probability for the events above this reference represents the risk to be overloaded.

If we assume the reference for theoretical capacity as the one providing a risk to be overloaded by 5%, it is possible to compare the two figures before and after 42 CDM airports in terms of maintaining the same risk as nowadays.

After implementing 42 CDM airports, if the same declared capacity and theoretical capacity are maintained, the risk of overload is 4%. The proposed approach is to increase the declared capacity while maintaining the theoretical capacity to get the same risk to be overloaded considered as nowadays (5%).

Simulation results for sectors saturation:

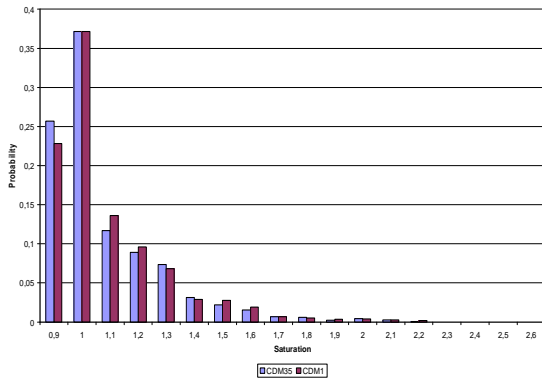


Figure 12: Sector saturations 23rd July

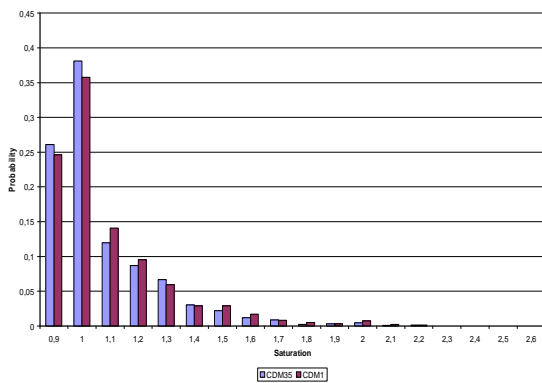


Figure 13: Sector saturations 24th July

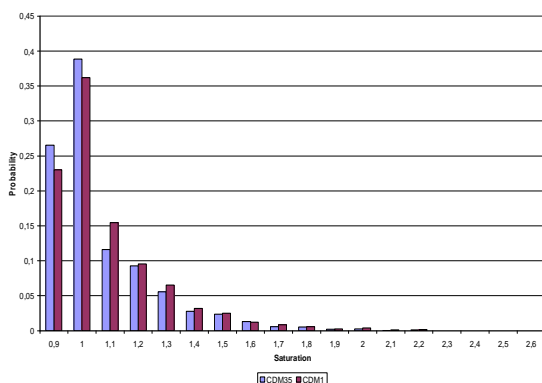


Figure 14: Sector saturations 25th July

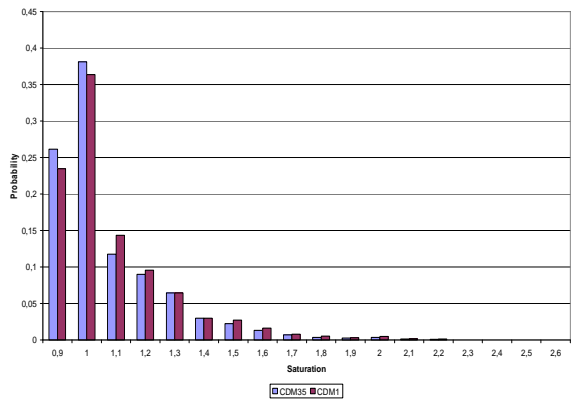


Figure 16: Sector saturations 23, 24 and 25th July

The results related to the declared capacities are included in the following table; X represents the potential increase in declared capacity.

Day	A(%)	B(%)	X
23	1.56	1.51	5%
24	1.56	1.50	6%
25	1.52	1.50	2%
23, 24, 25	1.55	1.51	4%

D. Impact of Airport CDM on Delays

By taking into account the gains in terms of the declared capacities for the identified sectors, delays simulations were performed for each day.

For both CDM1 and CDM35 scenarios, the used environment was the observed one and provided by CFMU. Opening Scheme and Regulation Plan are included in the CFMU Environment provided and they are the same for both scenarios.

A summary of the impact on delays is provided hereafter.

	CDM1				CDM35					
	Route%	AP%	En Rt	AP	Delay/Flt	Delay/Flt	AP	En Rt	AP%	Route%
21.07	74%	26%	2,0	0,7	2,7					
22.07	68%	32%	1,7	0,8	2,5	1,5	0,3	1,2	20%	80%
23.07	33%	65%	0,6	1,1	1,7	0,8	0,5	0,3	61%	39%
24.07	50%	50%	0,8	0,8	1,6	0,7	0,2	0,5	31%	69%
25.07	72%	28%	0,9	0,3	1,2	0,7	0,1	0,6	11%	89%
26.07	58%	42%	0,8	0,6	1,4	0,6	0,2	0,4	28%	72%
27.07	51%	49%	0,9	0,8	1,7	0,9	0,4	0,5	49%	51%

The Opening schema associated to 21st and 22nd July was unusable for this study. The delay results analysis is based on the remaining dates.

The CDM Network Impact Assessment study is focused on En Route Delays.

Conclusions on CDM impact on delays: Having a look on the above summary table, (the mean CDM1 delay=0.8 and mean CDM35 delay = 0.46) we could conclude on a significant gain in terms of delays due to Airport CDM implementation.

VI. CONCLUSIONS

As a resume of the results presented above, implementing Airport CDM would bring the following benefits:

- It has been clearly noted an impact from take off predictability into the sectors capacity.
- If Airport CDM were implemented in the main 42 delaying European airports with the same result in performance as Munich has experienced, then an increase in sectors declared capacity could be expected by up to 4%; that corresponds to an increase of 1 or 2 extra aircraft per hour per sector.
- The complexity analysis shows that the improved TTOT predictability is not expected to affect the theoretical capacity.
- The distribution of the TOT_Deviation values for the Munich airport (see Analysis of Munich characteristics) is the best one compared to Gaussian distributions observed for all the other airports: the mean value is the smallest one as well as the deviation value. Following the TOT_Deviation analysis, Munich airport could be defined as the Best In Class (BIC) airport by taking into account the fidelity to the ETOT.
- Analysis of the impact of Airport CDM on delays has highlighted a room for improvement of 33%-50%

(mean CDM1 delay=0.8 and mean CDM35 delay = 0.46). Such a gain in terms of delay, allows the European targets to be kept in terms of delays. A refined analysis is foreseen in order to better identify the delay gains distribution.

- The results from CDM1 versus CDM35 saturation in German sectors reveals how some expected saturated sectors are not actually saturated. It can be concluded that if the declared capacities are maintained then some regulations may not be required.

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- [2] EUROCONTROL COCA methodologies and tools
- [3] EUROCONTROL NEVAC fast time simulator

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