# Airport – Collaborative Decision Making (A-CDM) Local and Network Impact Assessment

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***Abstract* – Airport Collaborative Decision Making (A-CDM) is about sharing of information between all stakeholders that actively participate in the management of the arrival, turnaround and departure of an aircraft. The concept aims to integrate systems and processes to provide improved levels of turnaround predictability and take-off time accuracy that are of benefit to the ground operation locally and the Network Manager Operations Centre (NMOC) respectively.**

**A 12 month study was initiated by EUROCONTROL to investigate the impact of A-CDM on local and ATM operations. The local assessment was driven primarily by information shared by the first 17 fully implemented CDM airports. Local benefits that were confirmed as part of the study include the reduction in average taxi-out times and push-back delays, increased ground handling resource utilisation and more expeditious recovery from adverse conditions. The network assessment was developed based on the significant improvement in take-off time predictability generated by CDM airports. The EUROCONTROL NEST tool was used to conduct simulations of the entire European ATM network in which CDM airports departed flights more predictably than non A-CDM airports. This study verified that increasing the number of implemented airports would deliver increases to enroute capacity due to the reduction in sector overload potential within the most congested area of the European airspace. Results suggest that a 3.5%-5.5% increase in enroute capacity could be realised when Europe's top 50 airports become integrated. In addition, a discrete event simulation of a single enroute sector was developed to investigate the localised effects of increasing the proportion of flights arriving on each entry stream that originated from an airport that was transmitting Departure Planning Information (DPI) messages.**

**The conclusions reinforce the need to foster the implementation of A-CDM to more airports and to extend the concept to all airport processes (airside and landside) and therefore support the development of the SESAR Airport Operations Centre (APOC).**

*Keywords – A-CDM; Departure Planning Information; ETFMS, CASA, ATFM Delay, NMOC, Sector Capacity*

## I. INTRODUCTION

Airport CDM is about partners (airport operators, aircraft operators, ground handlers, ATC and the Network Manager) working more transparently and collaboratively so to improve the operational efficiency and resilience of the airport operation. The A-CDM concept integrates processes and systems and focuses particularly on the aircraft turnaround and pre-departure sequencing phases of the 'ground trajectory'. Through the sharing of data between stakeholders, A-CDM supports improved decision making through the provision of more accurate and timely information, thus generating the same operational picture across all airport partners.

One of the main advantages of the A-CDM process is more accurate Target Take-Off Times, which can be used to improve local operations as well as enroute planning of the European ATM Network. This is being achieved through the implementation of a full set of Departure Planning Information messages (DPIs) sent to the Network Manager Operations Centre (NMOC).

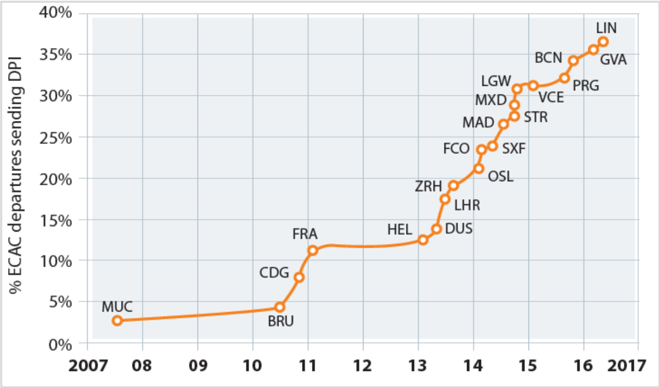


Figure-1 Proportion of ECAC departures transmitting DPI messages from CDM airports since 2007

Since its birth in the early 2000's, 20 airports have become fully A-CDM implemented, with a notable surge in adoption since 2013. As of January 2016, 34% of ECAC departures were transmitting Departure Planning Information (DPI) messages to NMOC from CDM airports, as illustrated in Figure-1.

The breadth of different airports in which A-CDM now operates has enabled a review of the different ways that A-CDM has been implemented. This has supported a deeper understanding of the operational constraints and implementation characteristics that result in the realisation of local benefits.

At the network level, this study has strived to define the impact of increased A-CDM adoption on enroute sector traffic predictability. This mechanism is an enabler for enroute capacity buffer and ATFM delay reductions and was initially quantified at the ECAC level by a previous EUROCONTROL study [Ref-1].

On the 5th November 2015, the proportion of transiting flights that had originated from an A-CDM airport exceeded 40% for many enroute Area Control Centres (ACC) - as illustrated in Figure-2. Increased data availability has enabled the more precise modelling of CDM airport take-off predictability performance. This has led to an investigation into the impact of A-CDM flight saturations on the potential for sector over-delivery reductions, as well as the refinement of the conclusions made within the previous A-CDM network impact assessment [Ref-1].

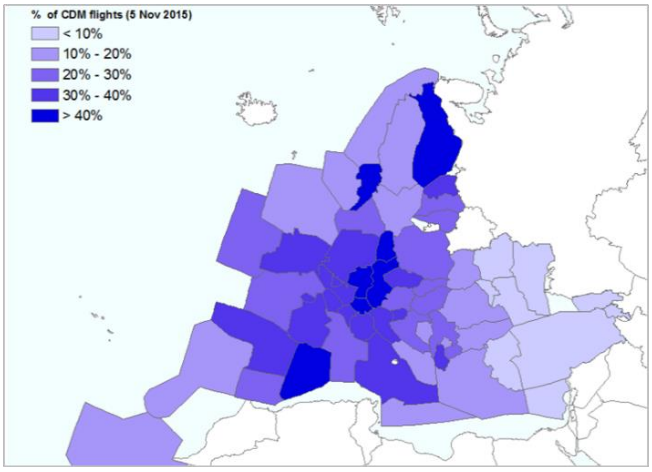


Figure-2 Proportion of flights from CDM airports entering European ACC on the 5th November 2015

## II. LOCAL A-CDM IMPACT ASSESSMENT

### *A. Benefit Mechanisms*

All tangible benefits attributable to A-CDM are realised due to the improvement in one or more of the following benefit mechanisms:

- Arrival Predictability;
- Off-Block Predictability;
- Take-Off Predictability.

These mechanisms are supported by both technical and procedural enablers. Take-off predictability improvements are barely possible without improvements to the off-block predictability, whilst the arrival predictability supports, but is not crucial to, improvements in off-block predictability.

A-CDM focuses on the principle that a departing flight is fundamentally a continuation and re-identification of an arrival flight that transitions through a ‘ground trajectory’ phase. The receipt of Flight Update Messages (FUM) provides a more accurate estimated landing time (ELDT) as early as 3 hours from touchdown.

Improved arrival time predictability supports the early and effective allocation of the turnaround and stand resources. Departure gates can be confirmed earlier with fewer disruptive late stand changes. Both qualitative and quantitative information acquired from the 17 participating airports conveyed the benefits of improved ELDT information that is received within either the FUM or Enhanced Traffic Flow Management System (ETFMS) Flight Data Message (EFD).

Airline Operational Control Centres (OCC) also benefit from improved arrival time predictability. An aircraft that is planned to fly several sectors over the course of the day can be proactively re-planned (or cancelled) based on delay notifications received during earlier legs.

### *B. Off-Block Predictability*

The Target Off-Block Time (TOBT) and Target Start-Up Approval Time (TSAT) are the most important data elements within the A-CDM process.

The TOBT is defined as the time at which the aircraft operator or ground handler estimates that an aircraft will be ready, all doors closed, boarding bridge removed, push vehicle available and ready to start up / push back immediately upon reception of ATC clearance. The TOBT must be accurate to within 5 minutes of the actual off-block time (AOBT).

The TSAT procedure is the mechanism for transparent and flexible pre-departure planning. The TSAT is owned by ATC and typically generated by a pre-departure sequencer (PDS) or departure manager (DMAN). The TSAT is the time that ATC is expected to clear the aircraft for engine start and push-back. The TSAT can never be earlier than the TOBT and must take into account local ATC and airport infrastructure constraints such as ground congestion, stand contention, runway demand and ATFM slots. The TSAT reflects the balance of infrastructure and airspace capacity to the demand picture generated from the TOBT.

For non CDM airports, the best estimate of when the aircraft might be ready to push is either the airport schedule or the latest estimated-off block time (EOBT) that is filed within the ATC flight plan. The schedule time will never be updated to reflect a delay and the EOBT is only required to be updated when the flight is delayed by 15 minutes or more. For CDM airports, the TOBT and TSAT provide a shared timestamp that reflects aircraft readiness and start-up respectively that is accurate to within 5 minutes.

One benefit of improved off-block predictability cited by A-CDM stakeholders covers the reduction of push-back delay after the start-up clearance due to the effective allocation of tug vehicles to the TOBT or TSAT. Figure-3 below illustrates the trending reduction in the difference between the AOBT and the actual start-approval time (ASAT) since the implementation of A-CDM at Helsinki airport (EFHK).

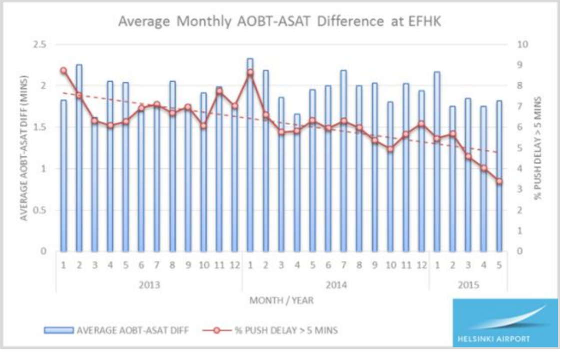


Figure-3 Improvement in proportion of push-back delay instances of greater than 5 minutes at Helsinki

### C. Taxi Out Time Reduction Trends

The reduction of taxi time is usually the main reported benefit of A-CDM implementations – being cited as the primary financial incentive for airlines to become engaged in the programme. In close co-operation with each participating airport, this study has adopted a rigorous and data centric approach to help discover or verify taxi-out time performance improvements.

The approach used to verify the presence of a time series trends in taxi-out times was the *Mann Kendal (MK) Test*. The MK Test is a test of whether there is a statistically significant monotonic upwards (or downwards trend) in a time series of data. In effect, it compares every value in the series with every other value to see whether a later value is higher than an earlier value more often than not, and applies some correction factors when they are the same.

The MK test can be used in place of a parametric *linear regression* analysis, which can be used to test if the slope of the estimated linear regression line is different from zero. As a parametric test, the linear regression approach assumes that the residuals of the fitted regression to be normally distributed - whereas the MK test requires no such assumption to be made.

Due to the seasonal effects of varying traffic demand, this analysis applied the seasonal MK tests (Gibbons, 1994) to determine if taxi-out times had decreased significantly as a result of the A-CDM processes.

The study has shown a taxi-time improvement average in the range of *0.25 to 3 minutes* per departure – as illustrated in Figure-4. Four CDM airports were unable to demonstrate a significant reduction in taxi-out times.

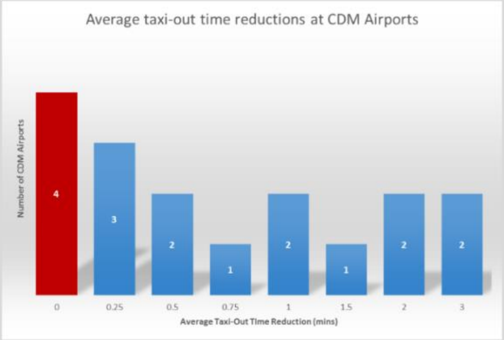


Figure-4 Histogram of average taxi-out time improvements for CDM airports

The infographic below summarises the annual consolidated savings generated from 13 of the 17 CDM airports that have demonstrated tangible taxi-time performance improvements. The emissions and fuel cost savings of Figure-5 have been calculated based on the parameters within the EUROCONTROL Standard Inputs for Cost Benefit Analysis [Ref-2].

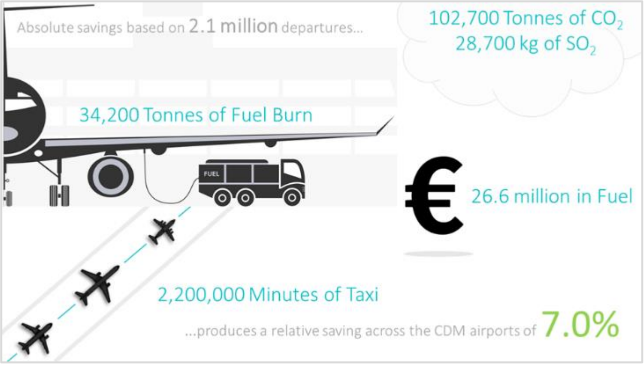


Figure-5 Infographic of consolidated annual taxi-time related savings for 17 CDM airports (estimated)

### D. Peak Departure Rates & Operations Recovery

Analysis of several CDM airports' departure flight data suggested that the implementation of A-CDM could contribute to improved peak departure rates at the runway.

Figure-6 illustrates how the distribution of departure rates at Madrid (LEMD) airport was impacted by the implementation of A-CDM. The analysis done to create the plots was careful to extract periods of significant difference in demand over the comparison periods – which consisted of many months of departing flight data. Both airports have seen an increase in the peak and modal departure rates since adoption. This has been achieved without any increase in runway pressure, but rather by ensuring a more optimal mix of aircraft at the runway holding point.

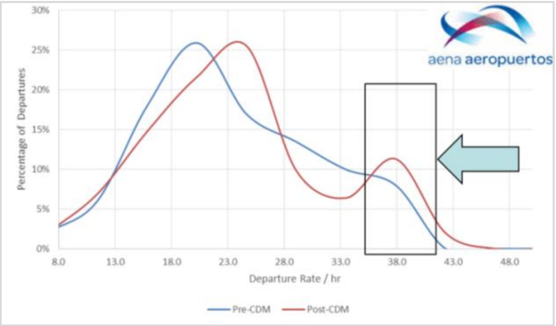


Figure-6 Distribution of departure rates at Madrid airport (LEMD) for a year before and after the A-CDM implementation

NATS, the Tower ATC services provider at London Heathrow (LHR) airport had suggested that A-CDM has supported the more expeditious recovery to normal operations after periods of disruption. The optimisation of the turnaround and improved visibility of aircraft readiness coupled with the effective streaming of aircraft to the runway is enabling full departure pressure to be realised sooner. The result is that departure runway capacity is fully utilised as soon as it becomes available. To verify this, LHR provided operational flight data over a 4 year period, of which 2 years fell either side of the A-CDM implementation date.

An analysis script (in JAVA) was built to automatically detect periods of reduced departure rates at London Heathrow. For an operation as constrained as LHR, this was simply a matter of ordering departure flights chronologically and flagging when the difference between subsequent departures was 3 minutes or more. When periods of reduced separation times was detected to last 60 minutes or more, the time for the airport to generate 60 departure movements from the moment of departure separation recovery was then calculated in 10 flight increments. Figure-7 illustrates the results of this analysis. In A-CDM operations, 60 departures will take-off an average of 20 minutes sooner than prior to implementation. This results in significant reductions to knock-on delay, flight cancellations and usage of the restricted noise and Night Jet Movement (NJM) quota.

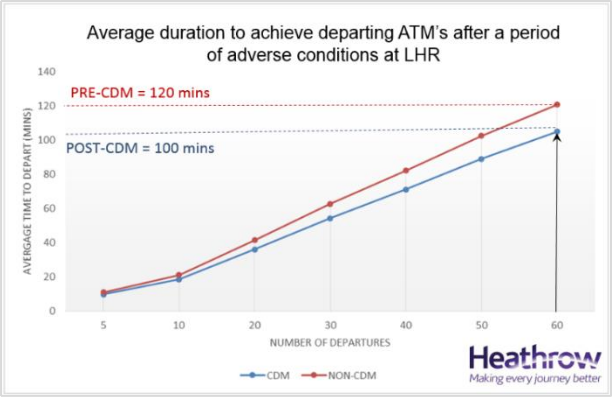


Figure-7 Average time to achieve number of departures after a period of reduced capacity at LHR

### E. Take-Off Predictability

Take-off predictability is defined by both the mean take-off accuracy and the standard deviation of that accuracy. Improved take-off predictably is the key enabler of network benefits which includes improved levels of safety and potential enroute capacity buffer reductions.

Take off accuracy is the difference between the actual take-off time (ATOT) and the time that NMOC expects the flight to become airborne. The estimated take-off time (ETOT) from the flight plan serves as the NMOC take off reference for non-CDM airports. Once connected, the reference becomes the target take-off time (TTOT) that is sent to NMOC within the DPI message payload.

All CDM airports have demonstrated significant improvements in take-off predictability which is observed as the convergence of the mean take-off accuracy towards zero and a significant reduction in the standard deviation of the take-off accuracy.

Figure-8 illustrates the difference in take-off predictability for airports that transmit DPI messages to NMOC – which includes CDM and Advanced ATC Tower airports.

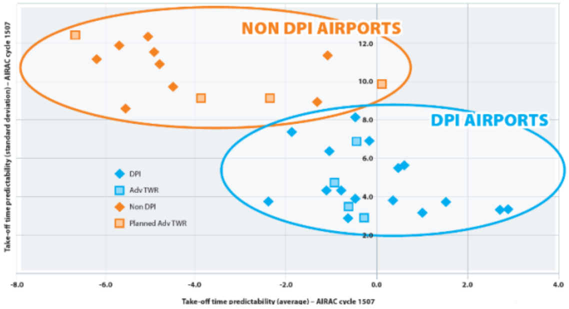


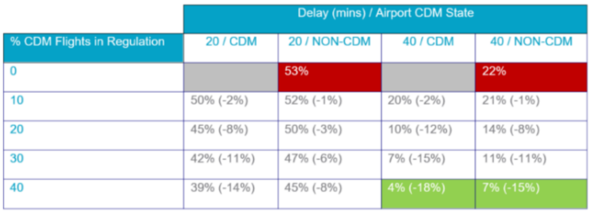
Figure-8 Quantifiable Take-off predictability improvements of airports transmitting DPI messages to NMOC in AIRAC 1507

### F. Quantifying ATFM Delay Reductions

EUROCONTROL provided ATFM delay data for all departures between January 2012 and December 2015, with the aim of deducing if CDM airports had benefitted from their DPI connection from the perspective of reduced ATFM delay.

Table 1 shows how the probability of receiving 20 and 40 minutes of ATFM delay is influenced by whether a flight is departing from a CDM airport and the proportion of CDM flights that are feeding the flow restriction. Values in this table are generated from the cumulative probability distributions of all regulations issued in the ECAC zone between January 2012 and December 2015

For a flow restriction with no participating A-CDM flights, the probability of receiving a delay of 20 and 40 minutes is 53% and 22% respectively (as indicated in red in Table-1). As the proportion of CDM flights moves above 10%, the probability of receiving the same delay reduces notably. For a restriction with 40% A-CDM flight participation, the probability of receiving a 40 minute delay reduces to 4% for CDM flights and 7% for non CDM flights – almost 4 times less (as indicated in green in Table 1).



| | Delay (mins) / Airport CDM State | | | |
|---|---|---|---|---|
| % CDM Flights in Regulation | 20 / CDM | 20 / NON-CDM | 40 / CDM | 40 / NON-CDM |
| 0 | | 53% | | 22% |
| 10 | 50% (-2%) | 52% (-1%) | 20% (-2%) | 21% (-1%) |
| 20 | 45% (-8%) | 50% (-3%) | 10% (-12%) | 14% (-8%) |
| 30 | 42% (-11%) | 47% (-6%) | 7% (-15%) | 11% (-11%) |
| 40 | 39% (-14%) | 45% (-8%) | 4% (-18%) | 7% (-15%) |

Table-1 Probability of receiving at least 20 and 40 minutes of ATFM Delay

The 'ATFM Delay Share Index' has been proposed to help quantify the competitiveness of a CDM airport in generating more favourable slots for its customers.

For any one flow restriction, this index is defined as the ratio of the proportion of total ATFM delay attributed to that airport across the whole restriction, to the proportion of total slots allocated to the airport. So, if an airport feeds 50% of flights through a flow restriction and receives 50% of the delay - then this ratio is 1. If the airport feeds 50% of flights but only receives 25% of the total delay, this ratio is then ½ .

$$\text{ATFM } Delay\ Share\ Index = \frac{Proportion\ of\ ATFM\ Delay}{Proportion\ of\ ATFM\ Slots}$$

If this ratio is greater than 1, then the airport is receiving a disproportional level of delay based on the total number of slots allocated. Lower than 1 suggests the airport generates less delay for the number of slots allocated. Analysis of regulation data since AIRAC 1201 (January 2012) has shown some clear and dramatic improvements in the average ATFM Delay Share Index for a CDM airport. This is realised almost immediately upon connecting to the network via the DPI mechanism – as illustrated in Figure-9 for Rome (LIRF), Oslo (ENGM) and Düsseldorf (EDDL) where these airports have realised an average ATFM Delay Share Index of between 0.8 and 0.9 after connection. Of all the CDM airports, Venice (LIPZ) has shown the best improvement since connection, with the Delay Share Index falling from 0.97 to 0.72.

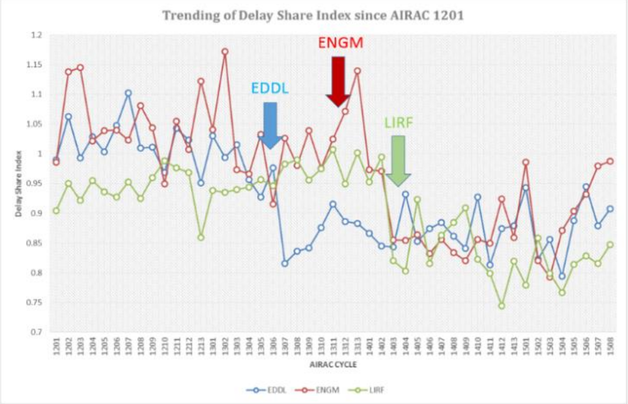


Figure-9 ATFM Delay Share Index evolution for Rome (LIRF), Dusseldorf (EDDL) and Oslo (ENGM) airports

An analysis was performed to evaluate the average ATFM Delay Share Index for each country within the ECAC zone between August 2012 (AIRAC 1207) and August 2015 (1507).This analysis clearly shows how the most penalised states within the core ECAC zone in August 2012have improved their ATFM Delay Share Index ranking since one or more NMOC connected CDM airports have come online in those states.

## III. NETWORK A-CDM IMPACT ASSESSMENT

From the perspective of the ATM network, flights departing from CDM or Advanced ATC Tower airports do so more predictably than those from airports that do not send DPI messages – as illustrated in Figure-8.

A study published by EUROCONTROL [Ref-1] demonstrated quantitatively that improved take-off predictability reduced the potential for sector over-delivery which in turn, could result in the reduction of enroute sector buffers without compromising levels of safety. The study was based on the take-off predictability performance of Munich airport in 2007.

Given that 18 CDM airports (as of January 2016) have now come online, an objective of this work was to use historical ETFMS data to refine the model parameters to more accurately reflect operational reality. Another objective was to explore the mechanism for sector-delivery in more detail in order to better determine the potential for declared enroute capacity increases at the state and ANSP level.

### A. *Methodology Overview*

EUROCONTROL’s NEST software tool was used extensively for this study. NEST is capable of generating trajectories for all ECAC departures that complies with the route availability document (RAD) and regulation plan for any operational day that is modelled. These trajectories may then be ‘shifted’ backwards or forwards in time to reflect the take-off time predictability at the departure airport at that time of day. Figure-10 illustrates just some of the generated trajectories through a particular sector over Germany during a single hour of a day.

Figure-10 Modelling trajectories through a single control sector in NEST over an hour

By modifying the take-off predictability at different airports, it is possible to quantify the impact of DPI connectivity on individual control sector over-delivery counts (like the sector illustrated in Figure-10 above) – which are also calculated by NEST. The instances of a sector over-deliveries may then be aggregated at the ANSP and ECAC level to approximate the enroute capacity buffer reduction that is enabled by the number of CDM or Advanced ATC Tower airports in the model.

### B. *Operational Scenarios*

The NEST simulation included 8 scenarios that increased the number of CDM airports incrementally from 0 to 70. Each scenario differs only by the number of CDM or Advanced ATC airports modelled. The order in which airports were integrated into the network was by virtue of their ranked IFR traffic movements as recorded in 2015. Figure-11 illustrates the percentage of ECAC departures that are publishing DPI for each operational scenario ranging from 28% to 83% between 10 and 70 airports respectively.

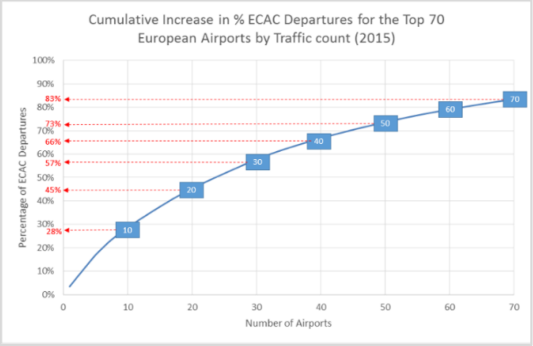


Figure-11 Number of airports modelled in each operational scenario and corresponding proportion of ECAC departures represented

### C. *Saturation Analysis*

For each experimental run, NEST calculates the saturation of each operational sector every 20 minutes – where saturation is defined as the number of aircraft in the sector as a parentage of the declared capacity. Any saturation over 100% counts as an over-delivery. Each saturation calculation across each run is then aggregated up to both the ECAC and ANSP level so that:

1. The exact number of sector over-deliveries can be calculated at the ANSP and ECAC level for each operational scenario.
2. A saturation distribution function can be developed to enable the estimation of enroute sector capacity increases at the ANSP and ECAC level for increasing number of network integrated airports.

### D. *Estimating enroute capacity improvements*

A distribution of saturation instances is developed for each of the operational scenarios. From the cumulative distribution function (CDF), it is possible to estimate the change in declared enroute capacity that would result in the same average overload risk in comparison with the baseline case (zero network integrated airports). This approach relies on the following 2 important assumptions:

1. A theoretical enroute capacity corresponds to a risk of sector overload of 5% (where 5% of all theoretical capacities are insufficient to prevent overload);
2. A declared enroute capacity for a 5% overload risk is approximately 70% of the theoretical capacity.

For each operational scenario, the theoretical reference is determined by the saturation value corresponding to 95% probability (5% overload risk – assumption 1 above). The capacity buffer in each case is then determined based on the calculated declared capacity of 70% of the theoretical reference (assumption 2 above). The difference in the calculated declared capacities between the baseline and operational scenarios represents the average capacity buffer reduction that can be generated – assuming the overload risk of 5% is maintained.

The previous A-CDM network study [Ref-1] generated Figure-12 to describe this principle of establishing the difference in buffer capacities of ‘A’ and ‘B’ of the baseline and network integration scenario respectively in maintaining an overload risk of ‘R%’ – which has been assumed as 5%.

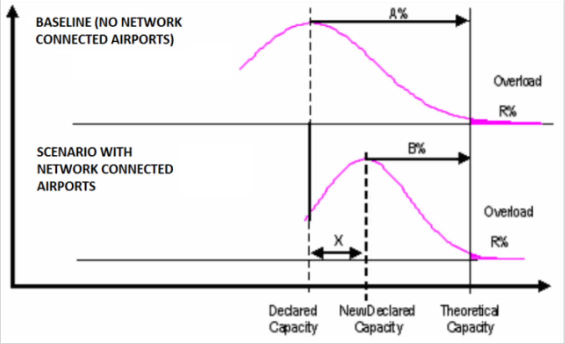


Figure-12 Estimating capacity improvements from enroute saturation distributions of each operational scenario [Ref-1]

### E. *NEST Over Delivery Results by ANSP*

Figure-13 illustrates the percentage reduction in sector over-delivery counts by ANSPs when 30 CDM or Advanced ATC Tower airports are integrated into the network. The most optimistic results are shown for NATS and Maastricht Upper Area Control (MUAC) – with an almost 20% reduction in over-deliveries could be generated.

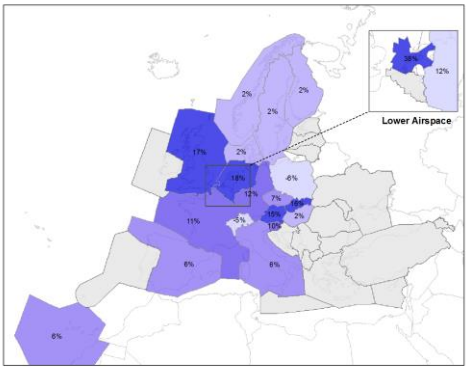


Figure-13 Reduction in over-delivery by ANSP for 30 integrated airports

### F. *Discrete Event Simulation of a Single Sector Flow*

The results generated from the NEST simulation suggests the existence of a mechanism which is responsible for driving both unstable and unpredictable sector over-delivery reductions as the number of network integrated airports increases. To better understand this, a numerical model was built to simulate the arrival of flights into a single sector with varying levels of predictability – as determined by the take-off accuracy at the departure aerodrome of each flight entering the modelled sector.

As shown on Simulation variables of this sector model included:

1. The number of sector entry streams – 2, 3, 4 and 5 streams were evaluated.
2. The proportion of flights on a sector stream sending DPI messages – evaluated in 10% increments from 0% to 100%.
3. The take-off predictability of flights departing from connected and non-connected airports – the study assumed a standard deviation of 14 minutes for non-connected airports and 3,5 and 7 minutes were evaluated for airports transmitting DPI. These values are consistent with actual performance of current CDM and Advanced ATC Tower airports, see Figure 8.

Two different modes of increasing DPI flight saturation within the sector were developed.

In the first mode, the proportion of ‘DPI flights’ within the sector opening window is increased ‘by stream’. This means that each arrival stream would be fully saturated with DPI flights before the next stream is permitted to increase. In the second mode called ‘uniform’, each stream increases the saturation of DPI flights by 10% in turn until all the streams are fully saturated with DPI flights.

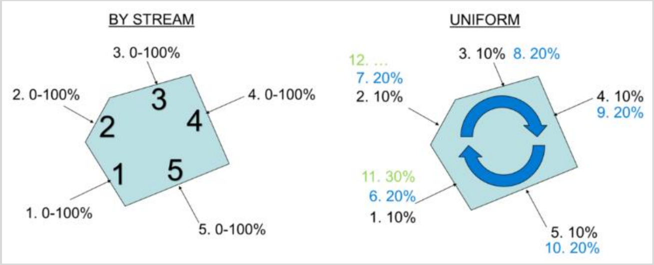


Figure-14 Visualisation of the 'By Stream' and 'Uniform' mode of increasing the proportion of DPI flights within the modelled sector

### G. *Sector Stream Analysis Results*

In the ‘by stream’ mode (Figure-15), consistent reductions in over-delivery potential are realised at around 30% DPI flight saturation – which corresponds to the first stream becoming fully saturated. The subsequent rate of improvement is then highly dependent on the arrival predictability of the flights into the sector. A standard deviation of 3 minutes generates more significant improvements than the 5 and 7 minute scenarios – with a peak over-delivery reduction of 50% estimated when the sector is fully saturated with flights transmitting DPI messages.

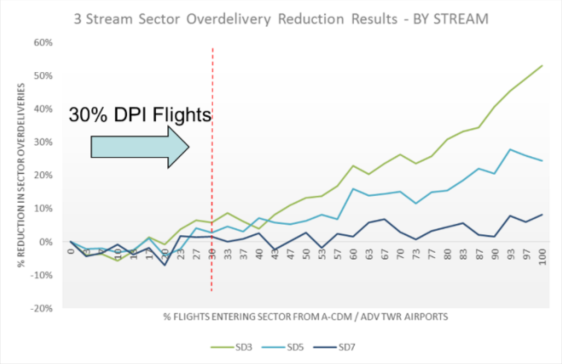


Figure-15 Reductions in sector over-delivery for the 3 stream scenario BY STREAM mode

Results of the ‘uniform’ mode (Figure-16) are quite different. Before 70% DPI flight saturation, the sector will most probably show an *increase* in the potential for over-delivery. The severity of the increase is determined by the take-off predictability of the flights entering the sector. Paradoxically, the more predictable the traffic, the worse the situation could become.

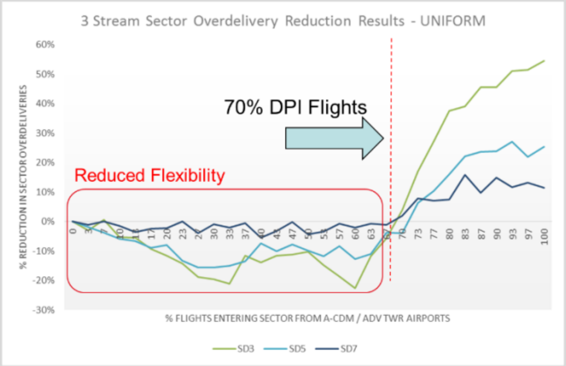


Figure-16 Reductions in sector over-delivery for the 3 stream scenario UNIFORM mode

The results show an arrival predictability standard deviation of 3 minutes could increase the over-delivery potential by 20% and a standard deviation of 7 minutes will result in little or no increase in over-deliveries. After 70% DPI flight saturation, the sector then starts to show dramatic reductions in over-delivery potential.

Both modes were randomly combined and the same sector parameters were simulated over thousands of runs to support more general conclusions regarding the impact of increased A-CDM and Advanced ATC Tower implementations across the ECAC zone. This analysis will also support local safety analysis teams to understand when safety buffers within their operational sectors could likely be reduced based on the location and performance of network connected airports that are feeding their enroute sectors.

Figure-17 and Figure-18 show the results of this simulation in which 2, 3 and 4 arrival streams are modelled. Both graphs differ only by the take-off predictability performance of the DPI flights (standard deviation of take-off accuracy) of 5 and 3 minutes respectively.

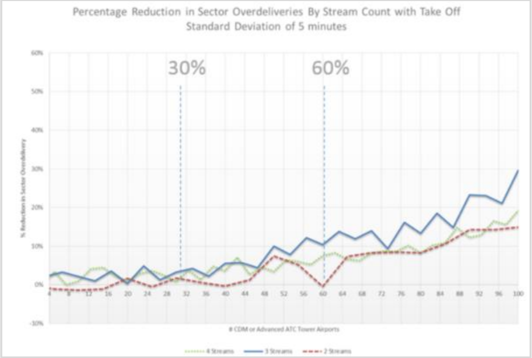


Figure-17 Results of random mode sector stream analysis with a take-off accuracy standard deviation of **5** minutes for DPI connected flights

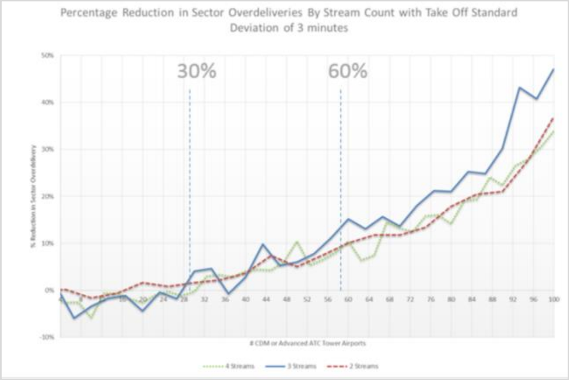


Figure-18 Results of random mode sector stream analysis with a take-off accuracy standard deviation of **3** minutes for DPI connected flights

The results from this analysis support the following conclusions about the response of an individual sector to increasing DPI flight saturation (between 0 and 100%):

- Below 30% DPI flight saturation, the response of a control sector to improved traffic predictability could be to increase the likelihood of sector over-deliveries.
- Between 30% and 60% DPI flight saturation, the risk of over-delivery tends to reduce but might not provide enough of an improvement at current levels of take-off

predictability (5 minutes) to support a reduction in safety buffers.

- 60% DPI flight saturation is required to generate strong and reliable over-delivery reductions.
- A sector with 3 arrival streams shows the most aggressive improvements after 60% DPI flight saturation.
- With a take-off predictability of 5 minutes, the maximum reduction in over-delivery potential that could be achieved is around 20%. An optimistic value of 3 minutes generates maximum reductions in over-delivery of between 35% and 50%.

### *H. ECAC Wide Conclusions*

Results from the NEST simulation and sector stream analysis has supported the refinement of the enroute capacity improvement projections within the ECAC core area – as was originally proposed within the previous EUROCONTROL study [Ref-1]. Figure-19 shows the new estimations – which include both a high and low response of the network to increasing DPI flight saturation.

The high response is generated when the standard deviation of take-off accuracy within ETFMS is 3 minutes, which is the current best in class value. The low response is generated based on the 5 minute standard deviation of take-off accuracy, which represents the current average of all Advanced ATC Tower and CDM airports.

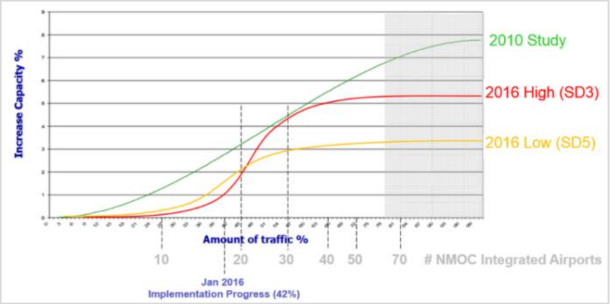


Figure-19 Estimated enroute capacity increase potential within core ECAC core area depending on standard deviation (SD) of take-of accuracy.

To remain consistent with the previous study, the implementation ordering that generated the curves in Figure-19 was by 2015 IFR traffic ranking. However, the actual order of implementation to date has been quite different and has not included some of the larger airports (i.e. EHAM, LOWW & EPWA) that were simulated to have implemented DPI earlier than some of the smaller airports (i.e. LKPR, UKBB and LIPZ).

As of January 2016, 42% of ECAC departures originate from a total of 36 CDM and Advanced ATC Tower airports. The top 18 airports of 2015 would have generated the same share of departures transmitting DPI messages to NMOC.

This study has resulted in the following high level conclusions regarding the impact of increased DPI flight saturation across the network:

- Enroute capacity improvements will commence later and will not be as significant as those suggested by the previous study [Ref-1].
- The results suggest that 45% of flights transmitting DPI is required to achieve a 2% improvement in enroute capacity. Based on the implementation progress in January 2016, this could be achieved after the integration of 2 or 3 more medium sized airports.
- Based on current levels of DPI saturation in the network, Europe is almost halfway (as of January 2016) to being able to achieve the full enroute capacity improvement potential.
- Around 80% of the available enroute capacity benefit will be realised when the top 30 airports are integrated (or 57% of ECAC departures are transmitting DPI).
- Based on current levels of take-off predictability, enroute capacity gains will peak at around 3.5% when the top 50 airports become network integrated (or 73% of ECAC departures are transmitting DPI).
- When more airports are able to show best in class levels of take-off predictability (standard deviation of 3 minutes), the benefits to enroute sector capacity could continue to increase to around 5.5%.

## IV. CONCLUSIONS

With the participation and support of 17 CDM airports, this study has explored both the local and network impacts of A-CDM implementations. The realisation of local benefits depends on the characteristics of the airport and the extent to which A-CDM procedures are adopted. The results confirmed many benefits of the concept for all major stakeholders; including airlines, ground handlers and the network manager. The study verified benefits in areas such as taxi-out time, ATFM delay, departure rates, fuel savings, FAM suspensions, enroute sector over-deliveries, enroute capacity and take-off time predictability.

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## AUTHOR BIOGRAPHIES

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