

Managing European Air Traffic Control Provision

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Abstract — We develop a network congestion game to test a series of scenarios in order to analyse potential paths for change in air traffic management in Europe. The two stage game models air traffic control (ATC) providers that set charges and in the second stage airlines that choose flight paths given an airline schedule and the charges from the first stage. The scenarios analysed in the model include (i) the impact of privatization and deregulation; (ii) defragmentation of the set of current providers; (iii) introduction of technology via the common projects and SESAR step 1; and (iv) the regional forerunner approach in which an ATC provider and a specific airline co-operate. The results show that horizontal integration across ATC providers, known as functional airspace blocks, would appear to be problematic with respect to incentives hence regional forerunners in a bottom-up institutional process would appear to be a preferable approach. Vertical integration between companies may succeed in accelerating change as long as the ATC companies are permitted to charge for improved quality, such as reduced congestion. Institutionally, a clear separation of the ATC providers from the Member States and subsequent franchising of the support services and ATC services could further encourage efficiency, consolidation and technology adoption.

Keywords-air traffic control provision, ownership form, pricing, functional airspace blocks, regional forerunner

I. INTRODUCTION

This research is one of the results of ACCHANGE, a WPE funded project. The aim of the project is to search for paths to accelerate change in the air traffic control (ATC) sector, in line with the Single European Skies initiative. Slow adoption of technology occurs in many industries (Katz and Shapiro [1]) and the specific reasons in the ATC industry in Europe include: the fragmentation of the ATC providers, the home-bias of each country for the national provider, the monopolistic nature of some of the ATC services, the network component of most ATC services and the split incentives which require the ATC providers to invest in new technology without enjoying any direct benefits. The fact that they are required to bear investment costs and to invest effort through increased coordination, while the airlines are the main beneficiaries, will most likely delay the implementation of new technology as advocated by the European Commission. Consequently, we develop a network congestion game that assesses potential changes in the industry in search of an implementation path towards improved ATC services by 2030.

Air traffic demand is estimated to increase by 20% by 2020 and 39% by 2030 (Eurocontrol [2]). In order to create greater homogeneity and cooperation across the 37 ATC providers in Europe that will better handle the increase in demand, the European Commission nominated Eurocontrol to be the network manager in July 2011. The ultimate aim is to reduce fragmentation, defined as the division of air navigation service provision into operational units smaller than would result from considerations of optimum scale, caused mainly by the organization of air navigation services along State borders. Today, the majority of European Air Navigation Service Providers (ANSPs) control fewer than 500,000 movements per year and reach a maximum size of 10 sectors, resulting in relatively low efficiency. The Performance Review Commission [3] compares the US and European ATC systems and shows that the latter are more expensive by 34%. The additional costs are caused by Europe having a large number of service providers, each procuring their own systems, mostly training their own staff, creating their own operating procedures and being limited territorially to providing services in a small airspace. To overcome fragmentation, the Single European Skies (SES) initiative has introduced the ideas of cross-border Functional Air Blocks (FABs) with a centralized Network Manager to run certain network level services. We note that the defragmentation process that began in 2004 has suffered from implementation issues. To date, of the nine FABs proposed, two have been formally established between the United Kingdom and Ireland and the Danish-Swedish FAB (Button and Neiva [4]). The Functional Airspace Block Europe Central (FABEC) has attempted to pursue convergence in technical services, processes and the infrastructure of the multiple partners, including air traffic services, communication and navigation services and aeronautical information services. The aim of the construction of FABEC was to encourage consolidation, i.e. the physical reduction in the number of centres, and commonality, i.e. the standardization of the various (sub)-systems. Physical consolidation of the centres has not been possible due to social resistance and technical defragmentation initiatives have failed due to the legacy of unsynchronized and misaligned investment plans of the FABEC ANSPs. This has proven particularly difficult for the expensive, long life cycle systems such as flight data processing and human machine interface systems where contracts were signed for the long term with the relevant ATC suppliers. Consequently, the European Commission intends to

strengthen the regulation further and is considering launching infringement proceedings against EU Member States that have failed to comply, which will be addressed through the SESII+ package.

The ATC sector consists of ANSPs with monopoly power in their regional territory hence economic regulation in conjunction with safety rules would appear to be the norm. The majority of Europe's ANSPs are currently autonomous public-sector bodies that are separated from the government yet remain state property (Cook [5]). Many ANSPs worldwide are public bodies that have been commercialized to varying degrees. For example, the Civil Air Navigation Services Organization counted 63 members in 2011, 51 of which were commercialized to some extent (Poole [6]). McDougall and Roberts' [7] study of commercialized versus government department ANSPs found that as the European, Australian and Canadian governments shifted their ANSPs to more private based enterprises, technology modernization and adoption increased. McDougall and Roberts argue that privatization led to more direct access to capital markets instead of competing for public funding, thus allowing the ANSPs more flexibility and discretion in purchasing technology. Eurocontrol [8] notes that while European air traffic is controlled by 37 separate ANSPs, five (those of Spain, France, the United Kingdom, Germany and Italy) control 60.3% of European gate-to-gate costs, and operate 54% of traffic. The remainder of the traffic and costs are borne by the 32 other ANSPs. All five of these major ANSPs are commercialized to varying degrees (Button and McDougall [9]).

According to the Chicago convention of 1944, air traffic control services were restricted to charging on a cost based, non-discriminatory principle such that all users were to be charged at a standard rate. The charging principle was deemed necessary due to the monopoly position and the international aspects of aviation. The European Commission established a new charging regime in 2010 in order to ensure a common pricing regime across Europe with financial and operational transparency (Huet [10]). The new rules replace the cost recovery system with financially incentivized targets and the concept of risk sharing. Under the previous cost recovery system, when traffic was lower than forecast, the unit rate increased in subsequent years. Under the new rules, the risks of traffic lower than forecast, together with any upside arising from higher traffic, is shared with airlines according to a charging formula set down in the regulation. The regulation also provides for some limited sharing of cost risks that are exogenous to ATC control. Furthermore, the benchmarking process by the Performance Review Commission sets a percentage level of charge reductions across all ANSPs in five-year periods.

The paper is organized as follows: in section 2 we develop the modelling approach, in section 3 we discuss the case study which is analysed in section 4 and section 5 concludes with potential future directions.

II. MODELLING APPROACH

In the network congestion model, we assume a two stage game in which the ATC providers make decisions in the first stage and then airlines respond in a second stage. The first stage requires the ATC providers to set their user charges according to particular objectives, such as revenue or profit maximization. In the second stage of the game, the airlines choose their flight paths such that they minimize their operational costs. The costs include variable costs specifically labour and fuel, congestion costs and the ATC charges, all of which are impacted to some degree by the ATC provision. For example, the more direct the flight path, the lower the fuel and staff costs for the airline. Equivalently, the lower the congestion in airspace and the higher the capacity, the lower the congestion costs for the airlines, which contribute about 10% to the total airline operating costs in Europe (ITA [11]). The direct ATC user charges add an additional 5 to 8% to the airlines' operating costs. Consequently, the decisions of the ATC providers will impact the airlines directly and these are the two main players in the game. The network analysed is depicted in Figure 1 and includes six ANSPs, represented by the coloured arcs, six major airports in each of the six regions, three regional airports and four nodes to aggregate flights to and from the region. Despite this being a clear simplification of reality, the network game should be sufficiently rich as to enable us to understand how the players will react to changes in institutional or regulatory rules.

Parameters

- L set of airlines, with index l
- S set of air traffic controllers (ANSP) with index s
- P set of airport nodes with indices o, d
- T set of transit nodes, whereby a flight crosses ANSPs
- N set of all nodes, $N = P \cup T$, with indices i, j
- $A_s \subseteq N \times N$ set of arcs belonging to airspace of ATC centre in ANSP s
- A set of all arcs, $A = \bigcup_s A_s$, with index $a = (i, j)$
- $s(a)$ ANSP controlling arc a
- θ_a distance in km of arc a
- D_{lod} demand of airline l from origin o to destination d
- C_{la}^o operating costs per km per average aircraft size of airline l per arc a
- C_{ls}^c congestion cost per km per airline l over arc a of ANSP s
- C_{od}^T outside option cost to fly from origin o to destination d
- C_s^S variable cost per km per ANSP s
- τ_s^0 current ANSP s charge per km

Decision Variables

- f_{loda} number of flights per period for airline l flying over arc a as part of flight path (o, d)
- f_{lod}^T non-flow for airline l from origin o to destination d
- τ_s ANSP s charge per km

The network (as depicted in figure 1) is composed of a set of airport and transit nodes and a set of arcs that are partitioned into air traffic control space sectors. We begin by explaining the second stage (which is solved first). In the second stage,

airlines choose which routes to fly given their origin-destination schedule and ANSP route charges. We compare two types of behaviour in the second stage: market behaviour

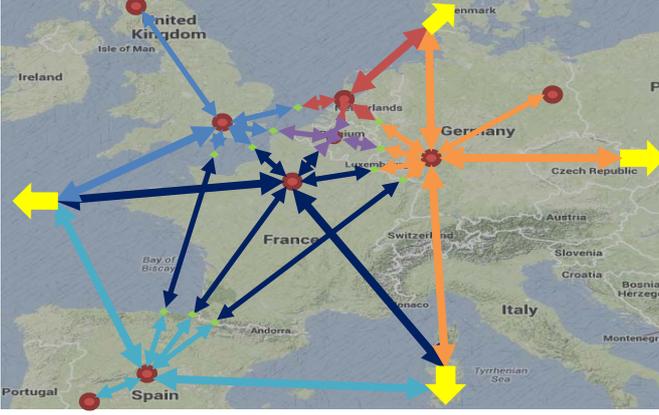


Figure 1. 6 ANSP network case study

in objective function (1), in which we minimize the costs of all the airlines simultaneously thus finding the system optimal solution. The second stage is described in equations (1) to (3):

$$\begin{aligned} & \text{Min}_{f_{loda}, f_{lod}^T} \sum_l \{ (\sum_{a \in A} [C_{la}^O + C_{ls(a)}^G (\sum_{l' \in A} f_{l'oda}) + \\ & \tau_{s(a)}] \vartheta_a \sum_{od} f_{loda}) + \\ & \sum_{od} C_{od}^T f_{lod}^T \} \quad (1) \\ & \text{s.t.} \\ & \sum_{j|(j,i) \in A} f_{lod(j,i)} - \sum_{j|(i,j) \in A} f_{lod(i,j)} \\ & = \begin{cases} f_{lod}^T - D_{lod} & \text{if } i = o \\ D_{lod} - f_{lod}^T & \text{if } i = d \\ 0 & \text{o.w.} \end{cases}, \forall l \in L, \forall o, d, i \in N \quad (2) \\ & f_{loda} \geq 0, f_{lod}^T \geq 0, \forall l \in L, \forall o, d \in N, \forall a \in A \quad (3) \end{aligned}$$

The quadratic objective function includes three cost components: operating costs C_{la}^O , a congestion cost C_{ls}^G , which increases with the square of the traffic flow, and ANSP charges $\tau_s \cdot f_{l'oda}$ represents the traffic flow on link a for airline l' . In order to account for demand elasticity, we model an outside option f_{lod}^T not to fly, with cost C_{od}^T per flight, which will be preferred if the total operating costs are too high. The cost of the outside option C_{od}^T is set at twenty times the sum of the ANSP charges for the least costly flight path from origin o to destination d because demand elasticity with respect to costs is considered to be relatively low. Given the fact that ANSP costs are approximately 5-8% of the airline's total operating cost, the likelihood of cancelling flights are very low. Constraint (2) sums the incoming less the outgoing flights to be equal to the (negative) demand at the (origin) destination and zero when using a transit point. The total flows are reduced by any flights that have been dropped via the outside option. Constraint (3) ensures non-negativity of the flows and non-flows. Solving this problem generates an optimal routing for airlines given that the ANSP charges represent the marginal cost of the ATC operations.

by airlines and optimal planning of all route choice by a central planner (Eurocontrol). We start by describing the latter option

The alternative to the system optimal routing of aircraft is the market equilibrium or user optimum. To compute a user optimal transport equilibria outcome, we solve the same set of constraints but adapt the objective function to (1') and solve using congestion game¹ principles (Rosenthal [12]). The potential game can be defined using a single global function for all airlines, such that the differential of the potential function is equal to the airline's marginal cost. We assume (i) that the airline considers only the congestion costs that it must pay and (ii) the marginal cost is represented by a linear congestion cost function ($c \cdot f$). Consequently, the potential function which is the integral of the marginal congestion cost, equals one half of the congestion cost parameter multiplied by the square of the total frequencies ($\frac{1}{2}c \cdot f^2$), in addition to the other costs. This will result in excess congestion on routes used by a large number of airlines as compared to the system optimal approach. The assumption in this model is that each airline chooses each flight path independently of the rest of its network.

$$\begin{aligned} & \text{Min}_{f_{loda}, f_{lod}^T} \sum_l \{ (\sum_{a \in A} [C_{la}^O + \frac{1}{2}C_{ls(a)}^G (\sum_{l' \in A} f_{l'oda}) + \\ & \tau_{s(a)}] \vartheta_a \sum_{od} f_{loda}) + \sum_{od} C_{od}^T f_{lod}^T \} \\ & (1') \end{aligned}$$

In the first stage of the model, the ATC providers simultaneously choose their charge τ_{ls} . Each ATC provider best responds to the choices of its competitors, taking as given the optimal airline flows f_{loda}^* that will result in the second stage of the game, thus leading to a Nash equilibrium. To compute this equilibrium we consider the following profit maximization problem per ATC provider.

$$\begin{aligned} & \text{Max}_{\tau_s} \sum_{a \in A_s} \sum_l (\tau_s - C_s^S) \vartheta_a \sum_{od} f_{loda}^* \\ & \text{s.t. } \tau_s \leq \tau_s^0 \quad \forall s \in S \quad (4) \end{aligned}$$

Model (4) maximizes the profits of the provider under the restriction that charges are capped at their current values ($\tau_s \leq \tau_s^0$) and taking the competitors' charges as given. We use a line search to solve model (4) per ATC provider and search for the equilibrium outcome iteratively. We model the ANSPs as profit maximizers however, as most are governmental bodies, one could argue that alternative objectives should be considered. For example, ANSPs could be instructed to maximize consumer surplus under a break even restriction. When the ANSP charges are not capped, one produces the pure monopoly solution which maximizes ANSP profits by restricting capacity.

III. CASE STUDY

In this section we first discuss the ANSPs to be modelled, then the five airlines and finally the scenarios tested, including

¹ Congestion games are isomorphic to finite potential games (Monderer and Shapley [13]) enabling the equilibria outcome to be computed by minimizing the potential function of the game.

a base-run which reproduces the outcome in 2011 as well as demand expectations for the years 2020 and 2030.

A. The ANSPs

We focus on 6 ANSPs, namely Aena (Spain), Belgocontrol (Belgium), DFS (Germany), DSNA (France), LVNL (Netherlands) and NATS (UK). In addition we also include

TABLE 1: 2011 ANSP DATA APPLIED IN MODEL

ANSP	Revenues (000 €)	Variable Costs (000 €)	Fixed Costs (000 €)	Total Distance (km)	Average Charge per km
Aena	794,710	498,756	135,599	859,175,623	0.925
Belgocontrol	155,805	82,605	13,884	166,751,138	0.934
DFS	739,112	631,983	129,285	1,007,485,777	0.734
DSNA	1,167,138	804,653	113,876	1,463,618,011	0.797
LVNL	169,365	102,058	11,378	191,563,198	0.884
NATS	651,366	368,015	153,001	707,474,135	0.921

the Maastricht Upper Airspace Control Centre (MUAC), which is in charge of the upper airspace (above 24,500 feet) in the Netherlands, Belgium and Northwest Germany. MUAC acts on behalf of these ANSPs but the airlines are charged by the ANSPs through Eurocontrol, hence this activity has been included as if the ANSPs were providing the service. According to the Performance Review Commission's 2011 Benchmarking Report, these ANSPs were responsible for 48.9% of European traffic (in terms of flight hours controlled) and 52.3% of total en-route ATC costs. Out of the total European ATC system, 62.3% of the delay minutes were attributed to the ANSPs in our case study. Consequently, based on data from [14], the total delay costs to the airlines flying in the relevant airspace amounted to €933 million, which mostly draws from additional fuel burn and crew costs. Real delay costs may be substantially higher were consumer surplus and schedule delay to also be considered within this analysis. Based on the data collected, Table 1 summarizes the parameters applied in the network congestion model. Staff and other operating costs constitute the variable costs whereas depreciation, capital and exceptional items were classified as fixed costs. The charges set were based on the use of a 150 seat aircraft taking into account the relevant weight factor.

B. The airlines modelled in the network congestion game

Hundreds of airlines fly over European airspace providing both scheduled and charter services. For the sake of simplicity, we aggregate the airlines into three groups which best represent the structure of commercial aviation today. The groups are: airline alliances, low cost carriers and non-aligned carriers. The aligned airlines group is represented by three airlines: Lufthansa, British Airways and Air France-KLM, the main European airlines in the three airlines alliances that exist today. Each airline is modelled with a two-hub system. Lufthansa utilizes Frankfurt and Brussels, BA utilizes London and Madrid whilst AF utilizes Paris and Amsterdam. EasyJet is taken as a representative carrier for the low cost carrier group. The airline was ranked fourth in terms of seat capacity in Western Europe in 2013. Emirates was chosen as the representative carrier for the non-aligned carrier group. The

Dubai based airline was ranked first among world airlines in terms of Available Seat Kilometres in 2013, while Europe was their largest market by seat capacity. The airline groups achieve different costs levels which are mostly a direct function of the level of service they provide, their output, their network, average stage length and the employment costs of the airlines' country of registration. There is a substantial gap in costs between the different airline groups (data drawn from airline financial accounting records). While for the aligned carriers Lufthansa, British Airways and Air France-KLM the Cost per Available Seat Kilometre is approximately 9 Euro cents, for Emirates it is 6 Euro cents, and for EasyJet it is 5.5 Euro cents.

C. Scenarios

In order to analyse the potential impact of changes in institutional or regulatory arrangements, in our base-run scenario we attempt to reproduce the 2011 equilibria outcome for the six ANSP network case study depicted in Figure 1. Per scenario, we analyse four subcases that represent alternative pricing and regulation regimes. We distinguish between the system optimal cost recovery approach, the user optimal cost recovery approach, the user optimal price-cap approach and the system optimal profit maximization approach. We model all four subcases for the following four scenarios. In the base-case, we reproduce the equilibria outcome of 2011 in the user optimal, price-cap approach. Based on airline demand, we analyse airline costs in the region as well as ANSP revenues and profits. We then analyse the potential changes had there been a system optimal approach in which a central planner chooses the flight paths in order to minimize airline costs, taking as given the average ANSP costs. Next we compute the likely result were the economic regulation on ANSP prices removed and the impact of higher ceilings on the price cap.

In scenario 2, we highlight the potential impact of the functional airspace blocks which are the equivalent of horizontal integration across ANSPs. We assume that there will be no savings in labour costs or reduction in air control centres due to the power of the labour unions and the politics of sovereign protection but savings of 30% are possible in the

sum of fixed costs due to joint purchasing power. This parameter could not be based on historic data since there is little evidence to date of the impact of integration, hence sensitivity analyses are undertaken. In scenario 3 we analyse the potential impact of technology on the equilibria outcomes by modelling the expected costs and benefits to both the

ANSPs and the airlines. We note that all parameters in these scenarios draw from the SESAR JU and Eurocontrol Masterplan documentation. In scenario 4, under vertical integration, an ANSP and its relevant hub airline adopt new technology and via the best-equipped best-served scheduling rule are able to achieve the benefits of the technology locally.

TABLE 2: BASE-RUN SCENARIO 1.1 – USER OPTIMAL COST RECOVERY

Airline	CASK	Annual Costs (000 €)	ANSP	Prices per km	Annual Revenues (000 €)	Annual Profits (000 €)
BA	0.073	7,114,640	NATS UK	0.921	859,244	221,111
LH	0.088	7,711,210	LVNL Netherlands	0.884	294,507	105,558
AF	0.073	4,246,816	DFS Germany	0.734	482,743	(58,912)
LC	0.054	10,175,621	Belgocontrol	0.934	135,828	49,958
Rest	0.054	8,204,802	DSNA France	0.797	1,120,230	233,297
			AENA Spain	0.925	395,514	11,489
Total:		37,453,090			3,288,066	562,501

Finally, we note that all scenarios are analysed using 2011 demand and subsequently 2020 and 2030 expected demand, which is forecast to increase by 19.5% and 38.7% respectively as compared to 2011.

IV. CASE STUDY RESULTS

In the base run scenario, the solution closest to the 2011 equilibria outcome is case 1.1, the user optimal, cost recovery model. As shown in Table 2, the total ANSP revenues from the airlines for the en-route sectors covering the 6 countries included in the analysis, sum to €3.29 billion, which is a close approximation to the outcome for 2011. It is also possible to match the cost per available seat kilometre per airline to those that occurred in 2011.

In scenario 1.2, Eurocontrol chooses the airline flight paths in order to minimize overall airline costs and manages to save a moderate 0.2% which is due to the relatively low congestion levels suffered in 2011 in the en-route sectors. However, whilst the three aligned carriers, BA, LH and AF-KLM achieve lower costs, the low cost carriers and international carriers are worse off. The reason is that the shortest flights are relatively more difficult to divert whereas longer flights have more potential routes hence the low cost carriers using smaller, more distant airports and the unaligned carriers serving more international routes are pushed towards the indirect or more expensive flight paths first in order to reduce overall congestion levels. The flows change slightly such that more flights are funnelled through Belgian and German airspace at the expense of the French and Spanish, resulting in overall increased profits in the ATC sector due to more indirect flight paths through Belgium. In summation, although airlines achieve lower costs overall, it is unlikely that they would prefer to leave the choice of flight paths to Eurocontrol because the system optimal approach may result in some airlines gaining at the expense of others. A more positive result is probably possible for all airlines and ANSPs were ANSP charges to include congestion pricing, given cost recovery, referred to as Ramsey pricing.

In the ATC price-cap approach (1.3), prices were limited to 50% higher values than charged in 2011. The ANSPs would charge according to their upper limit leading to increased profits approximately three times higher than those achieved in 2011. This suggests that each ANSP enjoys market power on its own routes and that the airlines are unlikely to reduce their schedule. It also means that the ANSPs could collect additional revenues to fund new technology were this deemed necessary. The results show that the airlines would continue to fly but their cost per available seat km would increase by approximately 4%.

In scenario 1.4, the ANSPs are free to set charges such that they maximize their profits. The results show that the prices would increase tenfold and profits accordingly. However, only the low cost carriers and international airlines would continue to fly and their CASKs would double. Of the three alliances, BA reduces their flight schedule by half and LH and AF-KLM would leave the market entirely. Consequently, we arrive at the conclusion that there is insufficient competition across ANSPs in order to justify the removal of economic regulation as has occurred in the airline industry globally and in the airport industry in the UK and Australia.

Scenario 2: Horizontal integration

Scenario 2 analyses the possibility that horizontal integration, namely functional airspace blocks, may lead to technology adoption and a reduction in costs. For the purposes of this scenario, we assume that there will be no changes in labour costs and any savings will draw from the ability to purchase capital goods jointly, resulting in a 30% saving in fixed costs through co-operation. The second question is the charge applied to the FAB. Harmonisation could result in a single rate that could lead to the use of more direct flight paths. We set the cap on charges per km to the weighted average of the 2011 prices according to the level of activity of each provider. In the case of 2a, we assume that Belgocontrol and DSNA cooperate and the weighted average price becomes 0.811 cents per km, which means that flights in French airspace

are slightly more expensive whereas Belgium becomes cheaper to the airlines. As a result, most airlines are worse off and only the low cost carriers manage to reduce their costs by flying through Belgium and less through France. In case 2b, we assume that the Dutch and German ANSPs cooperate, resulting in a weighted average charge of 0.758 which increases the costs of flying through German airspace but substantially reduces the price to fly over the Netherlands. The result is an

increase in costs for Lufthansa and the low cost carriers but lower costs for the other carriers. Consequently, unless some of the cost savings are passed on to the airlines through lower ATC charges, at least one or more airline is worse off as a result of such cooperation, which may explain why the airline industry has not pushed harder for the implementation of the

TABLE 3: SCENARIO 3.1 – PILOT COMMON PROJECT

Airlines	Base Case		PCP		
	Cask	Annual Costs (000 €)	Cask	Annual Costs (000 €)	% Change
BA	0.073	7,114,640	0.072	7,033,052	-1.15%
LH	0.088	7,711,210	0.087	7,608,041	-1.34%
AF	0.073	4,246,816	0.071	4,181,475	-1.54%
LC	0.054	10,175,621	0.053	10,031,229	-1.42%
Rest	0.054	8,204,802	0.053	8,112,521	-1.12%
Total:		37,453,090		36,966,319	-1.30%

ANSPs	Price	Base Case		PCP		
		Annual Revenues (000 €)	Annual Profits (000 €)	Annual Revenues (000 €)	Annual Profits (000 €)	% Change
NATS UK	0.921	859,244	221,111	859,244	228,202	3.21%
LVNL	0.884	294,507	105,558	294,507	117,971	11.76%
DFS	0.734	482,743	(58,912)	482,743	(52,716)	10.52%
Belgocontrol	0.934	135,828	49,958	135,828	52,950	5.99%
DSNA	0.797	1,120,230	233,297	1,120,230	273,181	17.10%
AENA	0.925	395,514	11,489	395,514	2,525	-78.02%
Total:		3,288,066	562,501	3,288,066	622,114	10.60%

single European skies approach. This result is also in line with the findings of Castelli, Debels and Ukovich [15].

For the FABs, annual revenues slightly increased for Belgocontrol-DSNA but are reduced in the LVNL-DFS combination, as a result of changes in the choice of flight paths by the airlines were the French and German airspace to become more expensive. The Belgocontrol-DSNA operating profits increase by 15% due to the fixed cost savings and if this profit can be used to pay for the effort required, such a FAB may indeed develop. However, the savings in fixed costs of the LVNL-DFS combination are insufficient to cover the loss in accumulated revenues across the joint airspace, suggesting that such a FAB would be unlikely to occur without strict regulation, since both the airlines and the ANSPs would prefer to avoid such a scenario.

In addition, we tested the second scenario under the assumption that the FABs will charge their users according to the lower rate, i.e. the French and German ANSP rates, which ensures that all airlines are strictly better off. In this case, the revenues of both FABs were reduced, although Belgocontrol-DSNA profits still increase but by 7% (instead of the 15% previously), whereas the LVNL-DFS FAB's profits are reduced by 52%. Consequently, horizontal integration will only occur if the costs to the ANSP are reduced sufficiently that the savings outweigh the reduction in revenues, which would

require a minimum reduction in fixed costs of 40% for the LVNL-DFS combination. Alternatively, FABs should be allowed to differentiate charges on flight legs according to the cost of that leg (including congestion) and according to the country in which the ATC is produced. This price differentiation, combined with a more aggressive cost reduction under a merger, is probably necessary to make FABs a more interesting option. This scenario could prove more positive were ANSP charges brought in line with the real system costs (including congestion). In order to ensure that all ANSPs achieve break-even profits would require transfers between ANSP's.

Scenario 3: Technology adoption

In scenario 3, we analyse the potential impact of technology implementation. In scenario 3.1 we analyse the impact of the Pilot Common Project on both airlines and ANSPs. As shown in table 3, the overall savings to the airlines outweigh the investment costs and all airlines are slightly better off, with average cost savings of 1.3%. The ANSPs are expected to reduce their variable costs but increase their fixed costs due to the purchase of technology without changing their current charges. Based on the cost-benefit parameters drawn from SESAR JU documents, all ANSPs are better off, in particular DSNA, LVNL and DFS but AENA is worse off, hence would be unlikely to participate. Based on a sensitivity analysis,

allowing the ANSPs to increase their charges by 10% would incentivize participation in the PCP such that the airlines and ANSPs all gain from this effort. This increase in ANSP charges could be justified when the overall costs for the airlines decrease strongly due to better routing and less congestion.

For the first step of SESAR, scenario 3.2, we have translated the SESAR Masterplan into a reduction in charges of 6.1% and a reduction in congestion of 27%, but the cost of the new technology outweighs the savings in fuel costs such that

the variable costs will increase by 0.1%. The results show that the airlines' costs will decrease by approximately 3% overall, hence the airlines should be willing to invest. However, the advantages of SESAR gradually fade as the demand increases, suggesting that by 2030, the cost advantage will have dissipated entirely. This result draws from the fact that step 1 reduces congestion at such a level that the increase in demand balances out the technology needs to be further improved or the cost of the technology ought to be lower, given their current

TABLE 4: SCENARIO 4 – VERTICAL INTEGRATION

Airlines	CASK	Base Case		Case 5a		Case 5b	
		Annual Costs (000 €)	Annual Costs (000 €)	% Change	Annual Costs (000 €)	% Change	
LH	0.088	7,711,210	7,622,793	-1.15%	-	-	
AF	0.073	4,246,816	-	-	4,244,132	-0.06%	
ANSP		Annual Profits (000 €)	Annual Profits (000 €)	% Change	Annual Profits (000 €)	% Change	
DFS		(58,912)	(52,716)	10.52%	-	-	
DSNA		233,297	-	-	273,181	17.10%	

likely impact. On the other hand, given the expected increase in demand by 2030 without the adoption of SESAR technologies, airline CASKs will increase by the order of 3% whereas ANSP profits, under the 2011 price cap scheme, will increase by the order of 43% (for LVNL) and up to 70% (for Belgocontrol and AENA). Belgocontrol will gain in particular due to increased demand flows that currently are avoided due to their relatively high price. In other words, Belgian airspace is currently avoided due to their relatively high charges but once congestion increases in line with higher demand, the Belgian airspace begins to appear more reasonable in comparison to the costs of serving alternative, crowded routes. We thus learn that there is substantial capacity in the system that could be better utilized, for example through congestion pricing (Raffarin [16]) or peak load pricing (Jovanović et al. [17]).

The ANSPs are expected to reduce their charges, achieve lower variable costs by increasing ATCO productivity and increase their fixed costs in order to purchase the new technologies according to the Eurocontrol Masterplan. The result is a reduction in revenues of 6.1% and a reduction in profits of 56% overall. On the other hand, by 2020 annual revenues will have increased although profits will still be low and by 2030, revenues will have increased by 30% and annual profits by 20% in comparison to the 2011 base-run. Consequently, the long term picture suggests that SESAR step 1 is in the interests of the ANSPs and the issue is the timing of costs and benefits. However, we also note that for DFS and AENA, the profits by 2030 remain negative which means that without an increase in charges, these organizations are unlikely to expend the effort required to undertake this step. A sensitivity analysis suggests that were the ANSPs permitted to increase their charges by an upper limit of 22%, both the airlines and the ANSPs are in position to gain from the new

technologies, although the impact on the airlines would now be rather marginal.

Scenario 4: Regional forerunner

In scenario 4, we analyse whether a vertical cooperation between an ANSP and local airline may help to implement the PCP technology. We assume that the ANSP invests in the PCP technology and achieves higher levels of output per controller and that the participating airline achieves slightly lower operating costs and congestion levels, but only on the flight paths associated with the relevant ANSP. A useful example of this type of cooperation would be FRAMaK, a Free Route Airspace Project run by a consortium of airspace users and ANSPs (MUAC, the Karlsruhe Upper Area Control Centre and Lufthansa). 298 new direct routes were implemented in 2012, increasing the number of direct, flight-plan able routes in the area to a total of 656. The development of free routes by FRAMaK created an advantage for Lufthansa, which is the largest airspace user in the Maastricht-Karlsruhe area, although all airlines can use the same direct routes and enjoy the benefits. This has led to further free and user preferred routes, under pressure from European airlines and Eurocontrol. By 2014, at least 16 of the 64 European ACCs implemented various new Free Route Operations and savings have been estimated in the range of 150,000 tons of CO₂ or 37 million Euros².

In scenario 4a we analyse a potential German regional forerunner such that DFS and LH cooperate and in scenario 4b, we analyse a potential French regional forerunner with both DSNA and AF cooperating. From the airline perspective, table

² Safety of Air Navigation, Eurocontrol, Belgium, July 8, 2013.

4 shows that both should be willing to cooperate as their costs are likely to decrease. Furthermore, the impact on the larger airline, LH, appears to be greater hence has stronger incentives to participate actively. Indeed, the incentive is likely to be underestimated because through the best-equipped best-served rule, which reduces congestion for the relevant airline, the airline's market share is likely to increase which is not accounted for within the current modelling approach. Both ANSPs are also likely to enjoy incentives from such cooperation, with DFS gaining 10% higher profits and DSN gaining around a 17% advantage, provided the PCP assumptions are reasonable i.e. that ANSP variable costs decrease by the order of 8% as compared to an increase in fixed costs of around 20%.

V. CONCLUSIONS

The EU is an important stakeholder in the ATC system. We identify a lack of incentives to encourage efficiency at the Member State level, which is overcome when intra-European traffic is analysed at the EU level. Consequently, centralized services are likely to lead to more direct flight paths for the customers (i.e. airlines) and to economies of scale at the ANSP level, which may reduce costs. We learn that there is insufficient competition across flight paths in different ANSP regions to permit the removal of economic regulation. Unregulated ANSP charges are likely to lead to a substantial increase in charges. In the airport industry, the UK removed price regulation from all but three of their airports, arguing that there is sufficient competition for catchment areas and across hubs although this is debatable (Starkie [18], Adler and Liebert [19]). This could occur in the ATC sector if and only if there are sufficient alternative flight paths between origin and destination. Consequently ATC competition is only likely to arise when ANSPs are in a position to compete for services over the same set of flight paths for example through virtual centres. Second, horizontal integration via functional airspace blocks is unlikely to facilitate cooperation across ANSPs due to the lack of financial incentives. If FABs set a single price across their entire network, an average price is likely to lead to some airlines winning and other losing whereas prices set at the lowest current ANSP level lead to lower profits for the FAB once the ANSPs combine. Consequently, FABs would need to set differential prices across their airspace. Furthermore, the cost of standardizing equipment in the shorter term will likely require subsidies or higher prices, which is in direct opposition to current PRU policies. Third, in order to encourage technology adoption that will reduce airline costs, whether PCP or Step 1 of SESAR, the ANSPs ought to be permitted to increase their charges in the range of 10 to 20% respectively. Consequently, the current system of incentives needs to be altered in order to accelerate change. Fourth, the regional forerunner approach may lead to piecemeal adoption of new technologies as in specific cases, this would be to the benefit of both the ANSP and the local airline, for example Lufthansa and DFS.

Furthermore, we note that the smaller FABs, such as Ireland and Britain, have achieved slightly more to date than

the larger groupings, such as FABEC. It would appear that regional forerunners involving an ANSP company and their largest airline customer may be more successful in achieving the ultimate goal of a single European sky than a top-down regulated approach. Institutional changes required to accelerate change involve separating the ANSP from the government and creating companies that are either 100% government owned or private companies. Indeed, the International Civil Aviation Organization and the Civil Air Navigation Services Organization both recommend that ANSPs change from government departments to independent corporations. This is an illustration of the belief that separating the ANSPs from the Member States administration may lead to a more business oriented approach and so to more cross border cooperation than occurs under the current equilibria. Finally, an independent regulator will then be charged with performing audits of safety and procedural practices and the PRU with economic regulation.

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