

ROUTE CHARGING POLICY FOR A FUNCTIONAL BLOCK OF AIRSPACE (CEATS)

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Abstract

The introduction of the CEATS UACC (Central European Air Traffic Services Upper Area Control Centre) controlling the upper airspace of several central European countries opens the doors for assessing different route charging policy scenarios in order to maximise its potential benefits in terms of efficiency, safety and cost-effectiveness, and minimise the drawbacks. In this study, first we compare three charging scenarios by computing the Unit Rate values to be set by each ANSP located in the CEATS area. Then we analyse the impact that such Unit Rate values may have on the Aircraft Operators flying in the CEATS area. We conclude that, without a compensatory mechanism, the policy of considering different Unit Rates for each ANSP in the area would adversely affect the regional carriers and all the airlines based in the CEATS area since the CEATS Unit Rate turns out to be significantly lower than the Unit Rates of the national ANSPs controlling the lower airspaces.

Introduction

In 1997 the EUROCONTROL Commission approved the creation of CEATS UACC (Central European Air Traffic Services Upper Area Control Centre) and signed, with eight National Contracting Parties (Austria, Bosnia-Herzegovina, Croatia, Czech Republic, Hungary, Italy, Slovak Republic, and Slovenia), an agreement that acknowledged the need for co-operation in the provision of Air Traffic Services within the airspace of the National Contracting Parties, in order to insure a safe, effective and expeditious flow of air traffic and to guarantee all airspace users maximum efficiency at minimum cost.

For all National Contracting Parties but Italy the upper airspace to be controlled by CEATS is approximately equal to their national boundaries. In the case of Italy, only the Italian upper airspace actually in charge of Padova ACC is part of the CEATS agreement (see Figure 1). Even though vertical separation between national Air Navigation Service Providers (ANSPs) and CEATS UAC provider slightly varies from country to country, in this study Flight Level 285 (FL285) is taken as threshold between lower and upper airspace.



Figure 1. CEATS Airspace

The main aim of this study is to provide a conceptual framework supporting CEATS decision making bodies in establishing the route charging policy for CEATS airspace.

Under the full cost recovery mechanism, we analyse three methods of defining the Unit Rate according to which aircraft operators are charged for services provided by CEATS and national ANSPs: Allocation to the National Cost Base (NCB), the Single Unit Rate in Upper Airspace (SUU) and the Single Unit Rate in All Airspace (SUA).

In particular, for each scenario we compute – for a specific test week – the Unit Rate values to be set by each ANSP located in the CEATS area.

In the following, for the same test week we calculate the route charges to be paid by each flight performed in the CEATS area according to the three scenarios under study, and we compare their impact on the Aircraft Operators.

Background

The current system for recovering costs for the provision of air navigation services in nearly all the European airspace has been under scrutiny for the past recent years. The main pillar of the present policy is that all the costs experienced by the ANSPs have to be sooner or later fully recovered by adequately charging the airspace users, i.e., the Aircraft Operators. The existence of the full cost recovery principle (in all countries but UK) and the fragmentation of the European airspace in about 35 ANSPs produce a charging mechanism whose ef-

fects on the ATM system and airline costs and behaviours are far from obvious. In this context, both the European Commission (DG TREN) and EUROCONTROL sponsored independent studies to analyse the present situation and suggest possible improvements to foster greater ANS efficiency while reducing costs and granting the appropriate level of safety. Relevant EC studies ([1] and [2]) address regulatory and financial issues of the air traffic management. On the EUROCONTROL side, we carried out a comprehensive project investigating the impact of changes in en-route charges with respect to the demand and supply sides of ATM in a view to improve the overall efficiency of the system [3]. In the above studies, the impact of the differentiation of unit rates between lower and upper airspaces are envisaged, but not fully explored. More recently, [4] explicitly deals with upper airspace-related issue such as the provision of aeronautical information for the European Upper Flight Information Region. A further interesting study is [5], whose 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 sense. Our work develops a theoretical framework for such issues by focusing on a specific airspace and relying on a very accurate analysis of flight plans and route charge data.

The current charging system

In 1969, the EUROCONTROL Member States adopted the principles for a harmonized regional en-route charges system, involving a single charge per flight, which came into operation in 1981. Accordingly, the Member States have agreed to implement a common policy for establishment and calculation of charges levied on aircraft operators of en-route air navigation facilities and services, called "route charges" (details and documents are available at www.eurocontrol.int/crco)

The total charge r_f to be paid by a flight f and collected by EUROCONTROL equals the sum of the charges r_{if} generated in the FIRs of the individual States i :

$$r_f = \sum_i r_{if} ,$$

where the individual charge r_{if} is equal to the product of the distance factor d_{if} and the weight factor p_f and the Unit Rate t_i :

$$r_{if} = d_{if} \times p_f \times t_i .$$

By defining $s_{if} = d_{if} \times p_f$ as the number of Service Units in State i for flight f , the route charges collected from flight f can be expressed as

$$r_f = \sum_i s_{if} \times t_i .$$

If in a given time interval the number of Service Units in State i are $s_i = \sum_f s_{if}$, the revenues collected by means of route charges by State i in this period are $R_i = t_i \times s_i$.

CEATS Route Charging Policy

In the new CEATS environment route charges are likely to be collected using the same formula as for individual states. However, different possibilities to calculate Unit Rates can be envisaged. This section aims at describing the possible CEATS route charging scenarios, analysing the benefits and the drawbacks of each proposed policy.

Route Charging Scenarios

Three methods of determining the Unit Rate to charge aircraft operators for services provided in the CEATS area are proposed.

These are Allocation to the National Cost Base (which will be named **NCB** in this study), the Single Unit Rate in Upper Airspace (**SUU**) and the Single Unit Rate in All Airspace (**SUA**). They are described in general terms as follows:

Allocation to the National Cost Base - NCB

CEATS makes no direct charge for its services and its costs are met by the eight national Air Navigation Service Providers (in accordance with an agreed sharing formula, possibly a combination of the number of air-traffic controllers and the airspace size), who then recover their costs within their own national Unit Rate.

This approach is the same as that currently used at Maastricht. Under this system, although CEATS controlled airspace would be a separate operational unit, it would not be recognized as such by the charging system.

Within the CEATS region there will be nine blocks of en-route airspace, one upper level block and eight lower level blocks (one above each state) and CEATS controlled airspace will be treated as eight separate charging blocks of airspace, each of which has a common charge with the airspace below it (controlled by national ANSPs); thus, although there will be nine services in the region, there will be only eight Unit Rates. According to this scenario, route charges for aircraft flying in the region would be collected by CRCO and distributed to the

eight ANSPs, each of which would pay to CEATS its share of CEATS costs.

Its main benefits are:

- It does not introduce drastic changes: CRCO would continue to collect the charges as currently; the sharing-costs formula is currently used for CEATS development cost recovery.
- It is already in operational use at Maastricht: well understood by airlines and easily implemented.

Its main drawbacks are:

- Not in harmony with the principles of the Single Sky Policy.
- Differences in route charges may lead to inefficient use of the available capacity of the airspace.
- Requires ANSPs to reach a cost sharing agreement each year.

Single Unit Rate in Upper Airspace - SUU

CEATS compiles its own Unit Rate for charging aircraft flying in the airspace it controls, while the eight national Air Navigation Service Providers separately compile Unit Rates for their lower airspace. Under this approach, CEATS could be considered as a distinct operational entity responsible for its own costs and revenues. According to this scenario, route charges for aircraft flying in the CEATS region would be collected by CRCO and distributed to each of the service providers (CEATS and the national ANSPs) through whose airspace the aircraft flew. In such way, within the region there would be nine services provided one in each of the nine blocks of en-route airspace, and nine corresponding prices.

In order to practically apply this scenario, it would be necessary for CRCO to know information on aircraft's altitude as well as its route, in order to distribute the route charges to the correct parties (to CEATS provider if above FL285, or to the national ANSPs if under FL285). According to this proposal, the Unit Rate for CEATS would likely be low, as it would be a purely upper airspace centre with a higher proportion of over-flights, and the Unit Rates for the national ANSPs would likely be higher than they are now, as they would be just lower airspace centres, carrying out more complex manoeuvres and covering shorter distance and providing additional services such as, e.g., S&R, Me-teo.

Its main benefits are:

- A simple but new system involving new procedures.

- It is supportive of the Single Sky Policy, because costs and charges are related to an operational unit (CEATS Upper Area) and not to a national system.

- Horizontal rerouting in the upper airspace would not depend on the route charges.

Its main drawbacks are:

- Requirement for CRCO to receive height data for the aircraft.
- The probable low Unit Rate of CEATS Upper Area could induce some airlines to perform more flights over FL285 and fewer flights under FL285, causing possible traffic congestions, reducing safety.
- High Unit Rate in the lower airspace may harm regional airlines flying mainly in the lower airspace thus triggering the need to implement a compensation mechanism.

Single Unit Rate in All Airspace - SUA

CEATS and the eight national service providers each charge aircraft flying in the airspace they control, but at the same rate. Also according to this scenario, route charges for aircraft flying in the CEATS region, would be collected by CRCO and distributed to each of the service providers (CEATS and the national ANSPs) through whose airspace the aircraft flew. In such way, within the region there would be nine services provided, one in each of the nine blocks of en-route airspace, but only one corresponding price.

Its main benefits are:

- Simple to operate as eight national rates would be replaced by one regional rate.
- It is totally supportive of Single Sky Policy: perfect correspondence between OAB (Operational Airspace Block) and ACB (Airspace Charging Block).
- Optimum use of airspace: flight plans or rerouting would not depend on route charges

Its main drawback is:

- CEATS and national ANSPs cannot all have the same levels of costs and traffic, thus they cannot all have the same Unit Rate (calculated in accordance with the cost-recovery mechanism). For this reason all parties in the region would have to agree on the level of the rate and on measures of compensating payments between each others.

Unit Rate computation

In this section we describe how to actually compute, under suitable hypotheses, the Unit Rate values for each country in each of the three scenarios.

Assumptions

As already mentioned, Unit Rates are determined on a national basis according to the Full Cost Recovery (FCR) principle, i.e., costs incurred by each national ANSP are fully recovered according to a procedure contemplating compensations for deviations between forecast and actual traffic volumes. It should be pointed out that the FCR principle is presently implemented in all EUROCONTROL states, except United Kingdom. Accordingly,

Assumption 1: *the costs incurred by the eight national ANSPs (each controlling its lower airspace) and CEATS (controlling the overall upper airspace) are fully recovered from route charges.*

Thus if C_i are the costs incurred by the i -th ANSP in a specific period of time and $R_i = t_i \times s_i$ are the revenues collected through route charges, it holds that $C_i = R_i$. In addition, the total costs C for providing ANSs in the area is equal to the sum of the costs incurred by each ANSP, i.e., $C = \sum_i C_i$. Among the benefits of the introduc-

tion of such a super-national ANS provider as CEATS UAC, a decrease of the total costs of providing ANSs in the area (while guaranteeing the adequate level of safety) is expected either globally either for each individual national ANSP. Hence

Assumption 2: *the overall and individual costs incurred by the eight national ANSPs and CEATS are respectively not larger than the overall and individual costs to be incurred by the eight national ANSPs when each of them is also responsible for its portion of upper airspace.*

According to the above assumptions the computation of the Unit Rates in each of the three scenarios might be straightforward: we consider a testing period T and we compute the revenues R_i collected by the i -th national ANSP during T . Since these revenues are also equal to the costs C_i incurred by the i -th ANSP in T , we set the costs of the same ANSP after the introduction of CEATS at most equal to C_i , and we derive the new Unit Rates for each of the three scenarios under study.

Relationship among costs

Let the superscript B refer to the scenario presently in operation and considered in the testing period T , i.e., the Baseline Scenario. Let the superscript S refer to any of the proposed scenario for setting Unit Rates when CEATS will be in operation.

From the above hypotheses it follows that $C^S \leq C^B$ and, in particular, $C_i^S \leq C_i^B \forall i$. Let α be the ratio between the total costs after and before the introduction of CEATS, i.e.,

$C^S = \alpha C^B$ where $0 \leq \alpha \leq 1$. Similarly, since we assume that each ANSP individually benefits of a cost reduction, we may write: $C_i^S = \alpha_i C_i^B \forall i$, where $0 \leq \alpha_i \leq 1 \forall i$. Hence

$$\alpha = \frac{\sum_i \alpha_i C_i^B}{\sum_i C_i^B}.$$

Since the CEATS provider is in charge of the upper airspace and its costs are shared among the eight national ANSPs, we need to distinguish – for each ANSP – between the costs for controlling the lower (L) and upper (U) airspace, i.e., $C_i^S = C_i^L + C_i^U$.

It turns out that

$$C^S = \sum_i C_i^S = \sum_i C_i^L + \sum_i C_i^U = \sum_i C_i^L + C_{CS}$$

where $C_{CS} = \sum_i C_i^U$ is the CEATS cost.

NCB, SUU and SUA scenarios – Description

By assuming that Unit Rates in upper and lower airspaces of the same Country i are possibly different, the revenues collected under scenario S in the testing period T are:

$$R_i^S = t_i^L s_i^L + t_i^U s_i^U. \quad (1)$$

The costs for providing ANSs are

$$C_i^S = \alpha_i C_i^B = \alpha_i t_i^B s_i^B. \quad (2)$$

As already mentioned, each ANSP has to recover all the costs it incurs in providing its services. However, this reimbursement can be attained by meeting either conditions:

- A) The revenues collected by each ANSP exactly match its costs.
- B) The overall amount collected by the nine ANSPs is equal to their overall cost (i.e., $R^S = C^S$).

Clearly, when condition A is implemented, condition B is automatically achieved. However, the vice-versa always holds only if a redistribution following the collection phase is envisaged.

The present system (i.e., the Baseline Scenario) complies with Condition A. Some of the proposed scenarios comply with Condition B only, thus requiring a redistribution phase. We now adapt Equations (1) and (2) to the three scenarios under study.

Allocation to the National Cost Base - NCB

In this case

$$t_i^L = t_i^U = t_i^{NCB}.$$

With little algebra, it follows that

$$t_i^{NCB} = \alpha_i t_i^B.$$

The *NCB* scenario parallels the present system. The national Unit Rate decrease with respect to the actual values is proportional to the cost benefits following the introduction of CEATS ANSP. This scenario does not exactly meet Condition A because CEATS costs are recovered following a redistribution of the revenues collected by the national ANSPs in accordance with the enforced cost sharing agreement.

Single Unit Rate in Upper Airspace - SUU

In this case

$$t_i^L s_i^L + t_i^U s_i^U = \alpha_i t_i^B s_i^B.$$

With a little algebra it turns out that:

$$\frac{t_i^L}{t_i^B} = \alpha_i + \frac{s_i^U}{s_i^L} \left(\alpha_i - \frac{t_i^U}{t_i^B} \right). \quad (3)$$

Clearly, the *NCB* scenario is a particular case where the ratio is always equal to α_i .

In the *SUU* scenario each of the nine ANSPs directly collects its revenues. Since we may expect that costs for providing ANSs in the upper airspace are significantly lower than costs for providing them in the lower airspace, it is highly likely that Unit Rates in the lower airspace are going to become significantly higher than those in the upper one. Equation (3) highlights how much the Unit Rate of the lower airspace would vary with respect to the actual one after the introduction of CEATS provider. Since CEATS is a unique and super-national entity, the Unit Rate in the upper airspace should be the same in each country, i.e.,

$$t_i^U = t_{CS} \quad \forall i.$$

The Unit Rate t_{CS} is simply computed by dividing the CEATS costs by the number of the expected Service Units in the CEATS (upper) airspace.

The *SUU* scenario perfectly fulfils Condition A considering CEATS as a separate ANSP.

Single Unit Rate in All Airspace - SUA

The *SUA* scenario meets Condition B only.

Since the total revenues of the whole airspace are $R^{SUA} = t^{SUA} \sum_i s_i^{SUA}$ the unique Unit Rate for the

(lower and upper) airspace of the whole region is:

$$t^{SUA} = \frac{\sum_i \alpha_i t_i^B s_i^B}{\sum_i s_i^{SUA}}, \quad (4)$$

where s_i^{SUA} represents the number of Service Units in Country i when the *SUA* scenario holds. This value is slightly smaller than the corresponding value of the Baseline scenario (i.e., $s_i^{SUA} \leq s_i^B \quad \forall i$). In fact, the distance factor between the entry and exit points of the CEATS region is simply the great circle distance between them and not a piecewise line taking into account internal national borders like in the Baseline Scenario. However, differences among the two values are generally small.

The Baseline Scenario

The three proposed scenarios are compared with respect to a Baseline Scenario which considers the week from 14 to 20 April 2003 as testing period. All data on flight plans and Service Units have been kindly provided by CFMU and CRCO, respectively. Table 1 summarizes the relevant figures for the Baseline scenario. Column 1 and 2 show the Countries (whose real names are hidden for confidentiality reasons) and their Unit Rates, respectively. Column 5 presents the number of Service Units per Country according to the CRCO database. Each entry in Column 6 is simply the product of the corresponding entries in columns 2 and 5. The Service Unit breakdown between lower and upper airspaces (Columns 3 and 4) has been computed by means of an extension of the currently available RSO Software. In fact, once the flight plan of a specific flight is known, distance factors in each country (and, as a consequence, route charges) can be exactly computed using the RSO Software freely provided by CRCO. However, in accordance with the actual charging system, the current version of RSO does not allow:

- to charge flights depending on their flight level. This limitation prevents to use RSO for evaluating the *SUU* scenario because in each country Unit Rates in the lower and upper airspaces are likely to be different.
- to charge flights depending on their 2D geographical coordinates within the same country. In fact, only the national borders of a whole country are recorded. But after the introduction of CEATS, Italy will be the only country where two different

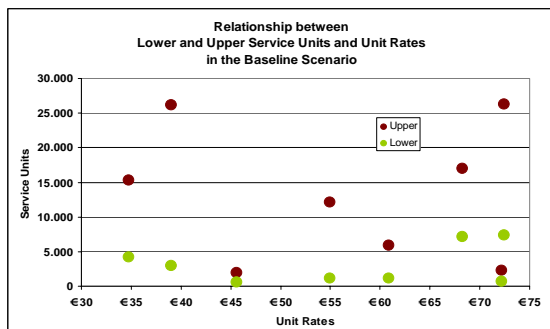
Unit Rates are likely to coexist: one for flying in the Padova ACC airspace, and the other one for flying in the rest of Italy.

To overcome the above shortcomings, an extension of the present RSO tool has been developed in this project research. Two fictitious countries have been created – Padova (PD) and CEATS (CS) – and their airspace data have been added to the current RSO database. Thus by matching CFMU and CRCO data, we performed an accurate computation of the Service Units in upper and lower airspaces of each country.

Ctry	t_i^B	s_i^U	s_i^L	s_i^B	$R_i^B = C_i^B$
L1	€72,49	26.273	7.333	33.606	€2.436.115
L2	€68,24	17.036	7.133	24.169	€1.649.291
L3	€39,03	26.199	2.959	29.158	€1.138.018
L4	€72,22	2.320	716	3.036	€ 219.265
L5	€34,80	15.228	4.174	19.402	€ 675.198
L6	€60,84	5.935	1.088	7.023	€ 427.287
L7	€54,94	12.064	1.092	13.156	€ 722.800
L8	€45,59	1.911	560	2.470	€ 112.625
TOT		106.966	25.055	132.021	€7.380.600

Table 1: Baseline Scenario 14 - 20 April 2003

Graph 1 shows the total number of Service Units versus the national Unit Rate for each individual CEATS Country when the breakdown between the number of upper and lower Service Units is introduced. There is no clear evidence that the Unit Rates charged are somehow related with the number of Service Units controlled, either in the lower or upper airspace. The relationship between Unit Rate and Service Units for Padova ACC is also presented. However, it is important to highlight that this specific value might be misleading: the Unit Rate is the Italian Unit Rate, computed by taking into account the overall costs of ENAV (Italian ANSP) and the forecasted Service Units in the whole Italian Airspace, whereas the Service Units are these of the Padova ACC airspace only.



Graph 1. Upper and Lower Service Units vs Unit Rates in the Baseline Scenario

NCB, SUU and SUA scenarios – Numerical Results

In the following, without loss of generality we set $\alpha = \alpha_i = 1 \forall i$. Hence we are going to compute the Unit Rates for each of the proposed scenarios by assuming that the introduction of CEATS would eventually not produce any cost reduction for the eight ANSPs. Even though this is unlikely to be the case (cost reductions in providing ANSPs are indeed expected following the introduction of CEATS), the above hypothesis allows us to uniformly compare the three scenarios. In addition, the Unit Rate values presented below can be considered as upper bounds of the new possible Unit Rates, for each ANSP and for each scenario.

NCB Scenario

Since $t_i^{NCB} = \alpha_i t_i^B$ and $\alpha_i = 1 \forall i$, the Unit Rate t_i^{NCB} is equal to the Baseline Unit Rate. Column 2 in Table 1 presents such values.

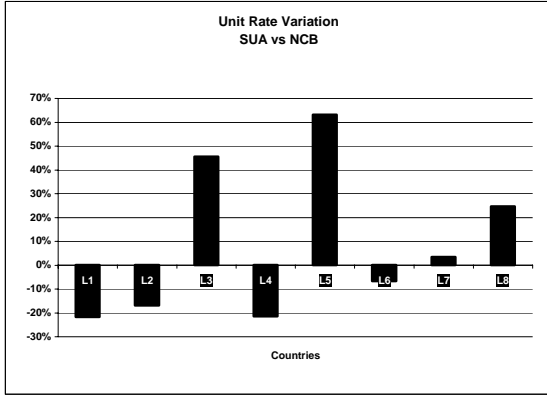
SUA Scenario

By inserting Column 2 and 5 values in Equation 4 (and $\alpha_i = 1 \forall i$), the common Unit Rate value is

$$t^{SUA} = €56,79.$$

The $\sum_i s_i^{SUA}$ value has been computed using our extended-RSO tool. It turns out that $\sum_i s_i^{SUA} = 129.960$. As expected, this value is slightly smaller than $\sum_i s_i^B = 132.021$. Had this latter value be

considered at the denominator of Equation 4, the Unit Rate value would have been equal to €55,90 thus producing a percentage error of 1,6%. This result complies with other studies [7] where it is shown that this percentage error is on average lower than 3%. Graph 2 highlights the percentage variation of national Unit Rates in the SUA scenario with respect to the NCB one. In 4 countries the SUA Unit Rate is higher than the NCB one, and in the other 4 countries it is lower. Due to the low NCB Unit Rates in L3 and L5, the introduction of the SUA scenario would significantly (40% – 60%) increase the cost of flying over them.



Graph 2. Unit rate variation between SUA and NCB scenarios

SUU Scenario

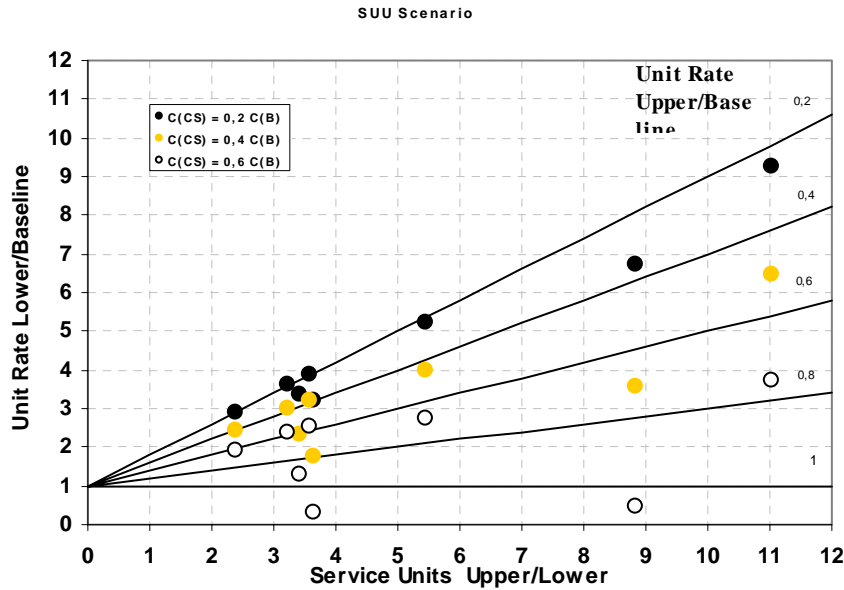
In this scenario nine different Unit Rates have to be computed: the unique Unit Rate t_{CS} for the upper airspace and the eight national Unit Rates for the lower airspaces. For clarity's sake, Equation (3) is re-written below when $\alpha_i = 1 \forall i$:

$$\frac{t_i^{SUU}}{t_i^B} = 1 + \frac{s_i^U}{s_i^L} \left(1 - \frac{t_{CS}}{t_i^B} \right). \quad (5)$$

It turns out that t_i^{SUU} depends on the Unit Rate of the upper airspace, and the higher t_{CS} , the lower t_i^{SUU} . This is an obvious result: being constant the sum, the higher the CEATS costs, the lower the costs for providing ANSs in the lower airspace must be, and vice-versa (to adhere to the principles of Assumption 2). However, the magnitude of in-

crease of the Unit Rate(s) of the lower airspace with respect to the Baseline scenario can be significantly large. Graph 3 shows some points of Equation (5), i.e., presents the ratio of the national Unit Rate in the *SUU* scenario over the national Unit Rate in the Baseline scenario as a function of the ratio of the Service Units in the Upper airspace over the Service Units in the Lower airspace. For each country, we show these values depending on three different estimates of the CEATS costs with respect to the total costs: dark colour dots correspond to CEATS costs equal to 20% of the total costs, light colour dots to 40% and empty dots to 60%, respectively. The corresponding CEATS Unit Rates t_{CS} are: €13,80, €27,60 and €41,40, respectively. The solid lines represent the t_i^{SUU}/t_i^B vs.

s_i^U/s_i^L points parameterised according to the t_{CS}/t_i^B ratio. The ratios go from 0,2 to 1 by steps of 0,2 from the top to the bottom of the figure (i.e., the horizontal line represents the $t_{CS}/t_i^B = 1$ case, i.e., the *NCB* scenario). When CEATS costs are assumed to be small (e.g., 20% of total costs – the dark colour dots), Unit Rates in the lower airspace are likely to increase from 200% to 850% in order to allow the ANSPs to fully recover their costs. Had the CEATS costs assumed to be significantly higher (e.g., 60% of total costs – the empty dots), the CEATS Unit rate ($t_{CS} = €41,40$) may become even larger than t_i^B for some country (i.e., L3 and L5). It follows that for these countries the Unit Rate in the lower airspace would be even smaller than the Baseline scenario Unit Rate



Graph 3. *SUU* Scenario

Impact of NCB, SUU and SUA scenarios on aircraft operators

Holding the Full Cost Recovery principle, each ANSP will eventually be repaid for all the expenses it has in providing ANSs regardless the way the Unit Rate is calculated. The reimbursement phase only can be more or less complex according to the used scenario. On the contrary, the value of the Unit Rate(s) may have impact on the airlines.

In principle, it is not straightforward to predict such impact because three main factors affect it: the Unit Rate for flying in the upper airspace (i.e., the CEATS costs), the airline's ratio of Service Units in the Upper and Lower airspace, and in which countries these Service Units are flown. However, from the data analysis of the testing week (i.e., 14 – 20 April 2003) some common patterns arise.

In this week, 25.594 flights belonging to 684 different aircraft operators (AOs) have flown through the lower and/or upper airspaces of the CEATS area. We compare the three scenarios under study assessing their impact on route charging costs of these AOs. With respect to the SUU scenario, we only consider the case where the CEATS costs are equal to the 30% of the total costs. This assumption leads to a value of the unique Unit Rate t_{CS} for the upper airspace of approximately 20 € and to very high values for the national unit rates. In such a way, we investigate the worst-case situation with respect to the impact of the SUU scenario on some AOs. Table 2 shows in each column the values of the unit rates for the different scenarios computed according to Table 1, Equations (5) and (4), respectively.

Ctry	NCB	SUU	SUA
L1	€72,49	€258,03	€56,79
L2	€68,24	€181,79	
L3	€39,03	€201,33	
L4	€72,22	€239,24	
L5	€34,80	€86,24	
L6	€60,84	€279,79	
L7	€54,94	€433,18	
L8	€45,59	€130,58	
CS		€20,70	

Table 2: Unit Rates in the three Scenarios

We compare the three scenarios by considering three smaller and smaller subsets of AOs: all the AOs (ALL), only those that flew in the testing week at least 100 SUs (>100) and at least 1000 SUs (>1000), respectively. Table 3 shows that 22% of the AOs flew more than 100 SUs in the testing

week accounting for approximately 90% in terms of number of flights performed, amount of money collected in the three scenarios and SUs flown. Furthermore, only 4% of the AOs flew more than 1000 SUs in the testing week accounting for approximately 60% in terms of number of flights performed, amount of money collected in the three scenarios and SUs flown.

	AOs	Flights	NCB	SUA	SUU	SUs
>100	22%	86%	93%	94%	89%	94%
>1000	4%	56%	59%	60%	59%	60%

Table 3: Subsets of AOs in the CEATS Area

First, we identify which scenario is the best and the worst option for each airline by exactly computing the route charges of all their flights of the testing week relying on the unit rates of Table 2 and the original flight plans. In Table 4 for each subset (i.e., ALL, >100, >1000) we present the percentage of AOs that are better off or worse off in each of the three proposed scenarios.

	BEST (=MIN)			WORST (=MAX)		
	ALL	>100	>1000	ALL	>100	>1000
NCB	20%	9%	14%	23%	35%	34%
SUA	42%	21%	17%	17%	39%	38%
SUU	37%	69%	69%	60%	26%	28%

Table 4: AO Scenario Preferences

Two main remarks arise from the data in Table 4:

1. There is a big difference between the ALL and >100 sets: in the former, 42% of AOs pay less under the SUA scenario, and 60% of AOs are worse off under the SUU scenario. In the latter, these proportions are reversed: only 21% of AOs are better off under the SUA scenario; the SUU is the worst case for only 26% of AOs and the best one for 69%. In the >1000 set the pattern is similar to the >100 one. The different AOs share of preferences among the ALL and >100 sets is mainly due to the fact than in the ALL set we take into account many AOs performing only a few short flights in the CEATS region, mostly in the lower airspace. Clearly, such AOs are severely affected by the SUU scenario.

2. AOs are not indifferent to the SUU scenario: data analysis shows that for an AO for which the ratio of SUs flown in the upper airspace over the total number of SUs flown is below 70% (above 85%), the SUU scenario maximizes (minimizes) its route charges. The narrow window (70% - 85%) where the SUU scenario is not necessarily the best or the worst option leads to the following conclusion: in all the three subsets, more than 95% of

AOs are either better or worse off under the SUU scenario.

Further insight on the impact of the three charging scenarios on AOs route charges costs is derived by clustering AOs in categories and comparing the three scenarios on these clusters.

AOs clustered by type. We consider 7 different airline categories: Major, National, Regional, Charter, Low-Cost, Cargo and Extra-European. We investigate the possibility that there is a preferred or disliked scenario for (nearly) all the AOs belonging to the same category. The clustering has been performed according to the procedure introduced in previous works [6] and to some “common sense”. Table 5 summarises the main results.

Category	AOs	Flights	SUs	BEST (=MIN)			WORST (=MAX)		
				NCB	SUU	SUA	NCB	SUU	SUA
Cargo	8	176	2133	2	6	0	1	2	5
Charter	10	992	4691	2	4	0	3	6	1
Major	7	4.891	29.433	2	4	1	2	3	2
National	16	5.924	24.481	6	3	7	4	9	3
Regional	14	2.724	4821	1	0	13	0	14	0
Low-Cost	5	1.165	3706	0	2	3	3	2	0
Extra EU	9	336	9209	1	8	0	1	0	8

Table 5: AO Clusterisation by type (1)

The main remarks are:

- the SUU scenario is the worst one for all the regional carriers and the best one for the Extra-European airlines;
- the SUA scenario is the worst one for the Extra-European airlines and the best one for the regional carriers.

This behaviour is explained as follows: Extra-European airlines not landing or departing in the CEATS region take full advantage from the very low CEATS Unit Rate ($t_{CS} = \text{€}20,70$) and would be penalised by the common unit rate because they would no longer be able to fly over the cheaper countries as they are doing today. On the other side, regional airlines performing short flights in the CEATS area are generally not able to reach the CEATS airspace, thus flying in the very expensive lower airspaces. This interpretation is confirmed in the 2nd Column of Table 6 which shows the percentage of SUs flown in the upper airspace per airline category: it appears that regional airlines fly only 24% of their SUs in the upper airspace. A further impact of the SUU scenario on regional carriers is described in Column 3 of Table 6. It shows the average (per category) increase of € per SU when the worst scenario holds rather than the best one. Figures are obtained by computing for each airline the difference in route charges between the

worst and the best scenario and dividing the result by its number of SUs. Then the mean for each airline category has been derived. It appears that regional airlines would pay sensibly higher route charges per SU (with respect to the most favourable scenario) than airlines of other categories, would the SUU scenario be introduced.

CATEGORY	% SU UP/TOT	€SU MAX - MIN
Cargo	94%	€ 47
Charter	79%	€ 33
Major	85%	€ 30
National	71%	€ 60
Regional	24%	€ 126
Low-Cost	71%	€ 70
Extra Europe	99%	€ 32

Table 6: AO Clusterisation by type (2)

As regards to the airlines belonging to the other categories, there is not a clearly defined pattern for them. In these clusters, the preferred airline scenario is not linked to the category it belongs to, but to the percentage of SUs flown in the upper airspace and to the location where the airline is based (see below).

AOs clustered by region. In this analysis we aggregate airlines according to the location where they are based (or where they perform most of their operations). In particular, we consider the most important airlines based in the CEATS region: Adria Airways, Air Bosna, Air Dolomiti, Air Slovakia, Alpi Eagles, Austrian Airlines, Croatia Airlines, Czech Airlines, Malev, Skyeurope, Slovak Airlines, Tyrolean Airlines, and Volare Airlines.

It turns out that for all airlines based in the CEATS region, the SUU scenario is the most expensive one. In fact, none flies more than 70% of its SUs in the upper airspace, regardless the airline category it belongs to. This result suggests that, without a compensation mechanism, the introduction of the CEATS airspace would penalise especially airlines whose base is located in this region and operating in such airspace when each of the nine ANSPs directly collects its revenues. This remark seems to lead to a weird outcome of the new airspace design: airlines heavily involved (due to geographical constraints) in the utilization of these ANSPs experience higher unit costs (i.e. €per SU) than those of airlines just (sporadically) passing through, as, e.g., Extra-European airlines.

Conclusions

The main aim of this study is to provide a comprehensive framework for decision makers such that they can correctly compare and assess different

route charging scenarios after the CEATS airspace is introduced .

Holding the Full Cost Recovery principle, each ANSP will eventually be repaid for all the expenses it has in providing ANSs regardless the way the Unit Rate is calculated. The reimbursement phase only can be more or less complex according to the used scenario. On the contrary, the value of the Unit Rate(s) does have impact on the airlines.

A major conclusion of this study is that the SUU scenario (i.e., charging according to the flight level) matters: AOs are not indifferent to it and, according to their characteristics in terms of operations, business, and geography, their route charges costs can be more or less affected. This is an interesting outcome, because the level of route charges does influence the routes actually flown by airlines [7] and should trigger the need for implementing a compensation mechanism. On the other side, the NCB and SUA scenarios seem to be equivalent (see also [8]) and there is not a common airline profile that would prefer any of them for minimising its route charge costs.

As a final remark, we observe that the Unit Rates values used in this study (Table 2) are upper bounds of the possible new Unit Rates that are likely to hold after the introduction of CEATS. The more CEATS will help to reduce the overall costs, the less it would cost to fly in the area, and to a lower level than today.

Consequently, further studies in this area include a) the definition of a compensation mechanism to guarantee a fair treatment of all ANSP and AOs, and b) a study to assess the impact of the different route charging scenarios on the AOs route selection and the impact on the use of the CEATS airspace.

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Key Words

Air navigation charges, route charges, Upper Airspace, CEATS.

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