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Performance Review Commission

Complexity Metrics for ANSP Benchmarking Analysis

Prepared by the ACE Working Group on Complexity

April 2006

EUROCONTROL

BACKGROUND

This Report has been commissioned by the Performance Review Commission (PRC).

The PRC was established in 1998 by the Commission of EUROCONTROL, in accordance with the ECAC Institutional Strategy (1997).

One objective in this Strategy is "*to introduce strong, transparent and independent performance review and target setting to facilitate more effective management of the European ATM system, encourage mutual accountability for system performance and provide a better basis for investment analyses and, with reference to existing practice, provide guidelines to States on economic regulation to assist them in carrying out their responsibilities.*"

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Complexity Metrics for ANSP Benchmarking Analysis

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SUMMARY

This report has been prepared for the Performance Review Commission by the ACE Working Group on Complexity, which comprises representatives of Air Navigation Service Providers, EUROCONTROL Experimental Centre and the PRU.

It defines complexity indicators for application in the context of ANSP benchmarking analyses.

Keywords

Complexity	En route	Traffic	
ATM	Airspace	Density	

CONTACT: **Performance Review Unit, EUROCONTROL, 96 Rue de la Fusée, B-1130 Brussels, Belgium. Tel: +32 2 729 3956, e-mail: pru@eurocontrol.int**
http://www.eurocontrol.int/prc

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EXECUTIVE SUMMARY

In September 2003, the members of the ATM Cost-effectiveness (ACE) Working Group, which comprises European Air Navigation Service Providers (ANSPs), the EUROCONTROL Performance Review Unit, CANSO, representatives of airspace users and the European Commission, created a small Working Group to study complexity and to produce complexity metrics that could be applied in ANSP benchmarking analyses.

The ACE Working Group on Complexity met nine times between January 2004 and October 2005. It included representatives of major European ANSPs and EUROCONTROL.

The Working Group's overall objective was to define and agree a set of high level complexity indicators for en-route airspace that can be used for benchmarking purposes. Before doing so, the Working Group had to define "complexity" for the purposes of its work.

Definition of Complexity

The method of defining and measuring complexity depends on the intended application. For the purposes of benchmarking, complexity indicators should capture the external factors that impact on the controller workload and/or the level of difficulty of the ATC task, without considering the internal, ATC procedures-related factors. For example, reduction of controller workload arising from better management of the traffic by an ANSP should be attributed to the ANSP and not to a reduction of the complexity. However it is acknowledged that route structure, an internal factor, is inherent in the traffic samples and cannot be completely excluded from the analysis.

The Working Group considered a range of complexity dimensions, such as traffic density and flow structure. Within each dimension a set of possible indicators was considered. To keep the number of indicators to a manageable level, the most specific and interpretable ones were chosen.

Complexity indicators

The Working Group developed four complexity indicators:

Complexity Dimension	Indicator	Description
Traffic density	Adjusted density	A measure of the potential number of interactions between aircraft in a given volume of airspace.
Traffic in evolution	Potential vertical interactions (VDIF)	Captures the potential interactions between climbing, cruising and descending aircraft.
Flow structure	Potential horizontal interactions (HDIF)	Provides a measure of the potential interactions based on the aircraft headings.
Traffic mix	Potential speed interactions (SDIF)	Assesses the potential interactions based on the aircraft speeds.

Table 0.1: Complexity Indicators

The chosen indicators provide a consistent framework based on the concept of an "interaction" which is defined as the simultaneous presence of two aircraft in a cell of 20x20 nautical miles and 3,000 feet in height.

Interactions express the fact that it is the presence of several aircraft in the same area at the same time that generates complexity, particularly if those aircraft are in different flight phases, have different headings and/or different performances.

As the aim was to take a macroscopic view, the indicators do not focus on actual interactions but on potential interactions between flows of aircraft. This is achieved by looking at potential interactions within a one-hour period.

Results Obtained

The indicators were calculated at both ACC and ANSP level, for the entire ECAC area, using two weeks of CFMU data.

Week 3 (09-15/01/03) was considered to represent low traffic and week 36 (28/08-03/09/03) was considered to represent a typically busy week.

Each indicator's results were compared individually providing a ranking of the 67 ACCs and the 34 ANSPs. As the indicators capture different aspects of complexity some differences in the rankings can be observed. However the differences tend to be small and a high level of consistency exists across the four indicators.

The Working Group considered that a single metric incorporating the separate indicators would be one of the simplest ways to apply the results to benchmarking. This metric is referred to as the 'complexity score'. Weighting the indicators based on their perceived importance was also considered. However it was deemed unlikely that one set of weightings could be relevant for all types of airspace. Furthermore, several 'weighted' complexity scores were tested and the results were very similar to the 'un-weighted' version. For these reasons the un-weighted complexity score has been retained and the ANSP results are shown below.

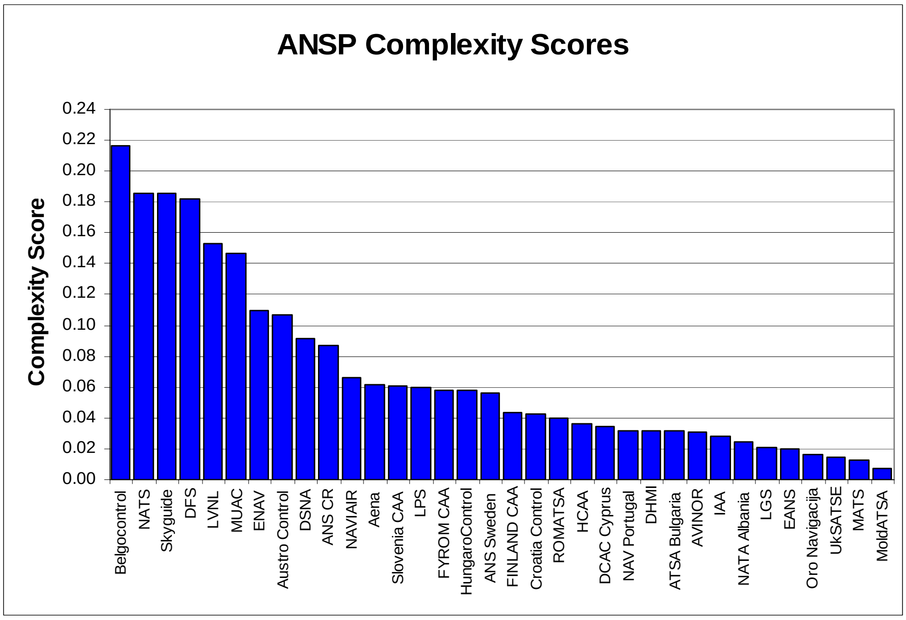

Figure 0.1: ANSP Complexity Scores

Conclusions

The Working Group involved a range of people with different backgrounds, experience and ideas about complexity. Through open and cooperative discussions the set of high level indicators was defined and agreed. The four chosen indicators, adjusted density, potential vertical interactions, potential horizontal interactions and potential speed interactions, look at a range of traffic characteristics while being manageable from an analysis point of view.

It is envisaged that the complexity score will be used for international benchmarking purposes. However, the individual indicator results will supplement the information and allow a better understanding of the differences and similarities between airspace environments. The individual results could also be used to cluster the ACCs for the productivity analysis.

The selected indicators have been chosen to calculate en-route complexity. It is recognised that the indicators may not be applicable in terminal areas. Further work would be required to identify specific terminal indicators.

It is also recognised that the indicators do not fully take into account the impact of external constraints such as the need to interface with systems having different capabilities (e.g. transition from RVSM to non RVSM or from imperial to metric standards).

The results show that complexity tends to decrease with altitude. Thus, the ANSPs/ACCs which work only in lower airspace tend to have higher values. It is important, therefore, to keep the scope of an ANSP/ACCs' activity in mind when comparing results. This is mainly an issue when comparing ACCs and also when comparing the ANSP results of Belgocontrol, LVNL and, to a lesser extent DFS, which handle the lower airspace vis-à-vis Maastricht UAC which handles only the upper airspace. For all other ANSPs, this is not an issue because the indicators look at complexity for all ANSP airspace above FL85, excluding oceanic services. The results, therefore, represent an averaged complexity score for each ANSP.

The two sample weeks used in this report have been chosen with care. Nevertheless traffic conditions vary significantly over Europe and peak periods do not occur at the same time in all ACCs. Ideally the traffic sample should be selected for each ACC taking into account the local traffic distribution or the indicators should be computed on a much wider traffic sample, ideally the full year.

The implementation of the complexity indicators within the EUROCONTROL PRISME data warehouse and the automated production of them following each AIRAC cycle will permit a consistent time series of complexity values to be built up.

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Glossary

ACC	Area Control Centre
ACE	ATM Cost-Effectiveness
ANSP	Air Navigation Services Provider
ATM	Air Traffic Management
BADA	Base of Aircraft DAta
CAA	Civil Aviation Authority
CENA	Centre d'Études de la Navigation Aérienne
CANSO	Civil Air Navigation Services Organisation
CFMU	Central Flow Management Unit
COLA	COmplexity Light Analyser
CTFM	Current Tactical Flight Model
ECAC	European Civil Aviation Conference
EEC	EUROCONTROL Experimental Centre
FIS	Flight Information Service
FTFM	Filed Tactical Flight Model
FPM	Flight Path Monitor
IFPS	Integrated Initial Flight Plan Processing System
nm	Nautical miles
OAT	Operational Air Traffic
PRC	Performance Review Commission
PRU	Performance Review Unit
RVSM	Reduced Vertical Separation Minimum
SDER	Sous Direction Etudes et Recherche appliquée
VFR	Visual Flight Rules

List of Air Navigation Service Providers

ANSP	Country
Aena	Spain
ANS CR	Czech Republic
ANS Sweden	Sweden
ATSA Bulgaria	Bulgaria
Austro Control	Austria
AVINOR	Norway
Belgocontrol	Belgium
Croatia Control	Croatia
DCAC Cyprus	Cyprus
DFS	Germany
DHMI	Turkey
DSNA	France
EANS	Estonia
ENAV	Italy
FINLAND CAA	Finland
FYROM CAA	FYROM
HCAA	Greece
HungaroControl	Hungary
IAA	Ireland
LGS	Latvia
LPS	Slovak Republic
LVNL	Netherlands
MATS	Malta
MoldATSA	Moldova
MUAC	
NATA Albania	Albania
NATS	United Kingdom
NAV Portugal	Portugal
NAVIAIR	Denmark
Oro Navigacija	Lithuania
ROMATSA	Romania
Skyguide	Switzerland
Slovenia CAA	Slovenia
UkSATSE	Ukraine

1. Introduction

Each year, the Performance Review Unit (PRU) produces a cost-effectiveness benchmarking report[1] using the information submitted by each Air Navigation Services Provider (ANSP) under the EUROCONTROL Information Disclosure requirement. In discussing these reports, members of the ATM Cost-Effectiveness (ACE) Working Group (which comprises European Air Navigation Service Providers, the EUROCONTROL Performance Review Unit, CANSO, representatives from airspace users and the European Commission) have stressed the likely importance of complexity as a factor influencing the cost-effectiveness and productivity analyses. Hence, at its September 2003 meeting, the ACE Working Group agreed to the creation of a small working group to examine complexity in more detail and to produce complexity metrics that could be applied in ANSP benchmarking analyses. Further details on this proposal were announced at the ACE Working Group meeting on 4 & 5 December 2003.

The first meeting of the ACE Working Group on Complexity was held on 29 & 30 January 2004 and the group was set the objective of producing this report for the main ACE Working Group. The group met nine times between January 2004 and October 2005.

The overall objective of the Working Group on Complexity was **to define and agree a set of high level complexity indicators for en-route airspace that can be used for benchmarking purposes**. These indicators were to be expressed primarily at a macroscopic level (ANSP and ACC), although this did not preclude the calculation of indicators at sector level where that seemed appropriate. The geographical scope of the analysis covered the entire ECAC area. It was acknowledged at the outset that it would be necessary to keep the overall number of indicators down to a manageable level.

Members of the Working Group on Complexity represented the following organisations (participants at the meetings are listed in Annex 1):

- Austro Control - Austria
- Belgocontrol - Belgium
- DFS - Germany
- DSNA - France
- EUROCONTROL (PRU and EEC)
- LVNL - Netherlands
- Maastricht UAC
- NATS - UK
- NAV Portugal
- Skyguide - Switzerland

The remainder of this report is structured as follows:

- Chapter 2 sets out the definition of complexity that was applied by the Working Group;
- Chapter 3 details the main complexity dimensions that were identified;
- Chapter 4 describes the complexity indicators that were selected;
- Chapter 5 sets out the data sources that were used;
- Chapter 6 summarises the results of the analysis;
- Chapters 7 and 8 describe the sensitivity analyses that were performed;
- Chapter 9 gives the conclusions drawn by the Working Group.

1 see references [1], [2] and [3]

2. Complexity Definition

The initial task of the Working Group was to obtain broad agreement on the definition of complexity for the purposes of this analysis. Complexity is a widely used term to represent 'level of difficulty', but there is no universally agreed definition applicable to ATM.

During the first two meetings members of the Working Group accepted the opportunity to present their own work to date on examining complexity. There seemed to be a common understanding that complexity related to the level of difficulty; a notion of 'additional' controller workload beyond that directly associated with the number of flights. The following aspects of complexity were identified:

- ATC procedures-related complexity – additional controller workload arising from the concept of operation, ATC procedures in operation, airspace organisation, route structure, etc. Arguably these aspects are mostly internal to the ANSP;
- Traffic characteristics complexity – additional controller workload arising from the concentration, type or interaction of traffic. Arguably these aspects are mostly external to the ANSP;
- External complexity – additional controller workload arising from the nature or structure of the airspace through which traffic is flying, also deemed to be mainly external to the ANSP.

These aspects of complexity contribute to controller workload and are illustrated in

Figure 1 where ATC procedures-related complexity is split into two components; airspace issues and concept of operation/technology.

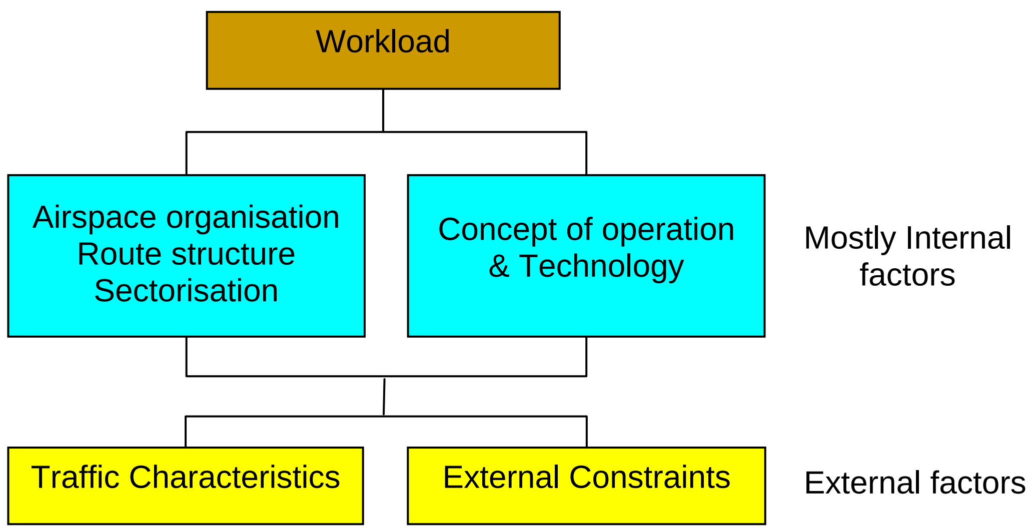

Figure 1: An illustration of the internal and external complexity factors

Defining and measuring complexity is context specific and the methods used will depend on the intended application. For the purposes of international annual benchmarking linked to performance and efficiency there is a need for high level indicators (at the level of ANSP/ACCs). Additionally, the indicators should not penalise ANSPs for investment. Improvement in the airspace organisation or new controller support tools can indeed help in reducing the complexity of the controllers' tasks and improve cost-effectiveness and productivity. However, for benchmarking purposes, those gains should not be attributed to a reduction of the complexity of the traffic but to better management of the traffic by the ANSP.

Therefore, for benchmarking purposes, complexity measures should, to the fullest extent possible, reflect the traffic characteristics and the external constraints, independently from the route network and sector design.

For the purposes of this study, complexity is therefore defined as **the external factors that impact the controller workload and/or the level of difficulty of the ATC task, without (considering) the internal, ATC procedures-related factors**.

There is a considerable body of international research on ATM complexity. Within each study the definition of complexity and what was measured varied depending on the study objectives. Many studies sought to define a set of complexity indicators with the main aims being to improve the accuracy of capacity estimates and to develop predictive complexity models. These studies generally used much larger sets of indicators, many of which have not been included in this study as they relate to the operational environment (which has been excluded as much as possible). The COCA Project has recently published a literature review, Cognitive Complexity in Air Traffic Control – A Literature Review, EEC Note No. 04/04, see reference [4], which provides a summary of much of the ATM complexity research.

3. Complexity Dimensions

The complexity dimensions, as defined in this report, each capture a feature of the ATM environment which is considered to influence the complexity experienced by a controller. During the first meetings comprehensive sets of complexity dimensions and associated candidate indicators were compiled. The dimensions could be divided into three categories; traffic characteristics, airspace and external constraints.

The following table describes the complexity dimensions that were considered to be most relevant by the Working Group. The complete initial list of complexity dimensions and candidate indicators identified can be found in Annex 2 where comments on the influence of each dimension on productivity and costs are also included.

Traffic Characteristic Complexity Dimensions	
Traffic density	This dimension captures the distribution of aircraft in the airspace. The aircraft can be geographically concentrated in certain parts of the airspace or they can be concentrated in time with peaks and troughs of traffic over the day. Complexity tends to increase when aircraft are not evenly spread and the controller has to handle more aircraft in a smaller volume of airspace and/or less time. Traffic density can be influenced by internal factors such as route structure. However, the uneven distribution of flights is mainly due to external factors. These factors include: • the underlying traffic demand, which may be focussed in certain parts of the airspace and/or at certain times of the day. • military areas which restrict the available airspace.
Traffic in climb or descent (evolution)	This dimension looks at the vertical movement of the traffic. It is considered that, in general, handling a mix of climbing, cruising and descending aircraft is more complex than handling only climbing and cruising aircraft. The proportion of traffic in climb and descent mainly depends on the proximity of major airports (external factor). This dimension can also be influenced by transfer conditions where aircraft must be transferred at agreed altitudes.

Traffic Characteristic Complexity Dimensions	
Flow structure	This dimension looks at the horizontal movement of the traffic. It is assumed that aircraft on crossing flows are more complex to handle than aircraft in parallel flows. The presence of crossing flows is mainly a function of the traffic demand (external factor). However their location can be affected by the route structure. For example, if a change in an ANSP's route structure results in a crossing point moving from one ACC to another ACC, this will impact the respective controllers' complexity (internal factor). The route structure in adjoining ANSPs can also influence the presence and location of crossing points (external factor).
Traffic mix	This dimension looks at the variation in the aircraft speeds and aims to capture the differences in performance characteristics. The assumption is that a situation is less complex when aircraft have similar speeds but that the arrival of aircraft with significantly different speeds increases complexity. In general, the differences in speeds are due to aircraft type characteristics and as such are considered as an external factor.

Airspace Complexity Dimensions	
Sectorisation	This dimension captures the effects of the sectorisation on complexity. The decisions on how to divide the airspace can increase or reduce complexity, although this is also linked to the route structure. In general an ANSP can change their sectorisation so this is considered as an internal factor because they could reduce complexity. However the external constraints of military airspace and sovereign boundaries can hinder their ability to optimise the sectorisation.
Route structure	This dimension looks at the route structure within the airspace. While the route structure tends to reflect the underlying traffic demand (external factor), its optimisation is largely an internal factor. For example, ANSPs can restructure the routes within their airspace or change bi-directional routes, which are more complex, to uni-directional ones. However, it must be noted that an ANSP's ability to fully optimise their route structure is often constrained by external factors such as military areas.

External Constraint Complexity Dimensions	
Military areas	This dimension looks at the influence of military airspace. Complexity can be increased because the controller has less airspace in which to handle the traffic or they have to use alternate routes. The location and extent of military areas are usually external constraints which are beyond the control of the ANSP but can heavily influence the complexity experienced by the controller. The impact of military airspace on the controller workload depends also on the type and quality of the civil-military coordination arrangements.
Interface with adjacent units	This dimension looks at the impact of the relationship between neighbouring ACCs. The interface between two different operating environments can contribute to complexity. This is particularly relevant when the separation standards have to be increased (e.g. transfer from radar separation to procedural separation or from RVSM to non-RVSM). The interface with adjacent units is mainly an external factor although measures can be put in place to streamline the transfer of aircraft between ACCs (e.g. through Letters of Agreement).

Table 1: Complexity Dimension Descriptions

The first category, Traffic Characteristics, groups a number of dimensions related to the traffic characteristics which are clearly relevant to ACE benchmarking.

The second category, Airspace, tends to capture ATC procedures-related complexity. Although the dimensions may contribute to reducing (or increasing) the complexity of the traffic as experienced by the controller, they are mainly internal factors which, to a large extent, can be controlled/managed by the ANSP. As indicated in section 2, performance improvements arising from a more efficient route structure should be attributed to better traffic management by the ANSP and not to a reduction in complexity. These internal factors should be excluded to the extent possible from the complexity indicators used in the context of ACE benchmarking. However it is acknowledged that the route structure cannot be completely excluded from the study as it is inherent in the traffic samples.

The dimensions in the third category, External Constraints, could also influence the traffic complexity although their impact cannot always be quantified. For example, the influence of military airspace is partly taken into account through its indirect impact on the traffic characteristics indicators, particularly adjusted density. Other external constraints such as the transition between RVSM and non-RVSM airspace and the transition between imperial and metric separation standards have been recognised but could not be quantified at this stage.

Other factors were identified, see Annex 2, but not considered further during the course of the study. These included the impact of special events, as well as traffic variability, predictability and weather.

Special events may have a significant impact on traffic complexity on a given day. Examples of special events include:

- Large scale military exercises,
- Additional traffic (e.g. Monaco Grand Prix).

Special events are not expected to significantly influence the average productivity over the year.

Traffic variability and predictability, particularly the seasonal variation of traffic, were recognised as important dimensions that might affect productivity and costs. However, they were not considered as being elements of complexity.

4. Complexity Indicators

The Working Group selected a set of indicators to represent the main dimensions of en-route complexity relating to traffic characteristics. One indicator was identified for each of the four traffic characteristic complexity dimensions in Table 1. The chosen indicators are shown in Table 2 and described in the following sections; further technical details can be found in Annex 3.

The applicability of the selected indicators in terminal airspace has not been explicitly explored within the study.

As previously mentioned the aim was to exclude the internal factors from this study. This has been done in that none of the indicators directly measure any internal factors. Yet it is acknowledged that the aim has not been fully met because the route structure is inherent in the traffic samples. The use of a grid with cells of a large enough dimension reduces but does not eliminate the impact of the route structure.

Complexity Dimension	Indicator
Traffic density	Adjusted density
Traffic in evolution	Potential vertical interactions (VDIF)
Flow structure	Potential horizontal interactions (HDIF)
Traffic mix	Potential speed interactions (SDIF)

Table 2: Selected Indicators

4.1. Grid Dimensions

The complexity indicators are calculated using a grid that divides the entire ECAC area, see Figure 2, into identical 4D cells. As the indicators are calculated in each cell this provides flexibility when combining and aggregating the data at ACC and ANSP level.

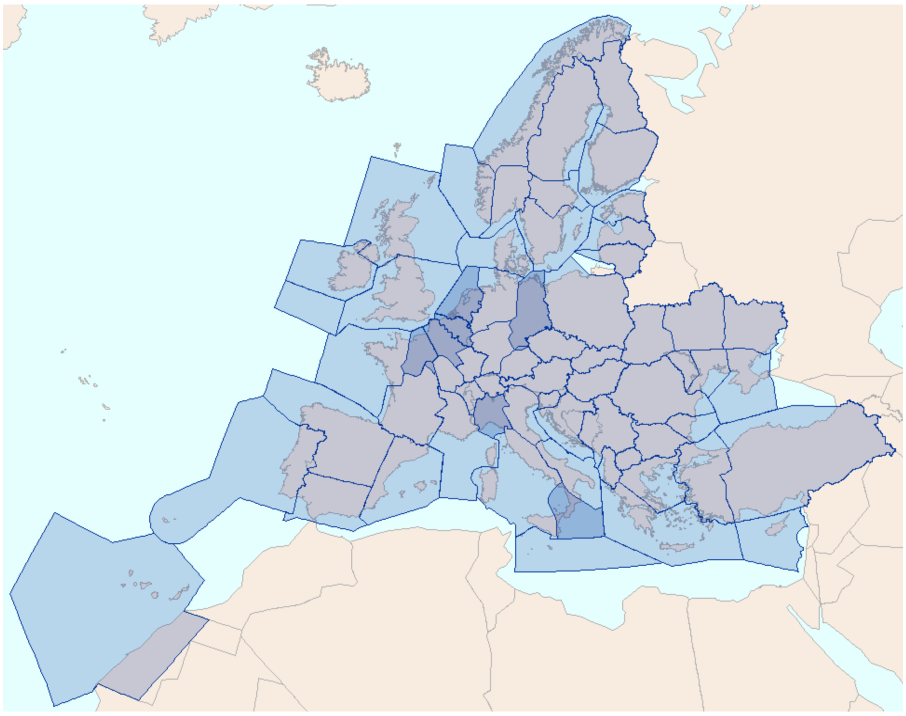

Figure 2: Map of the ECAC area

The choice of the cartographic projection is important to minimise the distortion caused by the curvature of the earth. The choice of the best projection depends upon the application. For this study the Albers equal area projection has been used. This projection ensures that all cells have equal volume.

Figure 3 shows the spatial (dx, dy and dz) and temporal (dt) parameters of the cells used in this study.

The 20nm cell size was chosen because it mapped the ACC boundaries more closely than a larger cell size while maintaining a macroscopic view.

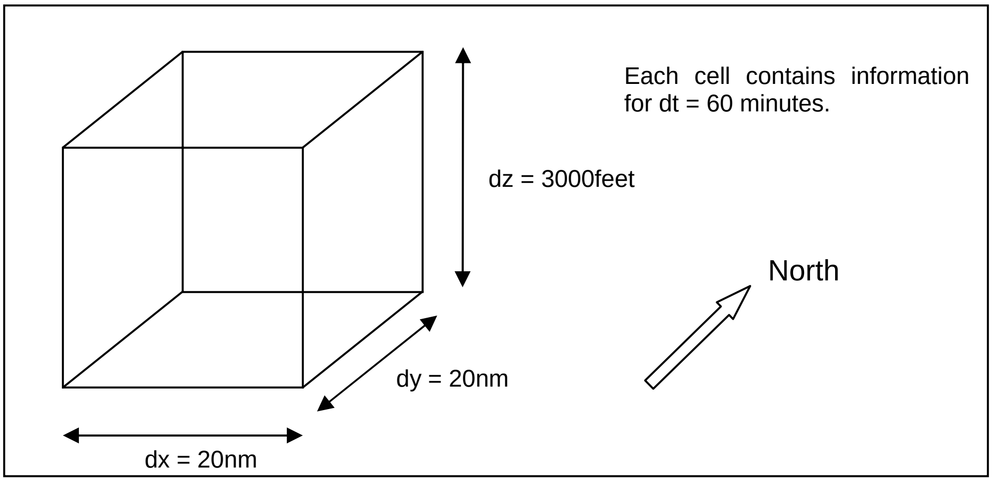

Figure 3: 4D Cell Dimensions used in this study

Data on the traffic within each cell are collected during discrete 60 minute periods; 0h00 – 0h59; 1h00 – 1h59; etc. So, for a one-day simulation there are 24 data sets for each cell; one for each hour.

To calculate the ANSP indicator values the first step is to identify which cells belong to which ANSP; where each cell can only belong to one ANSP. The data from the cells that straddle the airspace borders are allocated to the ANSP in which the cell's centre point is located both laterally and vertically. The values are then calculated for each ANSP using the data from the relevant cells. The same process is used for the ACCs.

To reduce the boundary effects that are associated with using grids, the indicators are calculated using 12 different grids. There are four horizontal grid shifts. The size of the shifts are combinations of 0nm and 10nm in the x and y dimensions; (0, 0), (0, 10), (10, 0) and (10, 10). Each of these grids also shifts vertically in 3 x 1000ft steps.

In the vertical plane the cells are 3000 ft high. For the first grid they start at FL85 and continue to FL415. Therefore, the division between cells are at FL85, FL115, FL145, FL175, FL205, FL235, FL265, FL295, FL325, FL355 and FL385. In the subsequent vertical shifts the lowest level will be from FL95 to FL125 and FL105 to FL135.

The results are presented as the average of the values from the 12 grids.

4.2. Terminology

This section provides some definitions for terms that will be used in the following descriptions.

Flight hours: Sum of the flight hours controlled in a given volume (a cell or a set of cells) over a period of time.

Number of aircraft simultaneously present: The intuitive concept of this term is that the two aircraft are physically present in the cell at the same moment in time. However because the grid uses a one-hour time step it is more relevant to consider the average number of aircraft that will be simultaneously present at any moment during the hour. This is equivalent to the number of flight hours flown in each one-hour time step. So one flight-hour recorded during one hour represents an average of one aircraft in the cell.[2]

Interaction: Aircraft (a) is said to interact with aircraft (b) if the 2 aircraft are simultaneously present in the same cell.

Hours of Interaction: sum of the duration of the different interactions that occur in a given airspace (a cell or a set of cells) over a period of time.

European system value: the indicator value calculated using all the data from all the ANSPs or ACCs. These values assess complexity for the entire ECAC area as if it were a single ANSP or ACC.

4.3. Interactions

The notion of an interaction constitutes the key concept arising from this work on complexity. It is the presence of several aircraft in the same area at the same time that generates complexity, particularly if those aircraft are in different flight phases, have different headings or different speeds.

Within this study an interaction is defined as the simultaneous presence of two aircraft in the same cell viewed from each aircrafts' perspective. So in Figure 4, $cell_k$ has two interactions and $cell_{k+1}$ has six interactions. Each interaction takes place between two and only two aircraft[3].

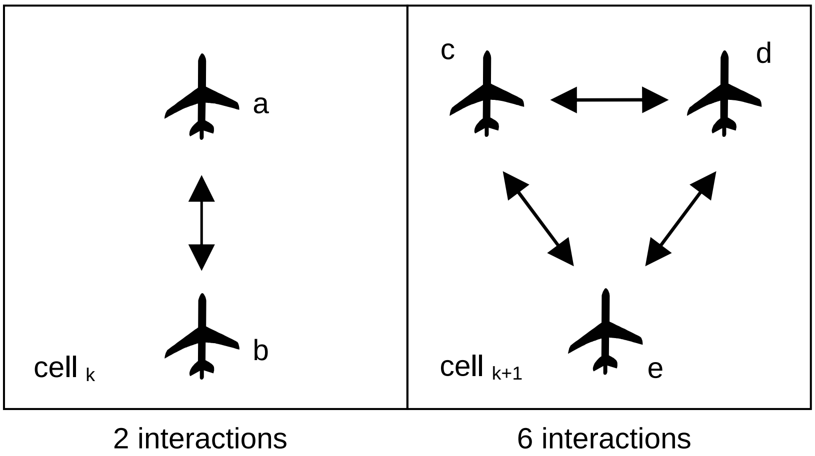

Figure 4: Interactions

As this study is taking a macroscopic view it looks at potential interactions and not actual interactions. The indicators do not aim to capture the actual number of interactions that

2 The number of aircraft simultaneously present in a cell should not be confused with the flow; the number of aircraft that enter the cell during the hour. Assuming that during one hour there are 30 aircraft which each enter and spend, on average, 2 minutes (1/30 of an hour) in the cell then the flow in the cell is 30 aircraft per hour. The total flight time is one flight hour which corresponds to an average of 1 aircraft being present in the cell at any given time. If the total flight time was two hours then this would correspond to an average of 2 aircraft being simultaneously present in the cell at any given time.

3 In $cell_k$ a interacts with b and b interacts with a, in $cell_{k+1}$ the six interaction pairs are c & d, c & e, d & c, d & e, e & c and e & d.

occurred on a particular day but rather the probability of interactions arising from the traffic flows.

The method only looks at how long each aircraft is in the cell during the hour and considers that each aircraft may have passed through the cell at any time during the hour. In these conditions if t_a and t_b are the recorded durations of aircraft (a) and (b) in the cell during the hour, then the expected duration[4] (in hours) of the interaction between aircraft a and b is equal to the product $t_a \times t_b$.

So the expected duration of one interaction between two aircraft which each spend three minutes in the cell (1/20 of one hour) is:

$$\left(\frac{1}{20} \times \frac{1}{20}\right) = \frac{1}{400} \text{ or 0.0025 hours}$$ [5]

If the two aircraft in cell_k each spend three minutes in the cell then the expected duration of the interactions (a with b and b with a) during the one hour period is:

$$2 \times \left(\frac{1}{20} \times \frac{1}{20}\right) = \frac{1}{200} \text{ or 0.005 hours}$$

Assuming that each aircraft spends three minutes in cell_{k+1} the expected duration of the six interactions is:

$$6 \times \left(\frac{1}{20} \times \frac{1}{20}\right) = \frac{3}{200} \text{ or 0.015 hours}$$

These calculations are performed for each pair of aircraft in a cell and the sum of the durations provides the hours of potential interactions for that cell. These values are then aggregated at ANSP or ACC level.

4.4. Adjusted Density

Complexity Dimension – Traffic Density

Traffic density is a measure of the amount of traffic that exists within a given unit of volume over a given unit of time. Within this study adjusted density was chosen as it is more specific than raw (un-adjusted) density which is the ratio of the number of aircraft (or flight hours) to the volume considered (ANSP/ACC). Raw density is not meaningful enough as it does not take into account whether the traffic is evenly spread or concentrated in one part of the centre (busiest sectors) or one part of the day (peak periods).

Adjusted density is defined as the ratio between the hours of interactions and flight hours.

Adjusted density = Hours of interactions / Flight hours

The hours of interactions are calculated by adding the durations of all the interactions in all the cells associated with an ANSP/ACC. This is then divided by the total flight hours within the ANSP/ACC to get the adjusted density indicator.

The European system value is around 0.11 hours of interactions per flight hour.

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[4] The expected duration is a function of both the probability and the duration of the interaction. Depending on the exact entry time of each aircraft in the cell, the 2 aircraft may interact some days and not interact some other days. Over a large number of days, the average duration of the interaction will approach the expected duration.

[5] This interaction duration will be used in the following examples to standardise the explanations.

The result can also be interpreted as interactions per flight. This value represents the average number of interacting aircraft (i.e. the number of aircraft present in the same cell) that a flight crossing the ANSP/ACC airspace might expect to encounter.

The density is ‘adjusted’ because cells with no flights do not add anything to the calculation as they contain no interactions and no flight hours. Cells with only one flight do not contain any interaction duration but do contribute flight hours to the calculation. In this way the distribution of aircraft is reflected in the calculation.

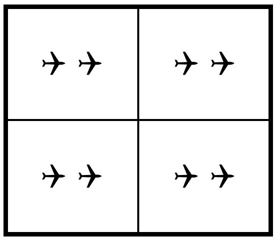
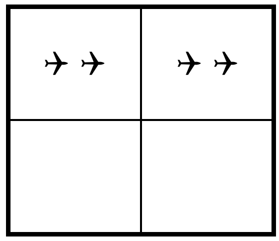
 **Centre 1**		 **Centre 2**
2+2+2+2=8	Number of interactions	2+2=4
To produce results in terms of expected duration, the time spent in the cell (three minutes in this example) must be taken into account. Adjusted density = Hours of interactions / Flight hours		
$8 \times \frac{1}{400} = 0.02$	Hours of interactions	$4 \times \frac{1}{400} = 0.01$
$8 \times \frac{1}{20} = 0.4$	Flight hours	$4 \times \frac{1}{20} = 0.2$
$\frac{0.02}{0.4} = 0.05$	Adjusted Density	$\frac{0.01}{0.2} = 0.05$

Figure 5: Adjusted Density Indicator

Figure 5 provides an example of the computation of the adjusted density for two hypothetical centres. Centre 2 has half the number of aircraft and therefore a raw density which is half that of Centre 1. However, the adjusted density and the number of interactions per flight are equal in both centres.

This example shows that adjusted density is describing the density experienced by an aircraft. While the number of aircraft in the two centres differs the adjusted density for each flight is the same.

The concentration provides further information on how the traffic is distributed in space or in time.

$$\text{concentration} = \frac{\text{adjusted density}}{\text{raw density}}$$

The concentration could be due to a range of factors, e.g. the geographic distribution of the traffic demand, the hourly distribution of traffic within the day or a military area closing part of the airspace.

4.5. *Vertical Interactions*

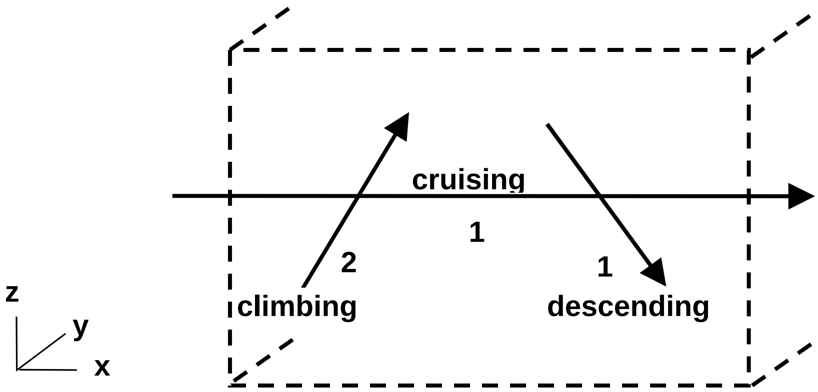
Complexity Dimension - Traffic in evolution

The Vertical Different Interacting Flows (VDIF) indicator is a measure of the complexity arising from the interactions between flights in different flight phases. It is expressed as the duration of potential vertical interactions (in hours) per flight hour.

Two aircraft are considered to interact vertically if they are simultaneously present in the same cell and have different attitudes (climbing-cruising-descending). Each aircraft's attitude is defined at the moment it enters the cell. A flight is considered in cruise if its rate of climb/descent is less than 500 ft per minute.

The concept of vertical interactions is illustrated in Figure 6. In the cell there are 4 aircraft entering the cell during the hour; 2 climbing, 1 in cruise and 1 descending.

Each of the climbing aircraft interacts with 2 other aircraft; the cruising and the descending aircraft but not with the other climbing aircraft. The cruising aircraft interacts with 3 aircraft; the 2 climbing and the 1 descending aircraft. The same logic applies to the 1 descending aircraft. There are no interactions between flights with the same attitude.[6]



Vertical interactions = (2 x 2) + (1 x 3) + (1 x 3) = **10**

Figure 6: Potential Vertical Interactions

In this example the total number of potential vertical interactions in the cell is 10. These interactions are only potential as the aircraft may have been present in the cell at different time during the hour. As previously described, the indicator does not aim to capture the actual number of interactions that occurred on a particular day but rather the probability of interactions arising from the traffic flows. If we consider that each aircraft stayed 3 minutes ($^1/_{20}$ hour) in the cell, then the expected duration of each interaction is $^1/_{400}$ hour (see section 4.3). The total expected duration of vertical interactions of all flights in the cell is therefore 10 x $^1/_{400}$ = 0.025 hours

The VDIF indicator is obtained by adding the expected duration of all potential vertical interactions in all the cells associated with an ANSP/ACC. This is then divided by the total flight hours within the ANSP/ACC.

VDIF = Hours of vertical interactions / Flight hours

The European system value for VDIF is around 0.03 hours of vertical interactions per flight hour.

6 However an interaction between two flights in the same flight phase which have a difference in heading of more than 20° will be counted as a horizontal interaction, see section 4.6.

4.6. Horizontal Interactions

Complexity Dimension - Flow structure

The Horizontal Different Interacting Flows (HDIF) is a measure of the complexity arising from the interactions between flights with different headings and is expressed as the duration of potential horizontal interactions (in hours) per flight hour.

A horizontal interaction is defined as the simultaneous presence of two aircraft with different headings in a cell. The heading used in the calculation is the one the aircraft was flying when it entered the cell. One interaction is counted when the difference between the headings of two aircraft is greater than 20°.

For example, in Figure 7 there are five aircraft entering the cell during the hour. The process assesses the angle between the routes of each pair of aircraft to see if it is less than or greater than 20°. The altitudes and attitudes of the aircraft within the cell are not taken into account.

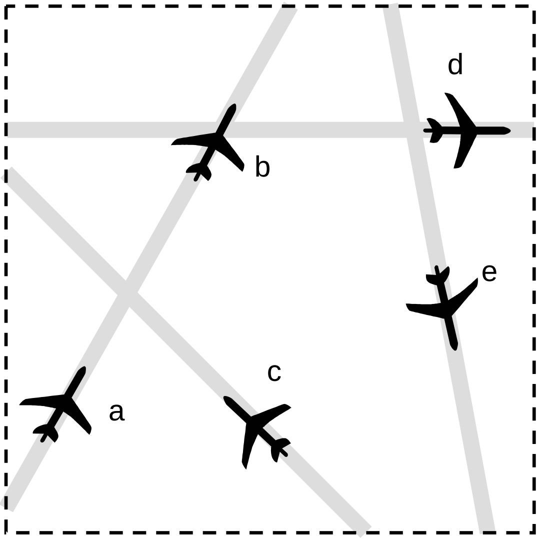


Figure 7: Potential Horizontal Interactions

For aircraft (a) the angle between its route and aircraft (b)'s route is less than 20° so no interaction is considered. The angle between aircraft (a) and aircraft (c)'s route is greater than 20° so it is counted as a potential interaction. Aircraft (a) and aircraft (d) are considered to potentially interact as are aircraft (a) and aircraft (e). So starting with aircraft (a) there are three potential interactions. Table 3 summarises the potential interactions for the other aircraft.

Aircraft	Number of Potential Interactions
a	3
b	3
c	4
d	4
e	4
Total	18

Table 3: Number of Potential Horizontal Interactions

As with the VDIF indicator, the HDIF indicator takes into account the expected duration of the interactions. In the example above the number of interactions is multiplied by the expected duration of an interaction (see section 4.3), giving an expected duration of horizontal interactions in the cell of 18 x $^{1}/_{400}$ = 0.045 hours.

The HDIF indicator is defined as:

HDIF = Hours of horizontal interactions / Flight hours

The expected duration of all potential horizontal interactions in all the cells associated with an ANSP/ACC are added together. This is then divided by the total flight hours within the ANSP/ACC to give the value of the HDIF indicator.

The European system value for HDIF is around 0.05 hours of horizontal interactions per flight hour.

4.7. Speed Interactions

Complexity Dimension – Traffic Mix

The Speed Different Interacting Flows (SDIF) indicator is a measure of the complexity arising from the interactions between aircraft with different speeds and is expressed as the duration of potential speed interactions (in hours) per flight hour.

A speed interaction is counted when the difference between the speeds of a pair of aircraft is greater than 35kts. The speed used in the calculations is the value given by the BADA performance table for the type of aircraft considered at the flight level of the centre of the cell.

Figure 7 is used to explain the process of identifying horizontal interactions. The figure describes equally well the SDIF process if you were to consider the difference in aircraft speeds instead of the aircraft headings when identifying interactions.

SDIF = Hours of speed interactions / Flight hours

The European system value for SDIF is around 0.03 hours of speed interactions per flight hour.

4.8. Complexity Score

During the initial discussions the Working Group discussed the aggregation of the indicators into a single complexity metric that could provide a ‘master’ ranking of the ANSPs and ACCs. However, the group agreed that the individual indicator results must also be presented to give a fuller picture. For example, two ANSPs may have very similar aggregated complexity scores yet closer inspection of the individual indicators may show that one result is heavily influenced by the structure of the traffic flows (DIF indicators) while the other is mainly influenced by the traffic volume (adjusted density).

However the DIF indicators are highly correlated with adjusted density, see Annex 4. This is due to vertical, horizontal and speed interactions being subsets of adjusted density which contains all interactions. These correlations are removed by using ‘relative’ indicators, r_VDIF, r_HDIF and r_SDIF, which are calculated by dividing the interaction indicators for each ANSP/ACC by their respective adjusted density result. These values can also be interpreted as the percentage of interactions which are vertical, horizontal or due to speed differences.

It should be noted that one adjusted density interaction can fall into the vertical, horizontal and speed categories depending on the attitudes, altitudes and speeds of the aircraft. For this reason the percentages do not add up to 100%. The maximum would be 300% if every interaction met all the criteria.

Structural Index

As previously mentioned, the ANSP complexity scores are influenced by two aspects; the structure of the traffic flows and traffic volume. The use of the r_DIF indicators allows these components to be separated. Adjusted density reflects the traffic volume while the structural index represents the structure of the traffic flows:

$$\text{Structural Index} = r\_VDIF + r\_HDIF + r\_SDIF$$

However, as both aspects affect the overall complexity they are combined in the chosen aggregation:

$$\text{Complexity Score} = \text{Adjusted Density} \times \text{Structural Index}$$

The European system value of the complexity score is around 0.10.

The Working Group did consider weighting the indicators based on their perceived importance, however, it was deemed unlikely that one set of weightings could be relevant for all types of airspace. Furthermore, several weighted complexity scores were tested and the results were very similar to the un-weighted score. For these reasons the un-weighted complexity score was retained. As the indicators evolved several weighting options and aggregation methods were tried; see Annex 5 for further details.

The idea of normalising the indicators was also considered. The main benefit was that when each indicator result was normalised with the relevant system value it allowed simple comparisons across the ANSP/ACCs. For example the ANSP with a value of 1 was the average, while a value of 1.5 represented an ANSP who was 50% more complex than the average. However this system has the disadvantage that results from different years cannot be directly compared unless the same system value is used each year.

A benefit of the chosen method is that an ANSP’s results will be directly comparable from year to year.

5. Data Sources

Traffic Data

The results have been produced using CFMU (model 3) data from 2003. This data does not include VFR or military OAT traffic. The CFMU data does not contain weather information.

There were discussions within the Working Group on which data source to use; model 1 (FTFM), the filed flight plan data or model 3 (CTFM), the updated flight plan data which identifies when a flight deviated[7] from its original flight plan.

To assess the differences between the two models some sensitivity analysis were undertaken, details of which can be found in Annex 6. The analyses indicated that both models lead to similar results. CTFM data has been used to produce the results contained in this report and will be used to produce future results.

Two weeks of traffic were used; week 3 (Thursday 09/01/2003 to Wednesday 15/01/2003) and week 36 (Thursday 28/08/2003 to Wednesday 03/09/2003).

These weeks were chosen to represent a typical week of low traffic (week 3) and a typical week of busy traffic (week 36). However, it must be remembered that traffic flows across Europe vary widely and no single week captures all the busy or low traffic for all the European centres.

It must also be noted that the same quality of data is not available for all ANSPs. The data is extracted from the CFMU's Integrated Initial Flight Plan Processing System. The ANSPs EANS, LGS and Oro Navigacija are not in the Flight Path Monitor area and therefore the CFMU data may not contain all the flights for those countries. This has affected the fidelity of the complexity calculations made for those ANSPs.

Airspace Definitions

The results are provided for 67 ACCs and 34 ANSPs. The ACC definitions were based on the CFMU environment data. The ANSPs were defined by the PRU and include all of the airspace under the control of the ANSP above FL85, including FIS areas but excluding oceanic services.

Delegated airspace is included in the calculations when it is declared in the CFMU environment data. However, some local operational practice delegations may not be captured within the airspace definitions.

During the study the results for selected terminal areas (above FL85) were calculated, see Annex 7. However, as the traffic characteristics around terminal airspace includes denser areas of traffic with more climbing and descending profiles, the selected indicators provided inflated results for terminal areas. The Working Group agreed that the indicators were valid for ACCs but that further work would be needed to develop terminal complexity indicators.

Base of Aircraft Data (BADA)

For the speed interaction indicator the true airspeed of each aircraft is extracted from the relevant Base of Aircraft Data (BADA) performance table. For each aircraft type the performance tables specify the true air speed, rate of climb/descent and fuel flow for climb, cruise and descent at various flight levels. The performance figures contained within the tables are calculated based on a total-energy model and BADA 3.6 performance coefficients.

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[7] By more than 5 minutes in time, 20NM laterally or 700ft vertically.

6. Results

The indicators were originally computed by the EEC and SDER (ex CENA).

The EEC used a fast time complexity simulator, COLA V0.7 (COmplexity Light Analyser), developed by the Complexity and Capacity (COCA) project. SDER used their own simulator to reproduce the EEC results thus enabling the results to be crosschecked and also providing data for the sensitivity analysis.

Subsequently the PRU developed a simulator to calculate the chosen indicators. This will provide greater flexibility when calculating results for the benchmarking process, e.g. by using many weeks of data. The PRU results were compared and assessed against those produced by the EEC and SDER. The results were found to be consistent.

The simulators all require the same type of input data:

- Flight data describing the individual aircraft trajectories (IFR flights) covering the study sample dates;
- Geographical environment data for the elementary sectors and centres;
- Sector configuration for the traffic sample date and the corresponding Aeronautical Information Regulation And Cycle (AIRAC) notice; and,
- Suitable parameters to calibrate the measurement of the complexity data set.

The simulators' output comprises complexity data sets that are used to produce the indicator results.

The following sections present the ANSP results for the two weeks of data. The data was produced by the PRU simulator.

6.1. Adjusted Density

Figure 8 shows the adjusted density values for the ANSPs. Skyguide has the highest adjusted density value, 0.17 hours of interactions per flight hour. Austro Control is considered as the average ANSP as its result is closest to the European system value of 0.11.

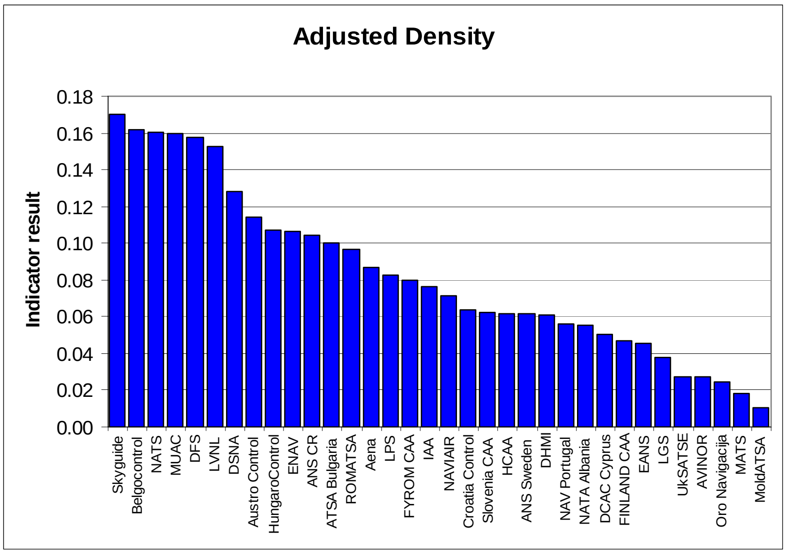


Figure 8: Adjusted Density results

These results agree with the general expectation that adjusted density is higher in the core area as those ANSPs are grouped to the left of the graph.

Average transit times and average daily flight hours for the ANSPs are shown in Annex 8.

Figure 9 shows the concentration for each ANSP; the ratio of adjusted to raw density. The order of the ANSPs is the same as in Figure 8. If all the aircraft were evenly spread then the raw and adjusted density values would be equivalent and the ratio would be 1. When the spread of aircraft is uneven and areas of the airspace are not used then the ratio increases. For example, Skyguide has a high adjusted density and a low concentration indicating that the traffic is relatively evenly spread. This trend is seen for most of the ANSPs on the left of the graph except NATS who have a high adjusted density and a high concentration. The high adjusted density reflects that there are high density areas while the high concentration reflects that the traffic is not evenly spread throughout the UK airspace.

High concentrations reflect that there are areas of the airspace which are not used; this could be because they are closed for military reasons or because there is no traffic demand.

High concentrations may also signal an uneven distribution of traffic through time, reflecting either large seasonal variations of traffic and/or a high variation of traffic during the day.

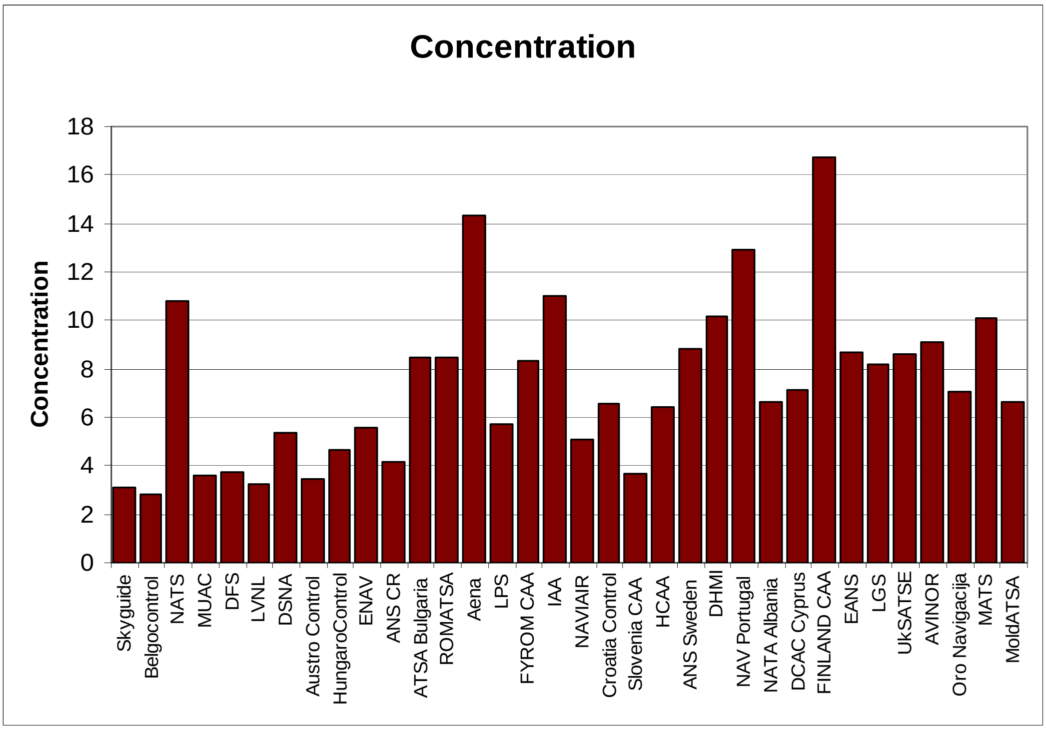


Figure 9: Concentration (adjusted density / raw density)

Density Plots

The following density plots show the distribution of flight hours over the ECAC area. Each plot represents the average time flown, over 24 hours, in each cell of the specified layer during the day 09/01/03. It is useful to bear in mind that a certain number of flight hours could be due to a few aircraft flying slowly (i.e. lower airspace) or a large number of aircraft flying at higher speeds (i.e. upper airspace). The reader is reminded that this figure can be interpreted as the average number of aircraft present in the cell during the day. The grey cells did not contain any traffic at these levels.

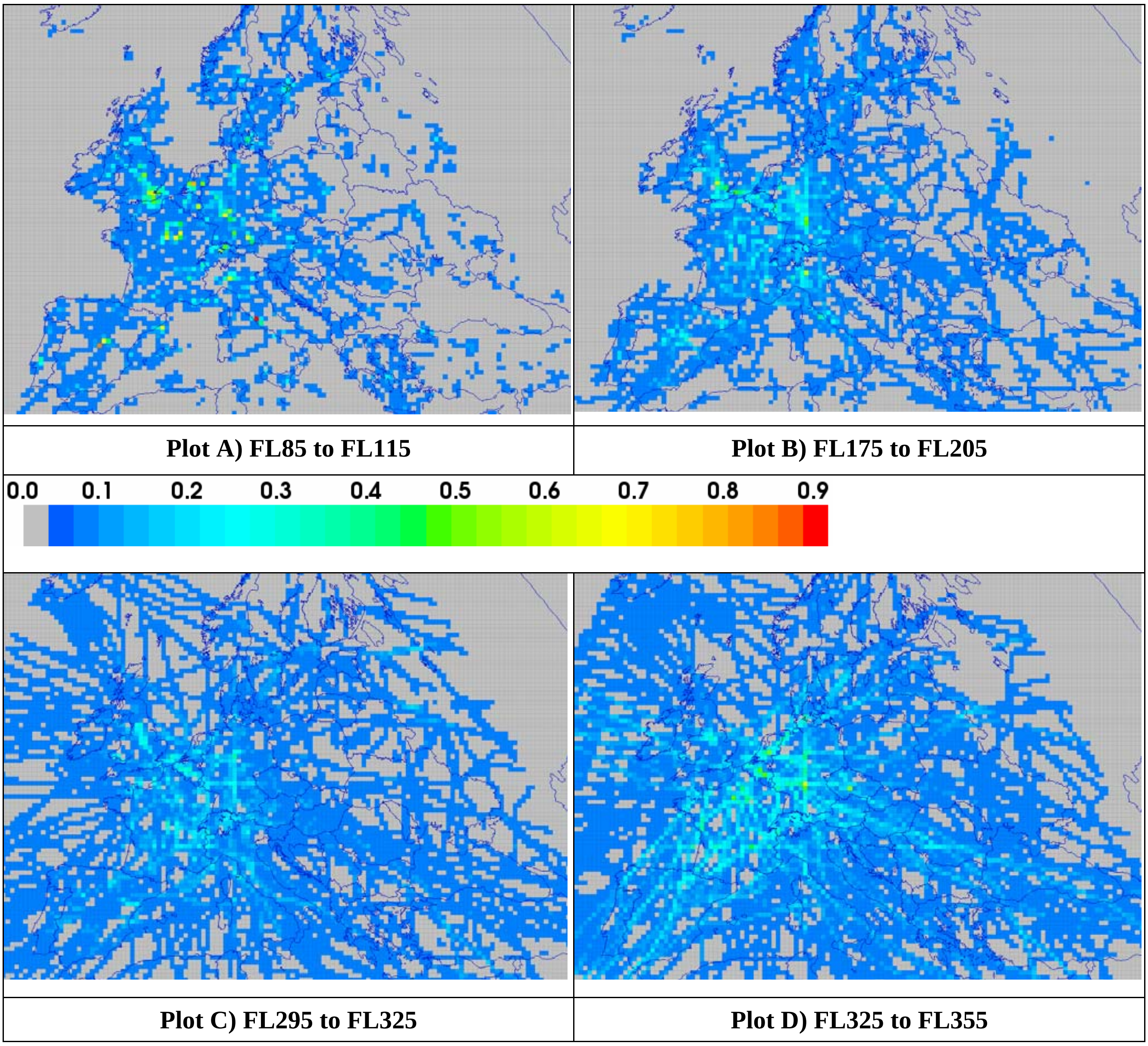


Figure 10: Density Plots of the ECAC Area

Plot A in Figure 10 shows some cells at the higher end of the scale (green to red); this indicates that there were a large number of flight hours flown in those cells. This is logical because it represents a layer of lower airspace where most of the aircraft are concentrated around the airports. Furthermore the flights were generally flying more slowly at these levels, hence spending more time in a cell.

Plot B provides a cross section of the airspace between FL175 and FL205. The traffic and the dense areas are more dispersed than in the lower levels. The scale shows that while more cells have higher densities than they had in Plot A (more pale blue cells), the peak value is generally lower (fewer green and yellow cells). Plot C shows the flight hours between FL295 and FL325, the traffic is continuing to disperse across the core European area. Plot D clearly shows the dispersion of the traffic and the tracks in the upper airspace between FL325 and FL355.

The range of values for flight hours per cell is quite similar in plots B, C and D, as is shown by the very similar colouring of the cells. However, the number of cells which are used and therefore have a colour has increased in each layer.

6.2. *Vertical Interactions (VDIF)*

Figure 11 shows the vertical interaction indicator results for the ANSPs. For Belgocontrol there are 0.068 hours of vertical interactions per flight hour.

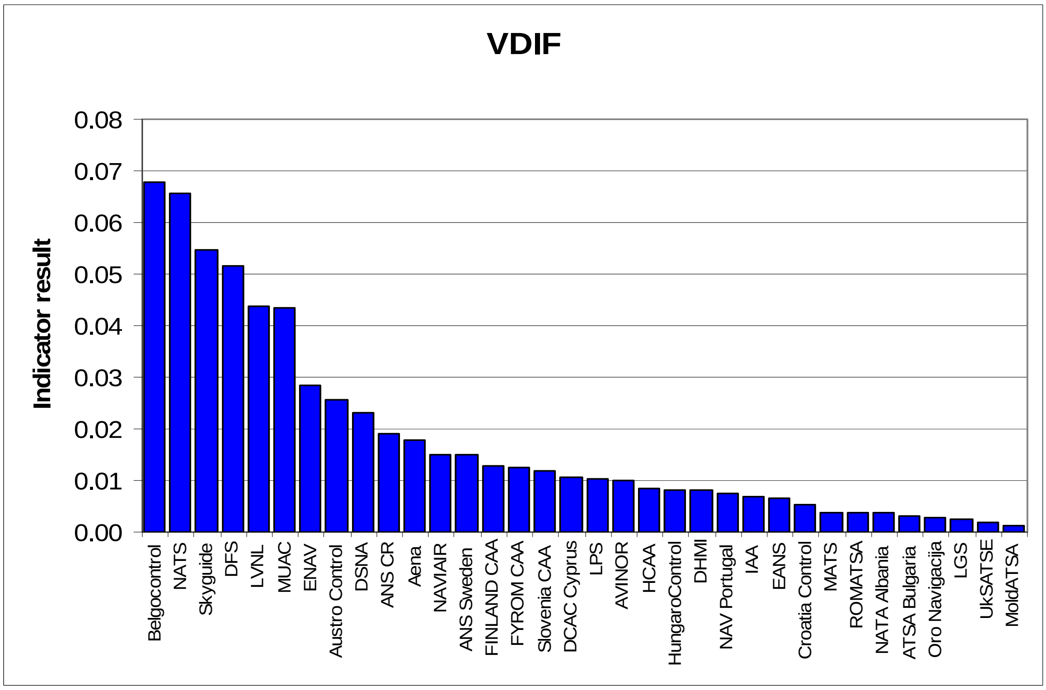


Figure 11: Vertical Interaction Indicator results

Belgocontrol has the highest number of vertical interactions per flight hour when compared to the other ANSPs. ENAV is considered as the average ANSP as its score is closest to the 0.028 European system value.

Belgocontrol, NATS, Skyguide DFS and LVNL all have high VDIF values which reflect the fact that they control traffic around major airports. MUAC also has a high value although it only controls traffic in the upper airspace (above FL245). However this is not surprising when considering that MUAC controls aircraft climbing from and descending to the major airports directly below them (e.g. Amsterdam, Brussels, Düsseldorf) and in their vicinity (e.g. London, Paris, Frankfurt).

ANSPs with high adjusted density also tend to have a high number of vertical interactions. This reflects that the number of interactions per flight is directly related to traffic numbers.

Figure 12 shows the relative VDIF (r_VDIF) which is the VDIF results divided by the adjusted density; the ANSP order is the same as in Figure 11. The results can also be interpreted as the percentage of aircraft pairs that are involved in vertical interactions.

Around 42% of the interactions that occurred in Belgocontrol were between aircraft with different attitudes. In contrast the percentage is only 3% for ATSA Bulgaria reflecting the fact that the traffic is mostly overflights.

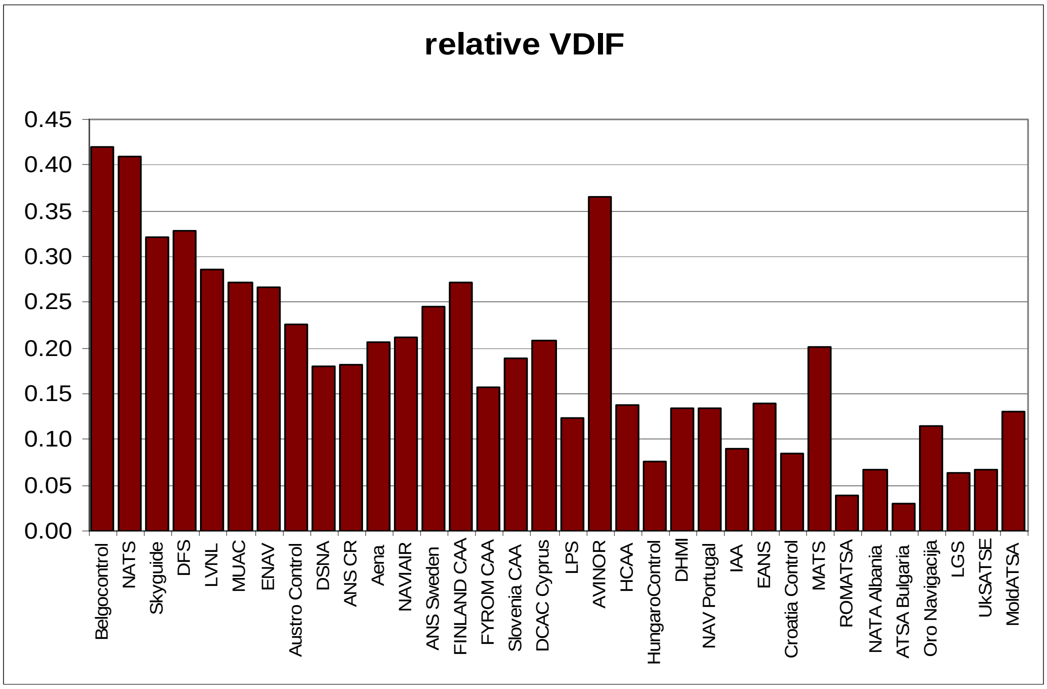


Figure 12: relative VDIF

6.3. Horizontal Interactions (HDIF)

Figure 13 shows the horizontal interaction indicator results for the ANSPs. For Skyguide there are 0.085 hours of horizontal interactions per flight hour.

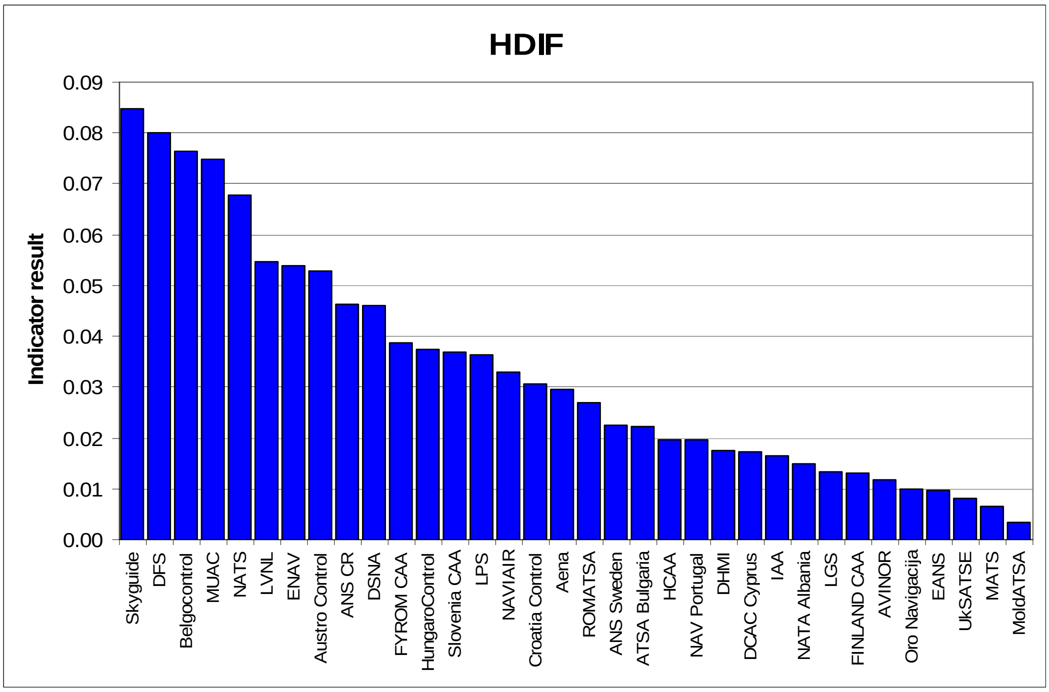


Figure 13: Horizontal Interaction Indicator results

Skyguide has the highest number of horizontal interactions when compared to the other ANSPs. DSNA is considered as the average ANSP as its score is closest to the 0.046 European system value.

Figure 14 shows the relative HDIF (r_HDIF) which is the HDIF results divided by the adjusted density; the ANSP order is the same as in Figure 13. The results can also be interpreted as the percentage of horizontal interactions, so around 59% of the interactions that occurred in Slovenia were between aircraft with different headings (above 20° difference). In EANS, IAA and ATSA Bulgaria it was around 20%.

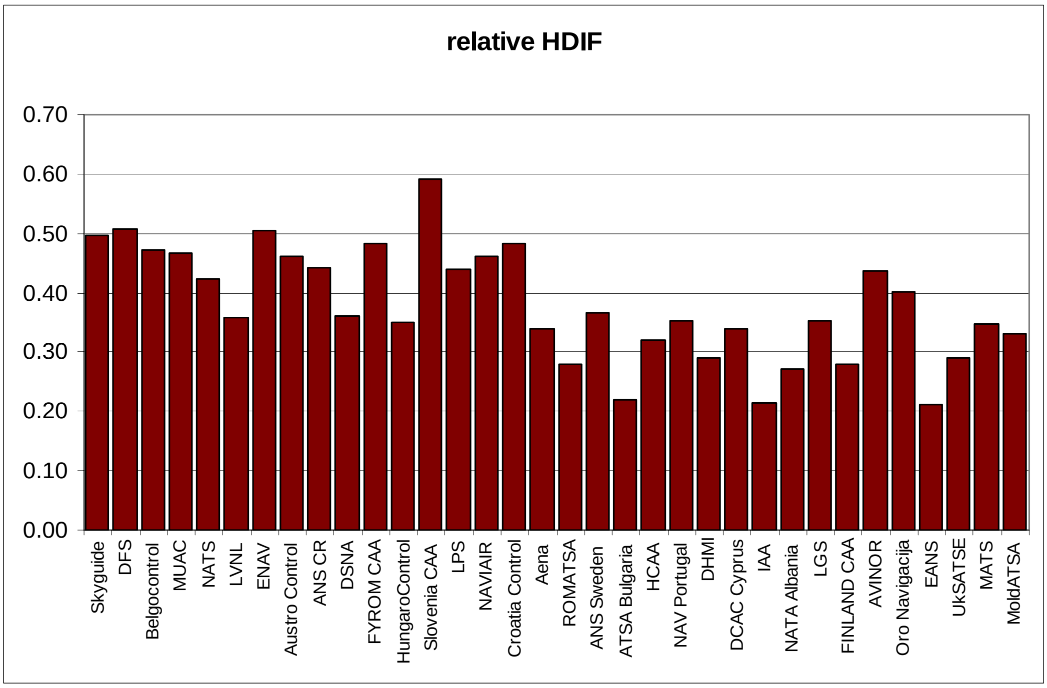


Figure 14: relative HDIF

6.4. Speed Interactions (SDIF)

Figure 15 shows the speed interaction indicator results for the ANSPs. For Belgocontrol there are 0.072 hours of speed interactions per flight hour.

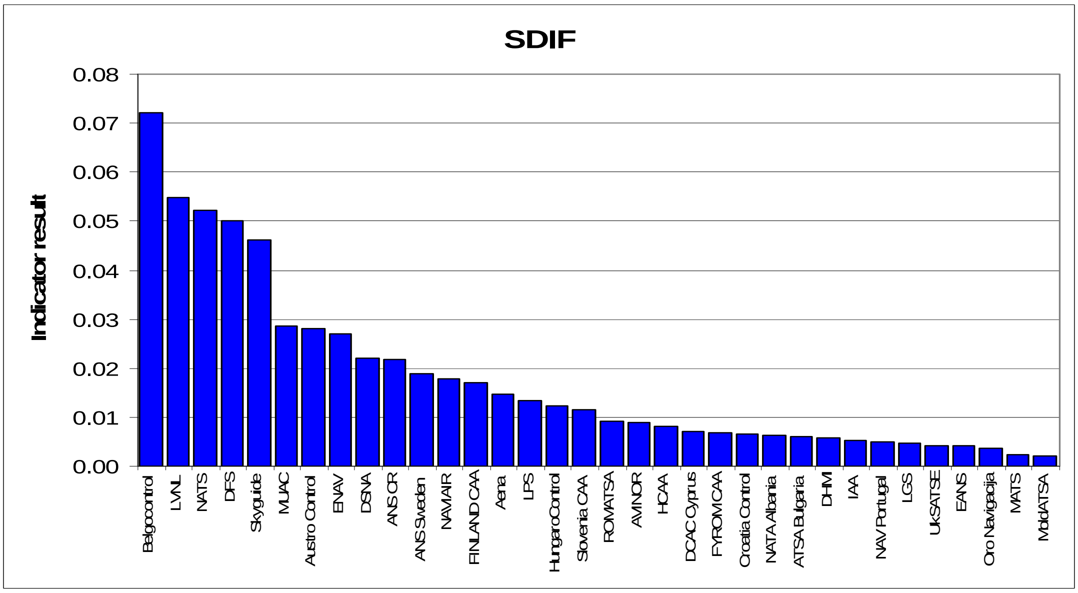


Figure 15: Speed Interaction Indicator results

Belgocontrol has the highest number of speed interactions. ENAV is considered as the average ANSP as its score is closest to the 0.025 European system value.

ANSPs with high adjusted density and a high VDIF also tend to have a lot of speed interactions because a large number of flights changing attitude will result in a wider range of speeds being flown.

ANSPs which have a large proportion of overflights will generally have fewer speed interactions than those which have large proportions of aircraft climbing and descending into airports.

Figure 16 shows the relative SDIF (r_SDIF) which is the SDIF results divided by the adjusted density; the ANSP order is the same as in Figure 15. The results can also be interpreted as the percentage of speed interactions, so around 45% of the interactions that occurred in Belgocontrol were between aircraft with different speeds (above 35 knots). In ATSA Bulgaria it was around 6%, again reflecting the high number of overflights.

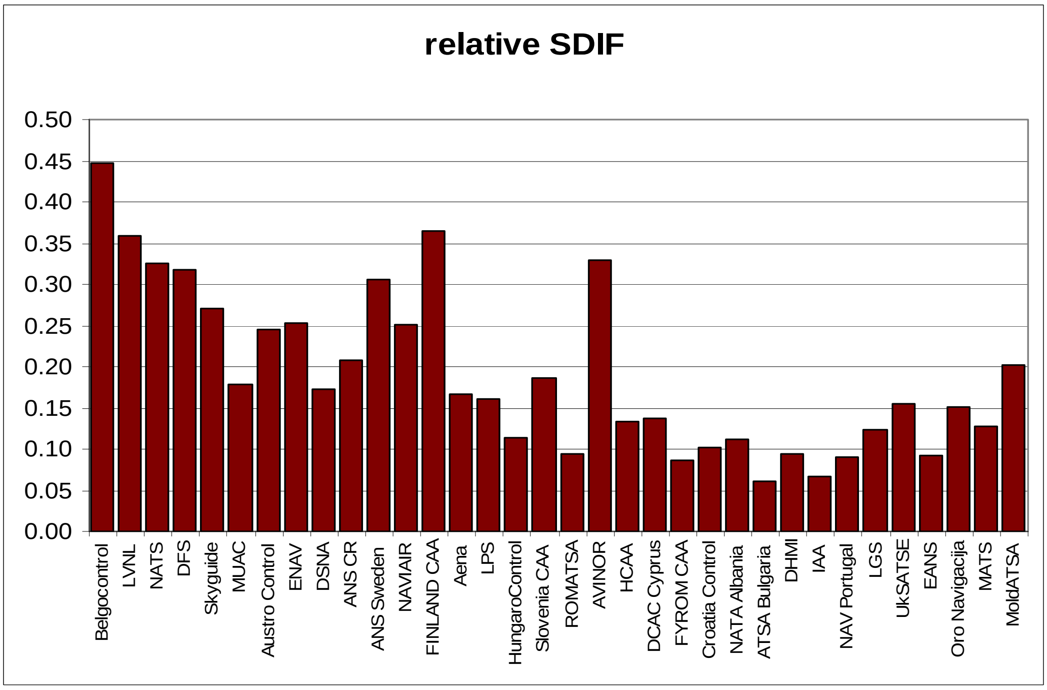


Figure 16: relative SDIF

6.5. Indicators and the number of flight hours

The results in this section show how the indicators vary with the traffic level (number of flight hours) for several ANSPs.

The results are shown for DSNA (Figure 17)[8] and ENAV (Figure 18) who had the highest average numbers of flight hours and for LPS (Figure 19) which had a significant difference in traffic between the two weeks. In all the graphs the bars represent the indicators and the blue dots represent the traffic expressed in flight hours.

It could be expected that an ANSP's complexity will increase with the number of flight hours where everything else is equal.

8 The scales on the graphs are not consistent, e.g. adjusted density goes to 0.18 for DSNA, 0.14 for ENAV and 0.12 for LPS. This is intentional. The aim of the graphs is to show the relationship between flight hours and the indicators for each ANSP, this link is less clearly shown when the indicator scales are forced to be consistent.

As can be seen in the following figures the four complexity indicators and the number of flight hours are quite closely linked in most cases.

There are, however, some interesting variations which could warrant further investigation. For example, differences between week-end and week days. Looking at the results for DSNA, it can be seen that Saturday 11 and Sunday 12 of January are the days when the traffic level is lowest. However those days have relatively high adjusted density compared to the week days. This may reflect a difference in traffic pattern and a higher concentration of traffic (in space or most probably in time).

Variations between the winter week and the summer week may also reveal differences in the traffic patterns between summer and winter traffic.

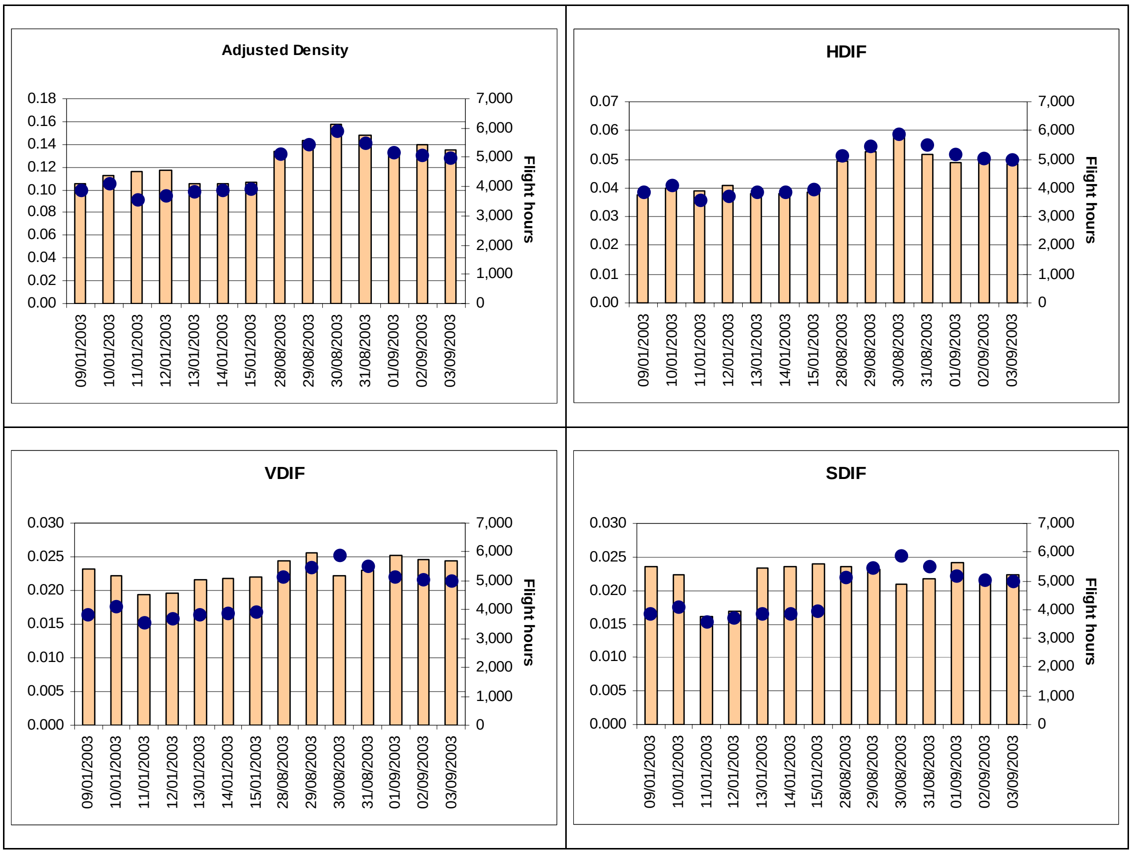


Figure 17: DSNA normalised indicators and the number of flight hours

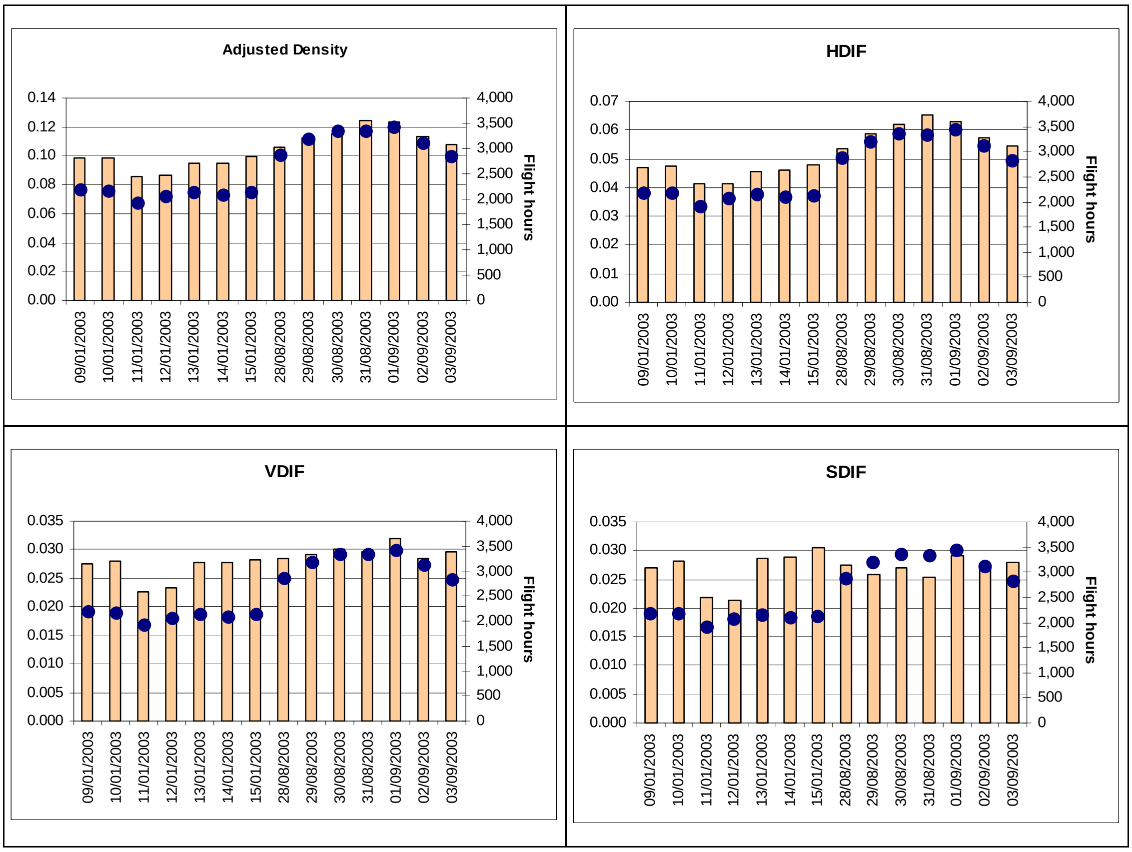


Figure 18: ENAV normalised indicators and the number of flight hours

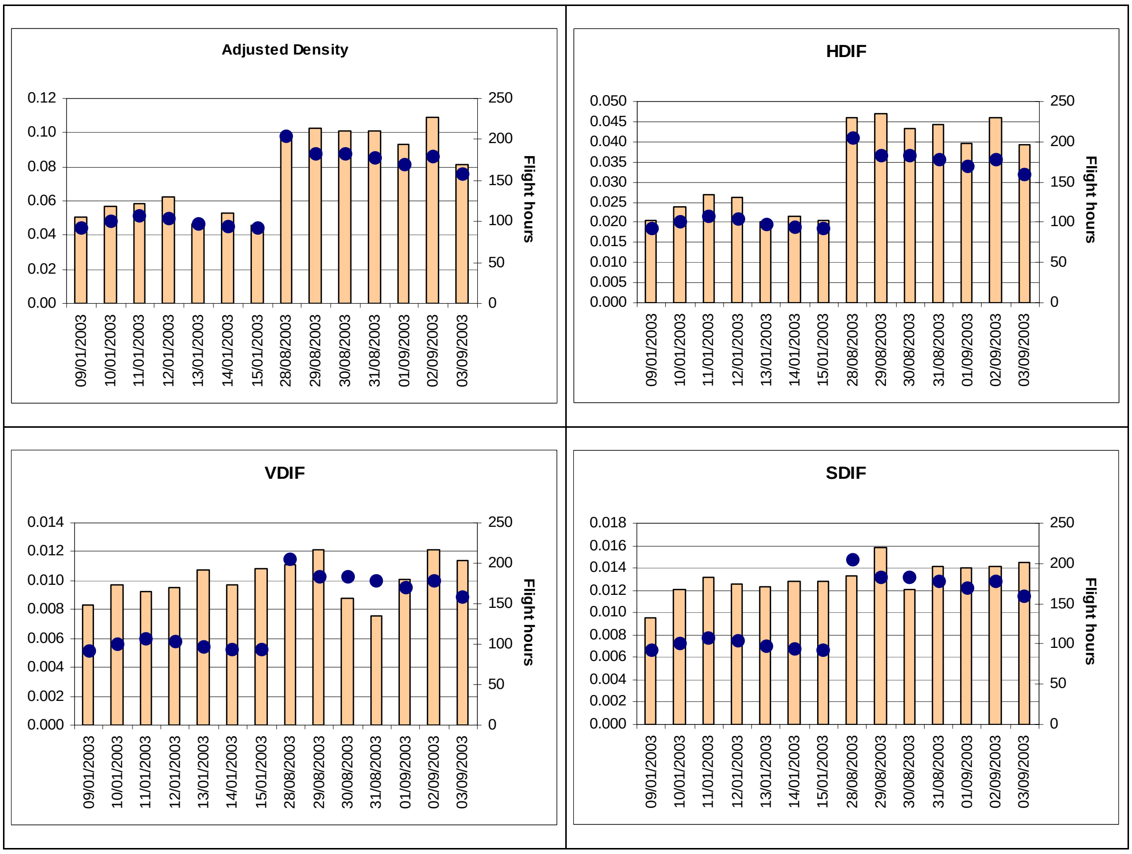


Figure 19: LPS normalised indicators and the number of flight hours

The step change seen in the flight hours in Figure 19 is reflected in the adjusted density and HDIF results. However it is not seen in the VDIF and SDIF results which, while variable, are more consistent across the two weeks.

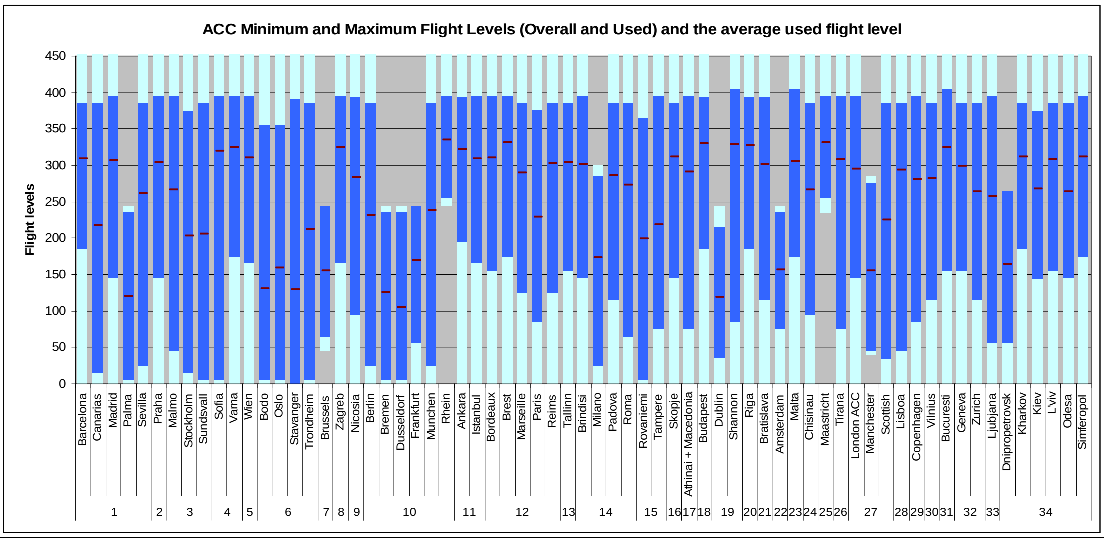
6.6. Indicators related to altitude

According to the set of indicators defined by the Working Group lower airspace tends to be more complex. In order to further investigate the behaviour of our indicators, complementary studies were conducted to see if there was any kind of correlation between the altitude and the complexity as measured with the selected indicators.

It appears that throughout the whole of Europe, measured complexity decreases with altitude.

It should be noted, however, that the focus of the present study was on en-route complexity. The Working Group agreed that the indicators were valid for ANSPs and ACCs but that further work would be needed to develop complexity indicators for terminal areas.

Figure 20 shows the overall minimum and maximum flight levels available within each ACC; the pale blue columns. The dark blue columns represent the 'used' flight levels which contain 90% of the traffic. The red line represents the average used flight level[9].



1	Aena	6	AVINOR	11	DHMI	16	FYROM CAA	21	LPS	26	NATA Albania	31	ROMATSA
2	ANS CR	7	Belgocontrol	12	DSNA	17	HCAA	22	LVNL	27	NATS	32	Skyguide
3	ANS Sweden	8	Croatia Control	13	EANS	18	HungaroControl	23	MATS	28	NAV Portugal	33	Slovenia CAA
4	ATSA Bulgaria	9	DCAC Cyprus	14	ENAV	19	IAA	24	MoldATSA	29	NAVIAIR	34	UkSATSE
5	Austro Control	10	DFS	15	FINLAND CAA	20	LGS	25	MUAC	30	Oro Navigacija		

Figure 20: ACC Minimum and Maximum Flight levels

The average used flight levels provide more information on where the traffic actually flew and aids the comparison between ACCs. For example, the four AVINOR ACCs have average used flight levels below FL220 while the five DSNA ACCs have values above FL220. In comparison the six DFS ACCs have a wide range of average used flight levels.

Care should be taken when comparing 2 ACCs, even if their airspace ranges are similar the traffic patterns often differ, as shown in Figure 20. This care is especially important when ACCs operate at different flight levels and particularly if the area of responsibility of one of the ACCs extends into the terminal area.

9 The average used flight level is the average flight level of all aircraft in the ACC. It is calculated using 1000 feet high cells and taking the average of the flight level at the centre of the cells weighted by the total flight hours in each cell.

Complexity by flight level

This complementary study looks at the indicator results by flight level. To do this all the data from each grid layer is allocated to the centre level of the cells so that the complexity in layer FL95 - FL125 is allocated to FL110. Each layer covers the entire ECAC area.

The following graphs present the results: flight levels are on the horizontal axis and values of the different indicators on the vertical axis. As mentioned above the flight levels correspond to the centre of a cell.

Adjusted Density and Flight hours by flight level over the ECAC area

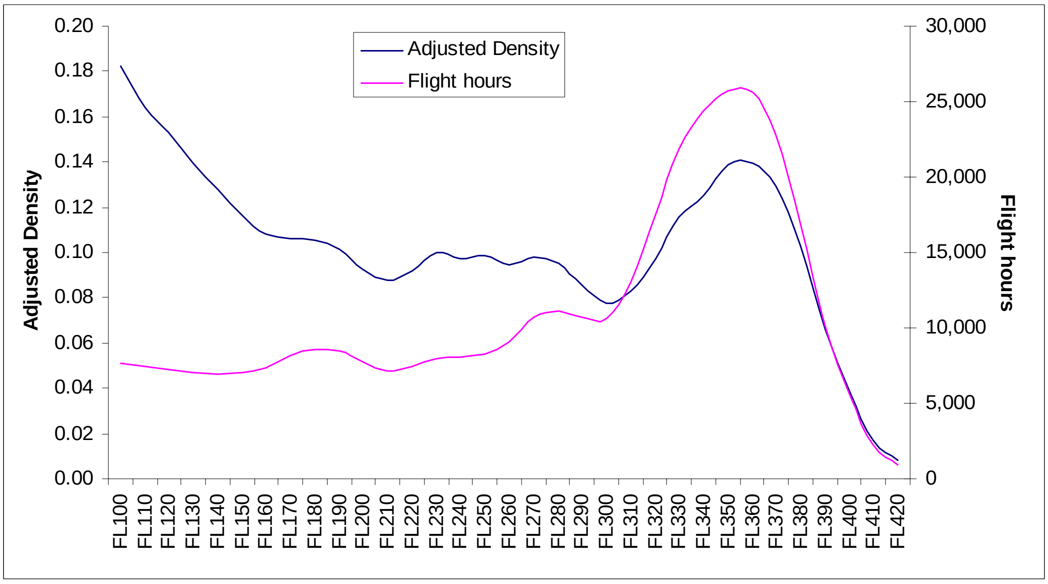


Figure 21: Adjusted Density and Flight hours by flight level

Figure 21 clearly shows that there is more traffic in the upper (cruising) levels but they are more dispersed.

The lower levels have less traffic but this traffic is concentrated around the airports.

The adjusted density varies with altitude; it is highest in lower airspace. The values then fall before peaking at around FL360; this coincides with the peak in flight hours.

Figure 22 shows that horizontal, vertical and speed interactions tend to decrease with altitude until FL300. Above this level HDIF increases sharply like adjusted density while VDIF and SDIF continue to fall. This reflects the fact that most flights at those levels are cruising, so there will be more horizontal interactions than speed or vertical interactions.

Vertical, Horizontal and Speed Interactions over the ECAC area

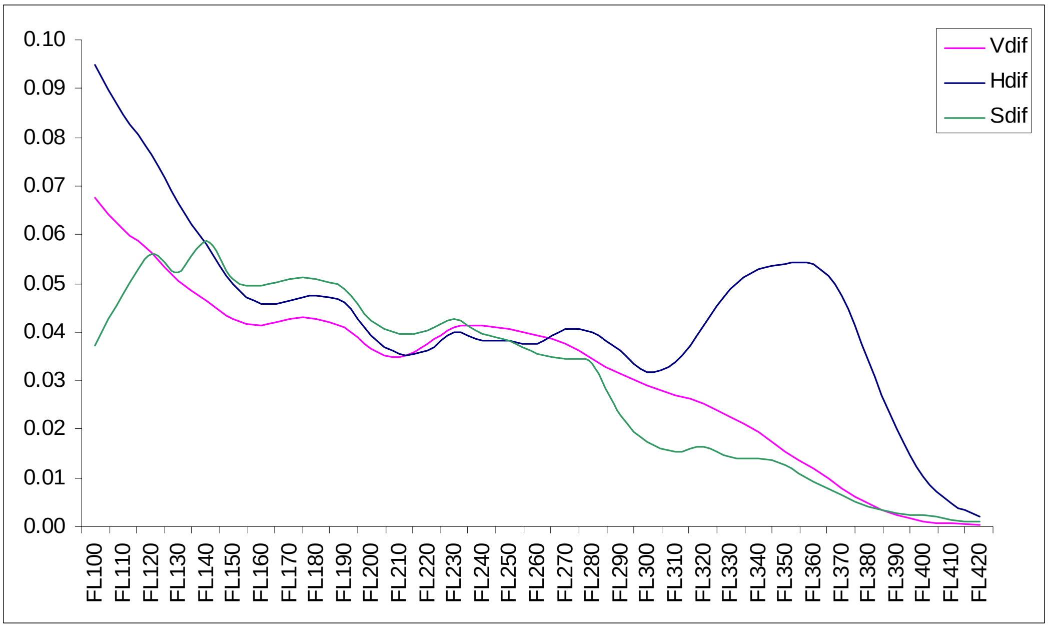


Figure 22: VDIF, HDIF and SDIF by flight level

Complexity Score over the ECAC area

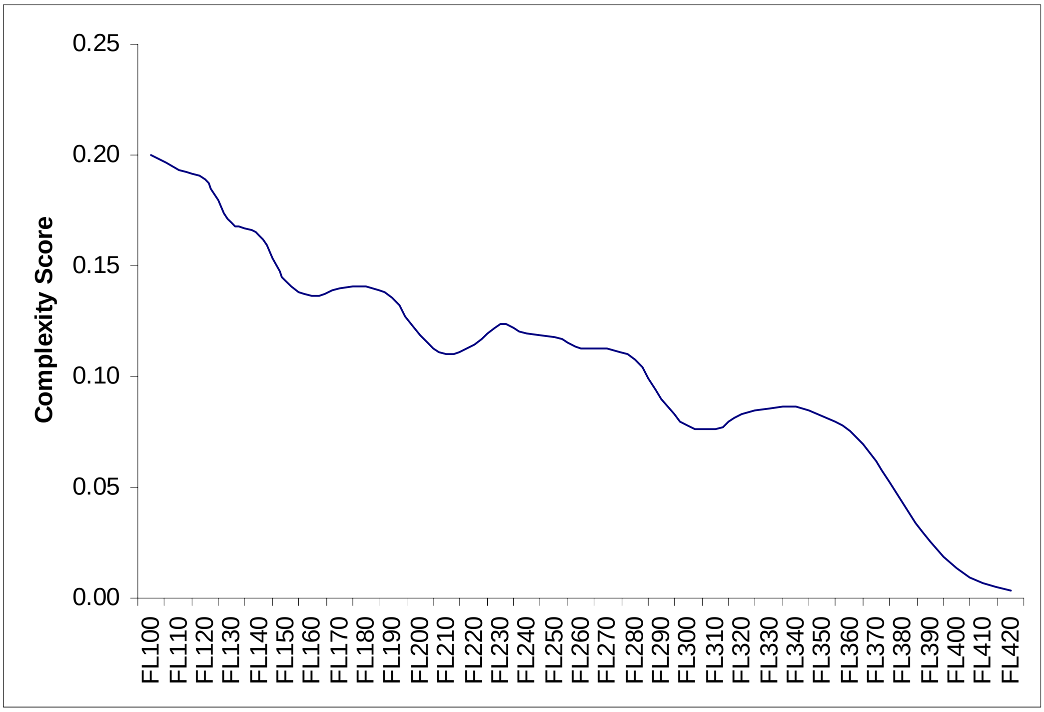


Figure 23: Complexity Score

Figure 23 shows that the complexity score tends to decrease with altitude although there are two noticeable drops around FL210 and FL300. The trends in the individual indicator curves are reflected in the complexity score curve.

6.7. Complexity Score

Figure 24 shows the ANSP complexity scores (adjusted density x structural index).

Belgocontrol has the highest complexity score when compared to the other ANSPs. DSNA is considered as the average ANSP as its score is closest to the 0.10 European system value. It should be noted that Belgocontrol and LVNL are only responsible for the lower airspace. Inversely MUAC is only responsible for the upper airspace.

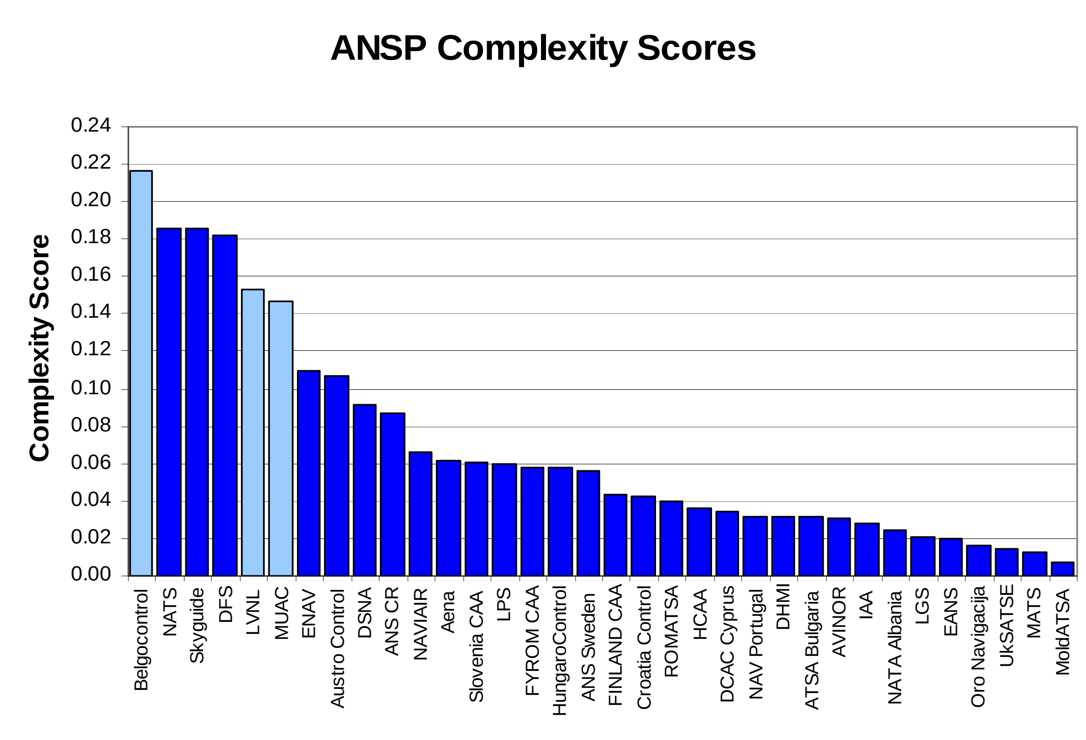


Figure 24: ANSP Complexity Scores

It should also be noted that while two ANSPs may have similar overall scores once the indicators are combined there is no way to see how the different indicators contributed to the value. Therefore the publication of the complexity score should complement and not supersede the publication of the individual complexity indicators.

As described in 4.8, the indicators look at different aspects of the traffic. The adjusted density describes the traffic volume while the r_DIF indicators describe the structural aspects of the traffic flows.

The following figure shows how the structural index and adjusted density affect the complexity scores of the ANSPs.

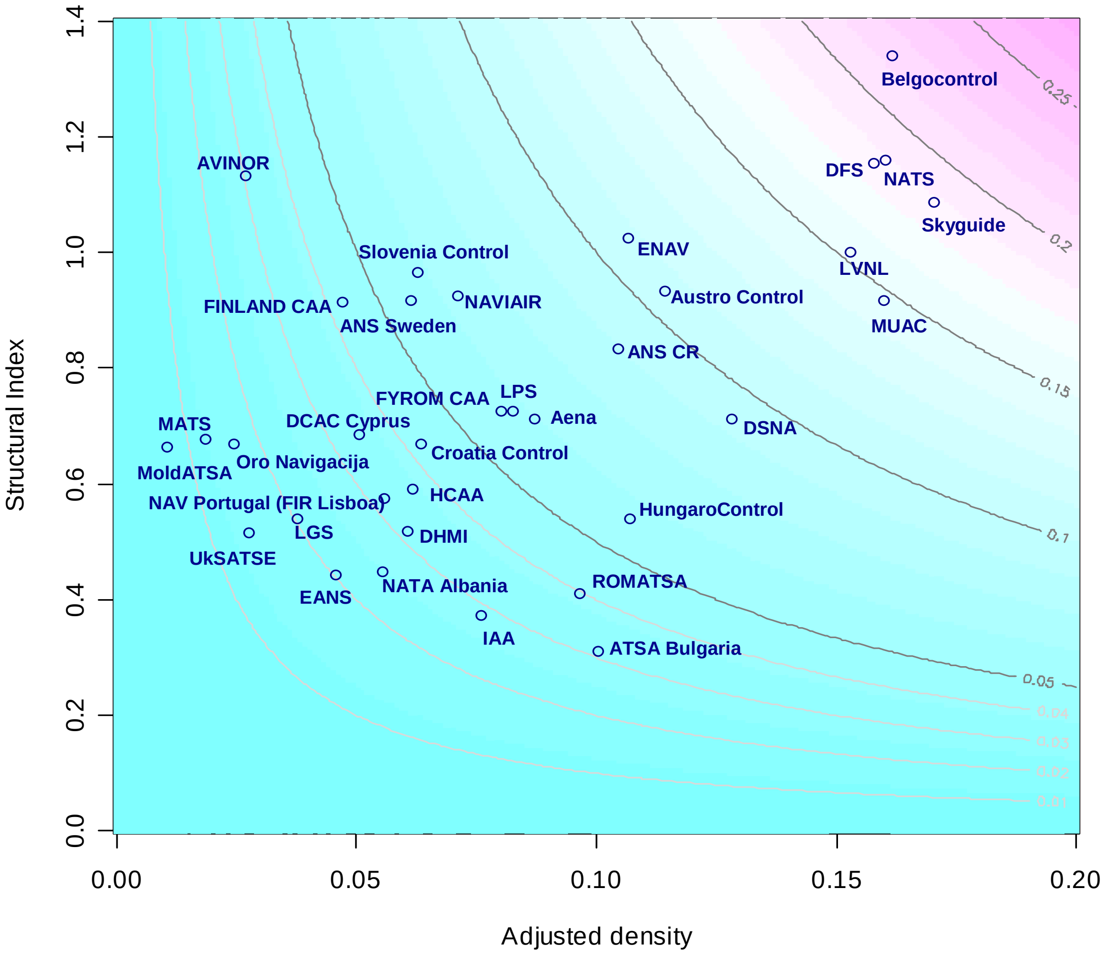


Figure 25: ANSP Complexity Map

Figure 25 shows how different ANSPs are influenced by adjusted density and the structural index. The coloured lines in the graph show points of equal complexity, i.e. all points along the pink line result in a complexity score of 0.05.

For example, ATSA Bulgaria and AVINOR both have complexity scores of 0.031 but while complexity in ATSA Bulgaria is much more heavily influenced by adjusted density than by the structural index, the reverse is true for AVINOR.

The values in Figure 24 can be calculated by multiplying each ANSPs adjusted density value by their structural index as found in Figure 25.

Figure 26 shows ANSP complexity scores calculated for the upper and lower airspace; the division is FL245. The figure shows that for the majority of ANSPs the lower airspace is more complex than the upper airspace. The ANSPs on the left of the graph tend to have the highest scores in both areas. Some ANSPs show a large difference between the two sections of airspace, e.g. NATS and IAA.

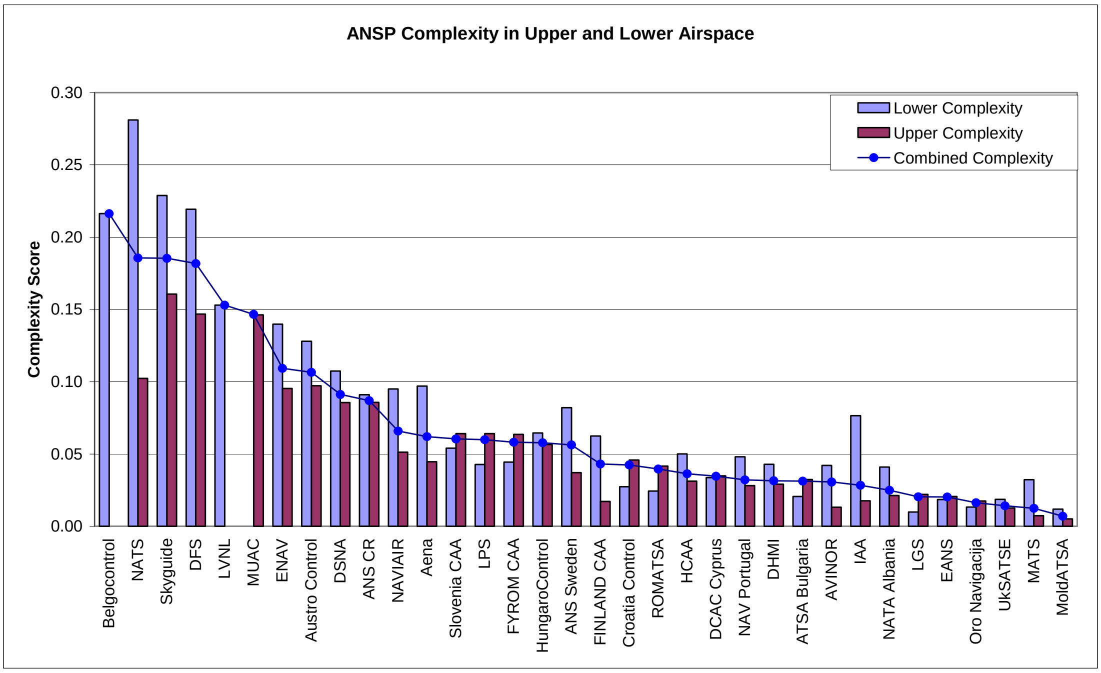


Figure 26: ANSP Complexity in Upper and Lower Airspace

6.8. ANSP Results Table

Table 4 contains the complexity results at ANSP level ordered by the column 'complexity score'. It includes the:

- country,
- ANSP name,
- complexity score,
- rank position,
- adjusted density,
- structural index (sum of the r_DIF indicators),
- individual relative indicator results,
- average number of daily flights.

Country	ANSP	Complexity Score	Rank	Adjusted Density	Structural Index	relative VDIF	relative HDIF	relative SDIF	Average Daily Flights
		a x b		a	b (c+d+e)	c	d	e	
Belgium	Belgocontrol	**0.216**	**1**	0.162	1.34	0.420	0.472	0.446	1500
United Kingdom	NATS	**0.186**	**2**	0.160	1.16	0.410	0.423	0.326	6075
Switzerland	Skyguide	**0.185**	**3**	0.170	1.09	0.321	0.497	0.270	3004
Germany	DFS	**0.182**	**4**	0.158	1.15	0.328	0.507	0.318	6467
Netherlands	LVNL	**0.153**	**5**	0.153	1.00	0.285	0.357	0.358	1486
Maastricht	MUAC	**0.147**	**6**	0.160	0.92	0.271	0.467	0.179	3550
Italy	ENAV	**0.109**	**7**	0.107	1.02	0.266	0.505	0.253	4025
Austria	Austro Control	**0.107**	**8**	0.114	0.93	0.225	0.462	0.246	1848
France	DSNA	**0.091**	**9**	0.128	0.71	0.179	0.360	0.172	7064
Czech Republic	ANS CR	**0.087**	**10**	0.104	0.83	0.182	0.443	0.209	1200
Denmark	NAVIAIR	**0.066**	**11**	0.071	0.92	0.212	0.462	0.250	1538
Spain	Aena	**0.062**	**12**	0.087	0.71	0.206	0.339	0.167	3858
Slovenia	Slovenia CAA	**0.060**	**13**	0.063	0.97	0.189	0.591	0.186	404
Slovak Republic	LPS	**0.060**	**14**	0.083	0.72	0.123	0.440	0.161	650
FYROM	FYROM CAA	**0.058**	**15**	0.080	0.73	0.158	0.482	0.086	287
Hungary	HungaroControl	**0.058**	**16**	0.107	0.54	0.076	0.350	0.114	1311
Sweden	ANS Sweden	**0.056**	**17**	0.061	0.92	0.246	0.367	0.306	1729
Finland	FINLAND CAA	**0.043**	**18**	0.047	0.91	0.271	0.278	0.364	626
Croatia	Croatia Control	**0.043**	**19**	0.064	0.67	0.085	0.482	0.102	653
Romania	ROMATSA	**0.040**	**20**	0.097	0.41	0.038	0.278	0.094	934
Greece	HCAA	**0.036**	**21**	0.062	0.59	0.138	0.320	0.133	1392
Cyprus	DCAC Cyprus	**0.035**	**22**	0.051	0.69	0.208	0.339	0.138	566
Portugal	NAV Portugal	**0.032**	**23**	0.056	0.58	0.133	0.353	0.089	1146
Turkey	DHMI	**0.032**	**24**	0.061	0.52	0.134	0.290	0.095	1334
Bulgaria	ATSA Bulgaria	**0.031**	**25**	0.100	0.31	0.030	0.221	0.061	945
Norway	AVINOR	**0.031**	**26**	0.027	1.13	0.366	0.438	0.329	1198
Ireland	IAA	**0.028**	**27**	0.076	0.37	0.090	0.215	0.067	1222
Albania	NATA Albania	**0.025**	**28**	0.055	0.45	0.067	0.271	0.112	271
Latvia	LGS	**0.020**	**29**	0.038	0.54	0.064	0.352	0.123	290
Estonia	EANS	**0.020**	**30**	0.046	0.44	0.140	0.210	0.092	254
Lithuania	Oro Navigacija	**0.016**	**31**	0.024	0.67	0.115	0.402	0.151	198
Ukraine	UkSATSE	**0.014**	**32**	0.028	0.51	0.068	0.292	0.156	648
Malta	MATS	**0.013**	**33**	0.018	0.68	0.201	0.348	0.128	195
Moldova	MoldATSA	**0.007**	**34**	0.010	0.66	0.131	0.330	0.202	56

Table 4: ANSP Results Table

Table 4 summarises the complexity indicator results for both weeks of data. Tables for each week can be found in Annex 9.

The results have been rounded to three decimal places for convenience; however when two ANSPs have the same score their ranks have not been averaged because there are differences in the un-rounded scores.

Belgocontrol has the highest score, 0.216 and is ranked number 1. The green columns show the three relative DIF values which are summed to produce the structural index. Belgocontrol has very high scores across all the indicators.

Belgocontrol, LVNL and MUAC have high positions in the rankings. However, it should be noted that Belgocontrol and LVNL only control aircraft up to FL245, and that MUAC only controls aircraft from FL245 and above. In general the other ANSPs control traffic across all flight levels, see Figure 20.

Comparisons can be made between ANSPs with similar rankings, for example, Hungarocontrol is 16th and lies between FYROM CAA, 15th and ANS Sweden, 17th. The main difference between the three ANSPs is that Hungarocontrol has a higher density but lower structural complexity. This reflects the high proportion of overflights in Hungarocontrol airspace.

6.9. ACC Results Table

Table 5 provides the ACC results for both weeks of data; it has essentially the same layout as Table 4. Tables for each week of data can be found in Annex 10.

The table can be interpreted in the same way as the ANSP table. However it also shows the results for the different ACCs which make up an ANSP. For example, DFS has the highest ranked ACC (Frankfurt) but is the fourth ranked ANSP. This is due to the ANSP score being based on six ACC's[10]. While four of the six rank in the top eight ACC's the other two are in positions 14 and 21. This reflects that the indicators are not showing the peak complexity managed by an ANSP but the complexity averaged over all their airspace, both the more and less complex areas.

In contrast, Belgocontrol is the highest ranked ANSP but only the third highest ranked ACC. This reflects that Belgocontrol only has one ACC and its high score is not offset by less complex areas. This is also the case for Skyguide which is the third highest ranked ANSP while its ACC's are ranked seventh and ninth.

NATS is ranked 2nd in the ANSP ranking. This is influenced by Manchester ACC ranked 2nd, London AC ranked 12th, Scottish ranked 27th and also by the London TC airspace which is not considered as an ACC within this study.

The IAA is 27th in the ANSP ranking; this is influenced by Dublin ACC which is ranked 17th and Shannon ACC which is 54th.

As previously mentioned, care should be taken when comparing 2 ACCs operating at different flight levels, in particular if the area of responsibility of one the ACCs extends into the terminal area, see Figure 20.

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10 The ANSP score also includes terminal and FIS airspace above FL85.

ANSP	ACC	Complexity Score	Rank	Adjusted Density	Structural Index	relative VDIF	relative HDIF	relative SDIF	Average Daily Flights
		a x b		a	b (c+d+e)	c	d	e	
DFS	Frankfurt	**0.263**	**1**	0.19	1.39	0.43	0.50	0.46	2345
NATS	Manchester	**0.221**	**2**	0.15	1.50	0.46	0.54	0.50	1436
Belgocontrol	Brussels	**0.216**	**3**	0.16	1.34	0.42	0.47	0.45	1315
DFS	Dusseldorf	**0.208**	**4**	0.14	1.44	0.41	0.56	0.46	1270
ENAV	Milano	**0.206**	**5**	0.15	1.35	0.40	0.57	0.38	1686
DFS	Munchen	**0.197**	**6**	0.17	1.13	0.35	0.45	0.33	2504
Skyguide	Zurich	**0.189**	**7**	0.16	1.18	0.37	0.48	0.33	1872
DFS	Rhein	**0.182**	**8**	0.19	0.95	0.22	0.54	0.18	2261
Skyguide	Geneva	**0.164**	**9**	0.17	0.94	0.24	0.50	0.20	1585
LVNL	Amsterdam	**0.154**	**10**	0.15	1.00	0.29	0.36	0.36	1365
MUAC	Maastricht UAC	**0.147**	**11**	0.16	0.92	0.27	0.47	0.18	3550
NATS	London AC	**0.138**	**12**	0.14	0.98	0.36	0.35	0.27	4870
ENAV	Padova	**0.122**	**13**	0.11	1.12	0.28	0.57	0.26	1542
DFS	Bremen	**0.121**	**14**	0.08	1.55	0.44	0.60	0.52	904
DSNA	Reims	**0.112**	**15**	0.14	0.82	0.24	0.39	0.20	2038
DSNA	Paris	**0.110**	**16**	0.14	0.81	0.25	0.27	0.29	3270
IAA	Dublin	**0.109**	**17**	0.09	1.18	0.43	0.46	0.28	509
Aena	Palma	**0.097**	**18**	0.11	0.92	0.27	0.33	0.32	663
Austro Control	Wien	**0.096**	**19**	0.11	0.86	0.21	0.46	0.20	1474
ENAV	Roma	**0.091**	**20**	0.10	0.91	0.23	0.46	0.21	2374
DFS	Berlin	**0.088**	**21**	0.08	1.09	0.29	0.48	0.32	1665
ANS CR	Praha	**0.084**	**22**	0.10	0.81	0.17	0.44	0.20	1189
DSNA	Marseille	**0.084**	**23**	0.10	0.81	0.21	0.40	0.20	2557
DSNA	Brest	**0.077**	**24**	0.14	0.57	0.11	0.38	0.08	2097
ANS Sweden	Stockholm	**0.075**	**25**	0.07	1.10	0.33	0.36	0.41	1023
DSNA	Bordeaux	**0.074**	**26**	0.12	0.60	0.13	0.35	0.12	1990
NATS	Scottish	**0.070**	**27**	0.08	0.88	0.28	0.29	0.31	1468
Slovenia CAA	Ljubjana	**0.061**	**28**	0.06	0.96	0.19	0.59	0.19	397
LPS	Bratislava	**0.060**	**29**	0.08	0.72	0.12	0.44	0.16	634
FYROM CAA	Skopje	**0.059**	**30**	0.08	0.71	0.15	0.48	0.08	278
Aena	Barcelona	**0.057**	**31**	0.08	0.72	0.23	0.35	0.14	1720
HungaroControl	Budapest	**0.055**	**32**	0.11	0.51	0.06	0.34	0.10	1226
NAVIAIR	Copenhagen	**0.052**	**33**	0.06	0.85	0.19	0.47	0.20	1237
ENAV	Brindisi	**0.052**	**34**	0.08	0.68	0.10	0.45	0.13	820
Aena	Madrid	**0.049**	**35**	0.09	0.54	0.13	0.30	0.11	2258
ANS Sweden	Malmo	**0.044**	**36**	0.06	0.72	0.17	0.35	0.20	1170
Croatia Control	Zagreb	**0.043**	**37**	0.06	0.66	0.08	0.48	0.10	618
DHMI	Istanbul	**0.041**	**38**	0.09	0.45	0.12	0.24	0.09	937
Avinor	Oslo	**0.040**	**39**	0.04	1.02	0.33	0.41	0.28	707
ROMATSA	Bucuresti	**0.039**	**40**	0.10	0.40	0.04	0.28	0.09	932
Aena	Sevilla	**0.038**	**41**	0.06	0.60	0.21	0.27	0.12	861
ATSA Bulgaria	Sofia	**0.036**	**42**	0.13	0.29	0.02	0.23	0.05	562
DCAC Cyprus	Nicosia	**0.035**	**43**	0.05	0.69	0.21	0.34	0.14	565
Finland CAA	Tampere	**0.034**	**44**	0.04	0.85	0.28	0.24	0.33	485
HCAA	Athinai+Makedonia	**0.032**	**45**	0.06	0.54	0.12	0.32	0.10	1332
NAV Portugal	Lisboa	**0.031**	**46**	0.06	0.55	0.12	0.35	0.09	922
Aena	Canarias	**0.026**	**47**	0.05	0.57	0.20	0.24	0.13	740
DHMI	Ankara	**0.026**	**48**	0.05	0.52	0.11	0.32	0.09	935
NATA Albania	Tirana	**0.025**	**49**	0.06	0.45	0.07	0.27	0.11	271
ATSA Bulgaria	Varna	**0.022**	**50**	0.06	0.38	0.08	0.19	0.11	372
LGS	Riga	**0.021**	**51**	0.04	0.52	0.06	0.35	0.12	267
EANS	Tallinn	**0.020**	**52**	0.05	0.43	0.14	0.21	0.08	213
Avinor	Bodo	**0.019**	**53**	0.01	1.30	0.48	0.39	0.44	297
IAA	Shannon	**0.019**	**54**	0.07	0.26	0.04	0.18	0.04	862
Oro Navigacija	Vilnius	**0.016**	**55**	0.02	0.67	0.12	0.40	0.15	193
Avinor	Stavanger	**0.015**	**56**	0.01	1.20	0.36	0.50	0.33	413
UKSATSE	L'viv	**0.015**	**57**	0.02	0.64	0.04	0.43	0.16	200
UKSATSE	Simferopol	**0.015**	**58**	0.04	0.35	0.01	0.25	0.08	318
Avinor	Trondheim	**0.015**	**59**	0.02	0.92	0.32	0.37	0.23	269
UKSATSE	Dnipropetrovsk	**0.012**	**60**	0.01	0.89	0.29	0.20	0.40	52
UKSATSE	Kiev	**0.012**	**61**	0.02	0.63	0.15	0.25	0.23	284
ANS Sweden	Sundsvall	**0.012**	**62**	0.01	0.80	0.21	0.35	0.24	232
UKSATSE	Odesa	**0.010**	**63**	0.02	0.63	0.07	0.41	0.15	112
UKSATSE	Kharkov	**0.009**	**64**	0.02	0.39	0.07	0.21	0.11	150
MATS	Malta	**0.009**	**65**	0.02	0.55	0.14	0.29	0.11	195
Finland CAA	Rovaniemi	**0.008**	**66**	0.01	0.99	0.40	0.42	0.16	90
MoldATSA	Chisinau	**0.007**	**67**	0.01	0.66	0.13	0.33	0.20	56

Table 5: ACC Results Table

Annex 11 includes a table combining these ACC results with the selected terminal area results.

7. Sensitivity Analysis of the Grid

As described in section 4.1 the indicators are calculated using a grid comprised of 20nm x 20nm x 3000ft x 1hr cells. Twelve grids are used to reduce the boundary effects.

During the development of the indicators different aspects of the grid were investigated to see how they affected the results.

7.1. Cell Dimensions

Horizontal

Tests were carried out with cells of 20nm, 40nm and 60nm. The results showed that with the larger cell sizes the smaller ACCs were covered by significantly fewer cells and that the ACC boundaries were not well matched by the cell boundaries. For these reasons the 20nm cell size was chosen.

Vertical

Simulations were run with 4000ft, 3000ft and 2000ft cells (all 20nm horizontally). The results were quite consistent. However, the 3000ft cell was chosen as it simplified the allocation of cells to ANSPs. For example, at the boundary between MUAC and Belgocontrol a 4000ft cell from FL225 to FL265 would be allocated to FL245 and the centre of the cell would not lie within either ANSP. However a 3000ft cell from FL225 to FL255 would be allocated to FL240, clearly in Belgocontrol, and one from FL235 to FL265 would be allocated to FL250, clearly in MUAC.

Temporal

Both the EEC and SDER looked at the length of the time step. SDER looked at 5, 10, 20 and 60 minute periods, while the EEC looked at 20 minutes, 60 minutes and 24 hours.

For the first study the different time steps were shown to have very little impact on the ranking of the centres. The smaller time steps also increased the required computation time.

In the second study the 20 minute, 60 minute and 24 hour time step results were highly correlated.

However the use of a 24 hour time step did not take into account the distribution of traffic across the day; a factor that can vary significantly between ACCs.

On the other hand, the 20 minute step was more sensitive to temporal events while also increasing the computing time.

The use of a 60 minute time step appears, therefore, to be a good compromise between accuracy on one side and processing time on the other. It allows the daily cycle to be captured and taken into account while maintaining a macroscopic view.

7.2. Grid Shifts

Horizontal

When looking at the effect of moving the grid horizontally, it was noticed that the results may vary considerably from one grid position to another. For example, the indicators were computed for a certain grid position, then the grid was shifted 7nm west and the indicators were computed again. This produced new scores with a standard deviation (new scores – old scores) of 0.65. There were variations in the ranked order of the ACCs with a maximum change in the ranked position of 16 places (with 103 ACCs and terminal areas[11]).

A way to reduce this variability in the results is to consider the value of an indicator as the average of the values obtained after several horizontal shifts of the grid (4 in this study). The indicator value is then far less dependant on the initial position of the grid. When this was performed on the above example the standard deviation was reduced to 0.30, with a maximum change in the rankings of 7 places.

It follows that the indicator value will be reliable, whatever initial horizontal position of the grid is chosen.

Vertical

Vertical shifts of the grid were introduced to improve the robustness of the grid against any future airspace changes which may include airspace splits at different levels from today.

Temporal

The grids are placed on the following temporal axis: 0h00→0h59; 1h00→1h59; 2h00→2h59; etc. Results were produced using starting times of 0h20 and at 0h40 to investigate the impact of the time dimension boundary effect.

The results did not change significantly showing that the boundary effect of the time dimension was negligible. Hence, there was no need to introduce a temporal shift to the grid.

[11] This study was carried out while both ACC and selected terminal areas results were being calculated; subsequently selected terminal area results have only been produced for Table 9 in Annex 7 and Table 15 in Annex 11.

8. Sensitivity Analysis of the Indicators

The following results were produced to investigate the sensitivity of the indicators. For example, how did the results change if a horizontal interaction was defined as being greater than 30° instead of 20°?

The sensitivity analysis was performed on one day's data; that from 03/09/03.

The sensitivity analyses were performed before the decision to use 3000ft cells was taken: these results relate to 4000ft cells. However, a comparison between the nominal values used in both the 3000ft and 4000ft cells show a high level of correlation; see Figure 35 in Annex 6.

8.1. Definition of vertical interactions

A flight is defined as in cruise unless its climb/descent rate is above 500ft per minute; the nominal value. In order to test the sensitivity of the indicator to the value of this parameter the results were recalculated using 750ft per minute, the high value, and 250ft per minute, the low value.

The number of aircraft considered to be in evolution is higher when the cut-off value is lower, e.g. more flights are considered to be in evolution when the 250ft per minute value is used.

As a result the number of vertical interactions increases in the upper airspace due to a higher number of interactions between cruising aircraft and climbing/descending flights. However, the number of vertical interactions slightly decreases in the lower airspace where most of the traffic is in evolution.

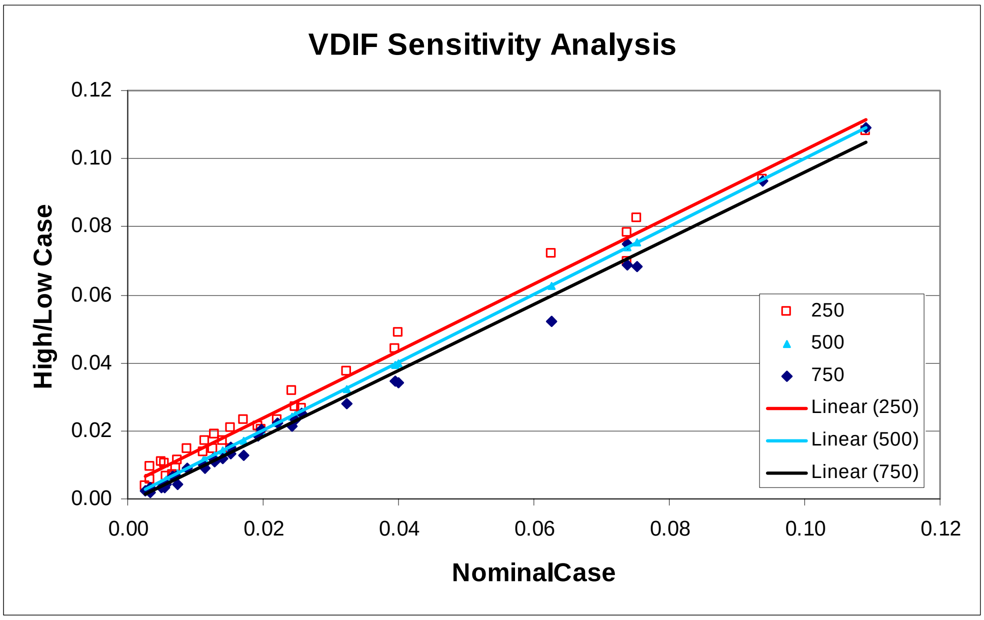


Figure 27: VDIF Sensitivity Analysis

Figure 27 shows that the use of 750ft per minute generally produced lower results than using 500ft per minute and that, as expected, 250ft per minute produced the highest results. However the band of difference between the highest and lowest values is quite narrow.

Figure 28 shows which ANSPs were most heavily affected by the change in threshold. Those represented by a dot with very short or no arms indicate that all three options give similar values.

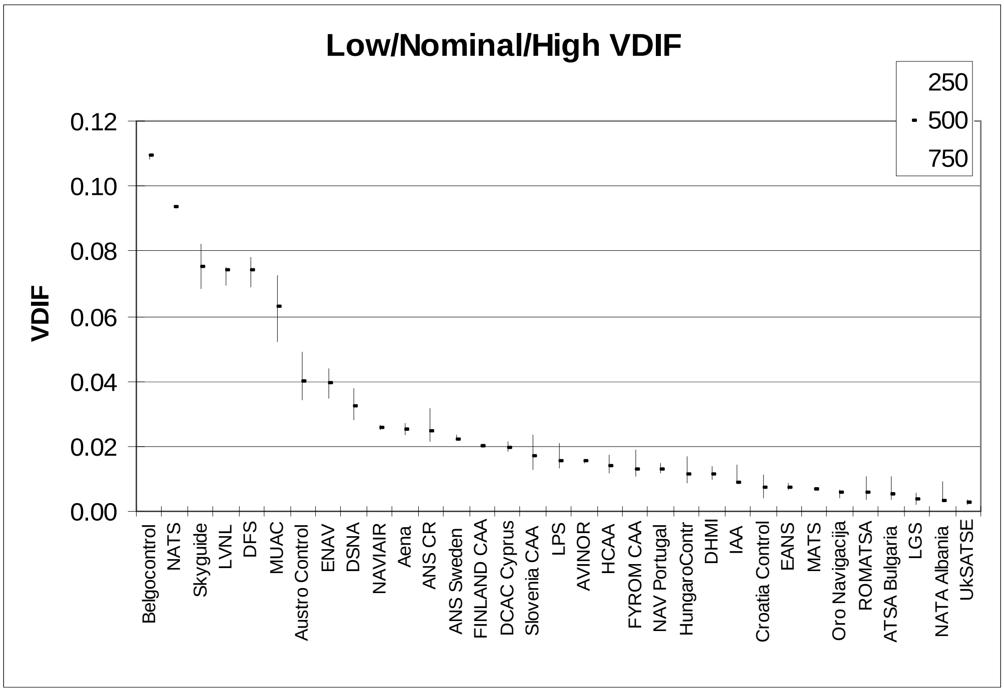


Figure 28: Low / Nominal / High VDIF values by ANSP

8.2. Definition of horizontal interactions

In the original indicator a horizontal interaction was identified when the angle between the routes of two aircraft was greater than 20°, the nominal case. For this indicator 30° was the high value and 10° was the low value. Here all the 10° results include all the 20° and 30° results.

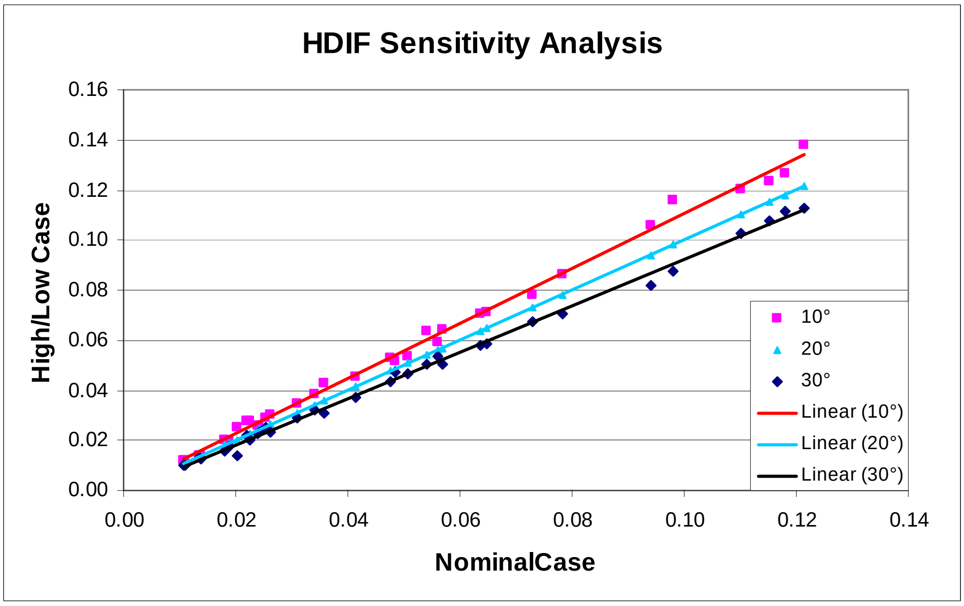


Figure 29: HDIF Sensitivity Analysis

Figure 29 shows a high level of correlation between the three sets of results.

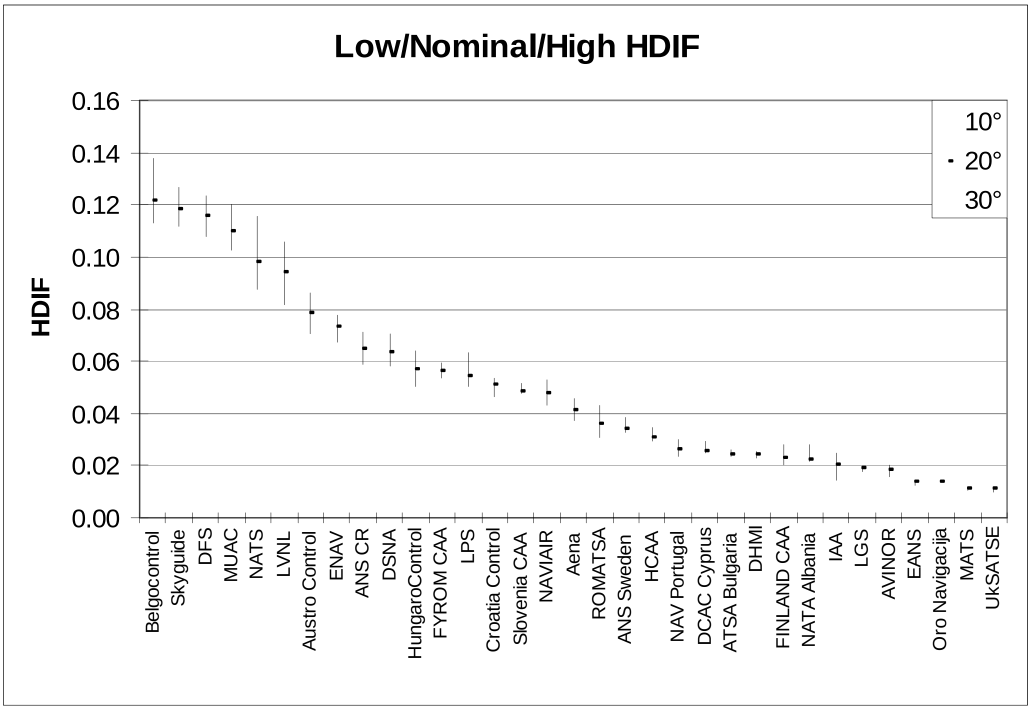


Figure 30: Low / Nominal / High HDIF values by ANSP

Figure 30 shows how the different ANSP results were affected by alternative thresholds for the HDIF indicator.

The length of the arm from the top of the line (10 ° results) to the dot (20° results) indicates whether there are interactions with heading differences between 10° and 20°. Where there is little or no arm then there are very few interactions between 10° and 20°.

8.3. Definition of speed interactions

The interactions due to speed differences were identified when the speed difference was greater than 35kts, the nominal case. For this indicator 50kts was the high value and 20kts was the low value. Here all the 20kts results will include all the 35kts and 50kts results.

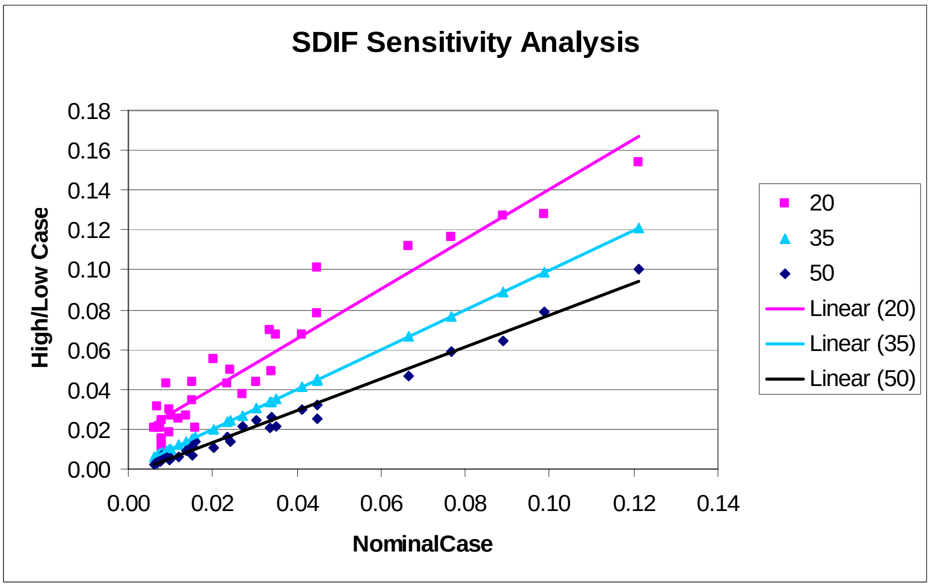


Figure 31: SDIF Sensitivity Analysis

Figure 31 shows a high level of correlation between the 35kts and 50kts results. The 20kts results were however much more varied.

Figure 32 shows how the different ANSP results were affected by the alternative thresholds for the SDIF indicator.

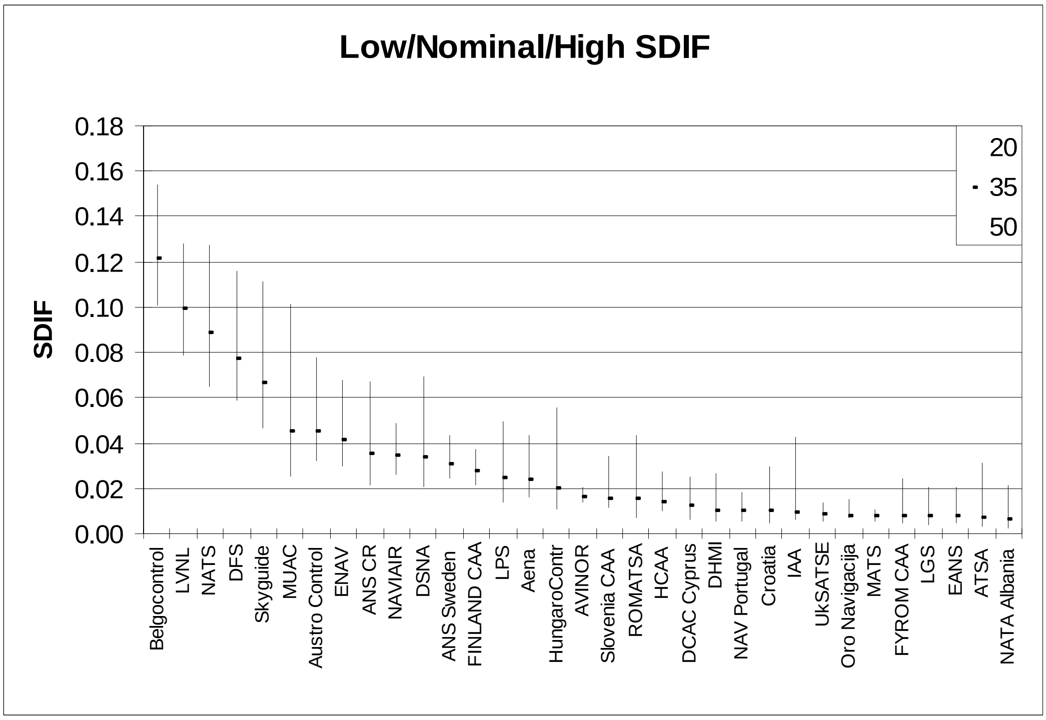


Figure 32: Low / Nominal / High SDIF values by ANSP

In Figure 32 the lines tend to be longer than for the VDIF and HDIF indicators implying that the choice of cut-off point has more impact on the results of this indicator.

The longer lines above the dot reflect the variability of the 20kts results seen in Figure 31. While the shorter lines below the dot show the correlation between the 35kts and 50kts results.

9. Conclusions

The Working Group involved a range of people with different backgrounds, experience and ideas about complexity. Through open and cooperative discussions the set of high level indicators was defined and agreed. The four chosen indicators, adjusted density, potential vertical interactions, potential horizontal interactions and potential speed interactions, look at a range of traffic characteristics while being manageable from an analysis point of view.

It is envisaged that the complexity score will be the metric used for international benchmarking purposes. However, the individual indicator results will supplement the information and allow a better understanding of the differences and similarities between airspace environments. The individual results could also be used to cluster the ACCs for the productivity analysis.

The selected indicators have been chosen to calculate en-route complexity. It is recognised that the indicators may not be applicable in terminal areas. Further work would be required to identify specific terminal indicators.

It is also recognised that the indicators do not fully take into account the impact of external constraints such as the need to interface with systems having different capabilities (e.g. transition from RVSM to non RVSM or from imperial to metric standards).

The results show that complexity tends to decrease with altitude. Thus, the ANSP/ACCs which work only in lower airspace tend to have higher values. It is important, therefore, to keep the scope of an ANSP/ACCs' activity in mind when comparing results.

This is mainly an issue when comparing ACCs and also when comparing the ANSP results of Belgocontrol, LVNL and, to a lesser extent DFS, which handle the lower airspace vis-à-vis Maastricht UAC which handles only the upper airspace. For all other ANSPs, this is not an issue because the indicators look at complexity for all ANSP airspace above FL85, excluding oceanic services. The results, therefore, represent an averaged complexity value for each ANSP.

The two sample weeks used in this report have been chosen with care. Nevertheless traffic conditions vary significantly over Europe and peak periods do not occur at the same time in all ACCs. Ideally the traffic sample should be selected for each ACC taking into account the local traffic distribution or the indicators should be computed on a much wider traffic sample, ideally the full year.

The implementation of the complexity indicators within the EUROCONTROL PRISME data warehouse and the automated production of them following each AIRAC cycle will permit a consistent time series of complexity values to be built up.

10. References

[1] ATM Cost-Effectiveness (ACE) 2001 Benchmarking Report, PRU (2003)

[2] ATM Cost-Effectiveness (ACE) 2002 Benchmarking Report, PRU (2004)

[3] ATM Cost-Effectiveness (ACE) 2003 Benchmarking Report, PRU (2005)

[4] Cognitive Complexity in Air Traffic Control – A Literature Review. EEC Note No 04/04. COCA Project. Hilburn, B. (2004).

ANNEX 1 - ATTENDANCE AT THE WORKING GROUP MEETINGS

Table 6 lists the participants who were involved in the Working Group.

Organisation	Name	Email
Austro Control	Rupert Hörmann	rupert.hoermann@austrocontrol.at
Belgocontrol	Catharina de Decker	catharina_de_decker@belgocontrol.be
DAS/AFN	George Ranga	george.ranga@eurocontrol.int
DAS/AFN	Thierry Champougny	thierry.champougny@eurocontrol.int
DFS	Christoph Czech	christoph.czech@dfs.de
DFS	Michael Morr	michael.morr@dfs.de
DSNA	Benoît Rulleau	benoit.rulleau@cena.fr
DSNA	David Combezoux	david.combezoux@cena.fr
DSNA	Frédéric Medioni	medioni@aviation-civile.gouv.fr
DSNA	Romain Troit	romain.troit@aviation-civile.gouv.fr
DSNA	Yann Le Fablec	lefablec@ath.cena.fr
EEC	Geraldine Flynn	geraldine.flynn@eurocontrol.int
EEC	Claire Leleu	claire.leleu.isasoftw@eurocontrol.int
EEC	Kirsteen Purves	kirsteen.purves@eurocontrol.int
LVNL	Vasco. Naudts	v.x.naudts@lvnl.nl
LVNL	Yoram Obbens	j.obbens@lvnl.nl
MUAC	Joachim Beckers	joop.beckers@planet.nl
NATS	Joanne Thornton	joanne.thornton@nats.co.uk
NATS	Peter Tullet	peter.tullett@nats.co.uk
NATS	Steve James	steve.james@nats.co.uk
NAV EP	Joao Batista	joao.batista@nav.pt
PRU	Francesco Preti	francesco.preti@eurocontrol.int
PRU	Giovanni Nero	giovanni.nero@eurocontrol.int
PRU	Philippe Enaud	philippe.enaud@eurocontrol.int
PRU	Sébastien Portet	sebastien.portet@eurocontrol.int
Skyguide	Klaus Affholderbach	klaus.affholderbach@skyguide.ch

Table 6: Attendance at the Working Group Meetings

ANNEX 2 - COMPLEXITY DIMENSIONS

Table 1a: Traffic characteristics

Complexity dimension	Influence on productivity and costs	Candidate indicators
Traffic density	**Concentration** in time and space and the relative position of aircraft determines the occurrence of **conflicts** and the controller **workload** associated with their identification and resolution. Airspace is sub-divided into sectors. All else being equal, the higher the concentration and the density, the smaller the size of the sectors and the shorter the **sector transit time**. Consequently, flights have to cross more sectors and spend less time within each sector. In dense airspace, controllers are required to deal with higher levels of traffic and therefore greater experience and prolonged periods of training may be required This may contribute to training costs. Controllers may become specialists and only be qualified to work on a few sectors, thus reducing flexibility and increasing manpower requirements. On the other hand, from an economic point of view, higher traffic density contributes to a better exploitation of the "scale" effect. Indeed, higher traffic volumes help in sharing fixed costs amongst a greater number of flights and therefore reducing unit costs.	raw density; adjusted density; concentration within specific time windows; spatial and temporal density; Sector transit time; Nb of conflicts;
Traffic in climb or descent	Aircraft need a controller clearance to climb/descend to a requested level. This is a fundamental controller responsibility and contributes to controller **workload**. Before giving the clearance the controller needs to ensure separation across the different flight levels. For this reason aircraft in "evolution" can be thought of as effectively occupying more space and generating more potential **conflicts**.	Nb of request for level changes; Level changes; Nb of airports in the vicinity; Nb of conflicts;
Traffic flow structure	The traffic flow structure can be considered as relatively simple if all aircraft are flying in the same direction and at the same speed. Conversely, the traffic flow structure can be considered as relatively complex if several flows have to be merged or if the flow structure results in a number of **crossing points**. Complex flow structure contributes to the number of **conflicts** and therefore controller **workload.** Complexity induced by the traffic flow structure also depends on airspace design and route structure.	Nb of conflicts; Nb of crossing points;
Traffic mix	The presence in the same airspace of aircraft with different performances contributes to the controller workload associated with the identification and resolution of conflicts. For the time being, VFR and OAT traffic are not captured by current traffic load measures.	Proportion VFR-IFR traffic; Proportion OAT-GAT traffic; Proportion JET – TURBO props traffic;

Table 1b: Traffic predictability and variability

Complexity dimension	Influence on productivity and costs	Candidate indicators
Spatial (flows) variability and predictability	Optimisation of resources (staff, route and airspace design) is made more difficult when faced with significant variations in the traffic flows. This is especially true for Trans-Atlantic tracks (NAT tracks) which are known only a few hours in advance. This is related to the predictability of traffic.	Spatial variability/predictability of traffic;
Seasonal variation of traffic	Significant differences in traffic levels between summer and winter can lead to under utilisation of resources during low periods of traffic and increased costs (overtime) during peak periods of traffic.	Ratio of summer traffic over yearly average traffic

Table 2: Airspace

Complexity dimension	Influence on productivity and costs	Candidate indicators
Sector	For a given volume of airspace, the higher the number of sectors, the more resources are needed and the higher the costs. This should be related to the traffic density described above.	number of sectors characteristics/dimensions (shape and size)
Route structure	Route structure reflects and organises the underlying demand of traffic. The route structure together with the constraints put on its utilisation (Letters of Agreement, flight level restrictions, bi or uni-directional routes, etc.) can contribute to reducing controller workload and increasing capacity and efficiency.	Nb of routes within a given volume of airspace. Nb of crossing and merging points within a given volume Direction of flows – uni, or bi directional

Table 3: External constraints

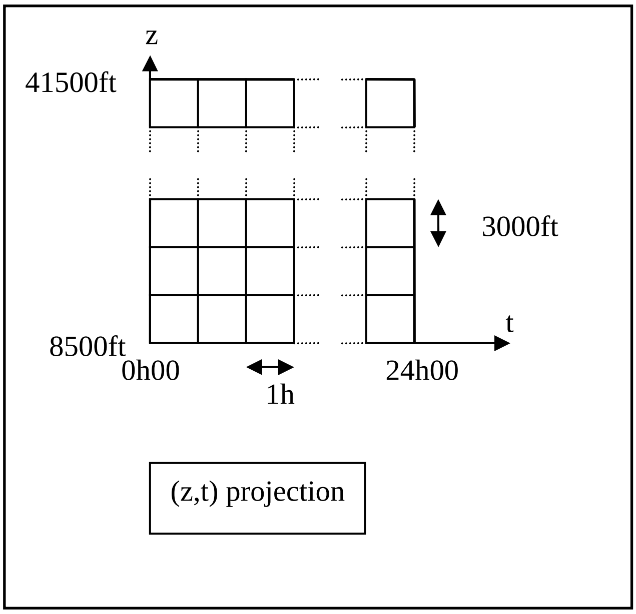
Complexity dimension	Influence on productivity and costs	Candidate indicators
Military area	The presence of military areas, when active they reduce the volume of airspace and the routes available for GAT traffic. This contributes to an increase in concentration and traffic density.	Presence of restricted or special use airspace areas (shape, size, utilisation)
Interface with adjacent units	There are many factors which can affect the efficiency of the interface between units: - Civil/Military interface; - Interface with non-ECAC area; - Transition from imperial (feet) to metric system units; - RVSM versus non-RVSM environment; - Requirement to increase/decrease separation.	
Special events	A number of special events may have a significant impact on traffic complexity on a given day : - Military exercises; - Bad Weather conditions; - Additional traffic due to special events. Special events are not expected to significantly influence the average productivity over the year.	

ANNEX 3 - INDICATOR SUMMARY

Cell dimensions: (20 nm x 20 nm x 3000ft x 1h).

The lat/lon coordinate system is transformed using the Albers equal area projection.

The first grid covers the entire ECAC area from FL85 to FL415 and from 0h00 to 23h59. The other grids are translated laterally and vertically from this grid.



A cell is considered to belong to a ANSP if the centre of the cell falls within the ANSP airspace, where the airspace is all that under the control of the ANSP above FL85.

The traffic data used is the CTFM (current traffic flight model, or Model 3) from the CFMU in TACT format with *ti* being the time flown in cell *k* by aircraft *i*:

* $T_k = \sum_{i \in cell_k} t_i$ is the sum of the time flown in cell k (in one hour).

* $D_k = \sum_{i \in cell_k} \left(\sum_{j \in cell_k \text{ and } j \neq i} t_i \cdot t_j \right)$ is the expected duration of potential interactions (in hours) in cell k.

Adjusted Density: $AdjDens_{ANSP} = \frac{\sum_{Days} \sum_{Cells} D_k}{\sum_{Days} \sum_{Cells} T_k}$

* $H_k = \sum_{i \in cell_k} \left(\sum_{\substack{j \in cell_k \\ i \text{ and } j \text{ have different headings}}} t_i \cdot t_j \right)$ is the 'hours of horizontal interactions' in cell k. The *heading* is the one the aircraft was flying when it entered the cell. Two headings are *different* if the difference between them is greater than 20°.

Potential horizontal interactions: $HDIF_{ANSP} = \frac{\sum_{Days}\sum_{Cells} H_k}{\sum_{Days}\sum_{Cells} T_k}$

* $V_k = \sum_{i \in cell_k} \left(\sum_{\substack{j \in cell_k \\ i \text{ and } j \text{ have different attitudes}}} t_i \cdot t_j \right)$ is the 'hours of vertical interactions'. Here one considers aircraft with different attitudes. There are three different attitudes: climbing, cruising and descending. A flight is considered in cruise if its rate of climb/descent is less than 500 ft per minute. It is defined when the aircraft enters the cell.

Potential vertical interactions: $VDIF_{ANSP} = \frac{\sum_{Days}\sum_{Cells} V_k}{\sum_{Days}\sum_{Cells} T_k}$

* $S_k = \sum_{i \in cell_k} \left(\sum_{\substack{j \in cell_k \\ i \text{ and } j \text{ have different speeds}}} t_i \cdot t_j \right)$ is the 'hours of speed interactions'. Here one considers aircraft with different speeds. The speed is the value given by the BADA performance table for the type of aircraft considered at the flight level of the centre of the cell. Two speeds are different if the difference between them is greater than 35 knots.

$Speed_f \xleftarrow{BADA} (type\_of\_aircraft_f,\ flight\_level_f,\ attitude_f)$ in knots

Potential speed interactions: $SDIF_{ANSP} = \frac{\sum_{Days}\sum_{Cells} S_k}{\sum_{Days}\sum_{Cells} T_k}$

Complexity score:

$$Score_{ANSP} = VDIF_{ANSP} + HDIF_{ANSP} + SDIF_{ANSP}$$

or

$$Score_{ANSP} = AdjDens_{ANSP} \left(\frac{VDIF_{ANSP}}{AdjDens_{ANSP}} + \frac{HDIF_{ANSP}}{AdjDens_{ANSP}} + \frac{SDIF_{ANSP}}{AdjDens_{ANSP}} \right)$$

or

$$Score_{ANSP} = AdjDens_{ANSP} \left(r\_VDIF_{ANSP} + r\_HDIF_{ANSP} + r\_SDIF_{ANSP} \right)$$

ANNEX 4 - RELATIVE INDICATORS

Figure 33 shows the correlations between the adjusted density and the DIF indicators. Adjusted Density is highly correlated with HDIF and also has a strong relationship with VDIF and SDIF. VDIF and SDIF are also highly correlated.

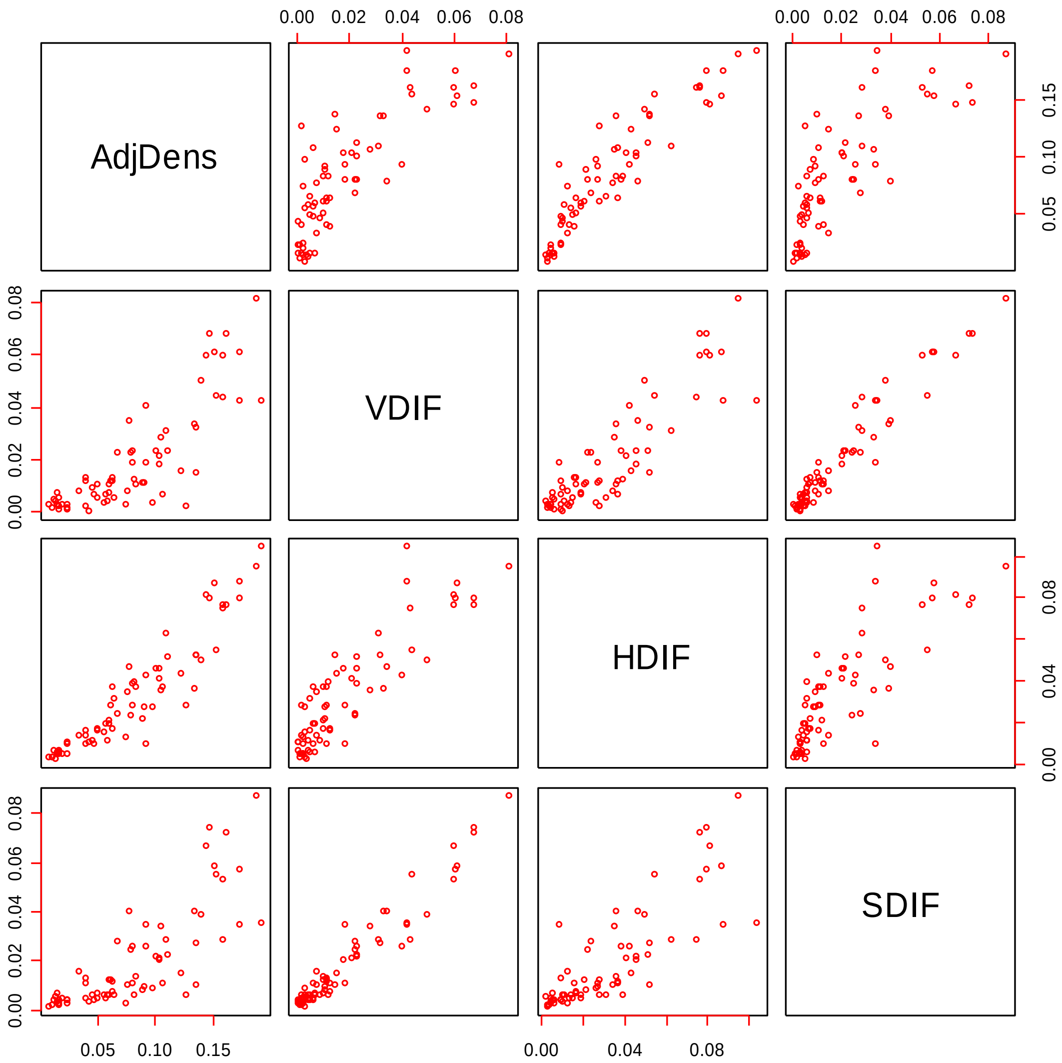


Figure 33: Correlations between adjusted density and the DIF indicators

Figure 34 shows the lack of correlation between adjusted density and the relative DIF indicators. The r_VDIF and r_SDIF are still correlated.

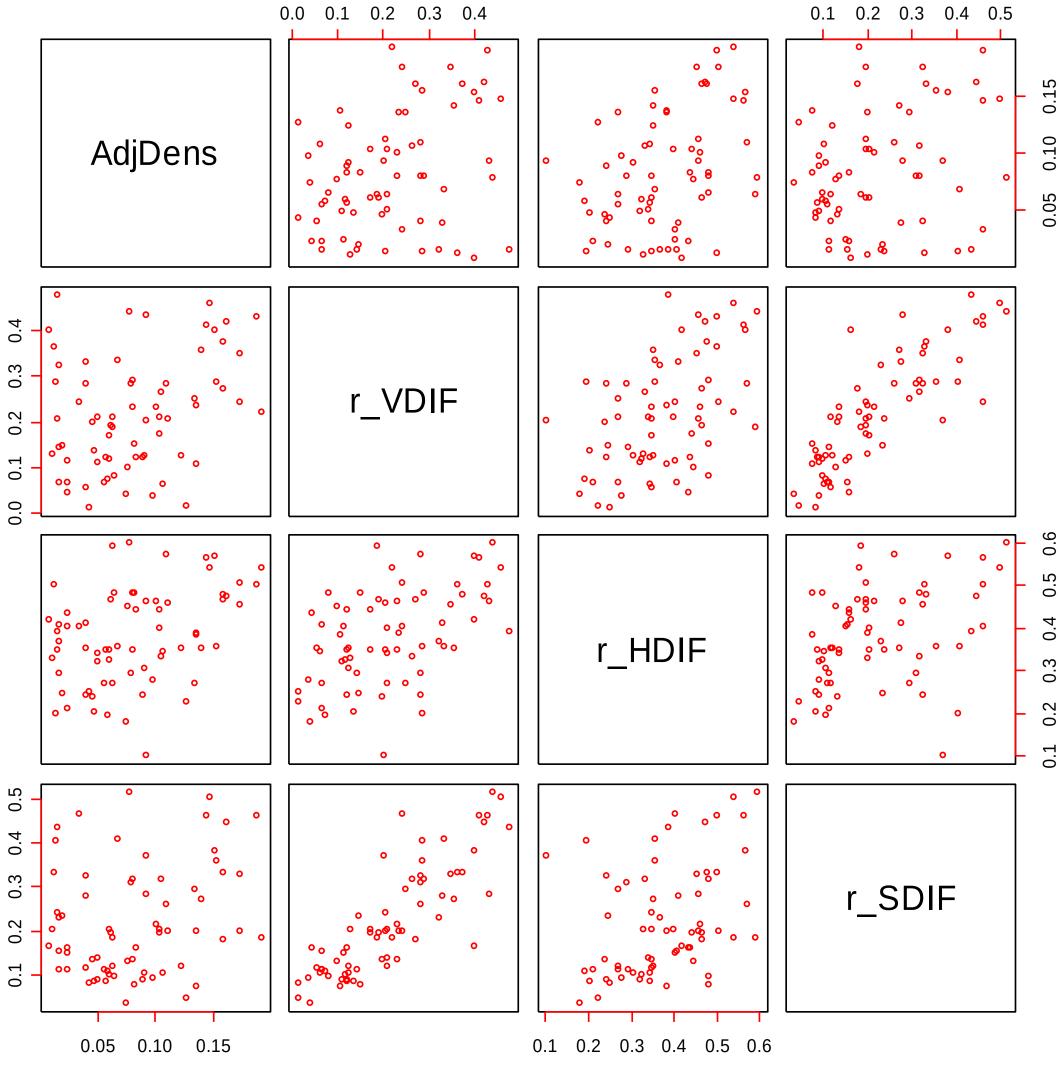


Figure 34: Correlations between adjusted density and the relative DIF

ANNEX 5 - COMPLEXITY SCORE AGGREGATIONS

As mentioned in section 4.8 the Working Group considered weighting the indicators based on their perceived importance. To find the weighting factors the Working Group members and their operational colleagues were asked to judge the importance of each indicator in relation to the other indicators. The Analytical Hierarchy Process (AHP) was then used to produce the weightings. It is expected that the relative importance of the indicators will differ between airspace environments and this was reflected in the spread of expert opinions. However as shown in Table 7 the correlation between the different sets of results was very high.

The AHP weightings were calculated before the final decision on the calculation methods was agreed. However as the weightings related to the chosen complexity dimensions and not the calculation method of the indicators, the results were used to assess the impact of weighting the indicators.

AHP weightings were calculated for the four indicators and also for the three DIF indicators (the chosen method to calculate the Complexity Score).

Table 7 shows the correlation matrix of the different weighting options that were tried.

Title explanation

The first letter of the name reflects the type of results:

R - raw — Each result taken directly from the simulator.

N - normalised — Each result divided by the relevant European system value.

S - standardised — Each result standardised to a distribution with a zero mean and a standard deviation of 1. (Take the mean from the result and divide by the standard deviation).

The subsequent number tells which indicators were included:

3 = DIF indicators only.

4 = DIF indicators + adjusted density.

If the title ends in a W then the results were weighted.

	R3	R3W	R4	R4W	N3	N3W	N4	N4W	S3	S3W	S4	S4W
R3	1.000											
R3W	0.999	1.000										
R4	0.984	0.979	1.000									
R4W	0.976	0.971	0.999	1.000								
N3	0.998	0.999	0.977	0.968	1.000							
N3W	0.997	0.999	0.972	0.964	0.999	1.000						
N4	0.998	0.997	0.991	0.985	0.997	0.995	1.000					
N4W	0.996	0.996	0.992	0.988	0.995	0.993	0.999	1.000				
S3	1.000	0.999	0.981	0.972	1.000	0.998	0.998	0.996	1.000			
S3W	0.998	1.000	0.976	0.968	0.999	1.000	0.996	0.995	0.999	1.000		
S4	0.996	0.993	0.996	0.992	0.992	0.989	0.999	0.999	0.994	0.992	1.000	
S4W	0.992	0.990	0.997	0.995	0.988	0.986	0.997	0.998	0.991	0.988	0.999	1.000

Table 7: Correlations between the different methods of weighting the indicators

The table shows that most of the results were highly correlated and that the difference between the weighted and un-weighted version of each set of results (R3, R3W; R4, R4W; etc) was negligible.

ANNEX 6 - SENSITIVITY ANALYSIS OF CFMU MODEL 1 (FTFM) AND MODEL 3 (CTFM)

As mentioned in section 5 the Working Group discussed the merits of the Model 1 (FTFM) and the Model 3 (CTFM) traffic. To assess the differences between the data sources one days traffic was run in the PRU model. The effect on the number of flight hours and the resulting indicators are shown in the table and figures below.

Airspace	Model 1 flight hours	Model 3 flight hours	difference	% change
Aena	2857.6	2788.2	69.4	0.02
ANS CR	428.3	413.7	14.6	0.03
ANS Sweden	1023.2	1004.8	18.4	0.02
ATSA Bulgaria	372.9	369.7	3.2	0.01
Austro Control	634.2	626.5	7.7	0.01
AVINOR	499.0	479.2	19.8	0.04
Belgocontrol	254.4	242.7	11.7	0.05
Croatia Control	328.8	329.9	-1.1	0.00
DCAC Cyprus	266.0	263.5	2.5	0.01
DFS	3068.1	2969.3	98.8	0.03
DHMI	1140.5	1136.7	3.8	0.00
DSNA	5204.6	5045.0	159.6	0.03
EANS	93.7	92.5	1.2	0.01
ENAV	2921.9	2858.0	63.9	0.02
FINLAND CAA	269.6	266.1	3.5	0.01
FYROM CAA	70.5	69.9	0.6	0.01
HCAA	1212.2	1211.9	0.2	0.00
HungaroControl	471.6	465.7	5.9	0.01
IAA	533.3	537.0	-3.6	-0.01
LGS	98.8	98.0	0.8	0.01
LPS	166.9	160.0	7.0	0.04
LVNL	248.8	261.1	-12.3	-0.05
MATS	89.8	89.8	-0.1	0.00
MUAC	1373.2	1337.8	35.4	0.03
NATA Albania	75.5	76.5	-0.9	-0.01
NATS	2832.5	2816.6	15.9	0.01
NAV Portugal	570.8	559.6	11.2	0.02
NAVIAIR	509.8	472.4	37.4	0.07
Oro Navigacija	56.8	56.6	0.2	0.00
ROMATSA	654.2	653.6	0.6	0.00
Skyguide	830.8	799.9	30.8	0.04
Slovenia CAA	67.3	64.5	2.8	0.04
UkSATSE	561.0	555.6	5.4	0.01

Table 8: Model 1 and Model 3 ANSP Flight Hour Comparison

Table 8 shows the difference and percentage change in the number of flight hours in the Model 1 and Model 3 data. The negative numbers show ANSPs whose number of flight hours increased in Model 3. The percentage changes of the number of flight hours were generally very small, 18 ANSPs had a change between -1% and +1%, 16 had a reduction of between 2 and 4%. NAVIAIR's reduction of 7% was the largest.

As previously mentioned in section 8 the cell height was changed from 4000ft to 3000ft: this occurred after the Model 1 and Model 3 sensitivity analysis had been performed. However, as Figure 35 shows, there is a high correlation between the indicators produced using both cell sizes so it was not necessary to recreate these results for 3000ft cells. It should be noted that the results from the 4000ft cells are on a larger scale than those from the 3000ft cells.

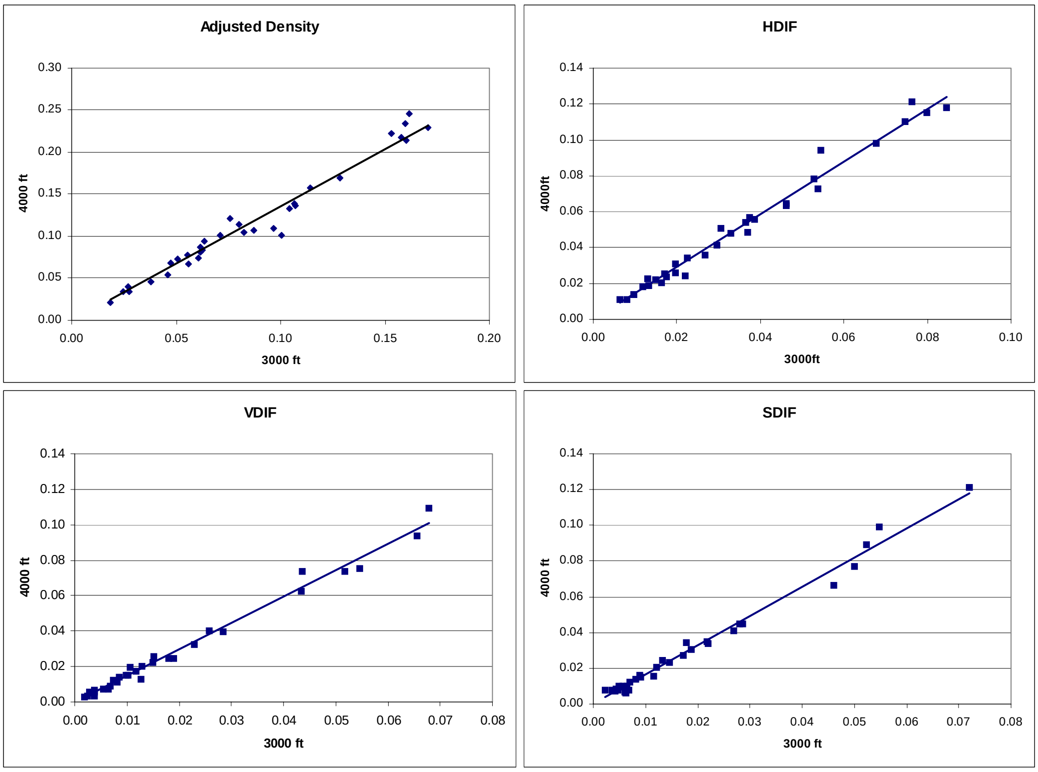


Figure 35: 3000ft and 4000ft ANSP Indicator Correlations

The graphs in Figure 36 show the correlations between the indicators calculated with Model 1 and Model 3 data for the ANSPs. The general trend is for a high level of correlation.

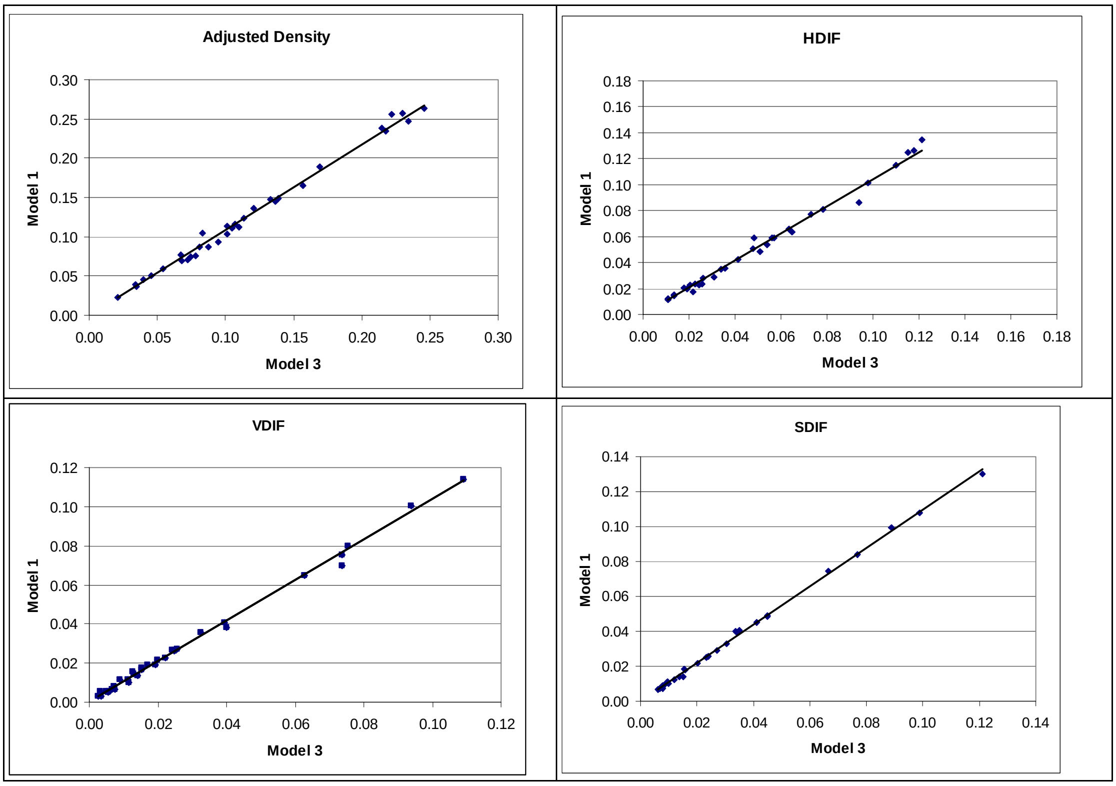


Figure 36: Model 1 and Model 3 ANSP Indicator Correlations

Figure 37 shows the Model 1 and Model 3 indicator results for each ANSP.

In general the adjusted density is slightly higher with the Model 1 data. Reasons for this include the Model 3 data being updated for direct routings where the result is that flights will fly through fewer cells in an ANSP, adding fewer flight hours and, therefore, having less impact on the adjusted density. Model 1 data may also include several flights scheduled to depart from the same airport at the same time. Those flights will be better sequenced in Model 3 which is updated according to the actual take off time.

The differences in HDIF and VDIF are generally smaller than those in adjusted density. In both cases the Model 3 data tends to produce lower indicator results than the Model 1 data.

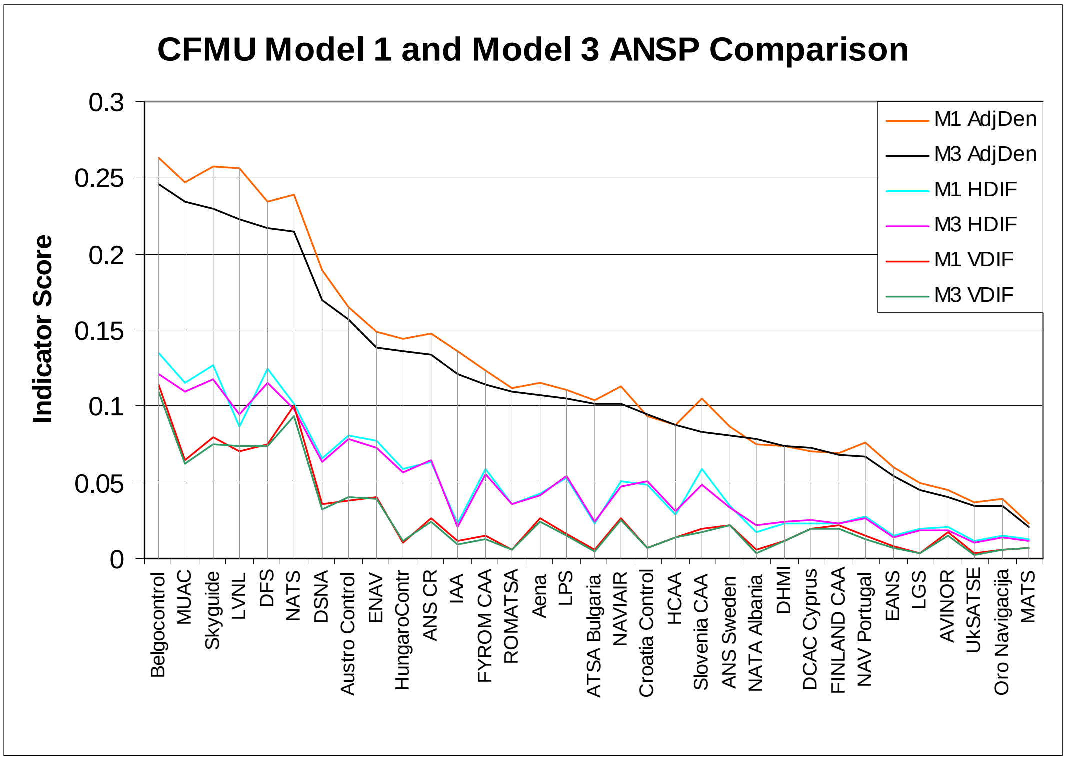


Figure 37: Model 1 and Model 3 Comparison; Adjusted Density, HDIF and VDIF

As the three DIF indicators have similar scales the SDIF values are shown in a separate graph to make them easier to read.

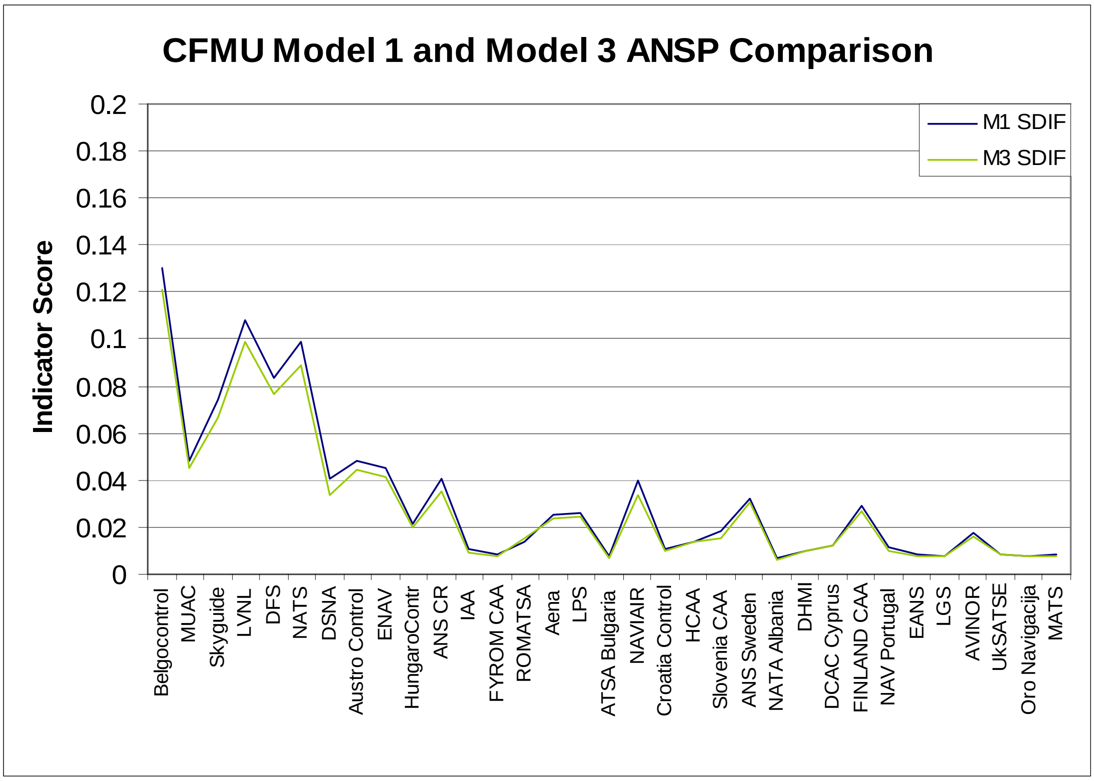


Figure 38: Model 1 and Model 3 Comparison; SDIF

Figure 38 shows the differences in the SDIF indicator, they are generally very small. It must be noted that this indicator is not based on the speeds recorded in the model data but on BADA speed data and the altitude and attitude of an aircraft at cell entry. If an aircraft maintained a similar climb and descent profile in both models then any differences would be minimal. However if flights were unable to fly at their requested (filed) levels and their allocated level was in a different speed band (based on BADA tables) then this could affect the number of speed interactions.

ANNEX 7 - SELECTED TERMINAL RESULTS

Table 9 provides the results for a selected number of terminal areas. It includes the, ANSP name, airspace ID, airspace name, maximum flight level, complexity score, adjusted density, the structural index and the individual relative indicator results.

These results only cover from FL85 up to the max FL of the terminal airspace. It is recognised that the indicators may not be a good measure of terminal complexity and that further work would be needed to develop terminal specific complexity indicators.

ANSP	ID	Name	FL Max	Complexity Score	Adjusted Density	Structural Index	relative VDIF	relative HDIF	relative SDIF
				a x b	a	b (c+d+e)	c	d	e
NATS	EGTTTC	LONDON TC	245	0.514	0.379	1.36	0.49	0.52	0.34
Skyguide	LSZHAPP	ZUERICH	115	0.486	0.365	1.33	0.47	0.61	0.25
DFS	EDDFAPP	FRANKFURT	115	0.466	0.436	1.07	0.41	0.50	0.16
NAVIAIR	EKCHAPP	COPENHAGEN	195	0.218	0.187	1.17	0.28	0.45	0.44
Skyguide	LSGGAPP	GENEVE	195	0.215	0.157	1.37	0.44	0.53	0.40
DFS	EDDSAPP	STUTTGART	145	0.213	0.139	1.53	0.48	0.56	0.50
Aena	LECMAPP	MADRID	245	0.209	0.214	0.98	0.26	0.44	0.27
ANS Sweden	ESSAAPP	ARLANDA	195	0.203	0.161	1.26	0.32	0.47	0.48
Austro Control	LOWWAPP	WIEN	245	0.194	0.151	1.28	0.32	0.47	0.50
DSNA	LFSBAPP	BALE-MULHOUSE	195	0.191	0.143	1.34	0.44	0.52	0.38
DSNA	LFPAPP	PARIS	195	0.188	0.263	0.72	0.18	0.36	0.18
Aena	LEBLAPP	BARCELONA	255	0.173	0.145	1.19	0.40	0.45	0.34
DSNA	LFMNAPP	NICE	175	0.163	0.122	1.34	0.40	0.51	0.42
ANS CR	LKPRAPP	PRAHA RUZYNE	145	0.161	0.136	1.19	0.31	0.43	0.44
DSNA	LFLLAPP	LYON	115	0.158	0.142	1.12	0.33	0.51	0.28
DSNA	LFMLAPP	MARSEILLE	145	0.139	0.101	1.38	0.53	0.48	0.38
FINLAND CAA	EFHKAPP	HELSINKI	195	0.136	0.129	1.06	0.24	0.36	0.46
HungaroControl	LHBPAPP	BUDAPEST	195	0.128	0.101	1.26	0.39	0.52	0.35
DFS	EDDNAPP	NUERNBERG	135	0.113	0.073	1.55	0.43	0.57	0.55
DHMI	LTBAAPP	ISTANBUL	165	0.113	0.108	1.04	0.36	0.53	0.15
Aena	LEMGAPP	MALAGA	145	0.107	0.127	0.85	0.25	0.39	0.21
HCAA	LGATAPP	ATHINAI	245	0.091	0.099	0.93	0.27	0.26	0.40
AVINOR	ENBRAPP	BERGEN/FLESLAND	155	0.089	0.052	1.70	0.51	0.61	0.58
ENAV	LIRNAPP	NAPOLI	245	0.082	0.089	0.92	0.20	0.31	0.41
NAV Portugal	LPFRAPP	FARO	245	0.073	0.065	1.13	0.45	0.53	0.14
Aena	LECLAPP	VALENCIA	245	0.071	0.059	1.21	0.35	0.48	0.38
ANS Sweden	ESGGAPP	GOTEBORG	245	0.063	0.043	1.46	0.49	0.52	0.45
HCAA	LGTSAPP	MAKEDONIA	245	0.057	0.044	1.31	0.42	0.47	0.42
DHMI	LTAIAPP	ANTALYA	245	0.043	0.083	0.52	0.19	0.22	0.11
DHMI	LTACAPP	ESENBOGA	245	0.041	0.030	1.36	0.42	0.58	0.36
Aena	LESTAPP	GALICIA	245	0.039	0.027	1.45	0.51	0.67	0.27
NAV Portugal	LPPRAPP	PORTO	245	0.031	0.024	1.30	0.47	0.50	0.33
DHMI	LTBJAPP	MENDERES	999	0.025	0.050	0.49	0.20	0.20	0.08

Table 9: Selected Terminal Airspace results

ANNEX 8 - ANSP AVERAGE TRANSIT TIMES AND AVERAGE FLIGHT HOURS

Table 10 shows the average transit time (in minutes) and the average daily number of flight hours flown for each ANSP.

Airspace	Average Transit Time (min)	Average Daily Flight Hours
Aena	39.5	2539
ANS CR	18.8	376
ANS Sweden	29.0	837
ATSA Bulgaria	20.9	329
Austro Control	17.2	528
AVINOR	20.5	410
Belgocontrol	7.3	184
Croatia Control	24.3	264
DCAC Cyprus	25.2	238
DFS	23.7	2555
DHMI	47.2	1048
DSNA	38.8	4569
EANS	18.6	79
ENAV	39.2	2627
FINLAND CAA	21.7	226
FYROM CAA	9.4	45
HCAA	42.8	993
HungaroControl	18.5	405
IAA	23.4	476
LGS	17.5	84
LPS	12.8	139
LVNL	8.2	202
MATS	24.9	81
MoldATSA	12.2	11
MUAC	20.5	1212
NATA Albania	13.0	59
NATS	24.8	2508
NAV Portugal	28.9	552
NAVIAIR	15.9	407
Oro Navigacija	15.1	50
ROMATSA	35.6	555
Skyguide	14.1	707
Slovenia CAA	8.3	56
UkSATSE	44.0	475

Table 10: ANSP Average Transit Times and Average Flight Hours

ANNEX 9 - ANSP RESULTS (WEEKS 3 AND 36)

ANSP Results Table - Week 3

Table 11 contains the winter complexity results at ANSP level ordered by the column complexity score. It includes the country, ANSP name, complexity score, rank position, adjusted density, the structural index, individual relative indicator results and the average number of daily flights.

Country	ANSP	Complexity Score	Rank	Adjusted Density	Structural Index	relative VDIF	relative HDIF	relative SDIF	Average Daily Flights
		a x b		a	b (c+d+e)	c	d	e	
Belgium	Belgocontrol	**0.210**	**1**	0.154	1.366	0.425	0.466	0.475	1400
United Kingdom	NATS	**0.186**	**2**	0.158	1.180	0.421	0.423	0.336	5429
Switzerland	Skyguide	**0.180**	**3**	0.155	1.157	0.356	0.494	0.307	2738
Germany	DFS	**0.179**	**4**	0.149	1.202	0.345	0.502	0.354	5792
Netherlands	LVNL	**0.150**	**5**	0.151	0.993	0.293	0.343	0.357	1375
Maastricht	MUAC	**0.139**	**6**	0.149	0.933	0.269	0.472	0.192	3212
Italy	ENAV	**0.099**	**7**	0.094	1.046	0.281	0.481	0.283	3299
Austria	Austro Control	**0.091**	**8**	0.094	0.963	0.236	0.435	0.292	1487
France	DSNA	**0.082**	**9**	0.110	0.746	0.195	0.354	0.196	6144
Czech Republic	ANS CR	**0.075**	**10**	0.085	0.887	0.208	0.435	0.244	948
Denmark	NAVIAIR	**0.068**	**11**	0.073	0.926	0.209	0.454	0.263	1436
Spain	Aena	**0.056**	**12**	0.081	0.697	0.199	0.327	0.172	3206
Sweden	ANS Sweden	**0.054**	**13**	0.060	0.905	0.247	0.348	0.309	1598
Slovak Republic	LPS	**0.045**	**14**	0.054	0.837	0.181	0.428	0.228	426
Finland	FINLAND CAA	**0.043**	**15**	0.046	0.920	0.262	0.266	0.393	608
Slovenia	Slovenia CAA	**0.042**	**16**	0.047	0.908	0.166	0.554	0.188	283
Hungary	HungaroControl	**0.041**	**17**	0.076	0.537	0.086	0.297	0.154	891
FYROM	FYROM CAA	**0.035**	**18**	0.031	1.141	0.340	0.482	0.319	159
Portugal	NAV Portugal	**0.030**	**19**	0.055	0.541	0.106	0.341	0.094	1022
Norway	AVINOR	**0.030**	**20**	0.026	1.127	0.368	0.444	0.316	1064
Cyprus	DCAC Cyprus	**0.028**	**21**	0.043	0.654	0.191	0.318	0.145	504
Ireland	IAA	**0.025**	**22**	0.074	0.345	0.079	0.200	0.066	1112
Romania	ROMATSA	**0.025**	**23**	0.066	0.380	0.036	0.225	0.119	636
Albania	NATA Albania	**0.024**	**24**	0.046	0.526	0.100	0.236	0.191	193
Croatia	Croatia Control	**0.023**	**25**	0.040	0.571	0.076	0.384	0.111	417
Turkey	DHMI	**0.023**	**26**	0.046	0.495	0.116	0.280	0.099	988
Estonia	EANS	**0.020**	**27**	0.042	0.480	0.165	0.195	0.120	220
Greece	HCAA	**0.020**	**28**	0.037	0.547	0.125	0.255	0.167	917
Latvia	LGS	**0.019**	**29**	0.035	0.564	0.070	0.348	0.146	248
Bulgaria	ATSA Bulgaria	**0.019**	**30**	0.062	0.305	0.039	0.178	0.089	595
Lithuania	Oro Navigacija	**0.014**	**31**	0.022	0.663	0.109	0.400	0.155	173
Ukraine	UkSATSE	**0.010**	**32**	0.023	0.456	0.062	0.263	0.131	496
Malta	MATS	**0.008**	**33**	0.017	0.459	0.077	0.308	0.074	158
Moldova	MoldATSA	**0.005**	**34**	0.006	0.878	0.216	0.488	0.173	41

Table 11: Winter ANSP results

ANSP Results Table - Week 36

Table 12 contains the summer complexity results at ANSP level ordered by the column complexity score. It includes the country, ANSP name, complexity score, rank position, adjusted density, the structural index, individual relative indicator results and the average number of daily flights.

Country	ANSP	Complexity Score	Rank	Adjusted Density	Structural Index	relative VDIF	relative HDIF	relative SDIF	Average Daily Flights
		a x b		a	b (c+d+e)	c	d	e	
Belgium	Belgocontrol	**0.222**	**1**	0.169	1.316	0.416	0.478	0.422	1599
Switzerland	Skyguide	**0.190**	**2**	0.182	1.043	0.297	0.499	0.246	3270
United Kingdom	NATS	**0.185**	**3**	0.162	1.142	0.401	0.422	0.319	6721
Germany	DFS	**0.184**	**4**	0.165	1.116	0.315	0.511	0.291	7141
Netherlands	LVNL	**0.156**	**5**	0.155	1.007	0.279	0.369	0.359	1596
Maastricht	MUAC	**0.153**	**6**	0.169	0.904	0.272	0.464	0.169	3889
Austria	Austro Control	**0.117**	**7**	0.127	0.919	0.220	0.475	0.223	2208
Italy	ENAV	**0.116**	**8**	0.115	1.012	0.258	0.517	0.237	4750
France	DSNA	**0.098**	**9**	0.142	0.693	0.170	0.363	0.159	7984
Czech Republic	ANS CR	**0.095**	**10**	0.117	0.807	0.169	0.446	0.191	1452
Slovenia	Slovenia CAA	**0.070**	**11**	0.071	0.986	0.197	0.604	0.185	525
Slovak Republic	LPS	**0.068**	**12**	0.099	0.692	0.106	0.444	0.142	875
FYROM	FYROM CAA	**0.067**	**13**	0.099	0.677	0.136	0.482	0.059	415
Hungary	HungaroControl	**0.067**	**14**	0.123	0.542	0.073	0.368	0.101	1732
Spain	Aena	**0.066**	**15**	0.092	0.721	0.211	0.346	0.164	4511
Denmark	NAVIAIR	**0.064**	**16**	0.069	0.922	0.215	0.469	0.237	1640
Sweden	ANS Sweden	**0.059**	**17**	0.063	0.929	0.244	0.382	0.303	1861
Croatia	Croatia Control	**0.052**	**18**	0.074	0.693	0.087	0.506	0.100	889
Romania	ROMATSA	**0.048**	**19**	0.113	0.420	0.039	0.295	0.086	1233
Greece	HCAA	**0.045**	**20**	0.074	0.601	0.141	0.337	0.124	1867
Finland	FINLAND CAA	**0.044**	**21**	0.048	0.907	0.281	0.291	0.335	644
Cyprus	DCAC Cyprus	**0.039**	**22**	0.056	0.704	0.218	0.352	0.134	627
Bulgaria	ATSA Bulgaria	**0.037**	**23**	0.118	0.314	0.028	0.231	0.054	1295
Turkey	DHMI	**0.037**	**24**	0.070	0.528	0.141	0.294	0.093	1679
Portugal	NAV Portugal	**0.034**	**25**	0.056	0.603	0.156	0.362	0.085	1269
Norway	AVINOR	**0.031**	**26**	0.028	1.137	0.364	0.433	0.340	1331
Ireland	IAA	**0.031**	**27**	0.078	0.396	0.099	0.228	0.069	1333
Albania	NATA Albania	**0.025**	**28**	0.061	0.416	0.053	0.285	0.078	349
Latvia	LGS	**0.021**	**29**	0.040	0.522	0.059	0.355	0.107	332
Estonia	EANS	**0.020**	**30**	0.049	0.418	0.124	0.220	0.074	288
Lithuania	Oro Navigacija	**0.018**	**31**	0.027	0.672	0.120	0.404	0.148	223
Malta	MATS	**0.016**	**32**	0.020	0.824	0.284	0.376	0.164	233
Ukraine	UkSATSE	**0.016**	**33**	0.030	0.540	0.070	0.304	0.166	800
Moldova	MoldATSA	**0.008**	**34**	0.013	0.609	0.109	0.290	0.210	71

Table 12: Summer ANSP results

ANNEX 10 - ACC RESULTS (WEEKS 3 AND 36)

ACC Results Table - Week 3

Table 13 provides the winter complexity results at ACC level ordered by the column complexity score. It includes the ANSP name, ACC name, complexity score, rank position, adjusted density, the structural index, individual relative indicator results and the average number of daily flights.

ANSP	ACC	Complexity Score	Rank	Adjusted Density	Structural Index	relative VDIF	relative HDIF	relative SDIF	Average Daily Flights
		a x b		a	b (c+d+e)	c	d	e	
DFS	Frankfurt	**0.270**	**1**	0.194	1.394	0.429	0.496	0.470	2233
NATS	Manchester	**0.233**	**2**	0.154	1.513	0.456	0.551	0.505	1163
Belgocontrol	Brussels	**0.210**	**3**	0.154	1.366	0.425	0.466	0.475	1225
DFS	Munchen	**0.195**	**4**	0.163	1.196	0.375	0.457	0.364	2129
DFS	Dusseldorf	**0.193**	**5**	0.132	1.458	0.430	0.563	0.465	1178
Skyguide	Zurich	**0.186**	**6**	0.148	1.254	0.404	0.473	0.377	1716
ENAV	Milano	**0.183**	**7**	0.140	1.301	0.384	0.537	0.380	1545
DFS	Rhein	**0.164**	**8**	0.167	0.984	0.225	0.532	0.227	1862
Skyguide	Geneva	**0.154**	**9**	0.153	1.007	0.276	0.506	0.225	1415
LVNL	Amsterdam	**0.150**	**10**	0.151	0.993	0.293	0.344	0.357	1268
MUAC	Maastricht UAC	**0.139**	**11**	0.149	0.933	0.269	0.472	0.192	3212
NATS	London AC	**0.131**	**12**	0.131	0.997	0.362	0.349	0.285	4332
DFS	Bremen	**0.109**	**13**	0.072	1.509	0.425	0.585	0.499	827
DSNA	Reims	**0.105**	**14**	0.118	0.887	0.256	0.395	0.235	1841
DSNA	Paris	**0.105**	**15**	0.125	0.840	0.268	0.270	0.302	2995
ENAV	Padova	**0.101**	**16**	0.082	1.227	0.339	0.566	0.322	1181
IAA	Dublin	**0.101**	**17**	0.088	1.151	0.410	0.431	0.310	453
DFS	Berlin	**0.085**	**18**	0.078	1.082	0.280	0.475	0.327	1465
ENAV	Roma	**0.083**	**19**	0.095	0.876	0.225	0.428	0.223	1907
Austro Control	Wien	**0.080**	**20**	0.089	0.903	0.219	0.436	0.248	1124
ANS Sweden	Stockholm	**0.073**	**21**	0.069	1.065	0.327	0.336	0.401	949
ANS CR	Praha	**0.072**	**22**	0.083	0.868	0.201	0.438	0.229	943
NATS	Scottish	**0.071**	**23**	0.075	0.946	0.302	0.297	0.347	1246
DSNA	Marseille	**0.068**	**24**	0.078	0.875	0.233	0.409	0.233	2099
DSNA	Bordeaux	**0.065**	**25**	0.100	0.646	0.142	0.348	0.156	1648
DSNA	Brest	**0.064**	**26**	0.116	0.551	0.102	0.370	0.079	1695
Aena	Palma	**0.057**	**27**	0.061	0.926	0.268	0.359	0.300	316
NAVIAIR	Copenhagen	**0.051**	**28**	0.061	0.833	0.183	0.454	0.197	1159
Aena	Madrid	**0.046**	**29**	0.087	0.524	0.129	0.289	0.107	2060
Aena	Barcelona	**0.045**	**30**	0.062	0.731	0.217	0.347	0.166	1261
LPS	Bratislava	**0.045**	**31**	0.054	0.835	0.179	0.429	0.227	416
Slovenia CAA	Ljubjana	**0.043**	**32**	0.047	0.908	0.166	0.554	0.188	279
ANS Sweden	Malmo	**0.040**	**33**	0.057	0.700	0.167	0.320	0.212	1056
Avinor	Oslo	**0.040**	**34**	0.039	1.033	0.340	0.431	0.262	654
HungaroControl	Budapest	**0.037**	**35**	0.076	0.491	0.065	0.283	0.142	813
ENAV	Brindisi	**0.034**	**36**	0.040	0.862	0.141	0.474	0.247	579
Finland CAA	Tampere	**0.033**	**37**	0.038	0.857	0.281	0.235	0.340	476
FYROM CAA	Skopje	**0.032**	**38**	0.030	1.080	0.326	0.469	0.285	151
Aena	Sevilla	**0.030**	**39**	0.058	0.518	0.176	0.229	0.112	729
NAV Portugal	Lisboa	**0.030**	**40**	0.057	0.529	0.099	0.339	0.091	828
DCAC Cyprus	Nicosia	**0.028**	**41**	0.043	0.654	0.191	0.318	0.145	503
DHMI	Istanbul	**0.028**	**42**	0.058	0.478	0.144	0.214	0.120	661
Aena	Canarias	**0.027**	**43**	0.052	0.518	0.184	0.220	0.115	692
ROMATSA	Bucuresti	**0.025**	**44**	0.067	0.369	0.032	0.222	0.115	634
NATA Albania	Tirana	**0.024**	**45**	0.046	0.526	0.100	0.236	0.191	193
Croatia Control	Zagreb	**0.023**	**46**	0.040	0.560	0.071	0.382	0.106	390
ATSA Bulgaria	Varna	**0.020**	**47**	0.051	0.393	0.066	0.201	0.126	258
LGS	Riga	**0.020**	**48**	0.036	0.550	0.061	0.347	0.141	229
EANS	Tallinn	**0.020**	**49**	0.044	0.448	0.162	0.183	0.103	181
DHMI	Ankara	**0.020**	**50**	0.043	0.461	0.083	0.294	0.084	741
ATSA Bulgaria	Sofia	**0.017**	**51**	0.073	0.240	0.017	0.159	0.063	344
Avinor	Bodo	**0.017**	**52**	0.014	1.258	0.462	0.359	0.437	280
IAA	Shannon	**0.017**	**53**	0.072	0.231	0.032	0.167	0.031	779
Avinor	Stavanger	**0.016**	**54**	0.012	1.313	0.407	0.536	0.370	334
HCAA	Athinai+Makedonia	**0.016**	**55**	0.034	0.465	0.094	0.249	0.122	902
Oro Navigacija	Vilnius	**0.014**	**56**	0.022	0.663	0.109	0.400	0.155	172
Avinor	Trondheim	**0.012**	**57**	0.016	0.793	0.275	0.309	0.209	240
ANS Sweden	Sundsvall	**0.012**	**58**	0.016	0.714	0.169	0.350	0.195	233
UKSATSE	L'viv	**0.012**	**59**	0.019	0.602	0.050	0.400	0.151	152
UKSATSE	Simferopol	**0.011**	**60**	0.038	0.286	0.010	0.218	0.058	239
UKSATSE	Kiev	**0.010**	**61**	0.015	0.635	0.170	0.241	0.224	231
Finland CAA	Rovaniemi	**0.009**	**62**	0.010	0.978	0.379	0.400	0.200	95
UKSATSE	Dnipropetrovsk	**0.009**	**63**	0.011	0.818	0.314	0.184	0.320	41
MATS	Malta	**0.007**	**64**	0.016	0.417	0.055	0.293	0.068	158
UKSATSE	Odesa	**0.006**	**65**	0.011	0.524	0.037	0.403	0.084	80
UKSATSE	Kharkov	**0.006**	**66**	0.014	0.402	0.080	0.209	0.114	107
MoldATSA	Chisinau	**0.005**	**67**	0.006	0.878	0.216	0.488	0.173	41

Table 13: Winter ACC results

ACC Results Table - Week 36

Table 14 provides the summer complexity results at ACC level ordered by the column complexity score. It includes the ANSP name, ACC name, complexity score, rank position, adjusted density, the structural index, individual relative indicator results and the average number of daily flights.

ANSP	ACC	Complexity Score	Rank	Adjusted Density	Structural Index	relative VDIF	relative HDIF	relative SDIF	Average Daily Flights
		a x b		a	b (c+d+e)	c	d	e	
DFS	Frankfurt	0.255	1	0.183	1.390	0.430	0.507	0.454	2457
ENAV	Milano	0.226	2	0.163	1.385	0.411	0.589	0.384	1826
Belgocontrol	Brussels	0.222	3	0.169	1.316	0.416	0.478	0.422	1405
DFS	Dusseldorf	0.222	4	0.156	1.419	0.399	0.563	0.457	1362
NATS	Manchester	0.212	5	0.143	1.486	0.459	0.529	0.498	1709
DFS	Munchen	0.198	6	0.183	1.085	0.330	0.453	0.302	2878
DFS	Rhein	0.194	7	0.211	0.922	0.219	0.548	0.156	2660
Skyguide	Zurich	0.192	8	0.169	1.135	0.353	0.481	0.301	2028
Skyguide	Geneva	0.171	9	0.189	0.906	0.222	0.502	0.183	1756
LVNL	Amsterdam	0.157	10	0.156	1.008	0.279	0.369	0.359	1462
MUAC	Maastricht UAC	0.153	11	0.169	0.904	0.272	0.464	0.169	3889
NATS	London AC	0.144	12	0.148	0.972	0.351	0.357	0.264	5408
ENAV	Padova	0.135	13	0.126	1.074	0.263	0.575	0.237	1904
DFS	Bremen	0.131	14	0.083	1.586	0.453	0.605	0.527	981
DSNA	Reims	0.117	15	0.150	0.780	0.224	0.380	0.177	2236
IAA	Dublin	0.115	16	0.096	1.195	0.453	0.482	0.260	564
DSNA	Paris	0.114	17	0.144	0.792	0.234	0.268	0.289	3545
Aena	Palma	0.110	18	0.120	0.915	0.265	0.330	0.321	1011
Austro Control	Wien	0.107	19	0.126	0.845	0.199	0.470	0.176	1823
ENAV	Roma	0.096	20	0.104	0.929	0.238	0.481	0.210	2842
DSNA	Marseille	0.093	21	0.119	0.786	0.199	0.396	0.191	3014
ANS CR	Praha	0.092	22	0.117	0.789	0.162	0.446	0.181	1435
DFS	Berlin	0.090	23	0.082	1.096	0.297	0.487	0.311	1865
DSNA	Brest	0.087	24	0.151	0.576	0.111	0.391	0.073	2499
DSNA	Bordeaux	0.080	25	0.140	0.577	0.120	0.353	0.104	2332
ANS Sweden	Stockholm	0.076	26	0.067	1.136	0.341	0.377	0.418	1098
Slovenia CAA	Ljubjana	0.071	27	0.072	0.985	0.196	0.604	0.184	514
NATS	Scottish	0.069	28	0.082	0.844	0.269	0.289	0.287	1691
LPS	Bratislava	0.069	29	0.099	0.690	0.105	0.444	0.141	853
FYROM CAA	Skopje	0.068	30	0.102	0.670	0.135	0.481	0.054	404
Aena	Barcelona	0.064	31	0.090	0.709	0.237	0.348	0.124	2180
HungaroControl	Budapest	0.063	32	0.123	0.514	0.061	0.362	0.091	1639
ENAV	Brindisi	0.061	33	0.095	0.641	0.092	0.443	0.106	1062
NAVIAIR	Copenhagen	0.054	34	0.061	0.873	0.199	0.477	0.196	1315
Croatia Control	Zagreb	0.052	35	0.076	0.682	0.083	0.505	0.095	847
Aena	Madrid	0.051	36	0.094	0.544	0.123	0.317	0.104	2455
ROMATSA	Bucuresti	0.048	37	0.114	0.416	0.038	0.295	0.083	1230
DHMI	Istanbul	0.047	38	0.105	0.448	0.118	0.250	0.081	1213
ANS Sweden	Malmo	0.047	39	0.063	0.740	0.175	0.368	0.197	1284
ATSA Bulgaria	Sofia	0.044	40	0.149	0.296	0.015	0.238	0.043	779
Aena	Sevilla	0.044	41	0.067	0.656	0.232	0.299	0.124	993
HCAA	Athinai+Makedonia	0.041	42	0.073	0.559	0.124	0.342	0.093	1762
Avinor	Oslo	0.040	43	0.040	1.009	0.322	0.395	0.292	759
DCAC Cyprus	Nicosia	0.039	44	0.056	0.704	0.218	0.352	0.134	627
Finland CAA	Tampere	0.036	45	0.043	0.844	0.284	0.247	0.313	494
NAV Portugal	Lisboa	0.032	46	0.056	0.574	0.140	0.353	0.081	1016
DHMI	Ankara	0.030	47	0.054	0.555	0.126	0.335	0.094	1129
Aena	Canarias	0.026	48	0.041	0.636	0.216	0.263	0.156	789
NATA Albania	Tirana	0.025	49	0.061	0.416	0.053	0.285	0.078	349
ATSA Bulgaria	Varna	0.023	50	0.062	0.368	0.081	0.190	0.097	486
LGS	Riga	0.022	51	0.043	0.505	0.051	0.353	0.101	304
Avinor	Bodo	0.021	52	0.016	1.339	0.489	0.415	0.435	314
IAA	Shannon	0.021	53	0.076	0.276	0.046	0.190	0.040	945
EANS	Tallinn	0.020	54	0.049	0.414	0.122	0.219	0.073	246
Oro Navigacija	Vilnius	0.018	55	0.027	0.672	0.120	0.404	0.148	214
UKSATSE	Simferopol	0.017	56	0.045	0.377	0.016	0.267	0.094	397
UKSATSE	L'viv	0.017	57	0.026	0.653	0.041	0.447	0.165	249
Avinor	Trondheim	0.017	58	0.016	1.031	0.363	0.418	0.250	298
Avinor	Stavanger	0.015	59	0.013	1.113	0.334	0.476	0.303	491
UKSATSE	Dnipropetrovsk	0.014	60	0.015	0.922	0.275	0.204	0.443	62
UKSATSE	Kiev	0.014	61	0.022	0.626	0.138	0.250	0.237	338
UKSATSE	Odesa	0.012	62	0.018	0.660	0.074	0.409	0.177	145
ANS Sweden	Sundsvall	0.011	63	0.012	0.912	0.258	0.349	0.305	230
UKSATSE	Kharkov	0.011	64	0.028	0.388	0.062	0.214	0.112	193
MATS	Malta	0.011	65	0.016	0.663	0.218	0.292	0.153	233
MoldATSA	Chisinau	0.008	66	0.013	0.609	0.109	0.290	0.210	71
Finland CAA	Rovaniemi	0.005	67	0.005	1.002	0.460	0.470	0.072	86

Table 14: Summer ACC results

ANNEX 11 - ACC AND TERMINAL RESULTS TABLE

Table 15 combines the ACC results from Table 5 with the terminal airspace results from Table 9. They are ordered by complexity score. The bolder coloured rows show terminal airspace results and the paler rows show ACC results.

ANSP	ACC / terminal	Complexity Score a x b	Rank	Adjusted Density a	Structural Index b (c+d+e)	relative VDIF c	relative HDIF d	relative SDIF e
NATS	London TC	0.514	1	0.379	1.36	0.49	0.52	0.34
Skyguide	Zuerich	0.486	2	0.365	1.33	0.47	0.61	0.25
DFS	Frankfurt	0.466	3	0.436	1.07	0.41	0.50	0.16
DFS	Frankfurt	0.263	4	0.189	1.39	0.43	0.50	0.46
NATS	Manchester	0.221	5	0.147	1.50	0.46	0.54	0.50
NAVIAIR	Copenhagen	0.218	6	0.187	1.17	0.28	0.45	0.44
Belgocontrol	Brussels	0.216	7	0.162	1.34	0.42	0.47	0.45
Skyguide	Geneve	0.215	8	0.157	1.37	0.44	0.53	0.40
DFS	Stuttgart	0.213	9	0.139	1.53	0.48	0.56	0.50
Aena	Madrid	0.209	10	0.214	0.98	0.26	0.44	0.27
DFS	Dusseldorf	0.208	11	0.145	1.44	0.41	0.56	0.46
ENAV	Milano	0.206	12	0.153	1.35	0.40	0.57	0.38
ANS Sweden	Arlanda	0.203	13	0.161	1.26	0.32	0.47	0.48
DFS	Munchen	0.197	14	0.174	1.13	0.35	0.45	0.33
Austro Control	Wien	0.194	15	0.151	1.28	0.32	0.47	0.50
DSNA	Bale-Mulhouse	0.191	16	0.143	1.34	0.44	0.52	0.38
Skyguide	Zurich	0.189	17	0.160	1.18	0.37	0.48	0.33
DSNA	Paris	0.188	18	0.263	0.72	0.18	0.36	0.18
DFS	Rhein	0.182	19	0.192	0.95	0.22	0.54	0.18
Aena	Barcelona	0.173	20	0.145	1.19	0.40	0.45	0.34
Skyguide	Geneva	0.164	21	0.174	0.94	0.24	0.50	0.20
DSNA	Nice	0.163	22	0.122	1.34	0.40	0.51	0.42
ANS CR	Praha Ruzyne	0.161	23	0.136	1.19	0.31	0.43	0.44
DSNA	Lyon	0.158	24	0.142	1.12	0.33	0.51	0.28
LVNL	Amsterdam	0.154	25	0.154	1.00	0.29	0.36	0.36
MUAC	Maastricht UAC	0.147	26	0.160	0.92	0.27	0.47	0.18
DSNA	Marseille	0.139	27	0.101	1.38	0.53	0.48	0.38
NATS	London AC	0.138	28	0.141	0.98	0.36	0.35	0.27
FINLAND CAA	Helsinki	0.136	29	0.129	1.06	0.24	0.36	0.46
HungaroControl	Budapest	0.128	30	0.101	1.26	0.39	0.52	0.35
ENAV	Padova	0.122	31	0.110	1.12	0.28	0.57	0.26
DFS	Bremen	0.121	32	0.078	1.55	0.44	0.60	0.52
DFS	Nuernberg	0.113	33	0.073	1.55	0.43	0.57	0.55
DHMI	Istanbul	0.113	34	0.108	1.04	0.36	0.53	0.15
DSNA	Reims	0.112	35	0.136	0.82	0.24	0.39	0.20
DSNA	Paris	0.110	36	0.135	0.81	0.25	0.27	0.29
IAA	Dublin	0.109	37	0.092	1.18	0.43	0.46	0.28
Aena	Malaga	0.107	38	0.127	0.85	0.25	0.39	0.21
Aena	Palma	0.097	39	0.106	0.92	0.27	0.33	0.32
Austro Control	Wien	0.096	40	0.112	0.86	0.21	0.46	0.20
HCAA	Athinai	0.091	41	0.099	0.93	0.27	0.26	0.40
ENAV	Roma	0.091	42	0.100	0.91	0.23	0.46	0.21
AVINOR	Bergen/Flesland	0.089	43	0.052	1.70	0.51	0.61	0.58
DFS	Berlin	0.088	44	0.080	1.09	0.29	0.48	0.32
ANS CR	Praha	0.084	45	0.104	0.81	0.17	0.44	0.20
DSNA	Marseille	0.084	46	0.103	0.81	0.21	0.40	0.20
ENAV	Napoli	0.082	47	0.089	0.92	0.20	0.31	0.41
DSNA	Brest	0.077	48	0.136	0.57	0.11	0.38	0.08
ANS Sweden	Stockholm	0.075	49	0.068	1.10	0.33	0.36	0.41
DSNA	Bordeaux	0.074	50	0.123	0.60	0.13	0.35	0.12
NAV Portugal	Faro	0.073	51	0.065	1.13	0.45	0.53	0.14
Aena	Valencia	0.071	52	0.059	1.21	0.35	0.48	0.38
NATS	Scottish	0.070	53	0.079	0.88	0.28	0.29	0.31
ANS Sweden	Goteborg	0.063	54	0.043	1.46	0.49	0.52	0.45
Slovenia CAA	Ljubjana	0.061	55	0.063	0.96	0.19	0.59	0.19
LPS	Bratislava	0.060	56	0.083	0.72	0.12	0.44	0.16
FYROM CAA	Skopje	0.059	57	0.083	0.71	0.15	0.48	0.08
Aena	Barcelona	0.057	58	0.080	0.72	0.23	0.35	0.14
HCAA	Makedonia	0.057	59	0.044	1.31	0.42	0.47	0.42
HungaroControl	Budapest	0.055	60	0.107	0.51	0.06	0.34	0.10
NAVIAIR	Copenhagen	0.052	61	0.061	0.85	0.19	0.47	0.20
ENAV	Brindisi	0.052	62	0.077	0.68	0.10	0.45	0.13
Aena	Madrid	0.049	63	0.091	0.54	0.13	0.30	0.11
ANS Sweden	Malmo	0.044	64	0.060	0.72	0.17	0.35	0.20
DHMI	Antalya	0.043	65	0.083	0.52	0.19	0.22	0.11
Croatia Control	Zagreb	0.043	66	0.065	0.66	0.08	0.48	0.10
DHMI	Esenboga	0.041	67	0.030	1.36	0.42	0.58	0.36
DHMI	Istanbul	0.041	68	0.089	0.45	0.12	0.24	0.09
Avinor	Oslo	0.040	69	0.039	1.02	0.33	0.41	0.28
ROMATSA	Bucuresti	0.039	70	0.098	0.40	0.04	0.28	0.09
Aena	Galicia	0.039	71	0.027	1.45	0.51	0.67	0.27
Aena	Sevilla	0.038	72	0.063	0.60	0.21	0.27	0.12
ATSA Bulgaria	Sofia	0.036	73	0.127	0.29	0.02	0.23	0.05
DCAC Cyprus	Nicosia	0.035	74	0.051	0.69	0.21	0.34	0.14
Finland CAA	Tampere	0.034	75	0.040	0.85	0.28	0.24	0.33
HCAA	Athinai+Makedonia	0.032	76	0.060	0.54	0.12	0.32	0.10
NAV Portugal	Lisboa	0.031	77	0.057	0.55	0.12	0.35	0.09
NAV Portugal	Porto	0.031	78	0.024	1.30	0.47	0.50	0.33
Aena	Canarias	0.026	79	0.046	0.57	0.20	0.24	0.13
DHMI	Ankara	0.026	80	0.049	0.52	0.11	0.32	0.09
NATA Albania	Tirana	0.025	81	0.055	0.45	0.07	0.27	0.11
DHMI	Menderes	0.025	82	0.050	0.49	0.20	0.20	0.08
ATSA Bulgaria	Varna	0.022	83	0.058	0.38	0.08	0.19	0.11
LGS	Riga	0.021	84	0.040	0.52	0.06	0.35	0.12
EANS	Tallinn	0.020	85	0.047	0.43	0.14	0.21	0.08
Avinor	Bodo	0.019	86	0.015	1.30	0.48	0.39	0.44
IAA	Shannon	0.019	87	0.074	0.26	0.04	0.18	0.04
Oro Navigacija	Vilnius	0.016	88	0.024	0.67	0.12	0.40	0.15
Avinor	Stavanger	0.015	89	0.013	1.20	0.36	0.50	0.33
UKSATSE	L'viv	0.015	90	0.023	0.64	0.04	0.43	0.16
UKSATSE	Simferopol	0.015	91	0.043	0.35	0.01	0.25	0.08
Avinor	Trondheim	0.015	92	0.016	0.92	0.32	0.37	0.23
UKSATSE	Dnipropetrovsk	0.012	93	0.014	0.89	0.29	0.20	0.40
UKSATSE	Kiev	0.012	94	0.019	0.63	0.15	0.25	0.23
ANS Sweden	Sundsvall	0.012	95	0.015	0.80	0.21	0.35	0.24
UKSATSE	Odesa	0.010	96	0.016	0.63	0.07	0.41	0.15
UKSATSE	Kharkov	0.009	97	0.023	0.39	0.07	0.21	0.11
MATS	Malta	0.009	98	0.016	0.55	0.14	0.29	0.11
Finland CAA	Rovaniemi	0.008	99	0.008	0.99	0.40	0.42	0.16
MoldATSA	Chisinau	0.007	100	0.010	0.66	0.13	0.33	0.20

Table 15: ACC and Selected Terminal results