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Airport CDM Network Impact Assessment

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Abstract :

The objective of this study is to assess the impact on the network if airports were to implement Airport CDM, assuming the same level of benefits in terms of predictability that current CDM airport has achieved and provide the CFMU with accurate Target Take Off Times via DPI messages.

EXECUTIVE SUMMARY

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 and pre-departure sequencing process. 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 as to more accurately plan the management of the whole of the European airspace. Munich Airport is the first airport to be considered fully Airport CDM compliant and has demonstrated local benefits such as a reduction in average taxi times and an improvement in CFMU CTOT conformance.

The objective of this study is to assess the impact on the network if 42 airports were to implement Airport CDM, assuming the same level of benefits that Munich Airport has achieved and provide the CFMU with accurate Target Take Off Times via DPI messages.

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

The study concluded that, following a wider implementation of Airport CDM, the benefits will be:

- **It could be possible to increase sector capacity within the core area by up to 4% which equates to between 1-2 aircraft per sector**
- **A room for improvement for an en-route delays of between 33%-50%.**
- **Some sectors which are expected to be saturated are not actually saturated. Therefore if the declared capacities are maintained then some regulations may not be required.**

The positive results recorded in this study show that the expected benefits from the implementation of Airport CDM could extend from the local airport environment to the network level, with emphasis on the European core area. However, the achievement of these potential gains depends on a large number of airports reaching the same level of Airport CDM implementation as Munich and supplying data to the CFMU to the same level of accuracy.

In addition to the results presented above, an additional study has been performed focusing on the benefits in terms of ATFM delays and to obtain an approximate figure to quantify the airports needed to detect benefits at network level.

This additional study concludes that:

- **Network benefits will start to become significant from the moment we have the 16 largest airports implemented, and will continue to increase until we reach around 100 airports. Implementation in more than 100 airports will only provide marginal benefits.**
- **The potential benefits in terms of ATFM delays if 42 airports implement A-CDM has been estimated as a reduction of minutes delay between 18% and 23% referred to the current situation. It will be reduced by the diminution of regulation allocation as well as reduction in the minutes delay for the needed regulations.**
- **A-CDM is a powerful enabler to reduce the delays in Europe which will contribute together with the other initiatives to match the challenging SESAR objective of reducing the delays.**

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REFERENCES

Airport CDM Implementation Manual

COCA User Manual

NEVAC User Manual(http://www.eurocontrol.int/nevac)

Table 1: List of abbreviations

A/C	Aircraft
ATOT	Actual Take Off Time
BIC	Best In Class
CDM	Collaborative Decision Making
CDM-BASE	CDM BASE scenario with only one CDM compliant airport, Munich
CDM-FUT	CDM FUTure scenario with 42 CDM compliant airports
CFMU	Central Flow Management Unit
COCA	COmplexity and CApacity analysis project
CTOT	Calculated Take Off Time
DPI	Departure Planning Information message
ETOT	Estimated Take Off Time
NEVAC	ATFCM fast time simulation platform
TSAT	Target Start Approval Time
TTOT	Target Take Off Time
VTT	Variable Taxi Time

DEFINITION OF TERMS

ATOT (Actual Take Off Time): The time that an aircraft takes off from the runway. (Equivalent to ATC ATD–Actual Time of Departure, ACARS = OFF).

CTOT (Calculated Take Off Time): A time calculated and issued by the Central Flow Management unit, as a result of tactical slot allocation, at which a flight is expected to become airborne. (ICAO Doc 7030/4 – EUR, Table 7)

ETOT (Estimated Take Off Time): The estimated take off time taking into account the Estimated Off Block Time plus the estimated taxi-out time.

TTOT (Target Take Off Time): The Target Take Off Time taking into account the Target Off Block Time or Target Start-up Time plus the estimated taxi-out time.

1. INTRODUCTION

1.1. 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. 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.

1.2. 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.

1.3. SCOPE

The baseline scenario was based on an ECAC wide assessment of the situation using the current airport and en-route capacities and the whole ECAC 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.

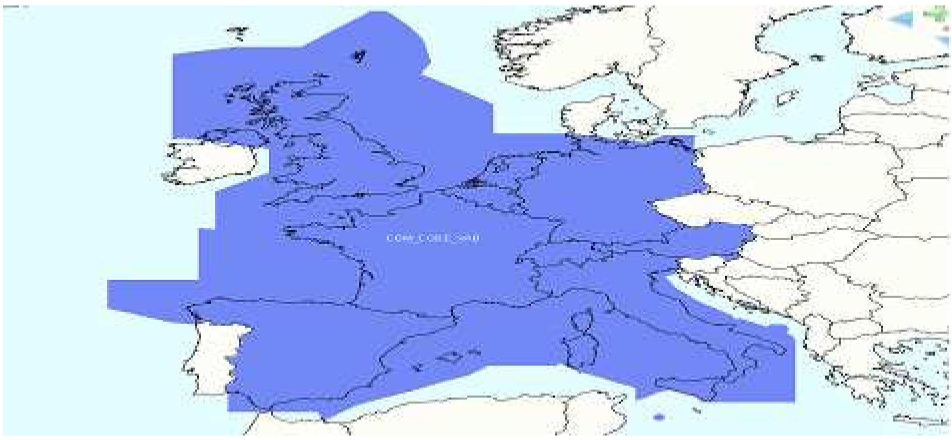


Figure 1: Core Area used in the Study

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 same Airport CDM benefits that have been shown at Munich Airport would apply 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.

2. APPROACH

2.1. 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 Airport CDM in the near future

Two scenarios were defined:

- **CDM-BASE** was the baseline scenario where only 1 airport (Munich EDDM) was considered as CDM compliant
- **CDM-FUT** is a hypothetical Future scenario "what could happen" in the same conditions as CDM-BASE but in the case where 42 airports would be Airport CDM compliant

2.2. 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 CDM-FUT scenario. See the chapter 4.1 for a complete description of the CDM-FUT 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.

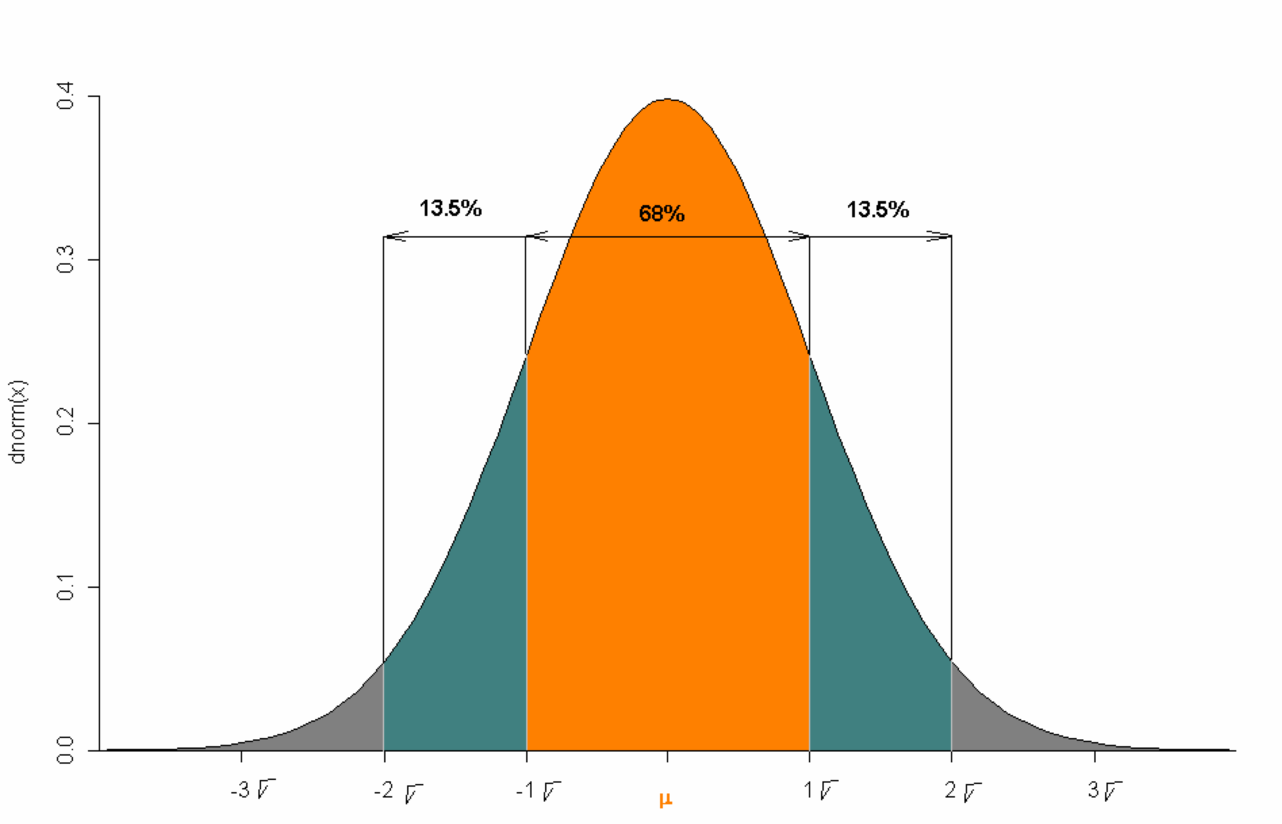


Figure 2: Gaussian distribution. General View

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 σ > 0 away from the mean µ; about 95% of the values are within two standard deviations.

Two scenarios were defined: CDM-BASE and CDM-FUT

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

CDM-FUT 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 CDM-FUT scenario the Munich recorded distribution is applied for the ATOT-ETOT value for all the listed airports.

The traffic departing from those 42 airports represents 41% of the total traffic in the whole ECAC (including over-flights). Looking only to the core area it represents 51% of the traffic.

Table 2: Airports considered to be Airport CDM compliant

EBBR	Brussels
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
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

2.3. TOOLS USED

- NEVAC fast time simulator 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 5.1 for a complete COCA description.

3. ANALYSIS OF MUNICH CHARACTERISTICS

Munich Airport being the first CDM fully compliant Airport was considered to be the reference and the other 42 airports in the CDM-FUT scenario were assumed to be performing in a similar manner after CDM implementation.

Results for Munich airport are presented together with Paris CDG, Zurich and Brussels airports. The three Airports listed above, other than Munich, have been chosen in a random manner but they are considered as representative.

All Airports, other than Munich, have similar figures, the data from the three representative Airports is listed below.

For each chosen Airport, the deviation and the mean value of the Gauss associated distribution are listed.

Summary of the comparison:

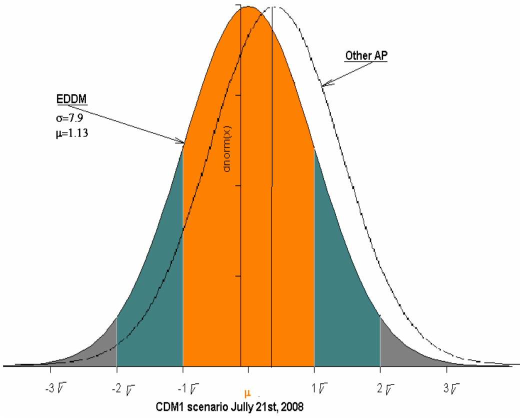


Figure 3: July 21st

21.07.2007	
Munich (EDDM)	
Deviation	**7,92**
Mean	**1,13**
Paris CDG (LFPG)	
Deviation	11,04
Mean	2,95
Zurich (LSZH)	
Deviation	10,35
Mean	2,96
Brussels (EBBR)	
Deviation	7,70
Mean	2,96

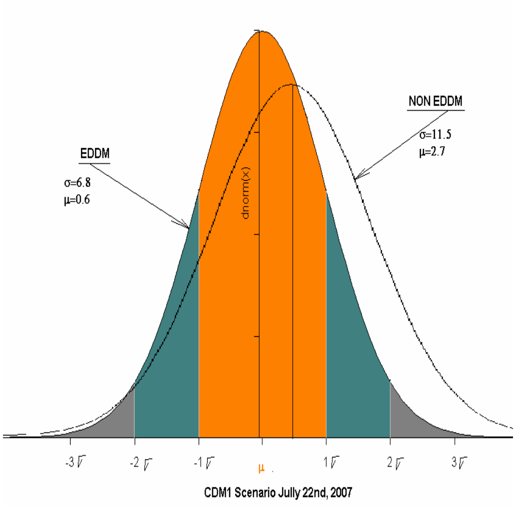


Figure 4: July 22nd

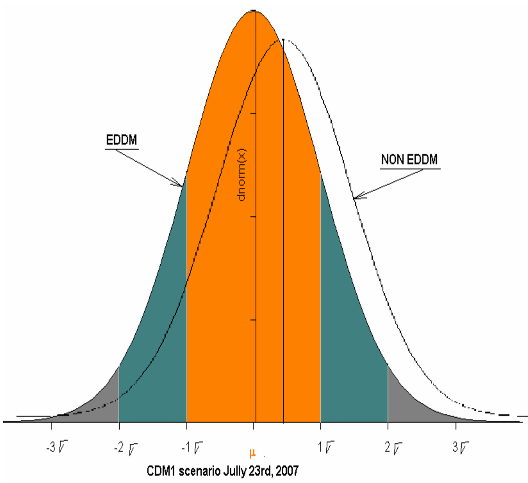


Figure 5: July 23rd

23.07.2007	
Munich (EDDM)	
Deviation	**7,1**
Mean	**-0,1**
Paris CDG (LFPG)	
Deviation	**10,5**
Mean	**4,3**
Zurich (LSZH)	
Deviation	**10,7**
Mean	**2,9**
Brussels (EBBR)	
Deviation	**9,2**
Mean	**2,8**

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 10 minutes

4. SCENARIO DEFINITION

4.1. TRAFFIC GENERATION

Munich CDM observed mean values and deviation values of the **ATOT-ETOT (or CTOT if defined)** are applied for all flights taking off from a CDM-FUT 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 CDM-FUT 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	EIDW	EGCN	1145		1145	694	1134	-11	FALSE	-11	FALSE	TRUE	Devi
3	EGPF	EGSS	1625	1649	[illegible]	989	[illegible]	[illegible]	FALSE	-20	FALSE	TRUE	Mea
4	EGCC	EDDV	1020		1020	618	1018	-2	-2	FALSE	TRUE	FALSE	Max
5	EDDF	EGBJ	1056		[illegible]	647	[illegible]	[illegible]	-8	FALSE	TRUE	FALSE	
6	LIEE	LIML	910		910	545	905	-5	FALSE	-5	FALSE	TRUE	Com
7	LEMD	LFPO	1625		1625	980	1620	-5	-5	FALSE	TRUE	FALSE	Devi
8	EGNM	EGNH	1110		1110	679	1119	9	FALSE	9	FALSE	TRUE	Mea
9	OMAA	LFPG	1015		1015	617	1017	2	FALSE	2	FALSE	TRUE	
10	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	MAX

Figure 6: 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.

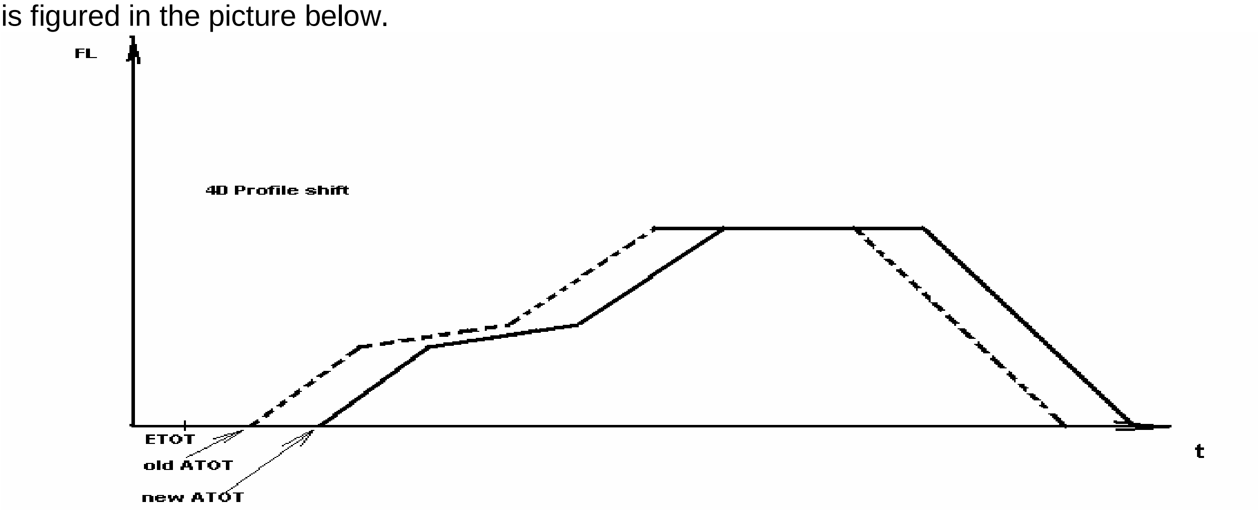


Figure 7: Flight profile. Shift mecanism

5. NETWORK IMPACT ANALISYS

5.1. IMPACT OF COMPLEXITY ON CAPACITY

*For a more detailed COCA complexity approach, see **Annex A: COCA Complexity***

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

The Macroscopic Workload Formula (**MWM)** is used and it is defined as follows:

MWM = w**AC * nAC +** w**LC * nLC +** w **CNF * nCNF**

Where: AC - nominates routine task

LC - nominates level change monitoring task

CNF - nominates conflict monitoring task

nAC, nLC, nCNF - are the numbers of occurrences for each elementary task

wAC, wLC, wCNF - are times necessaries for each of the elementary tasks

5.1.1. 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.

5.2. IMPACT OF PREDICTABILITY ON CAPACITY

5.2.1. Airport CDM benefit drivers

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

- Improvement in the process efficiency due to Airport CDM leading to timely and accurate information. The expected result is an improvement in punctuality.
- 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. Therefore the results presented herein have to be considered only as part of the potential Airport CDM benefits.

5.2.2. Key elements

The key elements influencing the capacity are:

- Maximum capacity (theoretical): maximum number of flights that can be handled in a sector at the same time under normal conditions of work.
- Capacity overload uncertainty: the actual traffic flown 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.

5.2.3. 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

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

The benefits in terms of capacity from the Airport CDM predictability will be related to the congested sectors (regulated and close to be regulated). Therefore, only sectors having the saturation bigger than 0.9 have been considered. The network effect is to be taken into account for both scenarios; that means the congested sectors map should be analysed.

The traffic taken into account considers all the flights in the ECAC area, including over-flights, departing or not from this area. The sectors considered for the saturation analysis correspond to the core area described in point 1.3.

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

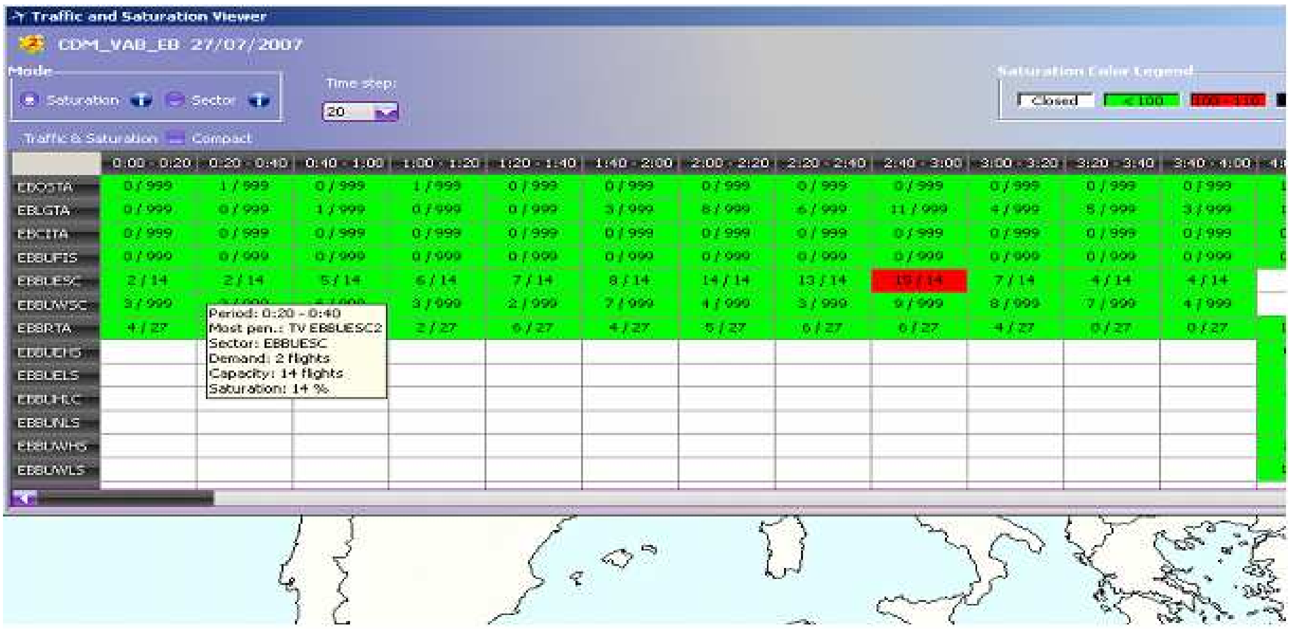


Figure 8: Saturation. NEVAC snapshot

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.

The first step is establishing the reference for the theoretical capacity. The assumption is to define R% as sector overload risk.
By obtaining the R% percentile from the actual traffic load for the congested sectors the reference for the theoretical capacity was established, as shown for the CDM-BASE in Figure 9 and Figure 10. Those figures represent the saturation for both the actual traffic for CDM-BASE and the simulated traffic for CDM-FUT. The X axis represents the traffic load and the Y axis represents the probability of saturation.

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.

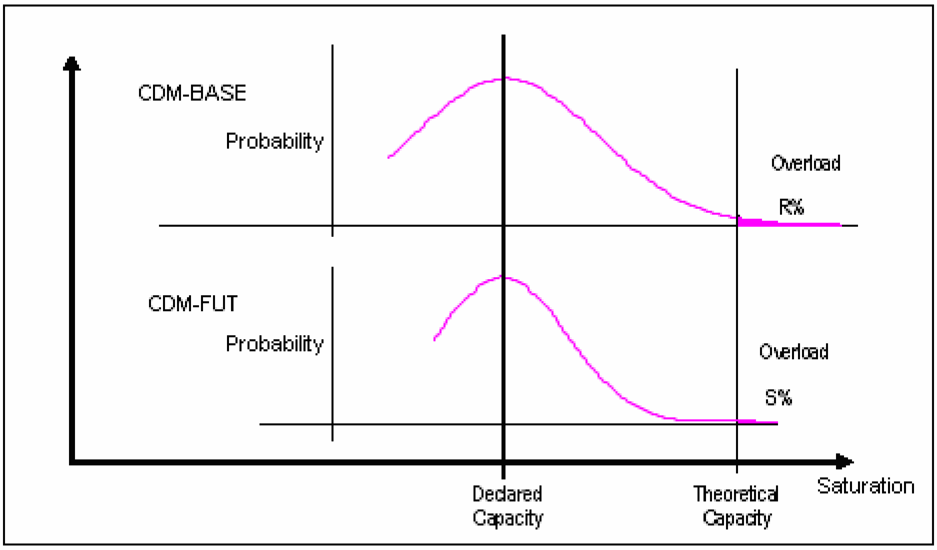


Figure 9: CDM-BASEvsCDM-FUT Saturations

If after implementing CDM-FUT the declared capacity for the sectors is maintained, the effect should be that fewer sectors are saturated and results in less sectors needing protection. In order to use the "new" available capacity the following approach is proposed to reduce the used declared capacity buffers, based on maintaining the figure for the sectors overload risk.

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

10 and Figure 11 show this process.

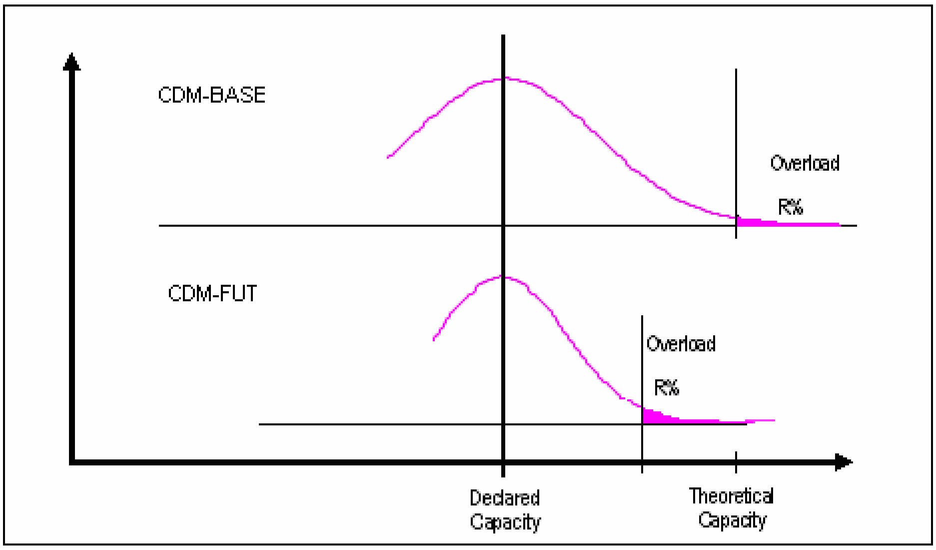


Figure 10: CDM-BASEvsCDM-FUT theoretical capacities reference

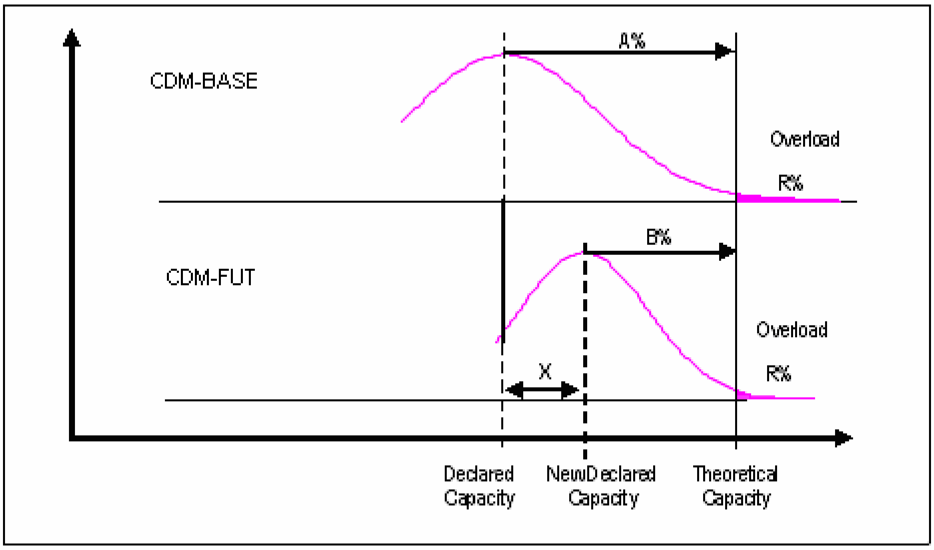


Figure 11: Increase declared capacity mechanism

In Figure 11, A and B represent the capacity buffers for CDM-BASE and CDM-FUT respectively. The difference between A and B is the potential declared capacity increase.

5.2.4. Results dissemination

The analysis is based on the traffic flown 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 has been obtained from the simulation results on sectors saturation. It shows the three days aggregated data for those traffic volumes where saturation (traffic flown 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. 1,2 means that the traffic flown exceeds the declared capacity by 20%). The Y axis represents the probability of saturation.

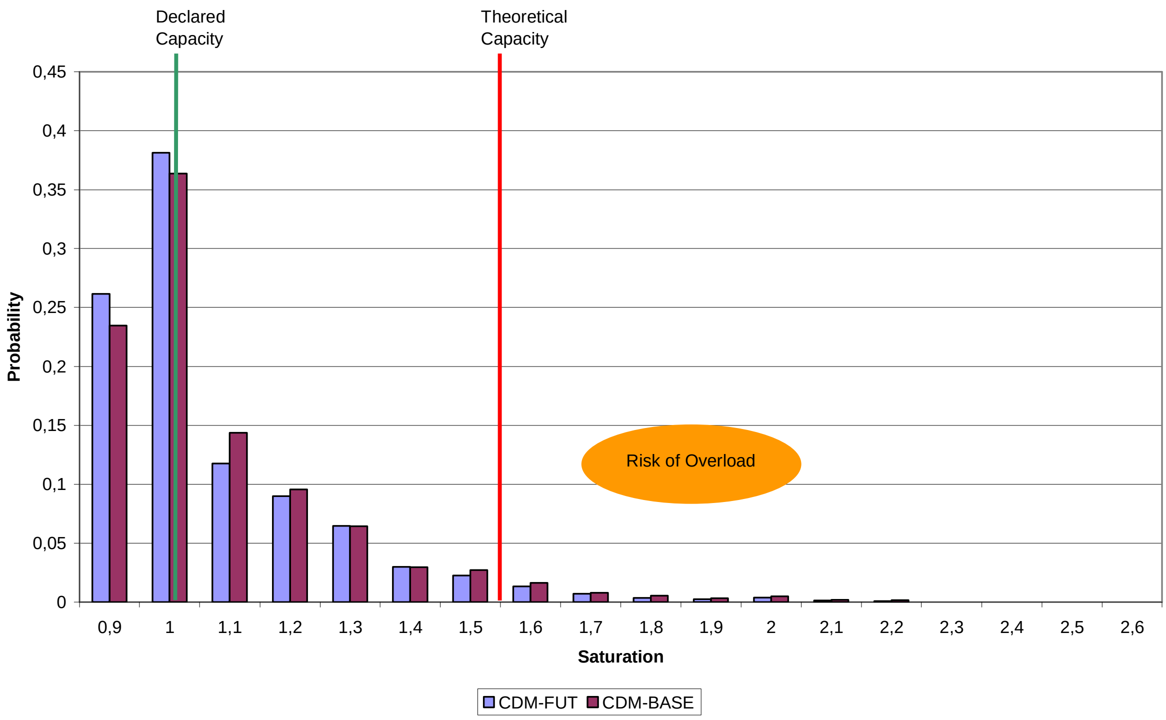


Figure 12: Declared and Theoretical Capacity. Key Elements

Figure 12: Declared and Theoretical Capacity. Key Elements, shows how the results from 42 CDM airports are less spread out compared to the current situation. Also it can be noted 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 is relevant for the standard deviation value but not for the average in this study 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. Current figures show the 5% overload risk approximately corresponds to a declared capacity of 70% of the theoretical capacity.

After implementing CDM at 42 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%). The results from this process are shown in the following figures.

Simulation results for sectors saturation:

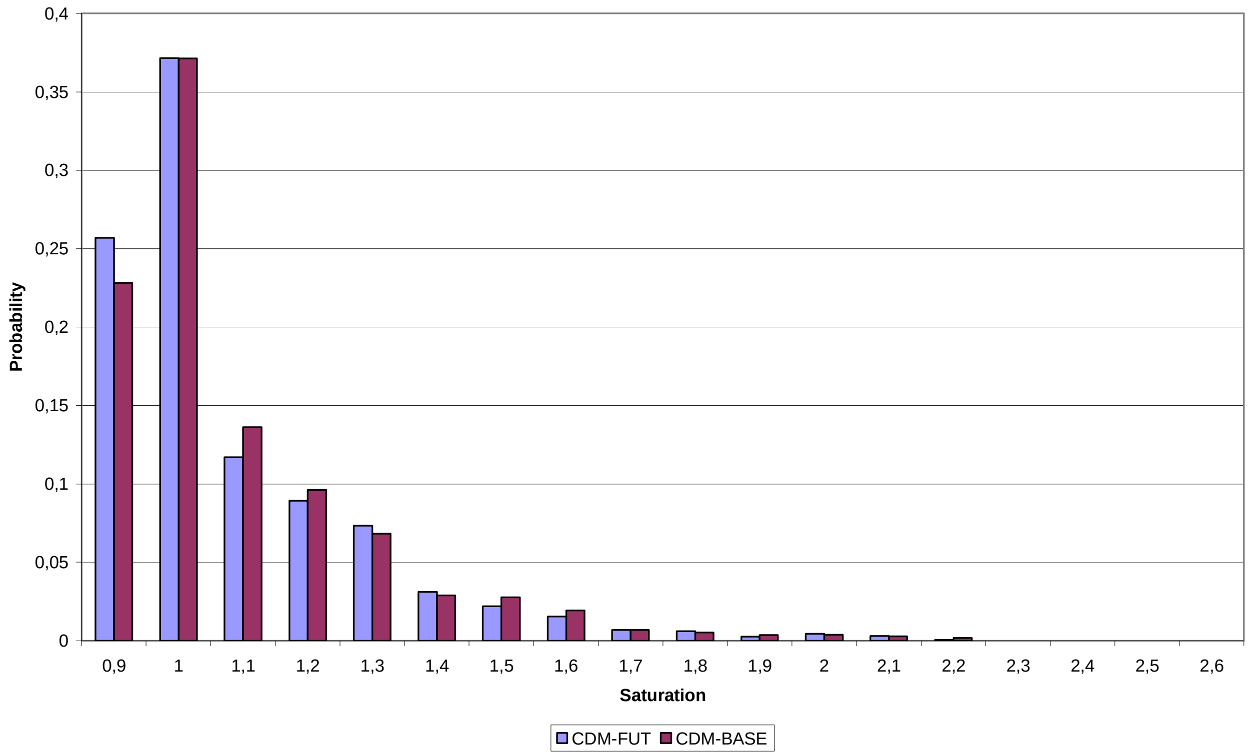


Figure 13: Sector saturations 23rd July

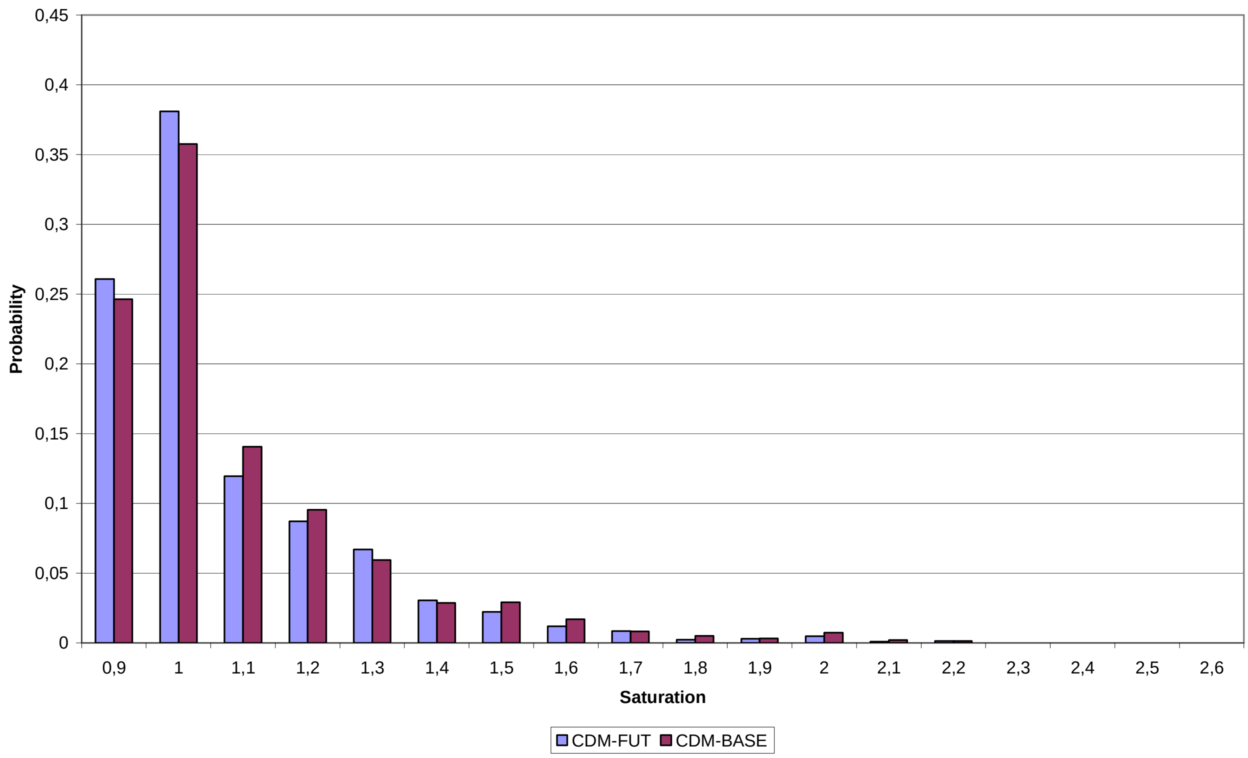


Figure 14: Sector saturations 24th July

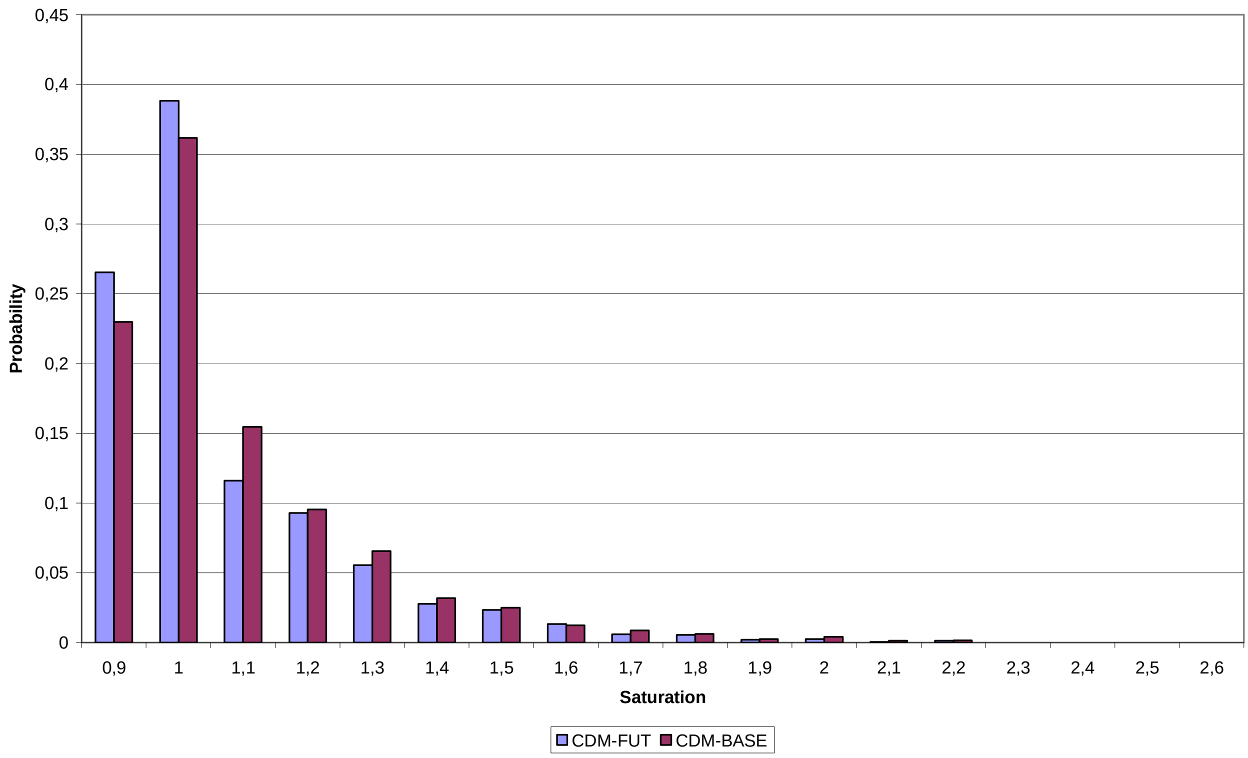


Figure 15: Sector saturations 25th July

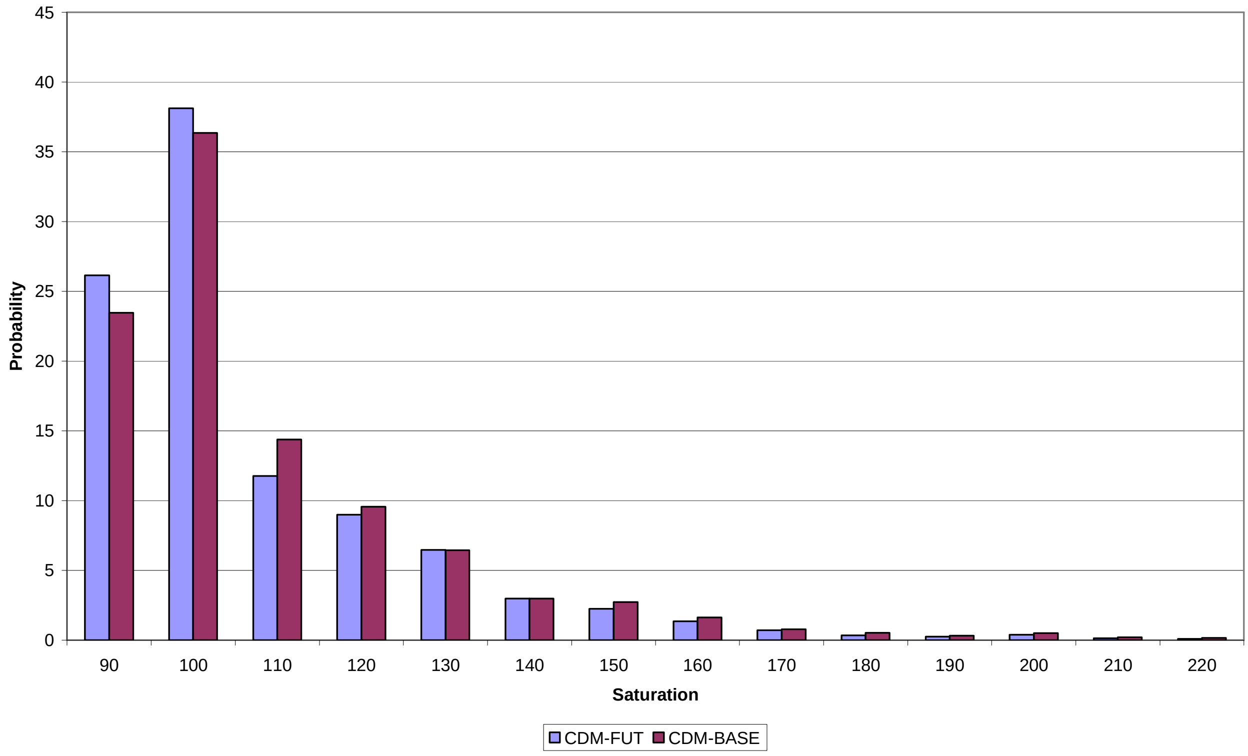


Figure 16: Sector saturations 23, 24 and 25th July

The results related to the declared capacities are included in the following table; X represents the potential increase in declared capacity according to Figure 11:

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%

Table 3: Capacity Results

The following result has been obtained from the traffic saturation:
Focused on the core area for CDM-BASE, 515 sectors present saturation greater than 0.9, and for CDM-FUT 351 sectors present saturation greater than 0.9. The Figure below shows the differences between CDM-BASE and CDM-FUT saturation maps in Germany only.

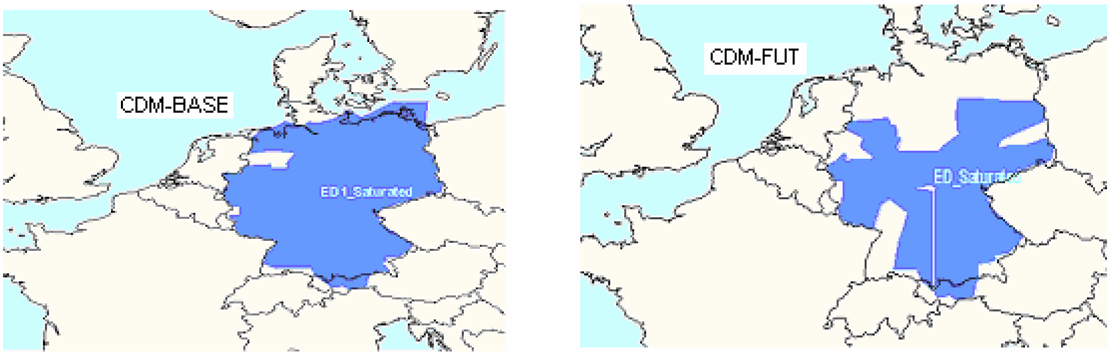


Figure 17: CDM-BASE vs CDM-FUT saturation of sectors

- In CDM-BASE the traffic shown (in blue) all sectors whose traffic load is 90% or greater than sector declared capacity.
- In CDM-FUT, an improved traffic forecast due to the improved predictability obtained with extended Airport CDM, shows how some of the initially overloaded sectors will actually operate under their maximum declared capacity and need no protection.
- In conclusion, 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 increase becoming closer to the theoretical maximum capacity.

5.3. IMPACT OF AIRPORT CDM ON DELAYS

In the same context that gains in terms of capacities having been highlighted in the previous chapters, gains are foreseen in terms of reduction in ATC delays.

Delays have an impact on the airspace users and they have been evaluated by means of NEVAC fast time simulations. CASA is the algorithm implemented by the NEVAC simulator.

For each saturated sector, a 4% increase of the declared capacities has been applied, as it was shown in the previous chapter; see 5.2.4

The current performance target of maximum 1 minute en-route maximum delay per flight for the summer season was kept.

For both CDM-BASE and CDM-FUT scenarios, the environment used was the real one provided by the CFMU. Opening Scheme and Regulation Plan are included in the environment provided and they are the same for both scenarios.

En route delays and airport delays are the components of the computed ATC delays. For each flight, used CASA algorithm attaches the computed delay to the most penalizing regulation.

The days of 21st and 22nd are not usable due to some inconsistencies in the provided Opening Scheme that have been highlighted on the fast time simulations time. Therefore, the delay results analysis is based on the remaining days.

A significant delays reduction for both En Route and Airport delays is observed; see Table 4: Delay Results Summary

	CDM-BASE					CDM-FUT				
	Route%	AP%	En Rt Delay	AP Delay	Delay/Flt	Delay/Flt	AP Delay	En Rt Delay	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	35%	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%

Table 4: Delay Results Summary

The CDM Network Impact Assessment study focused on en-route delays.

Conclusions on CDM impact on en-route delays: Having a look on the above Table 4: Delay Results Summary, (the **mean CDM-BASE delay=0.8** and **mean CDM-FUT delay = 0.46**) it can be concluded that there is a significant reduction in terms of delays due to Airport CDM implementation.

6. CONCLUSIONS

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

- It has been clearly noted that take off predictability has an impact on sector capacity.
- If Airport CDM was implemented in the main 42 delaying European airports with the same result in performance as Munich Airport has experienced, then it could allow an increase in sectors declared capacity by up to 4%; that corresponds to an increase of 1 or 2 extra aircraft per sector.
- The complexity analysis shows that the improved TTOT predictability is not expected to affect the theoretical capacity.
- Following the TTOT_Deviation analysis, it was highlighted Munich airport is 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 CDM-BASE delay=0.8** and **mean CDM-FUT 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 CDM-BASE versus CDM-FUT 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.

7. NEXT STEPS

The results and conclusions obtained in this study suggest developing the following actions:

- Evaluate the benefits in terms of ATFM minutes delay ("ATFM delay" is defined as the duration between the last Take-Off time requested by the aircraft operator and the Take-Off slot given by the CFMU).

- Repeat the simulation for 20 CDM airports and obtain an approximate figure to quantify the airports needed to detect benefits on the sectors declared capacity.

- Repeat the simulations taking into account timeliness (one of the key CDM characteristics). It is proposed to consider the time reference '40 minutes before AOBT' (about 50 min before ATOT) according to the CFMU needed for decision making. The next figure visualises the approach taken.

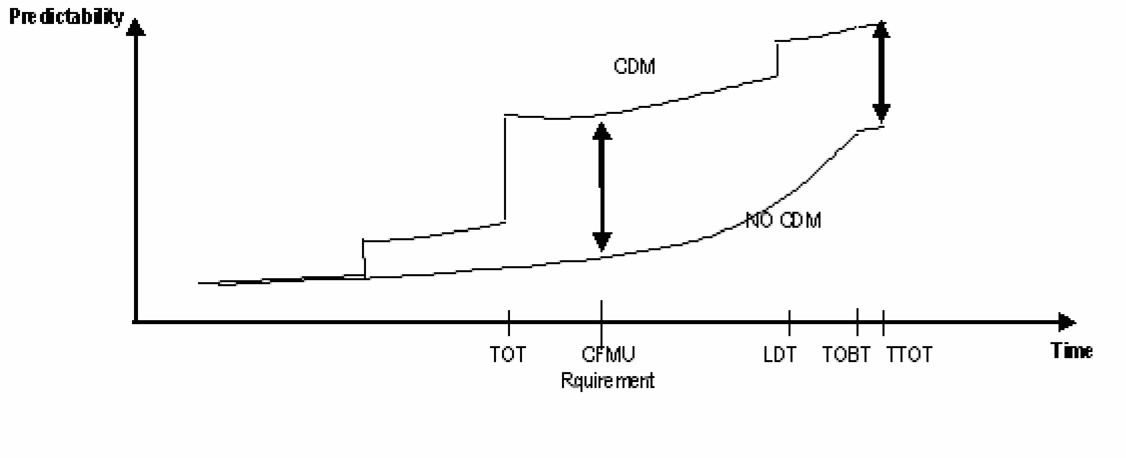


Figure 18: Timeliness effect

The figure shows how the data accuracy along the time follows different pattern for Airport CDM and Non Airport CDM airports. The Non Airport CDM airports present a strong data accuracy improvement some minutes before off-blocks. The Airport CDM airports follow a stepped pattern, at every milestone achieved the data accuracy shows a relevant improvement.

Annex A: COCA Complexity

The 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.

Macroscopic Workload Formula (**MWM)**:

MWM = w**AC * nAC +** w**LC * nLC +** w **CNF * nCNF**

Where: AC - nominates routine task

LC - nominates level change monitoring task

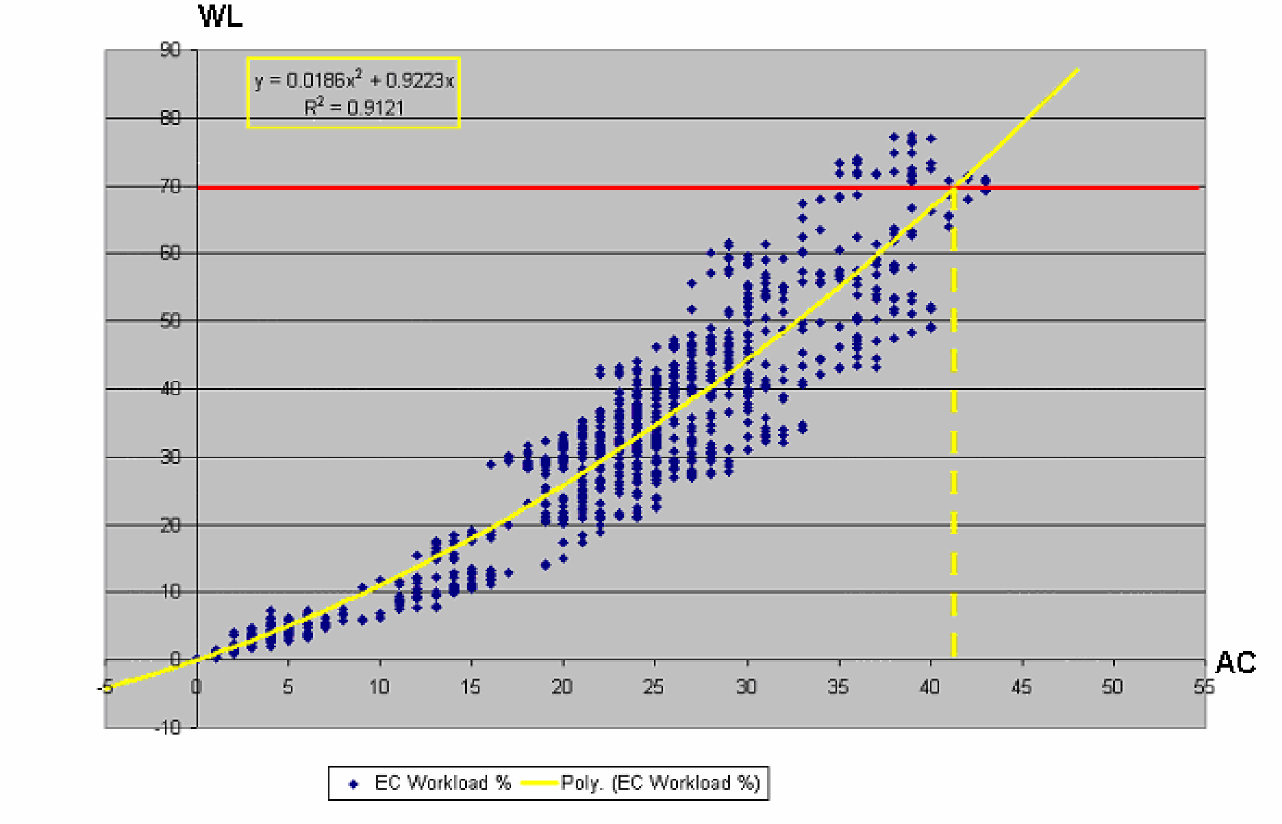
CNF - nominates conflict monitoring task

nAC, nLC, nCNF - are the numbers of occurrences for each elementary task

wAC, wLC, wCNF - are times necessaries for each of the elementary tasks

COCA methodology has found-out that, a sector is considered when the controllers Macroscopic Workload reach 70% value.

As it is shown in the figure hereafter, in order to compute the sector capacity, the MWM regression curve is identified and the crossing point with the 70% line is considered as the point when the sector capacity is reached. In our example, 42 is the sector capacity.



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.

APPENDIX: A-CDM Network Impact Assessment Part II

7.1. INTRODUCTION

7.1.1. A-CDM Network impact assessment background

The Airport CDM Network Impact assessment study has clearly noted that take-off predictability has an impact on sector declared capacity. It was assessed that implementing Airport CDM in the main 42 delaying European airports it could allow an increase in sectors declared capacity by up to 4% in average for Europe; that corresponds to an increase of 1 or 2 extra aircraft per sector per hour.

After presenting the results in the A-CDM Coordination Group it was identified as an interesting result for the airspace users and airports to translate this assessment on potential increase of declared sector capacity into ATFM minutes delay.

For the decision making process when implementing A-CDM at European level it was also identified the interest on obtaining an approximate figure to quantify the airports needed to detect benefits at network level and the evolution when more and more airports implement A-CDM.

As a result of those conclusions and needs, the current complementary study has been developed to provide an assessment on both requirements.

7.2. APPROACH

The study is focused on the same core area used in the previous study and taking exactly the same assumptions and simulation tools in order ensure the consistency between both studies.

The approach and the results are oriented to global impact in the European core area as defined in the first study, and the results should be considered as average expected benefits.

7.2.1. Benefits in terms of number of implemented A-CDM airports

To obtain the figure for the potential benefits in terms of declared capacity versus the number of A-CDM airports implemented, simulations have been exercised for three representative scenarios according to the number of A-CDM airports implemented: top ten airports in terms of number of movements, top 27 airports, and top 100 airports. Also the already obtained results from the 42 A-CDM airports from the previous study have been taken into account.

The results in terms of potential increase capacity from those four simulations together with the boundary conditions at early implementation phase and at maximum implementation will provide an approximate figure for the relation between expected benefits and the number of implemented A-CDM airports.

7.2.2. Benefits in terms of ATFM minutes delay

The assessment of benefits in terms of ATFM delays is based on the 42 A-CDM scenario already developed in the first study. This scenario corresponds to an intermediate state of implementation and it is the most significant between the developed scenarios mentioned above.

The starting point to analyse the impact in terms of delays is the expected increase in declared capacity from the 42 A-CDM scenario, which was assessed an increase by up to 4%. The assumption to calculate the ATFM delays is to increase the sector declared capacity by 4% in the core area and to use the ISA/CASA algorithms to simulate the ATFM delays using the NEVAC simulation tool.

Two working hypothesis have been addressed to assess the delays:

- Increase capacities and keep used regulations. Covered by “real behaviours”.
- Increase capacities and simulate regulations. Formal way but becomes abstract.

The first hypothesis based on current regulations will provide optimistic results as it does not reflect the effect of protected sectors.

The second hypothesis based on theoretical regulations will provide pessimistic results because simulated regulations are greater than the operational ones due to night period. Theoretical regulations are not realistic, which is also caused by not taking into account the operational actions as update regulations according to dynamic capacity management.

From these simulations it will be obtained a window for expected benefits in terms of ATFM delays that will be developed in chapter 7.3.2.

7.3. RESULTS

7.3.1. Capacity benefits results

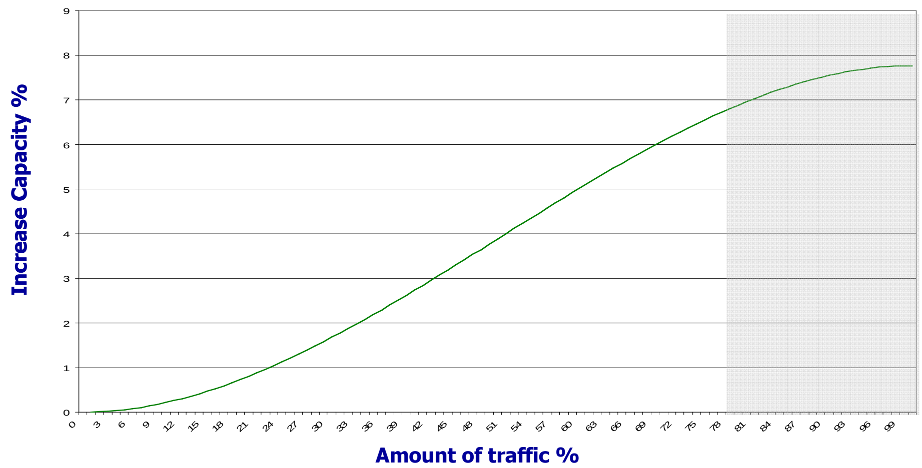
The objective is to obtain a figure which reflects the average capacity benefits in the core area in terms of number of implemented A-CDM airports. The direct relation with the sectors capacity is not the number of A-CDM implemented airports but the amount of traffic flying from those airports and hence providing better take-off predictability. This is the reason because the average capacity benefits figure has to be developed on the amount of traffic and afterwards the results are referred to number of airports.

As mentioned before, the scenarios considered are:

- The top ten European airports, which includes the main hubs. This scenario manage 22% of the departing traffic in Europe, without taking into account the over flights.
- The top 27 airports, which manages 41% of departing traffic.
- 42 A-CDM airports as defined in the first study, which manages 51% of departing traffic.
- The top 100 airports, which manages 70% of departing traffic.

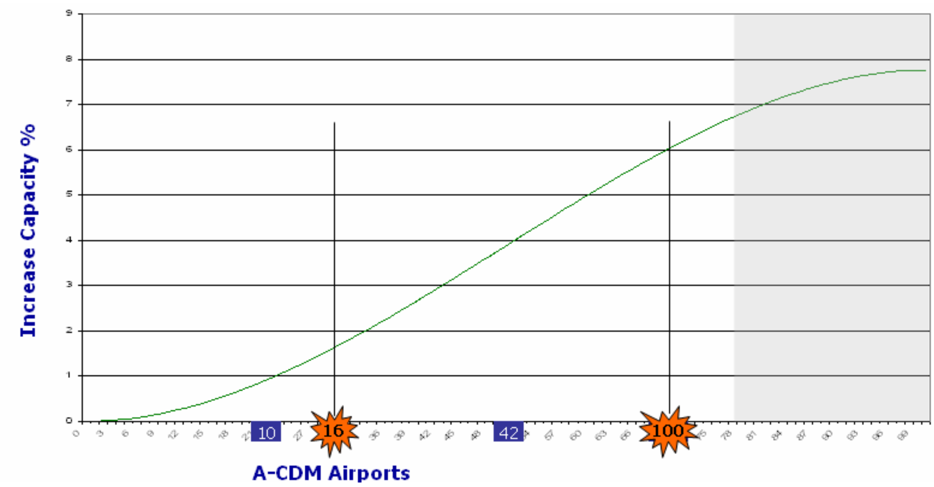
To obtain the figure it will be necessary to consider the boundary conditions as horizontal tangent at origin and at 100% traffic. The reason for this hypothesis is because the expected benefit if only one airport implements A-CDM will be inappreciable in the whole Europe reference, and similar to the last implemented airport. It is not the aim of this study to analyse the benefits when implementing A-CDM in most of the European airports, but the boundary condition is necessary to obtain the results.

The following figure shows the results. The X axis represents the percentage of traffic departing from airports implementing A-CDM. The y-axis represents the potential increase in declared sector capacity (on average for the core area).



The results included into the grey area should not be considered as representatives as the scenarios where most of the European airports implement A-CDM have not been addressed.

Using the amount of traffic referred to the number of airports as described in the scenarios, it can be stated that the benefits starts to be obtained when implementing A-CDM at around 16 top airports and the curve starts to slow down after around 100 airports. Therefore, this figure suggests that the network benefits will start to be significant from 16 main airports implemented and will continue at least until around 100 airports. Those airports around top 100 have about 60 movements per day and they may not need a full A-CDM implementation. It is important to remind that local benefits are not taken into account in this study.



7.3.2. Delay benefits results

According to the description in chapter 7.2.2, the reference for the delay analysis is the 42 A-CDM scenario with potential increased capacity of 4%. The first simulation corresponds to maintain the current ATFM regulations but increase the sector capacity in the core area by 4%. From this starting point, the Nevac tool simulates the CTOT allocation which is the reference to calculate the ATFM minutes delays as the difference between the CTOT and the EOBT for every single flight affected by regulations. The base line reference is the current ATFM delays. This simulation has shown a potential reduction of 25% in ATFM minutes delay.

The second simulation is a more formal approach where the base line scenario consists in maintaining the current sector capacity and the Nevac simulation tool allocates the CTOT using the ISA/CASA algorithms. From these result, the ATFM delay is calculated to establish the base line reference. In a second step, the new scenario is build by increasing the sector capacity in the core area y 4%. With these new capacity values the Nevac tool simulates the new CTOT allocation to calculate the ATFM delay as in the previous simulation. The comparison between those scenarios has provided a potential benefit in terms of ATFM minutes delay of 15%.

As it has been explained in chapter 7.2.2, the 25% result from the first approach is too optimistic and the 15% from the second one is too pessimistic. After analysing the mechanisms which drives the two approaches, the recommendation is to adopt an expected window for the ATFM delays benefits from 18% to 23% in terms of minute reduction.

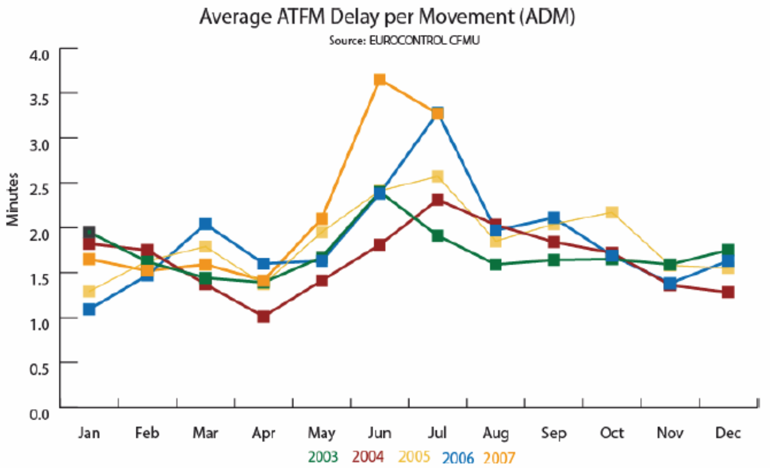
The following tables show the main results from the simulations:

Regulations	Reduced number of regulations	Reduced time duration of regulations
Average	11%	17%

Minutes delay	Potential minutes saved pessimistic	Potential minutes saved optimistic
Average	4097	5235

Mean ACC minutes delay*	Baseline	Capacity increase by 4%
Overall	3,6	2,7

*It is convenient to highlight the quite big ATFM delays during the period selected for the analysis as shown in the following picture from the PRU.



7.4. CONCLUSIONS

The conclusions have already been expressed in the document, but they can be resumed as follow:

- Network benefits will start to become significant from the moment we have the 16 largest airports implemented A-CDM, and will continue to increase until we reach around 100 airports.

Implementation in more than 100 airports will only provide marginal benefits.

- The potential benefits in terms of ATFM delays when 42 airports implement A-CDM have been estimated as a reduction of minutes delay between 18% and 23% referred to the current situation. It will be reduced by the diminution of regulation allocation as well as reduction in the minutes delay for the needed regulations.

- A-CDM is a powerful enabler to reduce the delays in Europe which will contribute together with the other initiatives to match the challenging SESAR objective of reducing the delays.

END OF THE DOCUMENT