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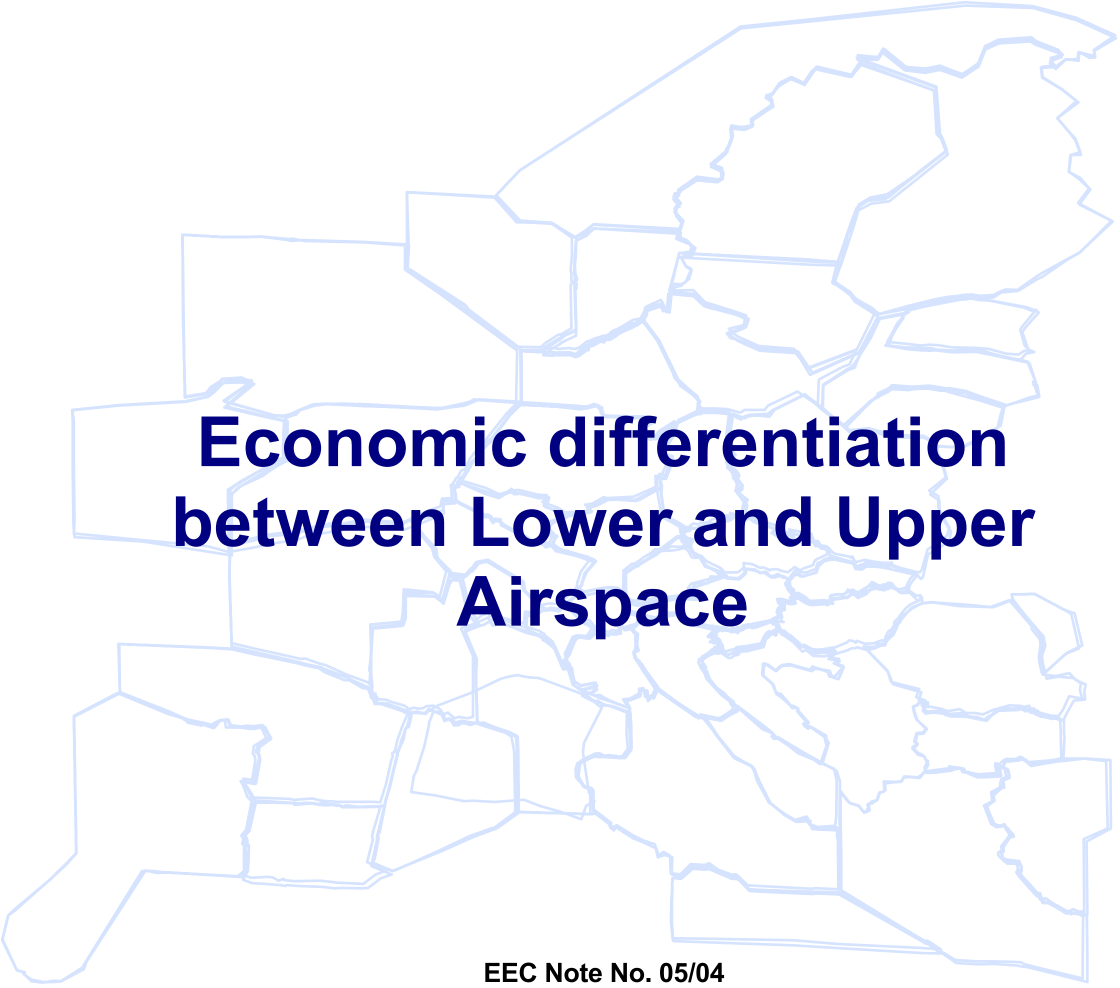

Economic differentiation between Lower and Upper Airspace

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TITLE:

ECONOMIC DIFFERENTIATION BETWEEN LOWER AND UPPER AIRSPACE

Author	**Date**	**Pages**	**Figures**	**Tables**	**Annexes**	**References**
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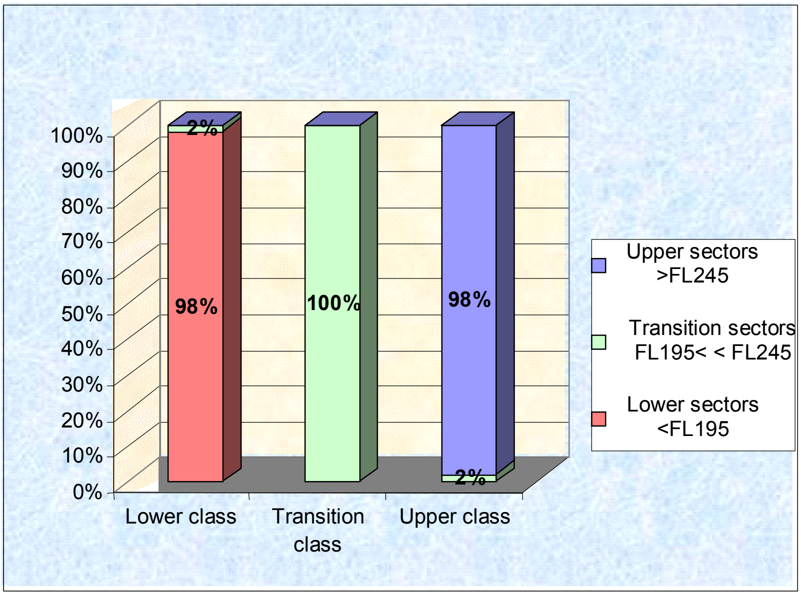
Abstract: .This study is consistent with the framework of the research of differentiated charging methods between lower and upper airspace lead by the European Single Sky initiative. The aim is to determine how the upper airspace could be differentiated from the lower airspace thanks to differences in their levels of traffic complexity as well as in their levels of unit cost of air traffic services, and consequently to determine if the unit rate differentiation by airspace category would make a sense.

Executive Summary

The Single European Sky legislation is likely to introduce major changes in tomorrow's European ATM. Among other themes, the airspace part of the legislative package can have a very substantial impact on the current service organisation, through for instance the implementation of Functional Blocks of airspace.

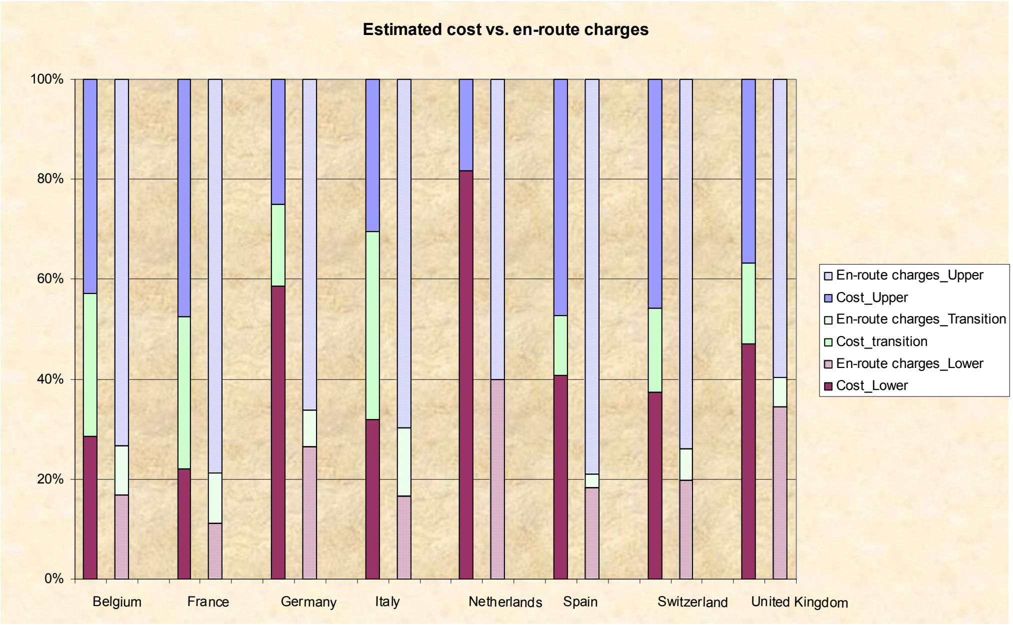
This study aims at better understanding the distinction between different parts of the airspace in operational as well as economic terms.

We show, through a complexity analysis, that there are three distinct, coherent categories of air traffic control sectors in the European (core area) airspace.



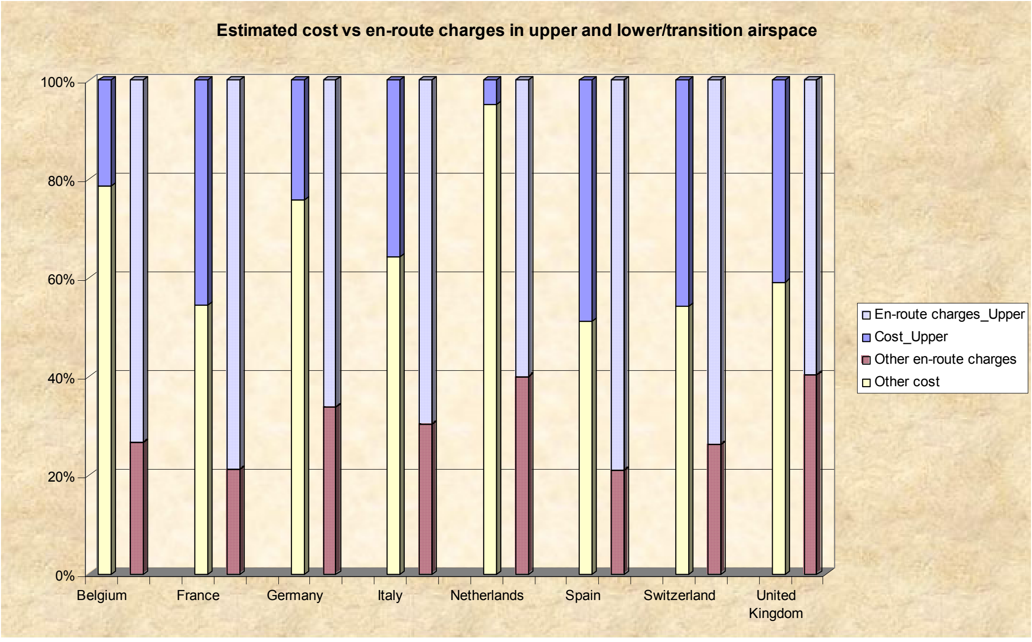
These categories correspond to different types of traffic (landing/departing, cruising, and the transition between these states) for which the physical design of air traffic control sectors is remarkably consistent. When we map these classes onto the existing air traffic control centres, we see that, with the notable exception of a few centres (Maastricht UAC for instance), most of the existing centres in Europe are composed of sectors from at least two categories. This was probably done for strictly geographical reasons since it seems to be unlikely that a flight will depart, transit and cruise within the same ACC. Our analysis, however, asks the question of the impact of having specific centres operating only one of our classes (namely, upper airspace) on the way transition into or from this centre will be organised.

We have then tried to analyse the economic differentiation between these different airspace classes. We have made for this purpose a number of simplifying assumptions, among which considering that the cost of a control sector was the same, regardless of its category (upper, lower, transition), within the same tariff zone (country). Because of these simplifying assumptions, we decided not to compute detailed figures on different countries costs, but to give general trends. Hence, we see a clear imbalance between the costs and revenues for different parts of the airspace, as described in the following graph.



This is a clear cross-subsidisation process, mostly due to the fact that the current charge formula is an increasing function of distance and Maximum Take Off Weight (MTOW). Further, should we have differentiated unit rates for different airspace categories, our analysis indicates that the unit rate in the lower airspace should be 6 times higher than in the upper airspace, whereas the transition airspace unit rate should be 4 times the upper airspace rate.

The Single European Sky legislation introduces a clear distinction between the upper airspace and the rest. We therefore decided to apply the same methodology in the assessment of cross-subsidies between upper airspace and other airspace, as described in the following graph:



If the upper airspace was to be served by independent providers, which would need to be economically self-sufficient, this would de facto imply that cross subsidies would no more be possible. If this was the case, our analysis shows that non upper airspace charges would have to be substantially increased. This would necessarily introduce a bias between intra Europe and other flights, since access to lower airspace would be more expensive than what it is today. One may wonder if the current charging formula is adapted to this new approach.

Our analysis shows that the introduction of a distinction between airspace classes will have an impact from an operational and economic point of view. There is certainly scope for more detailed, less simplified analysis, both on the operational and economic aspects.

Table of Contents

Abbreviations

ACC	Air traffic Control Centre
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
CFMU	Central Flow Management Unit
CRCO	Central Route Charges Office
EEC	EUROCONTROL Experimental Centre
EU	European Union
FAB	Functional Airspace Block

1. Introduction

European airspace is composed of airspace blocks, referred to as Sectors whose traffic safety is the responsibility of air traffic controllers. Sectors located in the lower airspace are generally devoted to the control of flights in evolution from their departure airport or toward their arrival airport. On the other hand, sectors located in the upper airspace are generally traversed by flights in their cruise phase.
Both the airspace design and the procedures are intrinsically linked to national borders. As a result flights often have to change flight level when they pass over the borders between two member states.

Part of the thrust behind the Single European Sky is the reduction of such system inefficiencies "by creating an airspace without frontiers where the procedures for airspace design, planning and management ensure the efficient and safe performance of air traffic management". This European harmonisation would lead to fundamental changes for the management of air traffic since sectors of control would no more be designed according to the national borders and would as a consequence not always belong entirely to the airspace of one state. The airspace controlled by Air traffic Control Centres (ACCs) could hence be strongly changed in term of sector design, number of sectors, surface, etc. New larger airspace portions, called Functional Airspace Blocks (FABs), would be defined for the upper airspace leading to a reduction on the number of air traffic control centres.
A further consequence of this new airspace design is the potential for application of different charging mechanisms to the upper and lower airspace. The task of evaluating the impact of such changes on both service providers and airspace users has been entrusted by the Central Route Charges Office (CRCO).

This study realised by the Eurocontrol Experimental Centre is in line with this task, the aim being to analyse differences inherent in the upper and lower airspace from the point of view of traffic complexity levels, controller workload but also in terms of air traffic service cost. This differentiation will be analysed in two phases: the first phase will consist in defining a typology of the European sectors by grouping them according complexity indicators while the second phase will consist in determining rough estimates of unit cost values by airspace type. This second phase will therefore identify whether upper and lower airspace can be differentiated from an economic point of view - an essential step in the research of a new charging system.
The definition of European sectors typology presented in **section 2** deals first of all with the definition of a clear flight level limit between lower and upper airspace. Once this limit is defined, sectors are classified according to different complexity indicators by applying the method of cluster analysis. The levels of controller workload by sector type are then computed with an aim to evaluate if the sector differentiation can also be observed in term of controller workload.

Section 3 uses this sector classification for estimating the difference in sector unit costs according to their type and consequently for estimating the ACCs cost repartition by airspace type. The comparison of this repartition with the repartition of billed en-route charges by airspace will show if there is an appropriateness between the spent budget and the charges amount collected by airspace category in order to analyse if the unit rate differentiation by airspace will make sense.

Section 4 aims to present the results obtained in the previous sections so as to analyse more precisely the cost and revenue differentiation when opposing the upper sectors to the other sector types.

Section 5 will conclude this study and present necessary further steps in the differentiation of charging system between lower and upper airspace.

2. Typology of European sectors

2.1. Determination of the limit between lower and upper airspace

Prior to performing any economic analysis relating to the characteristics of lower and upper airspace, it is first necessary to consider the current European sector structure in order to identify those sectors which should fall into each category.

Given that each state is responsible for the organisation of its own airspace, there is no commonly agreed definition or consistently applied division between what constitutes lower and upper airspace. Following the Single European Sky framework regulation, we have first of all applied the limit FL285 as defining the division flight level between upper and lower airspace.

In applying this criterion to a dataset containing 632 en-route sectors from Belgium, France, Germany, Italy, Luxembourg, Netherlands, Spain, Switzerland and United Kingdom, the distinction between upper and lower sectors can not always be made. Only 79% of sectors can be categorized in upper (their minimum level being above FL285) or lower sectors (their maximum level being below FL285). The 20% remaining sectors have vertical limits falling simultaneously into both lower and upper airspace (Figure 1).

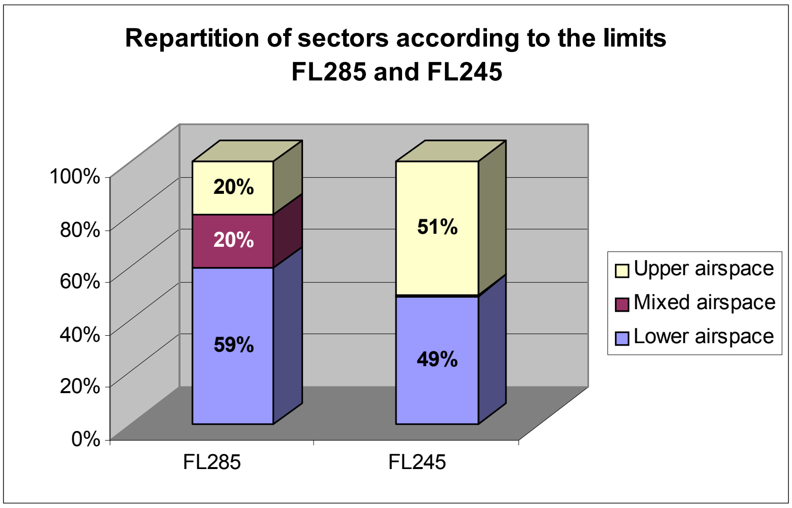


Figure 1

In order to find a more appropriate sector repartition, we have studied several flight level limits for differentiating airspace. FL245 proved to be the best limit since only 3 sectors were overlapping both airspace.

This flight level limit will be used in the rest of this study. When retaining this limit, 596 sectors with more than 10 flights per day and no sector overlapping both airspace, were kept for the analysis.

2.2. Database: complexity indicators

Taking into account flight plans information, the COCA (Complexity & Capacity) team has computed for each considered sector, indicators related to the traffic complexity. These indicators have been obtained for each day of the period from the 12th to the 18th of July 2002, and their average values have been kept for the analysis. This particular week can be considered as representative of the summer traffic in the studied area. Although this sample can not be considered as representative of the yearly activity in terms of traffic level (the traffic level in the winter season being significantly lower than in the summer), it is believed to give good indications of traffic complexity and specificities.

These indicators are:

- The daily number of flights
- The flight mean route length in Km
- The flight average transit time in Minutes
- The flight average number of level changes: one level change is considered each time the aircraft goes up or down of 100ft
- The flight average speed in Km/H
- The variance of flight speeds
- The sector surface in Km²
- The sector volume in Km^3

The comparison of indicator values between lower and upper sectors (Figure 2) shows that the upper sectors control 20% more flights than the lower (on average upper sectors control 270 flights daily vs. 225 flights for lower sectors). Upper sectors being large sectors (their surface is 71% larger than the surface of lower sectors) with flights mainly in their cruise phase (2 level changes per flights vs. 6 in lower sectors), controllers operating on upper sectors can control simultaneously more flights going faster over a greater distance.

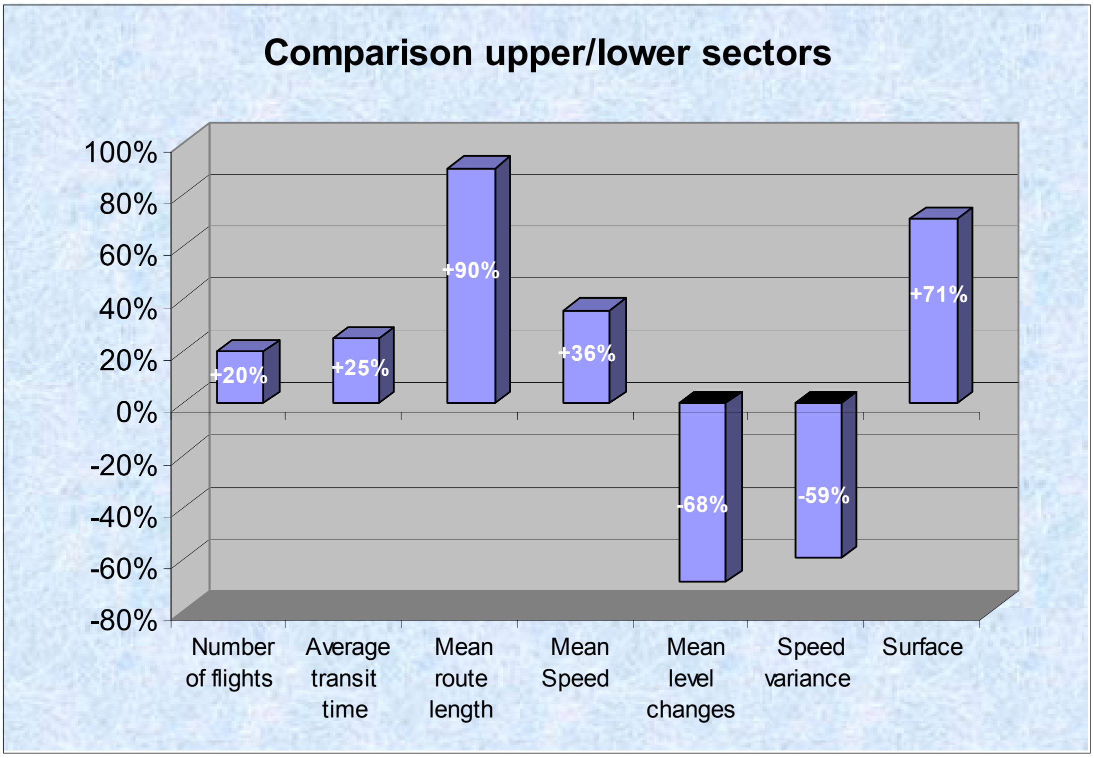


Figure 2

When analysing the number of sectors by kilometre in both airspace, it appears that there are 58% less sectors by kilometre in the upper airspace than in the lower. More precisely this percentage varies from 33% to 83% between the 8 studied states (Figure 3).

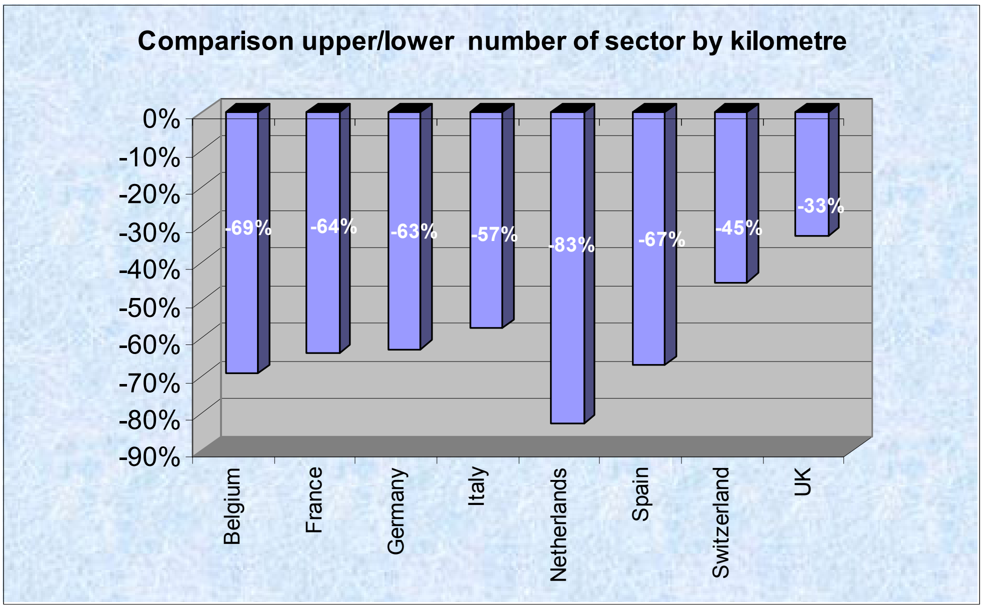


Figure 3

2.3. Cluster analysis

The aim of cluster analysis is to group data objects into clusters. A cluster is a collection of data objects so that objects are similar to one another within the same cluster and dissimilar to objects in other clusters. A good quality of clustering is not only related to the method but also to the explicative variables used for classification. In our case, we have chosen to take the complexity indicators as explicative variables.

The three most relevant complexity indicators allowing to group sectors into homogeneous classes, were kept for subsequent analysis, as an iterative result of the clustering method:

- *The mean speed (MSpeed)*
- *The average transit time (AvTime)*
- *Tthe normalised median of the number of level changes (NormMedLC)*

This last indicator is the median of the number of flight level changes divided by the number of possible levels in the sectors. This indicator ranges between 0 and 1: when flights are mostly in cruise the indicator value is close to zero while when flights cross a large number of possible flight levels the value is close to one.

The cluster analysis method is composed of two steps: the first one consists in determining the number of clusters (i.e. the number of groups in which sectors could be classified) by doing a principal component analysis. The second step consists in allocating each sector to one cluster by using the Partitioning Around Medoids (PAM) method.

2.3.1. Principal component analysis

The principal component analysis computes the best combinations of indicators in order to stress the sample particularities. These combinations are:

- Component1=0.502MSpeed-0.658NormMedLC+0.56AvTime
- Component2=0.775MSpeed-0.63AvTime
- Component3=0.383MSpeed-0.751NormMedLC+0.538AvTime

The quality of results of this analysis is very good since the first two components explain 83.37% of the observation variability meaning that the observation dispersion is in a very large proportion explained by the principal component analysis.

When drawing the observations according the two first components (Figure 4), the distinction between lower and upper sectors appears clearly. Sectors from the upper airspace (in blue) seem to be mainly characterised by a high mean speed, a high average transit time but a small number of levels crossed, while sectors from the lower airspace (in red) have the opposite features.

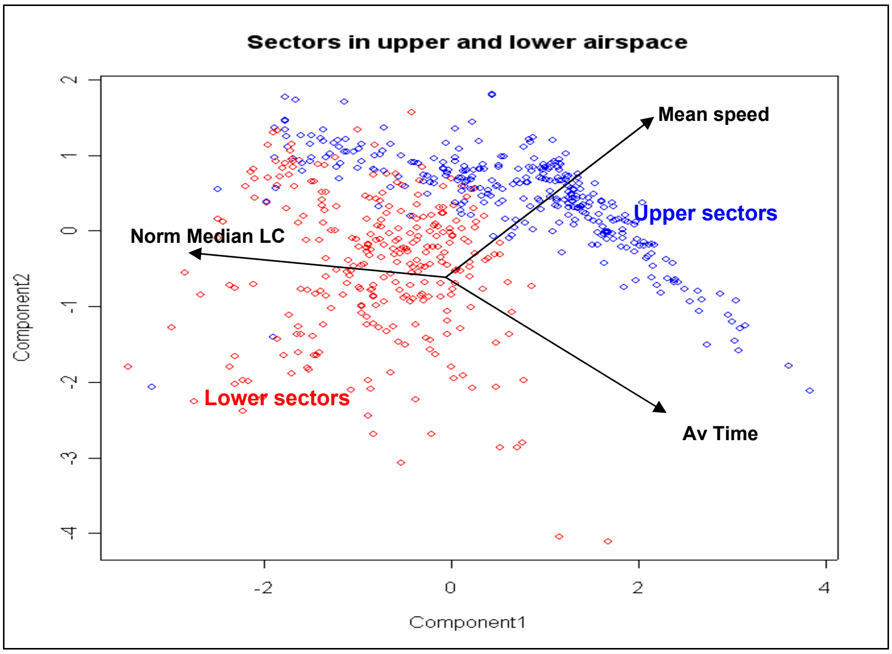


Figure 4

This graph also allows us to hypothesis that sectors could be classified in terms of their complexity into three categories: one mainly composed of lower sectors, one mainly composed of upper sectors and one other composed of both sector types since upper and lower sectors seem to be mixed at the top of the graph.

2.3.2.Partitioning Around Medoids (PAM)

The clustering method used is the **Partitioning Around Medoids (PAM)** method, also called k-medoids method. This method consists in finding in each cluster one representative observation called medoid, so that the distance between this medoid and the other observations of the cluster is minimized.

The PAM method was applied on the dataset for providing three clusters represented in Figure 5 and Figure 6.

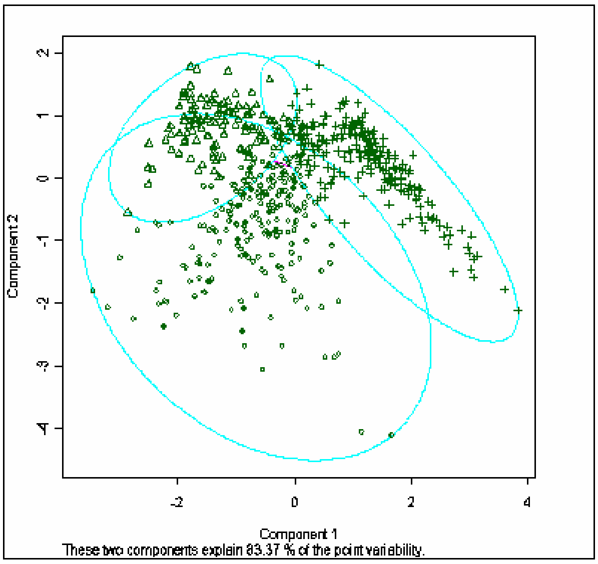


Figure 5

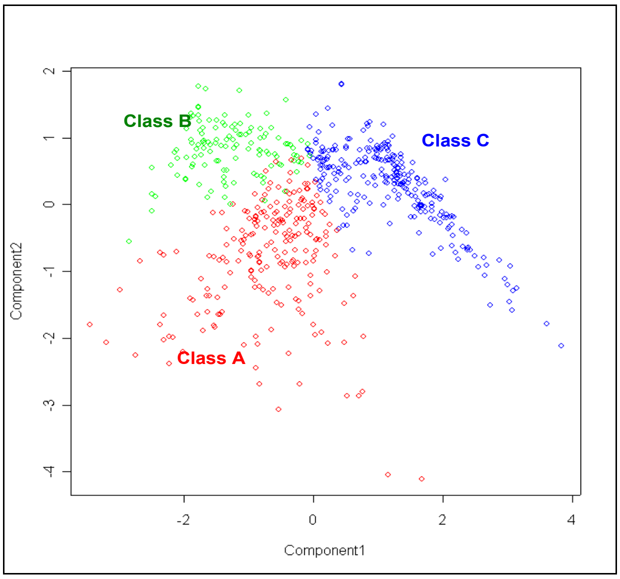


Figure 6

As expected in the principal component analysis, one class is located at the top of the graph (Class B) and should be composed of a mix of lower and upper sectors, while the two other classes should be composed of one type of sectors (see Figure 7).

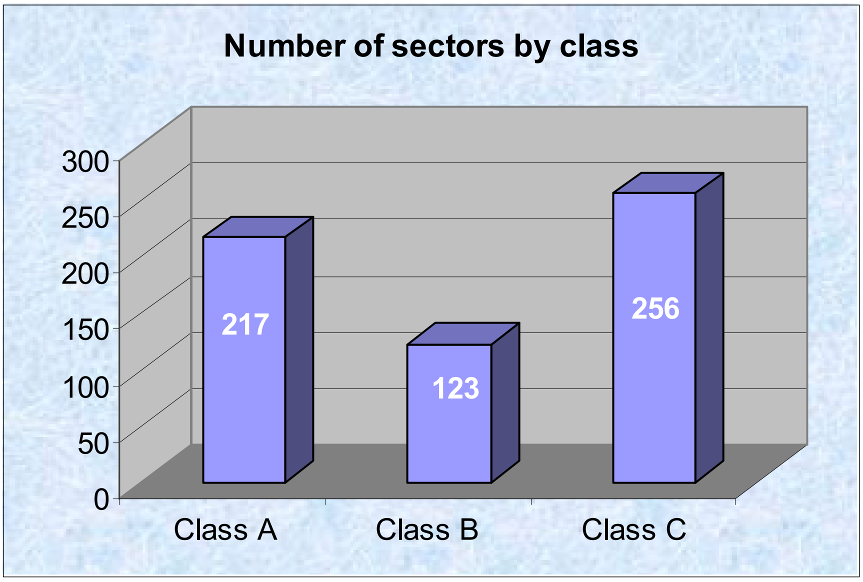


Figure 7

Each class being clearly shown when drawing the observations according to the two first components, each one has specific features giving indications on their nature:

- Class A groups 36% of the studied sectors (Figure 7), which are characterised by a low speed, a medium average transit time and a medium value of normalised median of level changes (flights tend to cross almost half of the possible levels). Moreover, controlled flights cover a relatively small distance and present a large variety of speed in these sectors. These characteristics would tend to correspond to **lower sectors** controlling flights in their climb and descent phase.

- Class C groups 43% of the studied sectors, which are characterised by a high speed, a high average controlled time and a low percentage of flight level crossed (flights tend to be in cruise in these sectors). Moreover, flights cover a large distance in big sectors. These characteristics would tend to correspond to **upper sectors** controlling principally flights in their cruise phase.

- Class B groups 21% of the studied sectors, which are characterized by a medium mean speed, a small average transit time and a high percentage of level changes crossed. An additional specificity of this class is that it contains both lower and upper sectors in equal proportion. The existence of this class would tend to show that some lower and upper sectors would present the same complexity features and would tend to correspond to **transition sectors**. Transition sectors prepare the transition between the lower and the upper airspace. Flights coming from the lower airspace are asked to accelerate when going up so as to attain the cruise speed when entering the upper airspace, and flights coming from the upper airspace are asked to decelerate when going down so as to attain the correct speed for entering lower airspace. Controllers also begin in transition sectors the sequencing of flights carried on in the lower airspace for landings.

Table 1

Class	Mspeed (Km/h)	AvTime (mn)	NormMedMCL
Class A	566	7.42	0.40
Class B	741	4.35	0.80
Class C	822	9.63	0.11

Table 2

Données	Mean route length (Km)	Nb of flights	Speed variance	Volume (Km^3)
Class A	64	234	24,225	99,816
Class B	52	178	16,530	22,733
Class C	132	299	7,538	384,100

2.3.3.Clusters operational validation

The previous chapters described a purely mathematical analysis. We then needed to analyse the composition of each cluster in order to check that this classification has an operational signification.
We have therefore analysed each of the 596 sectors composing our database so as to determine (without taking into account the classification presented in section2.3.2) the operational type of sectors. (Sectors can be lower, transition or upper).
We have considered for this purpose that lower sectors are below FL245, whereas upper sectors are above FL245. The difficulty was to distinguish which sectors could be considered as transition sectors.

In order to give a concrete example of what a transition sector is, Figure 8 presents a view of traffic flows through the LFBH1H sector from Bordeaux ACC. Red flows represent traffic going from north to south while yellow flows represent northbound. The lines width is proportional to traffic density.

Although this sector is located in the French airspace, it clearly appears to be a transition sector for the Barcelona airport, mostly for flows from London and Paris.

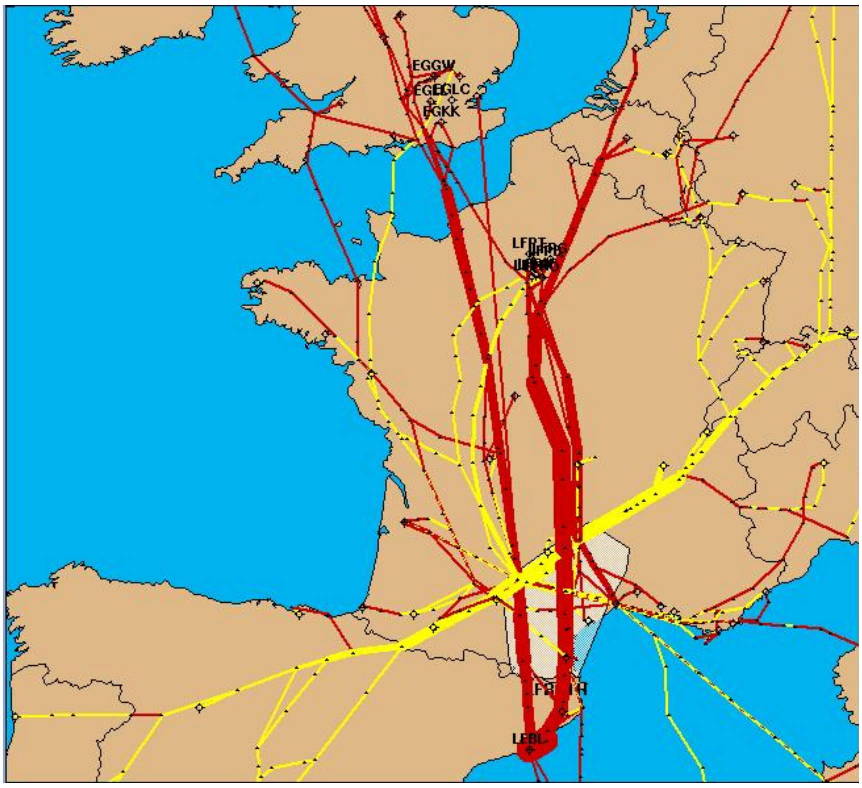


Figure 8

Although transition sectors limits are generally between FL195 and FL300, all transition sectors are not between these strict limits. For instance, our operational analysis has shown that 17 purely “upper” or “lower” sectors are operationally transition sectors.

Hence, the operational analysis of our sectors sample shows that from a total of 596 sectors, 132 are operationally considered as transition sectors. Among the 464 remaining sectors, 227 sectors are lower sectors and 237 are upper sectors.

When analysing the composition of each clusters defined in section 2.3.2 we observe that each class essentially groups one type of sector (Figure 9): Class A is mainly composed of lower sectors, Class B of transition sectors and Class C of upper sectors. These three clusters will then respectively be named for the rest of the study Lower class, Transition class and Upper class.

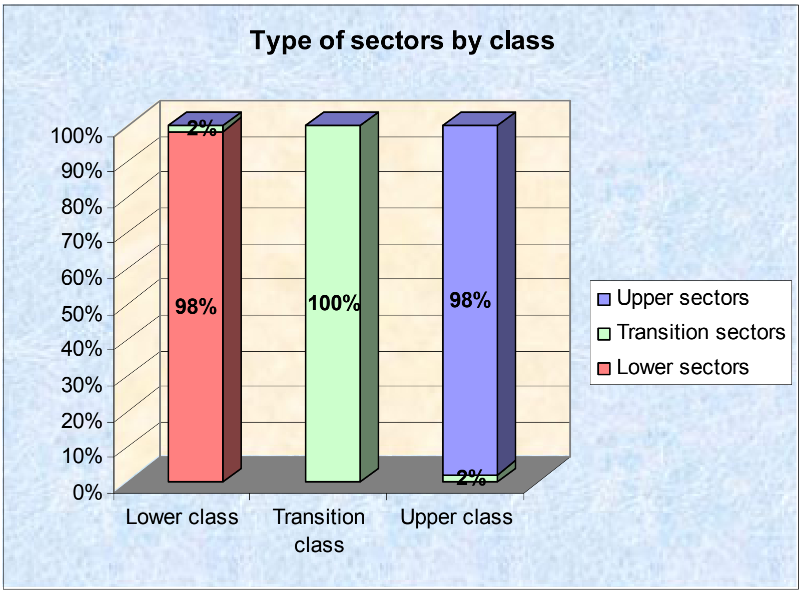


Figure 9

Finally, 98% of sectors can be put into the relevant cluster. **This indicates that our three clusters, issued from a purely mathematical analysis, provide an operationally meaningful description of the European airspace.**

The transition cluster can be decomposed in 49% of transition-Lower sectors (between FL195 and FL245) and by 51% of transition-upper sectors (between FL245 and FL300) (Figure 10).

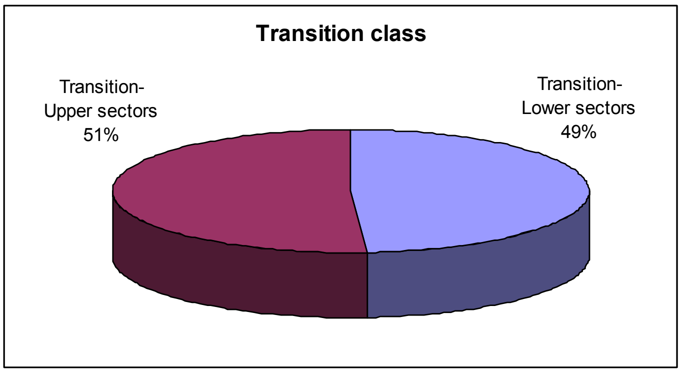


Figure 10

Although the Transition class is totally composed of transition sectors, Upper and Lower class have 2% of sectors not belonging to the relevant class. These sectors are represented in light blue and light green in Figure 11. They are transition sectors not correctly classified because of their specific features:

- Sectors in light green are from Padova ACC. These sectors surround a military zone and constitute the interface between Italy and Slovenia. Due to the special form of the sectors and of the few numbers of flights crossing them, they don't have general features of transition sectors and are not classified in the intermediate class.
- One sector in light blue from Munich ACC has a large military zone overlapping it. There is only one route inside with a few flights. Due to its special design and traffic flow, this sector can only be classified with difficulty and appears in the upper class

- Other sectors in light blue are transition sectors from Roma ACC. They should be classified in the intermediate class, but due to their large size and consequently their average transit time they have been classified in the upper class.

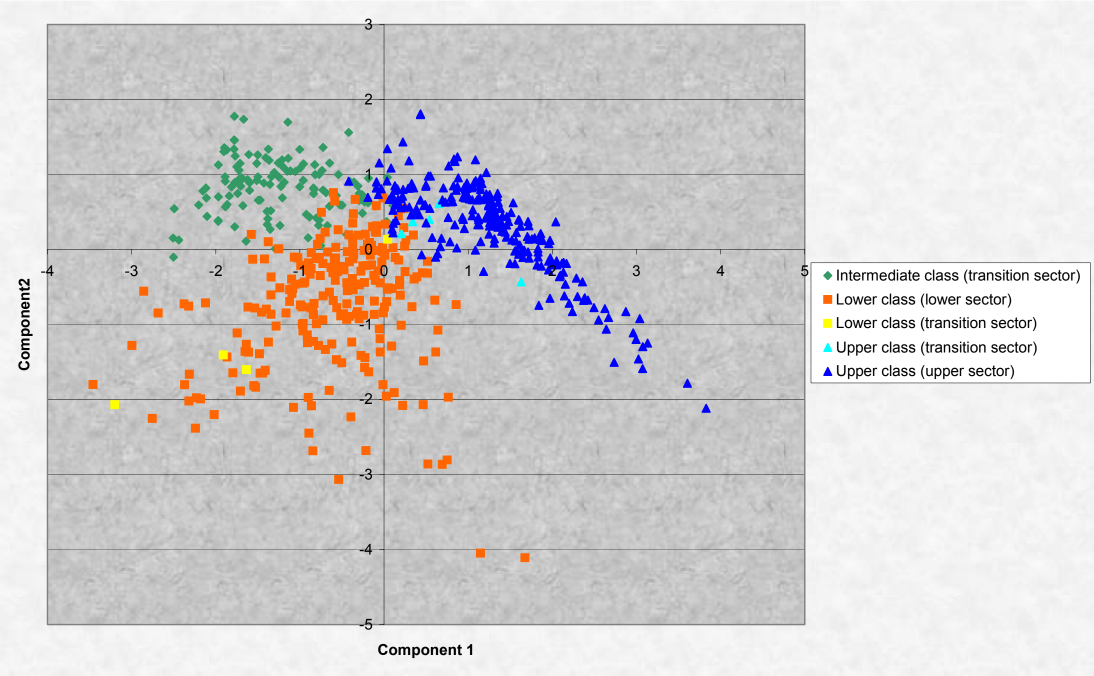


Figure 11

2.3.4.ACCs Composition

When observing the number of sector by class for each ACC (Figure 12), it follows that almost all ACCs have sectors belonging to the transition class and that few of them are specialised in one airspace category.
In particular, ACCs close to major European airports have a very large proportion of intermediate (transition) sectors.
Among the pure lower ACCs (i.e. ACCs with no transition or upper sectors), three are German ACCs. Germany has indeed specialised as most as possible its ACCs in lower or upper airspace (except Berlin and Muenchen). Karlsruhe is in charge of transition and upper airspace above Frankfurt and Maastricht is in charge of the transition and upper airspace above Düsseldorf.

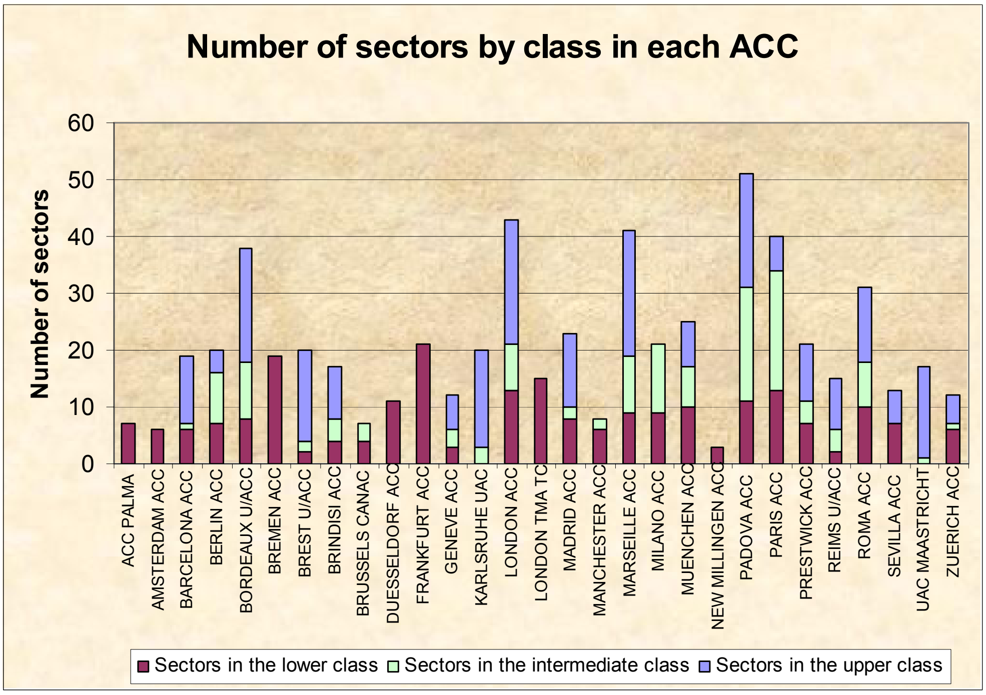

Number of sectors by class in each ACC
Number of sectors
60
50
40
30
20
10
0
ACC PALMA
AMSTERDAM ACC
BARCELONA ACC
BERLIN ACC
BORDEAUX U/ACC
BREMEN ACC
BREST U/ACC
BRINDISI ACC
BRUSSELS CANAC
DUESSELDORF ACC
FRANKFURT ACC
GENEVE ACC
KARLSRUHE UAC
LONDON ACC
LONDON TMA TC
MADRID ACC
MANCHESTER ACC
MARSEILLE ACC
MILANO ACC
MUENCHEN ACC
NEW MILLINGEN ACC
PADOVA ACC
PARIS ACC
PRESTWICK ACC
REIMS U/ACC
ROMA ACC
SEVILLA ACC
UAC MAASTRICHT
ZUERICH ACC
Sectors in the lower class
Sectors in the intermediate class
Sectors in the upper class

Figure 12

3. Cost differentiation by airspace

3.1. Sector cost estimation

Although the national costs of air navigation services are provided each year by the air navigation services providers, neither the cost repartition by ACC nor the sector cost are available. Nevertheless this information is essential to analyse the cost differentiation by airspace. We have therefore chosen to provide rough estimates of sector costs by ANSP. As a result, the proposed analysis gives orders of magnitude, and should not be considered as a detailed computation of "real costs".

When considering that sectors are control positions, their related cost is composed of:

- Direct costs:
    - Operating costs
    - Controllers salaries
- Indirect costs:
    - Infrastructure and equipment costs
    - Administration costs
    - Other operational costs (CFMU, AIS, MET…)
    - Other indirect costs (R&D, search and rescue, …)

We consider in this study that sector costs are the same for a given ANSP, irrelevant of their type (upper, lower, transition) or location. We have related all ANSPs cost to the elementary cost of one sector (**Equation 1**).

$$\boxed{\alpha_i = \frac{Cost_{State_i}}{NBSector_{State_i}}}$$

Equation 1

Where :

$Cost_{State_i}$ is the daily total cost of $State_i$

$NBSector_{State_i}$ is the number of sectors in $State_i$

α_i is the average sector cost in $\mathrm{State}_\mathrm{i}$

This means that ACC costs can be expressed as following:

$$\boxed{Cost_{ACC_{j,i}} = \alpha_i NBSector_{ACC_{j,i}}}$$

Equation 2

Where :

$Cost_{ACC_{j,i}}$ is the daily total cost of ACC_j from $State_i$

$NBSector_{ACC_{j,i}}$ is the number of sectors in ACC_j from $State_i$

α_i is the average cost of a sectors in $\mathrm{State}_\mathrm{i}$

The cost decomposition in lower, transition or upper airspace is obtained as follows:

$$\boxed{Cost_{ACC_{j,i}} = \alpha_i (NBSector\_Lower_{ACC_{j,i}} + NBSectorTransition_{ACC_{j,i}} + NBSector\_Upper_{ACC_{j,i}})}$$

Equation 3

Where:

$Cost_{ACC_{j,i}}$ is the estimated total daily cost of the ACC_j from the state_i

$NBSector\_Lower_{ACC_{j,i}}$ is the number of lower sectors of the ACC_j from the state_i

$NBSector\_Transition_{ACC_{j,i}}$ is the number of transition sectors of the ACC_j from the state_i

$NBSector\_Upper_{ACC_{j,i}}$ is the number of upper sectors of the ACC_j from the state_i

α_i is the average cost of sectors in state_i

This cost repartition is presented in Figure 13:

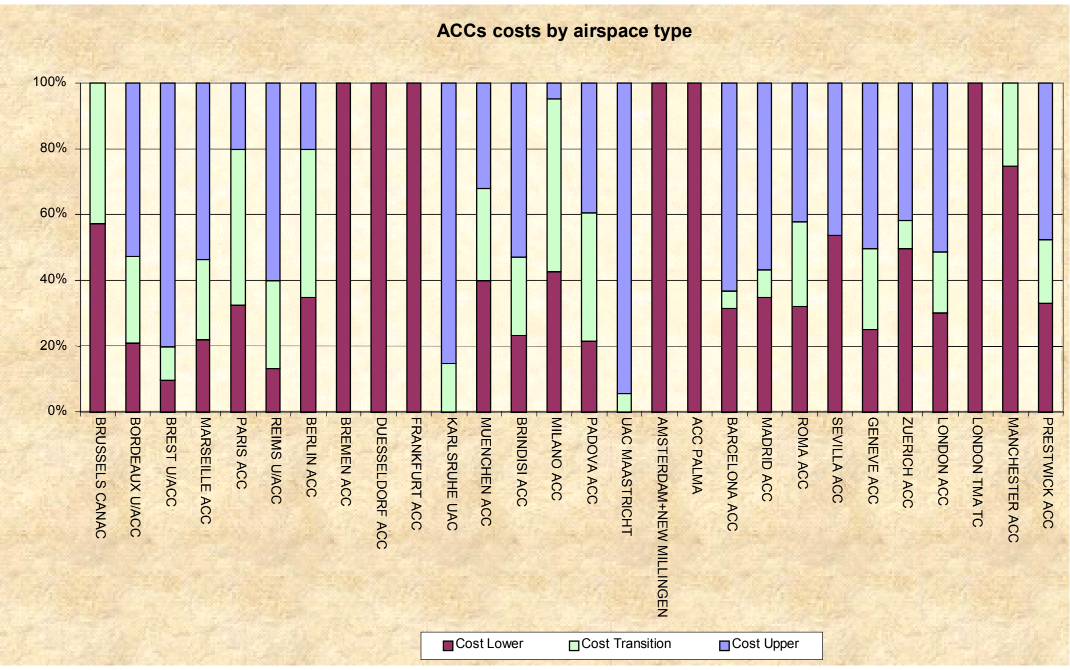


Figure 13

The estimated ACCs costs being proportional to the number of sectors in each airspace class, ACCs with more than 50% of upper sectors (as Bordeaux, Marseille, Brest, Madrid, Barcelona, etc.) would spend more than half of their budget for controlling upper sectors. This graph also displays the importance of costs related to the transition airspace since the proportion of this cost would attain more than 20% for ACCs with a large proportion of transition sectors (e.g. Paris, Milan, Berlin,…)

In general, the share of cost related to transition airspace would not be negligible since it would vary from 12% to 40% between the 8 studied states (Figure 14). In addition, the share of costs related to the other airspace (lower and upper) would not represent more than 55% (except for Netherlands which does not contain transition sectors).

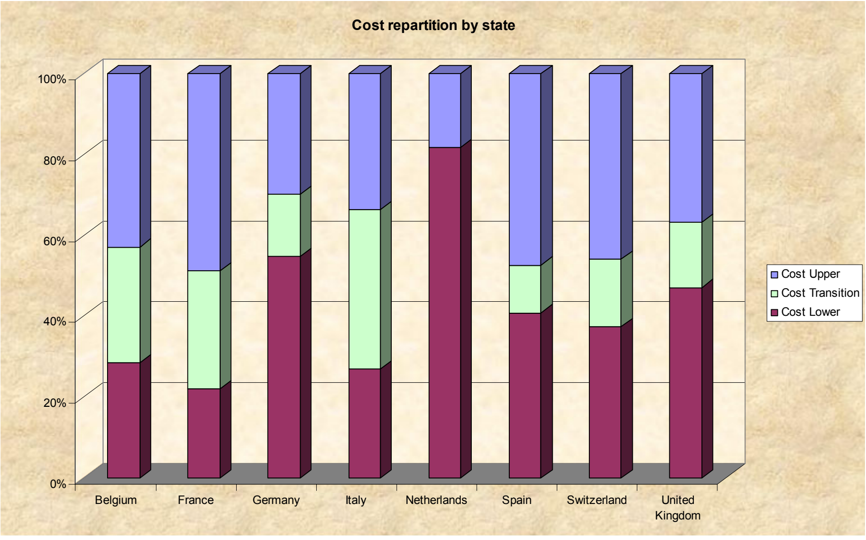


Figure 14

3.2. Cost and revenue by type of airspace

After having shown in section 3.1 the cost repartition by airspace, the next step consists in comparing cost and revenue by airspace type. This comparison will indeed show if the repartition of collected en-route charges by airspace corresponds to the cost differentiation, or if ANSPs cross subsidise their different production costs.

The main impact of the current route charge calculation method (presented in Annexe 2: En-route charging method) is that en-route charges billed to flights crossing the upper airspace are higher than charges billed in lower or transition airspace, since flights crossing the upper airspace are generally performed by large carriers flying over large distances.

Figure 15 compares the repartition of ANSPs' costs en-route charges, where the en-route charges have been computed for one day (July 16 2002)[1]..

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[1] CFMU traffic and maximum take off weight by aircraft type provided by the CRCO

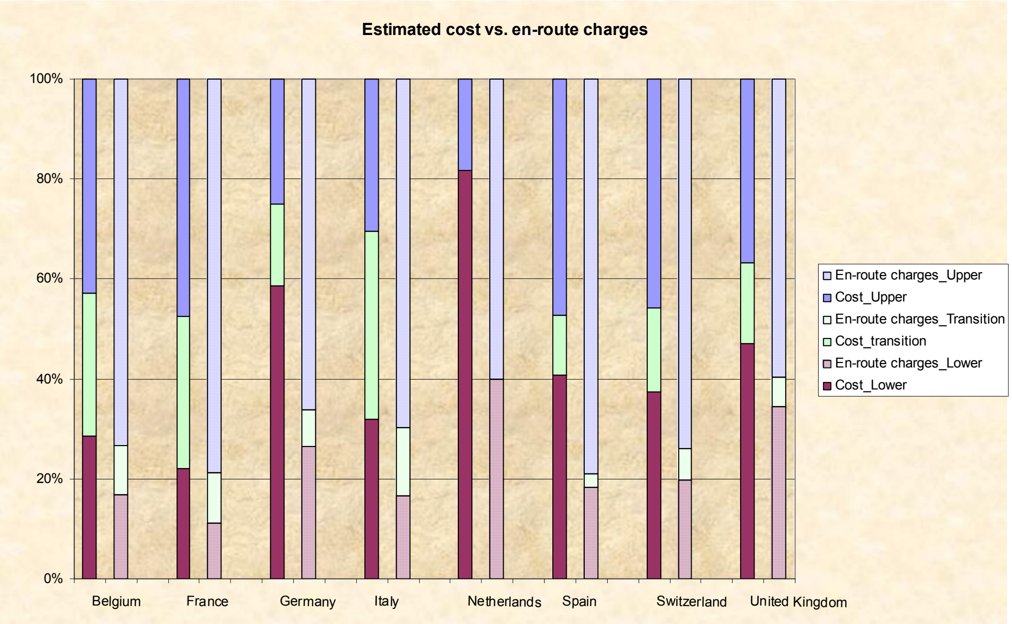

Figure 15

Flights operating in the upper airspace being performed by large aircraft flying over large distances, they have to pay the highest amounts of en-route charges given the fact that the charging formula takes into account the distance flown as well as the maximum take off weight. Although ANSPs would, according to our model, spend up to 50% of their budget controlling the upper airspace, 60% to 80% of their revenues are coming from this activity.

As a consequence, not only the revenues from the control activity in the upper airspace would cover the upper cost, but they would also cover a large part of the other costs (transition cost + lower cost). Upper charges would indeed be from 1/3 to 4 times higher than the upper cost.

These results would tend to prove that users of air traffic control services do not pay the “real“ service cost, since aircraft operators using upper airspace pay more than the service cost while aircraft operators using lower airspace pay less than the service cost.

3.3. Unit rate differentiation by airspace

When estimating the sector costs in section 3.1, we have assumed that the cost related to each sector of a same state would be the same independently of the sector type. Section 2 having however demonstrated a significant difference in the traffic and complexity levels in lower, transition or upper sectors, the unit cost of one service unit could differ according to the sector category.

This section provides rough estimates of unit costs by service unit which could proportionally correspond to unit rates to apply when differentiating the en-route charges by airspace category. The aim of this section is not to evaluate the absolute values of the different unit rate, as this would need a deeper analysis with information which is not in our possession, but more to provide rough estimates of their respective proportions.

3.3.1. Rough estimates of unit rates

Following the assumption that the cost of each airspace should be recovered by the collected en-route charges, the unit rate should be equal to the unit cost by service unit.

When applying a simple regression method to Equation 4, we can estimate coefficients a, b and c giving estimates of the average service unit costs in the lower, transition and upper airspace.

$$Cost_{ACC_i} = a \times SU\_Lower_{ACC_i} + b \times SU\_Transition_{ACC_i} + c \times SU\_Upper_{ACC_i}$$

Equation 4

where:

$Cost_{ACC_i}$ *is the* cost *of* ACC_i

$SU\_Lower_{ACC_i}$ *is the number of service units in the lower airspace of* ACC_i

$SU\_Transition_{ACC_i}$ *is the number of service units in the transition airspace of* ACC_i

$SU\_Upper_{ACC_i}$ *is the number of service units in the upper airspace of* ACC_i

The ordinary least square method provides the following results for our whole sample (where the percentage of explained variance is 87%):

$$\boxed{Cost_{ACC_i} = 143 \times SU\_Lower_{ACC_i} + 111 \times SU\_Transition_{ACC_i} + 26 \times SU\_Upper_{ACC_i}}$$

Equation 5

This means that providing one service unit in the lower airspace would cost 143 €, while it would cost 111€ in the transition airspace and only 26€ in the upper airspace. The current average unit rate is around 70€ in the considered zone.

We assume that the proportion between ***unit costs*** *is the same between* ***unit rates*** *differentiated by airspace category.* ***Hence, the unit rate applied in the lower airspace should be 6 times higher than the unit rate applied in the upper airspace, whereas the unit rate applied in the transition airspace should be 4 times higher than the upper unit rate****.*

3.3.2. Impact on en-route charges

Differentiating the unit rates by airspace would not affect the financial health of air navigation service providers, since the principle of cost recovery would be kept, but it would mainly affect the repartition of en-route charges according to airspace types.

Indeed, with this new pricing method, the en-route charges repartition would be quite inverted compared to the current repartition. The en-route charges billed in the upper airspace with the new method would represent 33% of the total en-route charges billed while more than half of the actual en-route charges are billed in the upper airspace (**Erreur ! Source du renvoi introuvable.**).

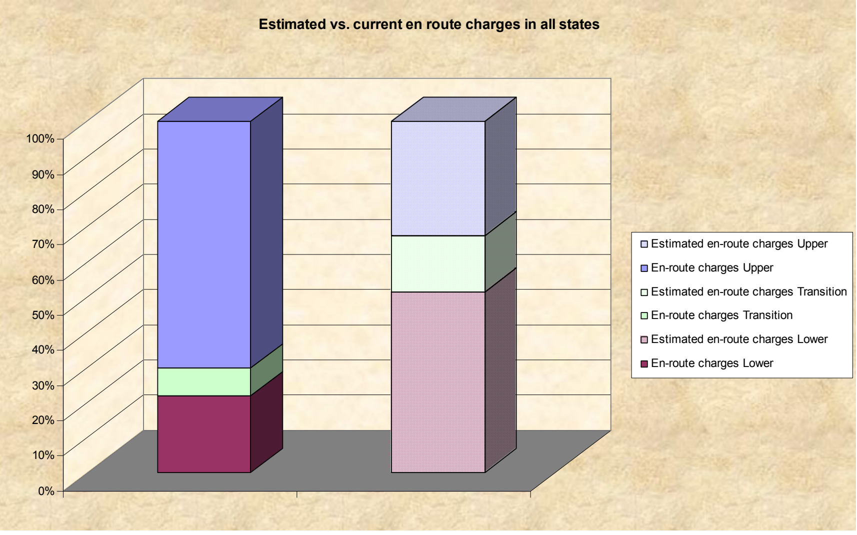

Figure 16

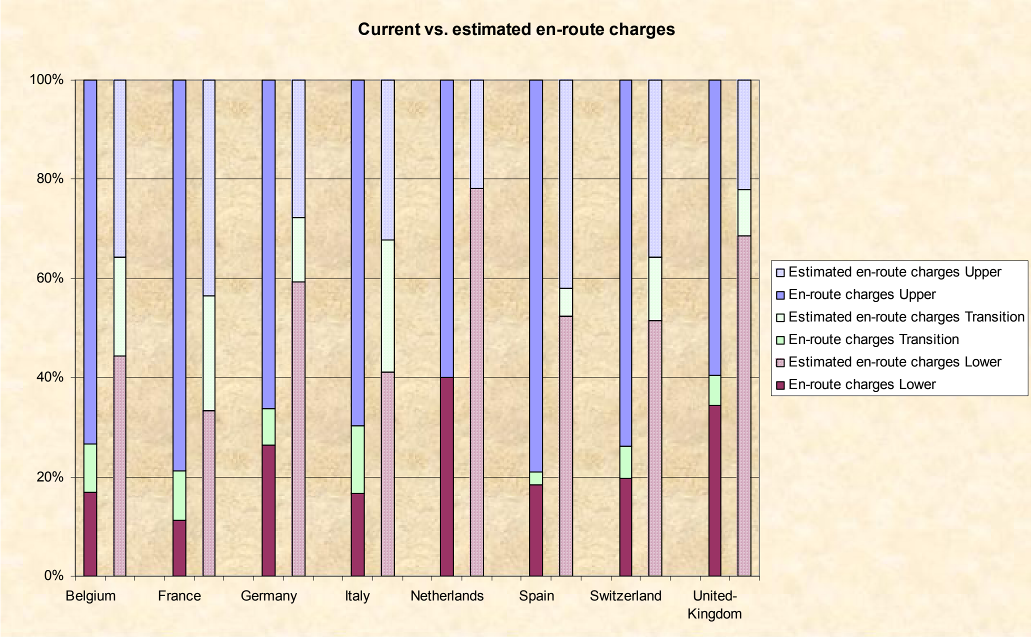

Figure 17

This effect is particularly striking for States having at least 80% of their service units in the upper airspace as France or Spain (Figure 18). Both would bill only 40% of the en-route charges in the upper airspace whereas this share reaches 80% with the current charging mechanism.

On the other hand the proportion of charges billed in the lower airspace would double when differentiating the unit rate. Hence, United-Kingdom, Netherlands, Switzerland, and Germany would see the proportion of lower en-route charges reaching at least 50% of the total billed amount.

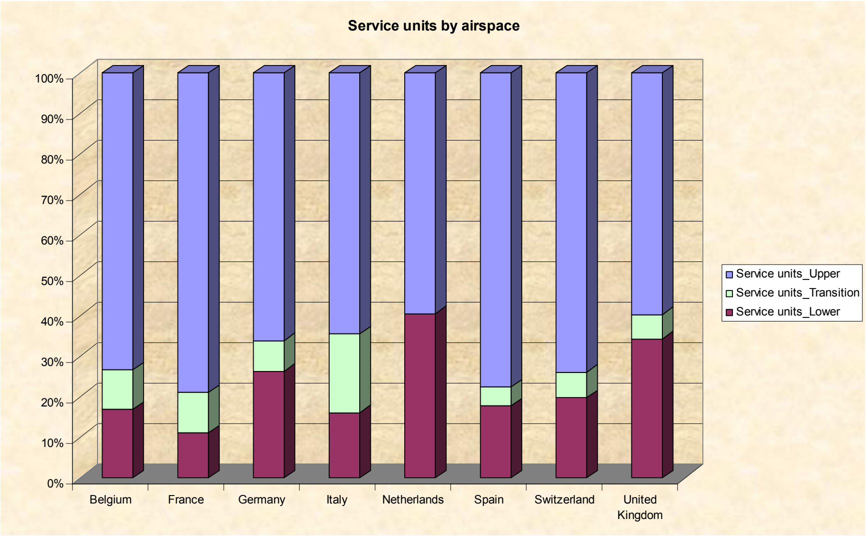
Service units by airspace
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Belgium
France
Germany
Italy
Netherlands
Spain
Switzerland
United Kingdom
Service units_Upper
Service units_Transition
Service units_Lower

Figure 18

4. Cost differentiation between the upper airspace and the lower/transition airspace

In the context of the single European sky, upper sectors will be built independently of national borders. The differentiation envisaged by the European Commission is then to separate the upper airspace from the transition and lower airspace.
This section will therefore present the cost and revenue differentiation between the upper airspace and the rest and will provide rough estimates of differentiated unit rates. *It will thus simulate the impact of having potentially differentiated economic structures addressing upper airspace only.*

4.1. Cost and revenue by airspace

Figure 19 compares the repartition of costs and revenues between the upper airspace and the lower/transition airspace.

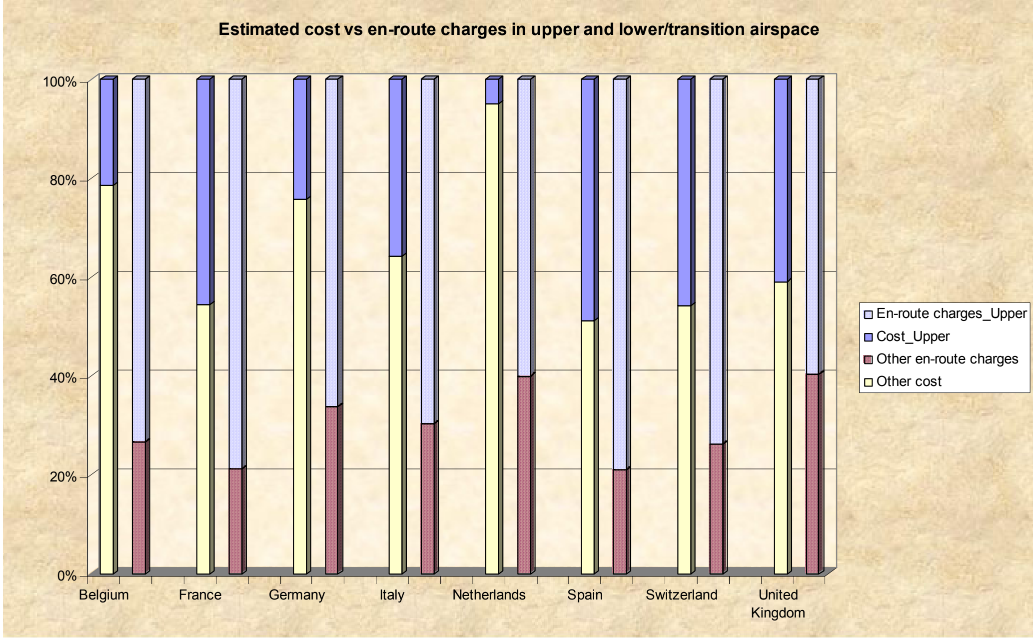

Figure 19

The presence of cross subsidies is once again clearly shown since at least half of the cost related to lower and transition airspace is covered by the charges amount collected in the upper airspace.
If the implementation of the Single European Sky results in the birth of specific structures providing air traffic control structures on Functional Blocks of Airspace, either these structures belong to a wider economic organisation which they would cross-subsidise, or they are economically self-sufficient, meaning that, under the cost recovery scheme, their revenue should match their costs. *It is the latter case which we have modelled, knowing that,* ***given the extremely simplifying assumptions we have made, we hence make a very theoretical exercise, aimed more at provoking ideas rather than proving anything****.*

4.2. Unit rate differentiation by airspace

When applying a simple regression to Equation 4, we can estimate the coefficients α and β which are estimates of the **average service unit costs** in the lower/transition and upper airspace.

$$Cost_{ACC_i} = \alpha \times SU\_Lower\_Transition_{ACC_i} + \beta \times SU\_Upper_{ACC_i}$$

Equation 6

where:

$Cost_{ACC_i}$ *is the cost of* ACC_i

$SU\_Lower\_Transition_{ACC_i}$ *is the number of service units in the lower / transition airspace of* ACC_i

$SU\_Upper_{ACC_i}$ *is the number of service units in the upper airspace of* ACC_i

The ordinary least square method provides the following results (where the percentage of explained variance is 86%):

$$\boxed{Cost_{ACC_i} = 136 \times SU\_Lower_{ACC_i} + 26 \times SU\_Upper_{ACC_i}}$$

Equation 7

This equation clearly shows that, with the current charging formula which is highly dependent on distance and MTOW, the unit rates for FBAs served by a self-sufficient operator would be much lower than what they are today. Their aggregated revenue would equal their cost, which means that, given the distinction between upper and lower/transition airspace, users would then pay for the real service that they are provided.

The difficulty is now that this new economic approach would necessarily introduce a bias, notably for intra Europe flights which would pay a substantially higher fare than international flights.

This would tend to suggest that the implementation of specific FBA economic organisations would need take into account a complete revision of the pricing principles for ATM.

Indeed, the result of such policy on en route revenues is synthesised in the following diagram.

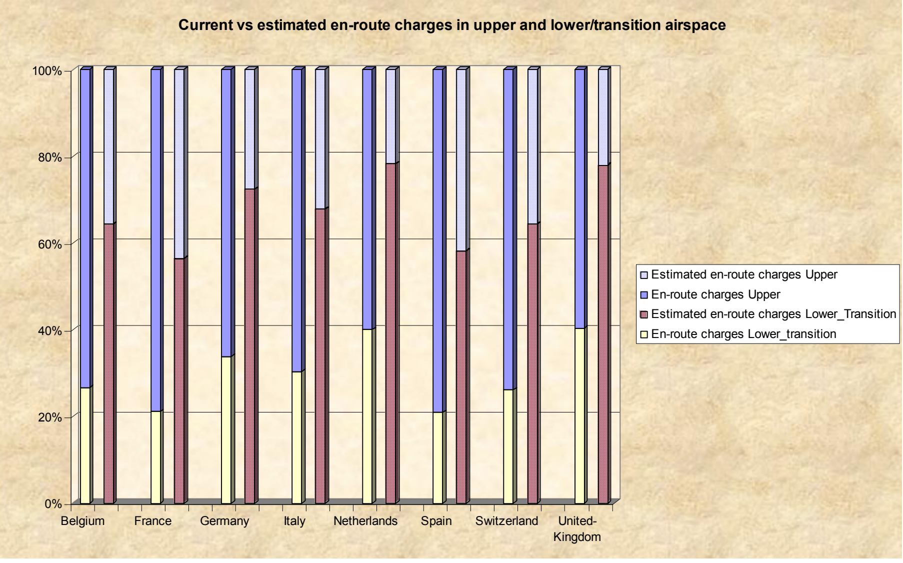

Figure 20

5. Concluding remarks

Our mathematical, validated by an “operational”, approach to European core area sectors classification has clearly shown the existence of three distinct classes of sectors. The lower and upper airspace classes are self explanatory, even though our analysis has come up with different physical limits than the ones widely used in the community (above FL 245 and below FL 195). The existence of a third class, consistent in terms of traffic patterns and characteristics, and therefore in terms of control complexity, is an interesting finding. This transition class links the upper and lower airspace, and represents certainly the most challenging area for further study. Indeed, air traffic control sectors in the transition class provide a service to upper or lower sectors, by preparing the flights for their cruise or landing. Most probably for this reason, we found out that air traffic control centres are usually composed of at least two categories of sectors, thus enabling under the same roof a better operational co-ordination between “feeding” sectors and “receivers”.

From an economic standpoint, and although our analysis may appear to be too simplistic, there is a clear cross-subsidisation process between upper and other airspace, due to the fact that the current ATC charging formula is a function of distance and MTOW, with a constant national rate which is independent from the airspace category. Although this may not be seen as a relevant issue since the cost recovery mechanism ensures that users pay nothing more than the service cost, it does however raise the question of who pays for what.

The Single European Sky legislation will *de facto* introduce a formal distinction between upper airspace and lower/transition airspace. The future Functional Blocks of Airspace have the potential for being operated by autonomous, economically self-sufficient organisations. If this were to be the case, the current equilibrium by which upper airspace activity funds a part of lower/transition airspace activity would be broken. We have estimated that, provided that the same charging formula is kept, this would lead to an upper airspace unit rate of 26€ and lower/transition rate of 136€, to be compared with a rate of 70€ in average today.

Without taking any position on which formula to use for a new ATM economic regime, we think that this study shows that the implementation of Functional Blocks of Airspace cannot be done independently of a new approach to the ATM economic regulation process. We would tend to think that in order to make full advantage of the FBAs generation, one should work on a specific charging regime, which has to be consistent with the overall ATM economic regulation constraints. This topic is certainly an interesting area for further work.

Acknowledgements

We would like to thank Eric Letreguilly (CRCO), Alain Jeunemaitre (CRG, Ecole Polytechnique), Alan Marsden (Eurocontrol Experimental Centre) and Jean-Pierre Nicolaon (Eurocontrol Experimental Centre) for their help in this work.

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Annexe1: List of studied sectors

State	ACC	Sector	Type
Belgium	BRUSSELS CANAC	EBBUHES	Transition
Belgium	BRUSSELS CANAC	EBBUHSS	Transition
Belgium	BRUSSELS CANAC	EBBUHWS	Transition
Belgium	BRUSSELS CANAC	EBBULES	Lower
Belgium	BRUSSELS CANAC	EBBULNS	Lower
Belgium	BRUSSELS CANAC	EBBULSS	Lower
Belgium	BRUSSELS CANAC	EBBULWS	Lower
Belgium	UAC MAASTRICHT	EBMABWH	Upper
Belgium	UAC MAASTRICHT	EBMALNLU	Upper
Belgium	UAC MAASTRICHT	EBMALUXL	Transition
Belgium	UAC MAASTRICHT	EBMALUXM	Upper
Belgium	UAC MAASTRICHT	EBMAOHI	Upper
Belgium	UAC MAASTRICHT	EBMAWSL	Upper
Belgium	UAC MAASTRICHT	EBMAXHI	Upper
France	BORDEAUX U/ACC	LFBBN	Lower
France	BORDEAUX U/ACC	LFBBS	Lower
France	BORDEAUX U/ACC	LFBC2	Upper
France	BORDEAUX U/ACC	LFBC3	Upper
France	BORDEAUX U/ACC	LFBH1H	Transition
France	BORDEAUX U/ACC	LFBH1L	Transition
France	BORDEAUX U/ACC	LFBH2	Upper
France	BORDEAUX U/ACC	LFBL1H	Upper
France	BORDEAUX U/ACC	LFBL1L	Lower
France	BORDEAUX U/ACC	LFBL2	Upper
France	BORDEAUX U/ACC	LFBN1H	Upper
France	BORDEAUX U/ACC	LFBN1L	Transition
France	BORDEAUX U/ACC	LFBN2	Upper
France	BORDEAUX U/ACC	LFBNL	Lower
France	BORDEAUX U/ACC	LFBP1H	Transition
France	BORDEAUX U/ACC	LFBP1L	Transition
France	BORDEAUX U/ACC	LFBP2	Upper
France	BORDEAUX U/ACC	LFBR2	Upper
France	BORDEAUX U/ACC	LFBRG	Upper
France	BORDEAUX U/ACC	LFBRYH	Transition
France	BORDEAUX U/ACC	LFBRYL	Transition
France	BORDEAUX U/ACC	LFBSL	Lower
France	BORDEAUX U/ACC	LFBT1H	Upper
France	BORDEAUX U/ACC	LFBT1L	Transition
France	BORDEAUX U/ACC	LFBT2	Upper
France	BORDEAUX U/ACC	LFBT3	Upper
France	BORDEAUX U/ACC	LFBTA	Lower
France	BORDEAUX U/ACC	LFBTG	Lower
France	BORDEAUX U/ACC	LFBV1H	Upper
France	BORDEAUX U/ACC	LFBV1L	Lower
France	BORDEAUX U/ACC	LFBV2	Upper
France	BORDEAUX U/ACC	LFBX1H	Upper
France	BORDEAUX U/ACC	LFBX1L	Transition
France	BORDEAUX U/ACC	LFBX2	Upper

State	ABB	Sector	Type
France	BORDEAUX U/ACC	LFBX3	Upper
France	BORDEAUX U/ACC	LFBZ1H	Upper
France	BORDEAUX U/ACC	LFBZ1L	Transition
France	BORDEAUX U/ACC	LFBZ2	Upper
France	BREST U/ACC	LFRAU	Upper
France	BREST U/ACC	LFRGU	Upper
France	BREST U/ACC	LFRIDL	Lower
France	BREST U/ACC	LFRIDU	Transition
France	BREST U/ACC	LFRINL	Lower
France	BREST U/ACC	LFRINU	Transition
France	BREST U/ACC	LFRJS	Upper
France	BREST U/ACC	LFRJU	Upper
France	BREST U/ACC	LFRNI	Upper
France	BREST U/ACC	LFRNS	Upper
France	BREST U/ACC	LFRNU	Upper
France	BREST U/ACC	LFROU	Upper
France	BREST U/ACC	LFRQS	Upper
France	BREST U/ACC	LFRQU	Upper
France	BREST U/ACC	LFRXI	Upper
France	BREST U/ACC	LFRXS	Upper
France	BREST U/ACC	LFRXU	Upper
France	BREST U/ACC	LFRZI	Upper
France	BREST U/ACC	LFRZS	Upper
France	BREST U/ACC	LFRZU	Upper
France	MARSEILLE ACC	LFMA1H	Transition
France	MARSEILLE ACC	LFMA1L	Transition
France	MARSEILLE ACC	LFMA2	Upper
France	MARSEILLE ACC	LFMB1H	Upper
France	MARSEILLE ACC	LFMB1L	Transition
France	MARSEILLE ACC	LFMB2	Upper
France	MARSEILLE ACC	LFMCO	Lower
France	MARSEILLE ACC	LFMD1H	Upper
France	MARSEILLE ACC	LFMD1L	Lower
France	MARSEILLE ACC	LFMD2	Upper
France	MARSEILLE ACC	LFMD3	Upper
France	MARSEILLE ACC	LFME1H	Upper
France	MARSEILLE ACC	LFME1L	Transition
France	MARSEILLE ACC	LFME2	Upper
France	MARSEILLE ACC	LFMF1H	Upper
France	MARSEILLE ACC	LFMF1L	Transition
France	MARSEILLE ACC	LFMF2	Upper
France	MARSEILLE ACC	LFMF3	Upper
France	MARSEILLE ACC	LFMG1H	Upper
France	MARSEILLE ACC	LFMG1L	Transition
France	MARSEILLE ACC	LFMG2	Upper
France	MARSEILLE ACC	LFMK1H	Upper
France	MARSEILLE ACC	LFMK1L	Transition
France	MARSEILLE ACC	LFMK2	Upper
France	MARSEILLE ACC	LFMLE	Lower
France	MARSEILLE ACC	LFMLO	Lower
France	MARSEILLE ACC	LFMLS	Lower

State	ACC	Sector	Type
France	MARSEILLE ACC	LFMM1H	Upper
France	MARSEILLE ACC	LFMM1L	Transition
France	MARSEILLE ACC	LFMM2	Upper
France	MARSEILLE ACC	LFMM3	Upper
France	MARSEILLE ACC	LFMML	Lower
France	MARSEILLE ACC	LFMMN	Lower
France	MARSEILLE ACC	LFMMO	Lower
France	MARSEILLE ACC	LFMST	Lower
France	MARSEILLE ACC	LFMW1H	Upper
France	MARSEILLE ACC	LFMW1L	Transition
France	MARSEILLE ACC	LFMW2	Upper
France	MARSEILLE ACC	LFMY1H	Upper
France	MARSEILLE ACC	LFMY1L	Transition
France	MARSEILLE ACC	LFMY2	Upper
France	PARIS ACC	LFFAO1	Lower
France	PARIS ACC	LFFAO2	Transition
France	PARIS ACC	LFFAR1	Lower
France	PARIS ACC	LFFAR2	Upper
France	PARIS ACC	LFFDS	Lower
France	PARIS ACC	LFFLN	Lower
France	PARIS ACC	LFFOG1	Transition
France	PARIS ACC	LFFOG2	Transition
France	PARIS ACC	LFFOT	Lower
France	PARIS ACC	LFFOY1	Transition
France	PARIS ACC	LFFOY2	Upper
France	PARIS ACC	LFFRT	Lower
France	PARIS ACC	LFFS	Lower
France	PARIS ACC	LFFSU	Upper
France	PARIS ACC	LFFTB1	Lower
France	PARIS ACC	LFFTB2	Transition
France	PARIS ACC	LFFTE1	Lower
France	PARIS ACC	LFFTE2	Transition
France	PARIS ACC	LFFTH	Transition
France	PARIS ACC	LFFTL1	Lower
France	PARIS ACC	LFFTL2	Transition
France	PARIS ACC	LFFTM1	Lower
France	PARIS ACC	LFFTM2	Transition
France	PARIS ACC	LFFTN1	Lower
France	PARIS ACC	LFFTN2	Transition
France	PARIS ACC	LFFTP1	Lower
France	PARIS ACC	LFFTP2	Transition
France	PARIS ACC	LFFTS1	Transition
France	PARIS ACC	LFFTS2	Transition
France	PARIS ACC	LFFTU	Upper
France	PARIS ACC	LFFUJ1	Transition
France	PARIS ACC	LFFUJ2	Upper
France	PARIS ACC	LFFUK1	Transition
France	PARIS ACC	LFFUK2	Transition
France	PARIS ACC	LFFUP1	Transition
France	PARIS ACC	LFFUP2	Upper
France	PARIS ACC	LFFUT1	Transition

State	ACC	Sector	Type
France	PARIS ACC	LFFUT2	Upper
France	PARIS ACC	LFFUZ1	Transition
France	PARIS ACC	LFFUZ2	Upper
France	REIMS U/ACC	LFEE	Lower
France	REIMS U/ACC	LFESE	Lower
France	REIMS U/ACC	LFEUE1	Transition
France	REIMS U/ACC	LFEUE2	Upper
France	REIMS U/ACC	LFEUF1	Transition
France	REIMS U/ACC	LFEUF2	Upper
France	REIMS U/ACC	LFEUH1	Transition
France	REIMS U/ACC	LFEUH2	Upper
France	REIMS U/ACC	LFEUN	Upper
France	REIMS U/ACC	LFEUR	Transition
France	REIMS U/ACC	LFEUY	Upper
France	REIMS U/ACC	LFEXE	Upper
France	REIMS U/ACC	LFEXH	Upper
France	REIMS U/ACC	LFEXN	Upper
France	REIMS U/ACC	LFEXR	Upper
Germany	BERLIN ACC	EDBBBERLIHI	Transition
Germany	BERLIN ACC	EDBBBERLILO	Lower
Germany	BERLIN ACC	EDBBNR1L	Lower
Germany	BERLIN ACC	EDBBNR1U	Transition
Germany	BERLIN ACC	EDBBNR2L	Lower
Germany	BERLIN ACC	EDBBNR2U	Transition
Germany	BERLIN ACC	EDBBOR1L	Transition
Germany	BERLIN ACC	EDBBOR1U	Transition
Germany	BERLIN ACC	EDBBSR1L	Lower
Germany	BERLIN ACC	EDBBSR1U	Transition
Germany	BERLIN ACC	EDBBT202SWAL	Lower
Germany	BERLIN ACC	EDBBT202SWAU	Transition
Germany	BERLIN ACC	EDBBUR1	Upper
Germany	BERLIN ACC	EDBBUR2	Upper
Germany	BERLIN ACC	EDBBUR3	Upper
Germany	BERLIN ACC	EDBBUR4	Upper
Germany	BERLIN ACC	EDBBWR1L	Lower
Germany	BERLIN ACC	EDBBWR1U	Transition
Germany	BERLIN ACC	EDBBWR2L	Lower
Germany	BERLIN ACC	EDBBWR2U	Transition
Germany	BREMEN ACC	EDWWNR1	Lower
Germany	BREMEN ACC	EDWWOR1	Lower
Germany	BREMEN ACC	EDWWOR2	Lower
Germany	BREMEN ACC	EDWWOR3	Lower
Germany	BREMEN ACC	EDWWOR4	Lower
Germany	BREMEN ACC	EDWWS3A	Lower
Germany	BREMEN ACC	EDWWS3C	Lower
Germany	BREMEN ACC	EDWWS3D	Lower
Germany	BREMEN ACC	EDWWS4A	Lower
Germany	BREMEN ACC	EDWWS4B	Lower
Germany	BREMEN ACC	EDWWS4C	Lower
Germany	BREMEN ACC	EDWWS4D	Lower
Germany	BREMEN ACC	EDWWS5A	Lower

State	ACC	Sector	Type
Germany	BREMEN ACC	EDWWS5B	Lower
Germany	BREMEN ACC	EDWWSR1	Lower
Germany	BREMEN ACC	EDWWSR2	Lower
Germany	BREMEN ACC	EDWWSR9	Lower
Germany	BREMEN ACC	EDWWWR1	Lower
Germany	BREMEN ACC	EDWWWR2	Lower
Germany	DUESSELDORF ACC	EDLLARE	Lower
Germany	DUESSELDORF ACC	EDLLARN	Lower
Germany	DUESSELDORF ACC	EDLLARS	Lower
Germany	DUESSELDORF ACC	EDLLBT1	Lower
Germany	DUESSELDORF ACC	EDLLBT2	Lower
Germany	DUESSELDORF ACC	EDLLDOM	Lower
Germany	DUESSELDORF ACC	EDLLGIX	Lower
Germany	DUESSELDORF ACC	EDLLGMH	Lower
Germany	DUESSELDORF ACC	EDLLMOH	Lower
Germany	DUESSELDORF ACC	EDLLMST	Lower
Germany	DUESSELDORF ACC	EDLLNOR	Lower
Germany	FRANKFURT ACC	EDFBOD1	Lower
Germany	FRANKFURT ACC	EDFBOD2	Lower
Germany	FRANKFURT ACC	EDFFEIF	Lower
Germany	FRANKFURT ACC	EDFFNR1	Lower
Germany	FRANKFURT ACC	EDFFNR2	Lower
Germany	FRANKFURT ACC	EDFFNR3	Lower
Germany	FRANKFURT ACC	EDFFNR4	Lower
Germany	FRANKFURT ACC	EDFFNR6	Lower
Germany	FRANKFURT ACC	EDFFNR7	Lower
Germany	FRANKFURT ACC	EDFFOR1	Lower
Germany	FRANKFURT ACC	EDFFOR2	Lower
Germany	FRANKFURT ACC	EDFFOR3	Lower
Germany	FRANKFURT ACC	EDFFOR4	Lower
Germany	FRANKFURT ACC	EDFFOR5	Lower
Germany	FRANKFURT ACC	EDFFSR1	Lower
Germany	FRANKFURT ACC	EDFFSR4	Lower
Germany	FRANKFURT ACC	EDFFSR5	Lower
Germany	FRANKFURT ACC	EDFFSR6	Lower
Germany	FRANKFURT ACC	EDFFWR1	Lower
Germany	FRANKFURT ACC	EDFFWR2	Lower
Germany	FRANKFURT ACC	EDFFWR4	Lower
Germany	KARLSRUHE UAC	EDUUER1	Upper
Germany	KARLSRUHE UAC	EDUUER2	Upper
Germany	KARLSRUHE UAC	EDUUFF0	Upper
Germany	KARLSRUHE UAC	EDUUFF1C	Upper
Germany	KARLSRUHE UAC	EDUUFF1D	Upper
Germany	KARLSRUHE UAC	EDUUFF2A	Transition
Germany	KARLSRUHE UAC	EDUUFU1	Upper
Germany	KARLSRUHE UAC	EDUUFU2	Upper
Germany	KARLSRUHE UAC	EDUUNTM1	Transition
Germany	KARLSRUHE UAC	EDUUNTM2	Upper
Germany	KARLSRUHE UAC	EDUUNTM3	Upper
Germany	KARLSRUHE UAC	EDUUNTM4	Upper
Germany	KARLSRUHE UAC	EDUUSL1	Upper

State	ACC	Sector	Type
Germany	KARLSRUHE UAC	EDUUSL2	Upper
Germany	KARLSRUHE UAC	EDUUTG1	Upper
Germany	KARLSRUHE UAC	EDUUTG2	Transition
Germany	KARLSRUHE UAC	EDUUWU0	Upper
Germany	KARLSRUHE UAC	EDUUWU1C	Upper
Germany	KARLSRUHE UAC	EDUUWU1D	Upper
Germany	KARLSRUHE UAC	EDUUWU2A	Upper
Germany	MUENCHEN ACC	EDMMAPPN	Lower
Germany	MUENCHEN ACC	EDMMAPPS	Lower
Germany	MUENCHEN ACC	EDMMHR12	Transition
Germany	MUENCHEN ACC	EDMMHR14	Upper
Germany	MUENCHEN ACC	EDMMINNL	Lower
Germany	MUENCHEN ACC	EDMMINNU	Transition
Germany	MUENCHEN ACC	EDMMKPTL	Lower
Germany	MUENCHEN ACC	EDMMKPTU	Transition
Germany	MUENCHEN ACC	EDMMNR1L	Lower
Germany	MUENCHEN ACC	EDMMNR1U	Transition
Germany	MUENCHEN ACC	EDMMNR2L	Lower
Germany	MUENCHEN ACC	EDMMNR2U	Transition
Germany	MUENCHEN ACC	EDMMNR4L	Lower
Germany	MUENCHEN ACC	EDMMNR4U	Transition
Germany	MUENCHEN ACC	EDMMSR2	Upper
Germany	MUENCHEN ACC	EDMMSR3	Upper
Germany	MUENCHEN ACC	EDMMSR4L	Lower
Germany	MUENCHEN ACC	EDMMSR4U	Upper
Germany	MUENCHEN ACC	EDMMSR5	Upper
Germany	MUENCHEN ACC	EDMMUR1	Upper
Germany	MUENCHEN ACC	EDMMUR2	Upper
Germany	MUENCHEN ACC	EDMMUR3	Upper
Germany	MUENCHEN ACC	EDMMWRNL	Lower
Germany	MUENCHEN ACC	EDMMWRSL	Lower
Germany	MUENCHEN ACC	EDMMWRSU	Transition
Germany	UAC MAASTRICHT	EDYCOHI	Upper
Germany	UAC MAASTRICHT	EDYCOLO	Upper
Germany	UAC MAASTRICHT	EDYHAHI	Upper
Germany	UAC MAASTRICHT	EDYHALO	Upper
Germany	UAC MAASTRICHT	EDYSOHI	Upper
Germany	UAC MAASTRICHT	EDYSOLO	Upper
Germany	UAC MAASTRICHT	EDYYMNS	Upper
Germany	UAC MAASTRICHT	EDYYRHR	Upper
Italy	BRINDISI ACC	LIBBES2	Upper
Italy	BRINDISI ACC	LIBBES3	Upper
Italy	BRINDISI ACC	LIBBES4	Upper
Italy	BRINDISI ACC	LIBBESA	Lower
Italy	BRINDISI ACC	LIBBESB	Transition
Italy	BRINDISI ACC	LIBBMD2	Upper
Italy	BRINDISI ACC	LIBBMD3	Upper
Italy	BRINDISI ACC	LIBBMD4	Upper
Italy	BRINDISI ACC	LIBBMDA	Lower
Italy	BRINDISI ACC	LIBBMDB	Transition
Italy	BRINDISI ACC	LIBBND2	Upper

State	ACC	Sector	Type
Italy	BRINDISI ACC	LIBBND3	Upper
Italy	BRINDISI ACC	LIBBND4	Upper
Italy	BRINDISI ACC	LIBBNDA	Lower
Italy	BRINDISI ACC	LIBBNDB	Transition
Italy	BRINDISI ACC	LIBBSWA	Lower
Italy	BRINDISI ACC	LIBBSWB	Transition
Italy	MILANO ACC	LIMMADE	Lower
Italy	MILANO ACC	LIMMADN	Lower
Italy	MILANO ACC	LIMMADS	Lower
Italy	MILANO ACC	LIMMARR	Lower
Italy	MILANO ACC	LIMMDEP	Lower
Italy	MILANO ACC	LIMMEN1	Lower
Italy	MILANO ACC	LIMMEN2L	Transition
Italy	MILANO ACC	LIMMEN2U	Transition
Italy	MILANO ACC	LIMMEN3	Upper
Italy	MILANO ACC	LIMMES1	Lower
Italy	MILANO ACC	LIMMES2L	Transition
Italy	MILANO ACC	LIMMES2U	Transition
Italy	MILANO ACC	LIMMES3	Transition
Italy	MILANO ACC	LIMMWN1	Lower
Italy	MILANO ACC	LIMMWN2L	Transition
Italy	MILANO ACC	LIMMWN2U	Transition
Italy	MILANO ACC	LIMMWN3	Transition
Italy	MILANO ACC	LIMMWS1	Lower
Italy	MILANO ACC	LIMMWS2L	Transition
Italy	MILANO ACC	LIMMWS2U	Transition
Italy	MILANO ACC	LIMMWS3	Transition
Italy	PADOVA ACC	LIPPMB1	Lower
Italy	PADOVA ACC	LIPPMB2	Lower
Italy	PADOVA ACC	LIPPMB3	Transition
Italy	PADOVA ACC	LIPPMB4H	Transition
Italy	PADOVA ACC	LIPPMB5	Transition
Italy	PADOVA ACC	LIPPMB6	Upper
Italy	PADOVA ACC	LIPPMB7	Upper
Italy	PADOVA ACC	LIPPMC1	Lower
Italy	PADOVA ACC	LIPPMC2	Transition
Italy	PADOVA ACC	LIPPMC3	Transition
Italy	PADOVA ACC	LIPPMC4H	Transition
Italy	PADOVA ACC	LIPPMC4L	Transition
Italy	PADOVA ACC	LIPPMC5	Upper
Italy	PADOVA ACC	LIPPMC6	Upper
Italy	PADOVA ACC	LIPPMC7	Upper
Italy	PADOVA ACC	LIPPMD1	Lower
Italy	PADOVA ACC	LIPPMD2	Transition
Italy	PADOVA ACC	LIPPMD3	Transition
Italy	PADOVA ACC	LIPPMD4H	Transition
Italy	PADOVA ACC	LIPPMD4L	Transition
Italy	PADOVA ACC	LIPPMD5	Upper
Italy	PADOVA ACC	LIPPMD6	Upper
Italy	PADOVA ACC	LIPPMD7	Upper
Italy	PADOVA ACC	LIPPME1	Lower

State	ACC	Sector	Type
Italy	PADOVA ACC	LIPPME2	Transition
Italy	PADOVA ACC	LIPPME3	Transition
Italy	PADOVA ACC	LIPPME4H	Transition
Italy	PADOVA ACC	LIPPME4L	Transition
Italy	PADOVA ACC	LIPPME5	Upper
Italy	PADOVA ACC	LIPPME6	Upper
Italy	PADOVA ACC	LIPPME7	Upper
Italy	PADOVA ACC	LIPPMF1	Lower
Italy	PADOVA ACC	LIPPMF3	Transition
Italy	PADOVA ACC	LIPPMF5	Upper
Italy	PADOVA ACC	LIPPMF6	Upper
Italy	PADOVA ACC	LIPPMF7	Upper
Italy	PADOVA ACC	LIPPN1	Lower
Italy	PADOVA ACC	LIPPN2	Lower
Italy	PADOVA ACC	LIPPN3	Transition
Italy	PADOVA ACC	LIPPN4H	Transition
Italy	PADOVA ACC	LIPPN4L	Transition
Italy	PADOVA ACC	LIPPN5	Upper
Italy	PADOVA ACC	LIPPN6	Upper
Italy	PADOVA ACC	LIPPN7	Upper
Italy	PADOVA ACC	LIPPS1	Lower
Italy	PADOVA ACC	LIPPS2	Lower
Italy	PADOVA ACC	LIPPS3	Lower
Italy	PADOVA ACC	LIPPS4H	Transition
Italy	PADOVA ACC	LIPPS5	Upper
Italy	PADOVA ACC	LIPPS6	Upper
Italy	PADOVA ACC	LIPPS7	Upper
Italy	ROMA ACC	LIRRARR	Lower
Italy	ROMA ACC	LIRRDEP	Lower
Italy	ROMA ACC	LIRRES1A	Lower
Italy	ROMA ACC	LIRRES1B	Transition
Italy	ROMA ACC	LIRRES2	Upper
Italy	ROMA ACC	LIRREW1A	Lower
Italy	ROMA ACC	LIRREW1B	Transition
Italy	ROMA ACC	LIRREW2	Upper
Italy	ROMA ACC	LIRRMIE	Upper
Italy	ROMA ACC	LIRRMIW	Upper
Italy	ROMA ACC	LIRRMUE	Upper
Italy	ROMA ACC	LIRRMUW	Upper
Italy	ROMA ACC	LIRRNE1A	Lower
Italy	ROMA ACC	LIRRNE1B	Transition
Italy	ROMA ACC	LIRRNE2	Upper
Italy	ROMA ACC	LIRRNW1A	Lower
Italy	ROMA ACC	LIRRNW1B	Transition
Italy	ROMA ACC	LIRRNW2	Upper
Italy	ROMA ACC	LIRROVS	Upper
Italy	ROMA ACC	LIRRSU1A	Lower
Italy	ROMA ACC	LIRRSU1B	Transition
Italy	ROMA ACC	LIRRSU2	Upper
Italy	ROMA ACC	LIRRTNR	Lower
Italy	ROMA ACC	LIRRTS1A	Lower

State	ACC	Sector	Type
Italy	ROMA ACC	LIRRTS1B	Transition
Italy	ROMA ACC	LIRRTS2	Upper
Italy	ROMA ACC	LIRRUNRA	Transition
Italy	ROMA ACC	LIRRUNRB	Upper
Italy	ROMA ACC	LIRRUS1A	Lower
Italy	ROMA ACC	LIRRUS1B	Transition
Italy	ROMA ACC	LIRRUS2	Upper
Netherlands	AMSTERDAM ACC	EHACOD	Lower
Netherlands	AMSTERDAM ACC	EHSECT1	Lower
Netherlands	AMSTERDAM ACC	EHSECT2	Lower
Netherlands	AMSTERDAM ACC	EHSECT3	Lower
Netherlands	AMSTERDAM ACC	EHSECT4	Lower
Netherlands	AMSTERDAM ACC	EHSECT5	Lower
Netherlands	NEW MILLINGEN ACC	EHMCTMAB	Lower
Netherlands	NEW MILLINGEN ACC	EHMCTMAD	Lower
Netherlands	NEW MILLINGEN ACC	EHMCTMAG1	Lower
Netherlands	UAC MAASTRICHT	EHDELHI	Upper
Netherlands	UAC MAASTRICHT	EHDELMD	Upper
Spain	ACC PALMA	LECPAPP	Lower
Spain	ACC PALMA	LECPE	Lower
Spain	ACC PALMA	LECPFD1	Lower
Spain	ACC PALMA	LECPFD2	Lower
Spain	ACC PALMA	LECPO	Lower
Spain	ACC PALMA	LECPWN	Lower
Spain	ACC PALMA	LECPWS	Lower
Spain	BARCELONA ACC	LECBCE1H	Upper
Spain	BARCELONA ACC	LECBCE1L	Lower
Spain	BARCELONA ACC	LECBCE2H	Upper
Spain	BARCELONA ACC	LECBCE2L	Lower
Spain	BARCELONA ACC	LECBENORH	Upper
Spain	BARCELONA ACC	LECBENORL	Lower
Spain	BARCELONA ACC	LECBESURH	Upper
Spain	BARCELONA ACC	LECBLEV1H	Upper
Spain	BARCELONA ACC	LECBLEV2	Upper
Spain	BARCELONA ACC	LECBLRDNH	Transition
Spain	BARCELONA ACC	LECBLRDNL	Lower
Spain	BARCELONA ACC	LECBLRDSH	Upper
Spain	BARCELONA ACC	LECBLRDSL	Lower
Spain	BARCELONA ACC	LECBMEDNH	Upper
Spain	BARCELONA ACC	LECBMEDNL	Lower
Spain	BARCELONA ACC	LECBMEDSH	Upper
Spain	BARCELONA ACC	LECBWA1	Upper
Spain	BARCELONA ACC	LECBWA2	Upper
Spain	BARCELONA ACC	LECBWA3	Upper
Spain	MADRID ACC	LECMASTH	Upper
Spain	MADRID ACC	LECMASTL	Lower
Spain	MADRID ACC	LECMBLV	Upper
Spain	MADRID ACC	LECMCCOH	Transition
Spain	MADRID ACC	LECMCCOL	Lower

State	ACC	Sector	Type
Spain	MADRID ACC	LECMCJNH	Transition
Spain	MADRID ACC	LECMCJNL	Lower
Spain	MADRID ACC	LECMCMA	Upper
Spain	MADRID ACC	LECMDGO	Upper
Spain	MADRID ACC	LECMPPNH	Upper
Spain	MADRID ACC	LECMPPNL	Lower
Spain	MADRID ACC	LECMRIA	Upper
Spain	MADRID ACC	LECMSCAH	Upper
Spain	MADRID ACC	LECMSCAL	Lower
Spain	MADRID ACC	LECMSIEH	Upper
Spain	MADRID ACC	LECMSIEL	Lower
Spain	MADRID ACC	LECMSTGH	Upper
Spain	MADRID ACC	LECMTLD	Upper
Spain	MADRID ACC	LECMVTBH	Upper
Spain	MADRID ACC	LECMVTBL	Lower
Spain	MADRID ACC	LECMZMR	Upper
Spain	MADRID ACC	LECMZZAH	Upper
Spain	MADRID ACC	LECMZZAL	Lower
Spain	SEVILLA ACC	LECSAPN	Lower
Spain	SEVILLA ACC	LECSAPS	Lower
Spain	SEVILLA ACC	LECSBANH	Upper
Spain	SEVILLA ACC	LECSBANL	Lower
Spain	SEVILLA ACC	LECSBASH	Upper
Spain	SEVILLA ACC	LECSBASL	Lower
Spain	SEVILLA ACC	LECSMANH	Upper
Spain	SEVILLA ACC	LECSMANL	Lower
Spain	SEVILLA ACC	LECSMASH	Upper
Spain	SEVILLA ACC	LECSMASL	Lower
Spain	SEVILLA ACC	LECSSEV	Upper
Spain	SEVILLA ACC	LECSYESH	Upper
Spain	SEVILLA ACC	LECSYESL	Lower
Switzerland	GENEVE ACC	LSAGIEA	Lower
Switzerland	GENEVE ACC	LSAGIEB	Transition
Switzerland	GENEVE ACC	LSAGINA	Lower
Switzerland	GENEVE ACC	LSAGINB	Transition
Switzerland	GENEVE ACC	LSAGISA	Lower
Switzerland	GENEVE ACC	LSAGISB	Transition
Switzerland	GENEVE ACC	LSAGMA3	Upper
Switzerland	GENEVE ACC	LSAGMA4	Upper
Switzerland	GENEVE ACC	LSAGMA5	Upper
Switzerland	GENEVE ACC	LSAGMS3	Upper
Switzerland	GENEVE ACC	LSAGMS4	Upper
Switzerland	GENEVE ACC	LSAGMS5	Upper
Switzerland	ZUERICH ACC	LSAZARF	Lower
Switzerland	ZUERICH ACC	LSAZESL	Lower
Switzerland	ZUERICH ACC	LSAZNNE	Lower
Switzerland	ZUERICH ACC	LSAZNNW	Lower
Switzerland	ZUERICH ACC	LSAZSSL	Lower
Switzerland	ZUERICH ACC	LSAZUP1	Upper
Switzerland	ZUERICH ACC	LSAZUP2	Upper
Switzerland	ZUERICH ACC	LSAZUP3N	Upper

State	ACC	Sector	Type
Switzerland	ZUERICH ACC	LSAZUP3S	Upper
Switzerland	ZUERICH ACC	LSAZUP4H	Upper
Switzerland	ZUERICH ACC	LSAZUP4L	Transition
Switzerland	ZUERICH ACC	LSAZWSL	Lower
UK	LONDON ACC	EG05BCNL	Lower
UK	LONDON ACC	EG05BCNU	Upper
UK	LONDON ACC	EG06BHDL	Lower
UK	LONDON ACC	EG06BHDU	Upper
UK	LONDON ACC	EG07WIRU	Upper
UK	LONDON ACC	EG08STUL	Lower
UK	LONDON ACC	EG08STUU	Upper
UK	LONDON ACC	EG09LND	Upper
UK	LONDON ACC	EG10NORL	Lower
UK	LONDON ACC	EG10NORU	Upper
UK	LONDON ACC	EG11NORL	Lower
UK	LONDON ACC	EG11NORU	Upper
UK	LONDON ACC	EG12CLEL	Lower
UK	LONDON ACC	EG12CLEU	Upper
UK	LONDON ACC	EG13CLW	Upper
UK	LONDON ACC	EG14CLWL	Lower
UK	LONDON ACC	EG14CLWU	Transition
UK	LONDON ACC	EG16DVRL	Transition
UK	LONDON ACC	EG16DVRU	Upper
UK	LONDON ACC	EG17LYDL	Lower
UK	LONDON ACC	EG17LYDU	Upper
UK	LONDON ACC	EG18SFDL	Lower
UK	LONDON ACC	EG18SFDU	Upper
UK	LONDON ACC	EG23BRSL	Lower
UK	LONDON ACC	EG23BRSU	Transition
UK	LONDON ACC	EG25LMWL	Transition
UK	LONDON ACC	EG25LMWU	Upper
UK	LONDON ACC	EG26LMEL	Transition
UK	LONDON ACC	EG26LMEU	Upper
UK	LONDON ACC	EG28DTNL	Transition
UK	LONDON ACC	EG28DTNU	Transition
UK	LONDON ACC	EG33NORU	Upper
UK	LONDON ACC	EG34DTN	Upper
UK	LONDON ACC	EGDTSL	Transition
UK	LONDON ACC	EGDTSU	Upper
UK	LONDON ACC	EGHEWL	Lower
UK	LONDON ACC	EGHEWU	Upper
UK	LONDON ACC	EGTT01G	Upper
UK	LONDON ACC	EGTT02G	Upper
UK	LONDON ACC	EGTT15G	Lower
UK	LONDON ACC	EGTT21G	Lower
UK	LONDON ACC	EGTTS3	Upper
UK	LONDON ACC	EGTTS4	Upper
UK	LONDON TMA TC	EGTTBIG	Lower
UK	LONDON TMA TC	EGTTBNN	Lower
UK	LONDON TMA TC	EGTTCOW	Lower
UK	LONDON TMA TC	EGTTCPT	Lower

State	**ACC**	**Sector**	**Type**
UK	LONDON TMA TC	EGTTDAG	Lower
UK	LONDON TMA TC	EGTTLAM	Lower
UK	LONDON TMA TC	EGTTLOR	Lower
UK	LONDON TMA TC	EGTTLOW	Lower
UK	LONDON TMA TC	EGTTOCU	Lower
UK	LONDON TMA TC	EGTTSAB	Lower
UK	LONDON TMA TC	EGTTSWD	Lower
UK	LONDON TMA TC	EGTTTIM	Lower
UK	LONDON TMA TC	EGTTVAT	Lower
UK	LONDON TMA TC	EGTTWEL	Lower
UK	LONDON TMA TC	EGTTWIL	Lower
UK	MANCHESTER ACC	EGCC29GL	Transition
UK	MANCHESTER ACC	EGCC29GU	Transition
UK	MANCHESTER ACC	EGCCBOL	Lower
UK	MANCHESTER ACC	EGCCIOM	Lower
UK	MANCHESTER ACC	EGCCRIB	Lower
UK	MANCHESTER ACC	EGCCSTF	Lower
UK	MANCHESTER ACC	EGCCTNT	Lower
UK	MANCHESTER ACC	EGCCW	Lower
UK	PRESTWICK ACC	EGPX57	Upper
UK	PRESTWICK ACC	EGPX59U	Upper
UK	PRESTWICK ACC	EGPXANTL	Lower
UK	PRESTWICK ACC	EGPXANTU	Transition
UK	PRESTWICK ACC	EGPXCNT	Upper
UK	PRESTWICK ACC	EGPXDXN	Upper
UK	PRESTWICK ACC	EGPXDXS	Upper
UK	PRESTWICK ACC	EGPXGWYL	Lower
UK	PRESTWICK ACC	EGPXGWYU	Transition
UK	PRESTWICK ACC	EGPXHLNL	Lower
UK	PRESTWICK ACC	EGPXHUN	Upper
UK	PRESTWICK ACC	EGPXMNE	Upper
UK	PRESTWICK ACC	EGPXMNW	Upper
UK	PRESTWICK ACC	EGPXMORL	Lower
UK	PRESTWICK ACC	EGPXMORU	Upper
UK	PRESTWICK ACC	EGPXSWE	Upper
UK	PRESTWICK ACC	EGPXTAYL	Lower
UK	PRESTWICK ACC	EGPXTAYU	Transition
UK	PRESTWICK ACC	EGPXTLAL	Lower
UK	PRESTWICK ACC	EGPXTLAU	Transition
UK	PRESTWICK ACC	EGPXWESL	Lower

Annexe 2: En-route charging method

The Eurocontrol Central Route Charges Office (CRCO) applies the following charging formula to each flight:

$$R_{\mathrm{State}_i} = UR_{\mathrm{State}_i} \sqrt{\frac{\mathrm{MTOW}}{50}} \times \frac{D_{\mathrm{State}_i}}{100}$$

Equation 8

Where:

R_{State_i} is the en-route charge due by the aircraft operator to the State_i for the flight

UR_{State_i} is the unit rate of State_i

MTOW is the aircraft maximum take-off weight

D_{State_i} is the distance flown in the airspace of State_i

This calculation can also be summarized as following:

$$R_{\mathrm{State}_i} = UR_{\mathrm{State}_i} \times SU_{\mathrm{State}_i}$$

where:

SU_{State_i} is the number of service units correponding to the flight in State_i

$$SU_{\mathrm{State}_i} = \sqrt{\frac{\mathrm{MTOW}}{50}} \times \frac{D_{\mathrm{State}_i}}{100}$$

The introduction of the maximum take-off weight in the calculation aims to reflect the equity guideline recommended by the International Civil Aviation (ICAO), since taking into account the MTOW prevents the large carrier from being helped by the fact that they carry more travellers than small carriers. Introducing the MTOW is therefore a way for taking into account the difference in aircraft operators' revenues.