InterFAB

Cooperation for Single European Sky

# Fragmentation in European ATM/CNS today: How is the link to Performance?

## DOCUMENT SUMMARY

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## INTRODUCTION

Fragmentation in the European Air Traffic Management (ATM) and Communications, Navigation and Surveillance (CNS) system is a concern for the Single European Sky (SES) initiative and reducing it is one of the objectives of the initiative. SES was launched in 2000 by the European Commission and entered into force in 2004 and has evolved since. The objective of SES is to improve the performance of ATM and air navigation services (ANS) through better integration of European airspace. One of the pillars of this initiative is to improve services and reduce costs to air transport passengers by reducing the fragmentation of the air traffic management in Europe. Thus, the objective of this work is to address and measure the different aspects of fragmentation and to see to what extent there is a link between fragmentation and performance.

Although addressing fragmentation is a policy objective for SES and therefore for the European Commission, there has been little work on it. The most relevant work on this topic is the report commissioned by the Performance Review Commission called "The impact of fragmentation in European ATM/CNS" that was prepared by Helios Economics and Policy Services (hereinafter called the Helios study). This report was published in 2006 and uses data from 2003, so an update would be useful. There have been many changes in the sector over the last two decades that have had a major impact on this topic that were not included in the Helios study because they did not exist in that time or were not relevant. In addition, several advances have been made in the study of the impacts of fragmentation in European ATM/CNS like academic works or an InterFAB Research Workshop about fragmentation which can now be considered.

### OBJECTIVES AND SCOPE OF THE STUDY

This report will cover the current state of fragmentation in European ATM/CNS and will compare it to the situation of 2006 by analysing progress on the aspects which were mentioned in the Helios study as being on the horizon, looking at new topics related to fragmentation such as new technologies or legislations and including the findings of the research that have been done about this topic since that time. Therefore, the report will be structured by fragmentation-related topics that are considered relevant in the Helios report but will also include new topics that may be relevant.

### DEFINITION OF FRAGMENTATION

The Helios study includes a definition of fragmentation that offers certain doubts from today's perspective. A proper definition of fragmentation is essential to be able to measure it, track it over time and detect how it impacts performance. In the Helios study, fragmentation was defined as "referring to the division of air navigation service provision into smaller decision-making or operational units than would result from considerations of optimum scale". The most controversial part of this definition is when the optimal scale is mentioned, as it does not describe what optimal scale is. Therefore, a better way to use the term fragmentation is to describe the heterogeneity and level of decomposition in ATM/CNS. It has not a negative connotation and does not set targets like optimum scale that are hard to define. In addition, this heterogeneity can be quantified with different indicators that measure the size or work volume of different ANSPs, such as, size of controlled airspace, total flight-hours controlled by the ANSP or total staff of the ANSP.

## METRICS TO MEASURE FRAGMENTATION

With a useful definition metrics can be developed to measure the level of fragmentation as well as how it evolves over time. Depending on the objective different metrics could be interesting such as flights, controlled flight hours, numbers of ACCs or sectors, size of controlled airspace or ATM/CNS costs. While each metric has its (dis-) advantages this work focuses on output criteria as these are out of the scope of influence of an ANSP and that can be scaled without any double counting. Thus we focus on controlled flight hours but also show other potential metrics. In order to show the level of heterogeneity we chose the Gini Coefficient as this measure of statistical dispersion intends to represent inequality. In the case Gini Coefficient has 0 as a value this would indicate equal distribution and each ANSP would control the same amount of controlled flight hours. A score of 1 would mean total inequality or that one ANSP control all flights and the others none. With this metric we can show that fragmentation has decreased from 0,6 in 2004 to 0,56 in 2020. The main reason is that the European core area with relatively high traffic has been experiencing lower growth rates than other areas of Europe and thus these areas have caught up. The market itself leads to a lower level of fragmentation as developing areas are experiencing higher growth rates.

## PROGRESS SINCE 2006

As it was mentioned in the introduction, the Helios Economics report was written in 2006 and used data from 2003. It is obvious that this is outdated, especially in a sector as changing and growing as the air industry has been in recent decades. In addition to that, the Helios report does not include several concepts that are nowadays crucial for the European ATM either because they did not exist at that time or because they were considered at that time to be left out of the scope of the study.
Some concepts that are not included in the Helios study but are included in this report are the following:

- Single European Sky (SES), Air Traffic Management Master Plan (ATM MP) and Single European Sky ATM Research (SESAR): these concepts did not exist when the Helios report was written and will be explained in detail in chapter 12.
- Functional Airspace Blocks (FABs) and Free Route Airspace: the Helios report does mention these concepts as future tendencies, but since they were not implemented, they could not be measured yet. It will be explained in chapter 7.
- Virtualization and other technological advances: new technologies will be explained also in chapter 7.
- New studies on fragmentation: as it was mentioned in the introduction, several studies have been carried out since the Helios report was published and will be included in this report. As it was mentioned in chapter 1, once fragmentation has become measurable one can investigate how it impacts performance. As an example, several research regarding economies of scale in the European ATM system will be included in chapter 13.
- Planned and implemented solutions to European civil-military ATM defragmentation

It is evident that there has been substantial progress on fragmentation over the last two decades whether on the regulatory framework such as SES or FABs, technology like virtualization and SESAR or new operational concepts such s Free Route or civil-military cooperation.

## PRINCIPLE OF SUBSIDIARITY

If there is a total defragmentation of European ATM/CNS there will not only be positive effects, but it may also lead to disadvantages which in a holistic view need to be addressed:

- States will not be able to make decisions in critical situations like pandemics or wars. That is why air traffic control is considered a critical infrastructure and States following the Chicago Convention need to have control of it.
- There would be only one single technology and operational provider, so if there is a problem with this provider everything will stop. A monopoly case will be created, which is not desirable.
- Positive impacts of fragmentation like the cases mentioned in this section (DNSA and MUAC case studies) would be nullified, as everything would be centralized, and the subsidiarity principle would not be applied.

As a conclusion, fragmentation cannot be easily measured with its different aspects. Its impact on the performance of the ATM system is not necessarily negative. In addition, the transition costs of implementing a more centralized system need also to be considered (this will be analysed in the chapters 5 and 7). The different case studies show that with fragmentation the system efficiency can be increased, and negative effects can be mitigated either by means of new technology or new processes. Defragmentation in itself is no asset as there may be a negative performance impact. Therefore, subsidiarity and the evolution of technology that changes the business model of ANS provision should be considered.

## WORKING CONDITIONS IN DEFRAGMENTATION

Defragmentation also means that salaries and working conditions are defragmented. In a totally defragmented European ATM/CNS environment there would be only one single Service Provider. In this case there would presumably be only one standard in terms of payment and working conditions. Due to fragmentation, there is a substantial spread both in salaries and e.g. working time which in turn would lead in a defragmented world to substantial changes for the staff. In order to minimize losses for works with current high salary and comparably low working hours a new standard would most likely be high in payment and low in working hours.

This chapter shows that a harmonization of working time and salaries would probably lead to higher costs with salaries multiplying up to six times whereas working time may drop by half. This study gives various scenarios as an example which show that the overall annual ATCO salaries may increase up to EUR 4,1 billion or may reduce by EUR 383 million while the number of ATCOs needed varies by more than 10.000 depending how many annual working hours they may have. The simulations prove on the one hand positive effects of fragmentation and on the other hand show the significance of transition costs which were neglected in the Helios report and will be further highlighted in the following chapter.

## TRANSITION COSTS

The Helios report mentions that the transition costs are not included in the study when talking about defragmentation. Nevertheless, they represent a substantial cost, and they should be addressed. There are different types of transition costs for defragmenting ANSPs, such as:

- **New facilities versus old facilities:** unless using the current facilities in a centralised mode (this implies high costs for the ATM standardisation processes) in the case of transitioning to a new bigger centre, obviously a new centre needs to be built and the old ones will not be used anymore. Nevertheless, selling such a specific facility is difficult.
- **Moving costs:** moving all the equipment and staff to a new centre will be a long and costly process.
- **Costs of new ATM System:** A new ATM system may be needed to harmonize the new defragmented centre.

- **Training costs and Time:** workers will need time to learn to operate with a different system.
- **Cost to harmonize working conditions:** Salary and working hours have been already discussed in chapter 5, but other issues like language, different working calendars, national laws, different costs of living and social standards can be problematic in a defragmentation process. Moreover, chapter 11 mentions that these issues were the reason why the US did not defragment the centres as the FAA wanted.

As a conclusion, transition costs although not addressed in the Helios report have a significant impact whether a project is beneficial or not and several initiatives and projects have been cancelled as the transition costs outnumbered the potential benefits.

## IMPACT OF TECHNOLOGY ON FRAGMENTATION

Technology has had a big impact on ATM performance and on fragmentation. Technological advances change the work environment, procedures and the way of working due to new functionalities. In some cases, negative impacts of fragmentation that the Helios report comments have been overtaken by technology. When comparing the situation of 2006 with the situation of nowadays, the technological advances have had an impact on fragmentation. Examples are:

- Functional Airspace Blocks (FAB) and the InterFAB initiative. As part of this initiative air traffic was planned regardless of national boundaries and with several projects has been implemented.
- Free Route Airspace (FRA): Free route airspace (FRA) is a specified airspace within which users may freely plan a route between a defined entry point and a defined exit point, without reference to the ATS route network, subject to airspace availability. FABs have facilitated the implementation of Free Route and via the InterFAB Platform the interfaces between the FABs are being recognized and improved.
- Virtualisation: with new technology available the IT and ATM Operations can be locally decoupled thus making benefits possible without the need to merge operational ATM units.

It can be noted that technology and its advances play a huge role in the evolution of air traffic control which in turn impact the potential optimal level of fragmentation making it a moving target.

## CNS/ATM PHYSICAL INFRASTRUCTURE EVOLUTION

In this chapter, a comparison between the physical infrastructure of 2003 and 2020 is made to see if and how fragmentation in physical infrastructure has changed. A main problem is that there are hardly data sources. The only sources found is the Helios report and a report called CNS evolution infrastructure evolution opportunities by Eurocontrol in 2020. However, as will be explained, they are not comparable as neither provides information how the counting has been made and e.g. in the area of communication the 2003 data counts complete systems and the 2020 data shows the number of networks. Although in navigation the data seems to be comparable but shows a 200% increase e.g. in NDB which is a declining technology which raises doubts concerning the comparison In the area of surveillance there is also an overlap in the data and the 2020 data includes infrastructure that did not exist at that point in time. When comparing ATM there are also doubts when looking at the number of sectors which indicate that in some two decades the number has more than tripled. However, this may also be seen as a greater flexibility in Service Provision as some of the sectors may have been created for combined use and in real life function as a collapsed airspace with only two ATCOs whereas the number of ACCs has remained nearly the same.

As a conclusion, to make a comparison a consistency of data is needed, and it does not exist nowadays. In practical terms, this comparison of 2003 and 2020 data does not give a realistic idea of the evolution of the CNS/ATM physical infrastructure. What can be taken from this comparison is that there is new technology in use today that did not exist in 2003 and that there is a phase of transition with an overlap of different technologies for the same purpose.

## EVOLUTION OF COSTS IN EUROPEAN ATM/CNS

Another important issue in judging the development of European ATM is the costs, as the 2006 report mentions that costs are higher than they should be due to fragmentation. Thus, the Helios report includes the 2003 en-route ATM/CNS costs table. To be able to compare it with more recent data, inflation until 2019 was applied to this data (as data of 2020 and 2021 may be biased due to the COVID pandemic) and compared with the actual costs of 2019. Whereas the Helios report suggests that ATM/CNS costs in 2003 were EUR 4,3 billion this would lead to EUR 5,6 billion in 2019 when applied the average inflation rate. However, the actual costs of ATM/CNS in 2019 were EUR 4 billion. So, costs during the 16 years have decreased by 29% and when considering the different volume of controlled flights the en-route ATM/CNS costs per controlled got reduced by 54%. As the Helios report estimates the overall costs of fragmentation to be in the magnitude of EUR 880-1400 Mio and in 2019 costs were down by EUR 1,6 billion one can assume that fragmentation costs are no longer significant. This will be discussed more into detail in the following chapter.

## NEGATIVE IMPACTS OF FRAGMENTATION

The Helios report includes a summary of areas where fragmentation was expected to have an adverse impact. In this chapter, it will be reviewed whether these areas remain causes of inefficiency in European ATM/CNS or not. In this way, it will be possible to analyse whether fragmentation, or the different consequences of fragmentation, is still a reason for inefficiency in the European ATM. The Helios report differentiates Common Issues, ACCs, ATM systems, CNS infrastructure and associated support.

Each of the areas is discussed: Common issues addressed by the Helios report have been mainly answered by the creations of FABs like e.g. the alleged fragmented planning. Furthermore, there are local cases which show that fragmentation may have positive effects as explained in chapter 4. With respect to ACCs, there are a number of studies which look into the optimum size of an ACC or ANSP and they don’t provide the evidence which the Helios report pledges for. In addition, the implementation of Free Route Airspace has made en-route a seamless experience – this concept is not linked with the size of an ACC. The development of very advanced ATM Systems has led to System families which are mainly led by Indra and Thales in Europe. The previous chapter has already shown that the main driver for CNS infrastructure is the evolution of technology and costs mainly depend on the speed of fading out of “old” technologies as otherwise both operating and replacement costs will increase substantially. With respect to associated support there are some barriers both in terms of language and culture. Although some cooperation as part of the FAB umbrella or outside like e.g. in Training or common procurement are noticeable.

To sum up, one can note that most of the areas where fragmentation has an adverse impact have been overcome or are in progress.

## COMPARISON EU-US

The Helios report makes a reference to the comparison between EU and US. It is mentioned that the US performs in a more efficient way, and it is suggested that the fragmentation is an important contributing factor to the performance gap between Europe and the US. It is shown in this chapter that there are more current studies available proving that the alleged performance gap depends mostly on exchange rate variations (USD / EUR), the traffic structure (scheduled passenger traffic, general aviation and military traffic), working conditions and methods (working time and single sector operations) as well as the charging regime (tax versus charges).

Further on, the way of counting ACCs in the US is quite different to Europe. If properly assessed and counted the "European" way there are more ACCs in the US than in Europe as the US doesn't consider major approach units as an ACC whereas e.g. ACC Brussels and Amsterdam are counted as ACCs in Europe although they mainly serve as an Approach unit. In addition, the Helios report suggests that the number of ACCs will reduce further due to possible efficiency gains. However, the contrary has happened and nowadays there is an additional ACC. The explanation made is that transition costs as well as a standardization of working hours and salaries would have led to higher costs. Finally, the use of special use airspace in the US and Europe gets addressed. It can be shown that the natural fragmentation in Europe in which each country has its own air force has partly been overcome with cross-border areas and the implementation of Flexible Use of Airspace (FUA).

## IMPORTANCE OF SESAR AND ATM MASTER PLAN

When the Helios report was written, SES was only at the horizon and SESAR as well as the ATM Master Plan were not on the agenda. SESAR is a programme for researching the future of air traffic management in Europe. SESAR 2020 (2016 – 2024) builds on its predecessor, SESAR 1 (2008 – 2016), to deliver high-performing operational and technological solutions for uptake by the aviation industry. SESAR has had a total budget of EUR 3.7 billion between 2008 and 2024. SESAR 2020 will support projects to deliver solutions in four key areas, namely:

- Airport operations
- Network operations
- Air traffic services
- Technology enablers

However, in 2021 the SESAR program was reorganized in SESAR 3 Joint Undertaking. In 2022, the (ATM) Master Plan has 11 implementation objectives. These objectives serve as a common investment guideline for stakeholders. Thus, these obligations serve to defragment the European ATM, as they all invest with the same objectives and along the same lines which will foster harmonization of ATM/CNS in Europe.

## COMPARISON OF ACCS

There is a common belief, especially when comparing European and American ATM (as it was discussed in topic 11), that big ANSPs and ACCs are more efficient. The Helios report elaborates on this idea throughout the report. Nevertheless, some research studies are included that disprove this belief and provide quantitative facts. Thus, data from European ANSPs is taken to measure the correlation between size and productivity. To see whether size is relevant in performance, the correlation between size and different performance indicators is calculated (data of 2019). Size is measured as total flight hours controlled. The data shows that there is not strong correlation between the performance indicators and ANSP size.

Different studies, using state-of-the-art methodologies such as Stochastic Frontier Analysis (SFA) or Data Envelopment Analysis (DEA) and data of all European ANSPs and in time-series, show that the correlation between the size and performance in the European ATM is not strong at all. Thus, there is no evidence of economies of scale in European ATM and that the performance gap between different ACCs or ANSPs has other reasons of being rather than size.

## FRAGMENTATION IN THE WHOLE VALUE CHAIN

When talking about the fragmentation of the European ATM/CNS, it is important to consider the fragmentation of the whole air transportation value chain to understand if ATM is fragmented or not comparing to the rest. The Helios report does not include information of the other steps in the value chain. Passengers and goods that require air transportation services make up a very broad spectrum, so they are really fragmented. However, the rest of the value chain is not.

The air transportation value chain is not fragmented and monopolies or oligopolies reign throughout the chain. The whole value chain is structured as monopolies or very narrow oligopolies, as the aviation sector does not generate much competition due to its own market characteristics. In the same way, the structure of the market itself determines the level of fragmentation of the ANS.

# 1 DEFINITION OF FRAGMENTATION

The report commissioned by the Performance Review Commission called "The impact of fragmentation in European ATM/CNS" that was prepared by Helios Economics and Policy Services address the fragmentation issue. Nevertheless, this report was published in 2006, from now on referred to as the Helios study or the 2006 study, includes a definition of fragmentation that offers certain doubts from today's perspective. A proper definition of fragmentation is essential to be able to measure it, track it over time and detect how it impacts performance. In the report, fragmentation was defined as "referring to the division of air navigation service provision into smaller decision-making or operational units than would result from considerations of optimum scale". The first thing that can be mentioned in this definition is that operational units are not properly defined. It is not very clear whether it refers to companies, air navigation service providers (ANSPs) area control centres (ACCs) or sector families.

The most controversial part of this definition is when the optimal scale is mentioned, as it does not describe what the optimal scale is. It must be mentioned that the optimum size is hard to define and may change over time. Bearing in mind that the airline industry is a highly volatile industry, traffic changes from one minute to another or from one year to another both in terms of flows and numbers. In addition, technological changes and cross-border areas may change operational procedures. Thus, the needs of air traffic control are very changeable, and it is not possible to determine an optimal scale that will last over time.

Moreover, when considering what is the optimum size, it can be considered from different perspectives, such as, safety, capacity, environment, or cost-efficiency. The optimum size of one of these perspectives will not be the same of the other ones and working towards one of them could be decremental to the others. There is not a clear definition of optimum size but when the term fragmentation is used to describe the European ATM system, it refers to a space whose management is separated in little pieces and suggests underperformance compared to centrally controlled airspace. Thus, it is implicitly stated that the larger the ATM the more efficient it will be.

Thus, a better way to use the term **fragmentation should in a neutral way describe the heterogeneity and level of decomposition in ATM/CNS**, defined by Standfuss et al. (2019). This is a better way to define fragmentation because it has not a negative connotation and does not set targets like optimum scale that are hard to define. In addition, this heterogeneity can be quantified with different indicators that measure the size or work volume of different ANSPs, such as, size of controlled airspace, total flight-hours controlled by the ANSP or total staff of the ANSP. This way, fragmentation can be also tracked over time to see the evolution. In the next chapter the different indicators that can be used to measure the fragmentation will be discussed in detail.

As a conclusion, defining fragmentation in a correct way is essential to be able to measure it and track it over time. The definition used in this report for fragmentation is a neutral way to describe the heterogeneity and level of decomposition in ATM.


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- Anton R, Lokman N, Pitton E, Whittome M. Is Fragmentation a sin? Discussion through some case studies. Research Workshop on Fragmentation in Air Traffic and its impact on ATM Performance.
- ALG Newsletter: European defragmentation through a single, harmonised and interoperable surveillance framework: https://algnewsletter.com/aviation/european-defragmentation-through-a-single-harmonised-and-interoperable-surveillance-framework/

# 2 METRICS TO MEASURE FRAGMENTATION

Fragmentation is used here in a neutral way to describe the heterogeneity and level of decomposition in ATM. Thus, performance data from European ANSPs can be used to measure fragmentation. It is important to determine the indicators to be used to measure fragmentation, as there are many different data on the performance of ANSPs. A study carried out by FABEC called "Is Fragmentation a sin? Discussion through some case studies" takes different key data of European ANSPs to be used as indicators of the level of fragmentation in the European ATM, such as the indicators included in table 1.

Table 1: Key Data of European ANSPs (2019)

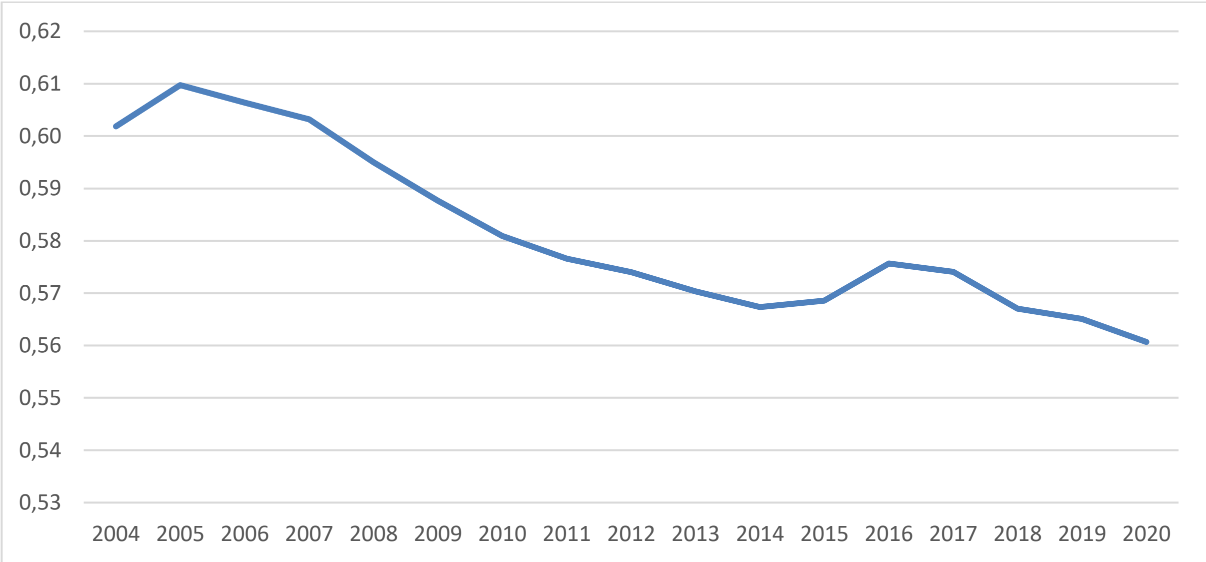
| | Minimum | Maximum | Average | Factor | Median |
|---|---|---|---|---|---|
| IFR ACC Movements | 51,862 | 5,491,511 | 1,152,878 | 106 | 720,578 |
| Size of controlled airspace | 20,500 | 2,190,000 | 344,683 | 107 | 158,000 |
| ATCOs in OPS | 50 | 2,813 | 462 | 56 | 249 |
| Total staff | 164 | 7,622 | 1,419 | 46 | 855 |
| Total IFR flights controlled by the ANSP | 55,299 | 3,302,045 | 911,468 | 60 | 683,152 |
| Total IFR km controlled by the ANSP | 8,368,338 | 1,809,736,736 | 324,207,667 | 216 | 206,243,369 |
| Total flight-hours controlled by the ANSP | 12,716 | 2,483,703 | 455,564 | 195 | 281,554 |
| Number of ACC operational units | 1 | 5 | 2 | 5 | 1 |
| Gate-to-gate ATM/CNS provision cost (in €´000) | 9,720 | 1,344,824 | 234,396 | 138 | 143,309 |

*Source: Eurocontrol ATM Cost-Effectiveness (ACE) report 2019*

Note that all these indicators measure the size of European ANSPs. The average column shows the central or typical value of the indicator. The factor column shows how big is the biggest ANSP when compared to the smallest ANSP. The median column shows the middle number of the ANSPs in that indicator. One may use indicators that measure the productivity of ANSPs like ATCO-hour productivity or support costs per composite flight hour. However, from a performance point of view the impact of fragmentation is crucial. Therefore, the chosen approach is rather to find a metric that represents the size of ANSPs and thus to see whether the different composition and heterogenity have an impact on productivity measures. As other studies measure fragmentation in other ways, the mentioned study uses the total flight-hours controlled by the ANSP to measure it. An advantage of the approach is that output data is out of control of an ANSP, cannot be manipulated and thus provides an adequate indication on the size of the unit.  In addition, controlled flight hours can be added or scaled and there is no double counting doing so.

When measuring inequality, a measure that is widely used is the Gini Coefficient. The Gini Coefficient is a measure of statistical dispersion intended to represent the inequality within a group, the coefficient of 0 indicates an equal distribution and 1 indicates total inequality. In this case 0 will mean an equal distribution of controlled flight hours between ANSPs and 1 will mean that all flight hours would be controlled by the same ANSP. It is important to qualify this, as someone might argue that a single ANSP controlling almost all air traffic is providing a defragmented ATM in Europe. However, given the legal structure of the European ATM where each country is sovereign and responsible for its airspace, the perfectely defragmented European ATM would be in which all European ANSPs would control the same flight-hours or only one centralised ANSP would provide the ATM. This implies that 1 will be perfect centralization and that the lower the number the more defragmentation there will be. Thus, this coefficient is applied to the hours controlled data from 2004 to 2020 using the Eurocontrol ATM Cost-Effectiveness (ACE) reports to see if fragmentation has increased or decreased. Figure 1 shows that the fragmentation has decreased through the 16 years of the study, as the smaller ANSPs have experienced higher growth rates in flight hours controlled than the larger ones And the Gini-Coefficient represented on the vertical axis has decreased over the time. The market itself leads to a lower level of fragmentation since the developing areas are catching up with the more developed areas.

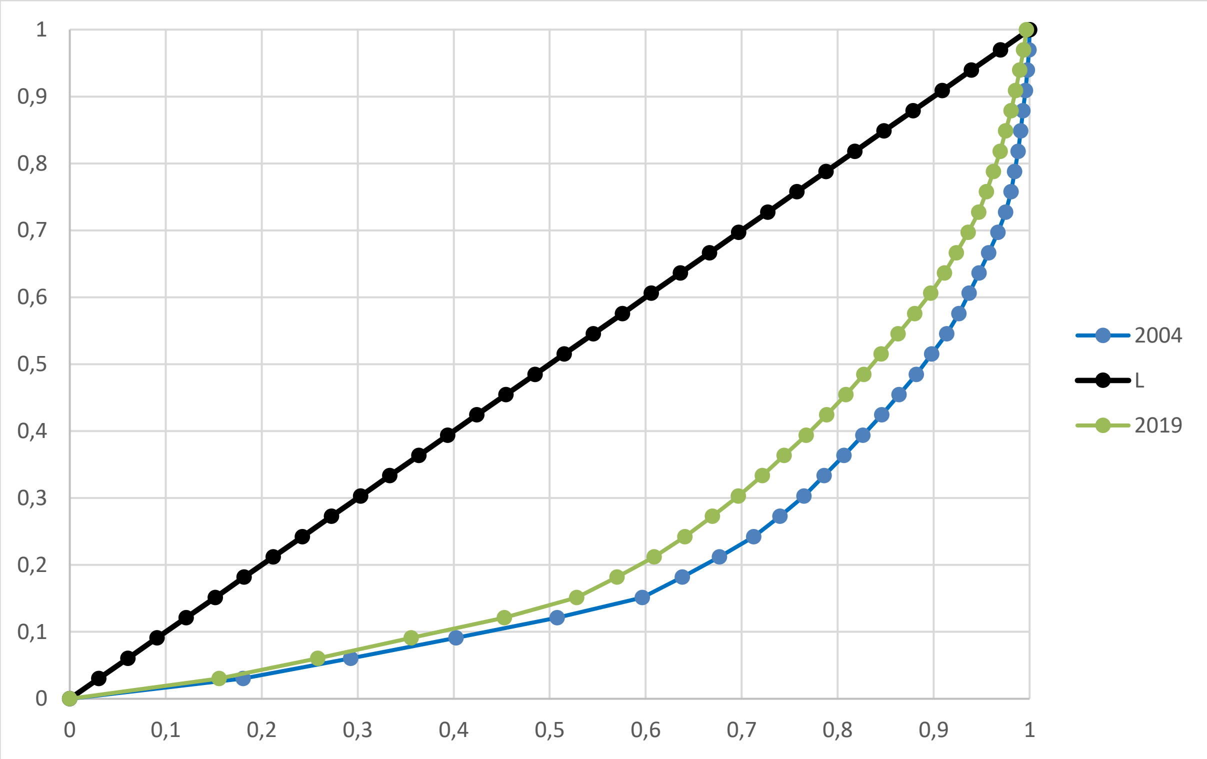
Figure 1:  evolution of the normed Gini coefficient (G*) for controlled flight hours from 2004 to 2020




*Source: Own elaboration*

In addition, the Lorenz curve is also included. The Lorenz curve is a graphical representation of the inequality in a group. The further away from the bisector (black line) the curve is, the greater the inequality. If each ANSP had the same size, the black line would represent total equality with each black dot representing one ANSP. This means that, as closer the Lorenz curve is to L, the less fragmentation there is. The data from 2004 and 2019 is taken to visually show the difference in equality that has been developed between these years. In 2004 the inequality was larger (blue line) with each ANSP again representing one blue dot. The smaller the ANSPs are the closer the dots are to each other. Compared to 2019 the inequality was reduced (green line) as it is closer to the black coloured Lorenz-Curve. The green dots, which again represent each one European ANSP have moved slightly more to the left compared to the blue dots showing again that inequality was reduced.

Figure 2: Lorenz curve for controlled flight hours in the European ATM as a share in % per ANSP




*Source: Own elaboration*

The Lorenz curve proves that there are changes over time. Therefore, any optimal structure will become suboptimal as the industry evolves (as mentioned in chapter 1) and there would be a constant need to adapt the structure which comes along with considerable transaction costs. Thus, we can see that fragmentation has decreased over the last 15 years (with Gini-Coefficient reduced from 0,6 to 0,56) as the differences between the different ANSPs that make up the European ATM has decreased. However, it must be considered that there is no consensus on indicators to measure fragmentation and obviously using other indicators the results may vary. Another crucial issue that was mentioned in the introduction and will be developed in the following chapters is whether fragmentation is an explainatory of perfomance or not, especially in the chapter 13.

In conclusion, different indicators can be used to measure fragmentation in European ATM and this report uses the total flight-hours controlled because is the best output to capture the en-route differences and that flight-hours can be added or scaled and there is no double counting. Tracking data from 2003 to 2019, fragmentation is now lower as it is understood here, since the differences between ANSPs have reduced and it mirrors the maturity of the market as mostly Eastern areas in Europe catch up in air traffic compared to Central and Western Europe.

<u>Sources:</u>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# 3 PROGRESS SINCE 2006

As it was mentioned in the introduction, the Helios Economics report was written in 2006 and used data from 2003. It is obvious that this is outdated, especially in a sector as changing and growing as the air industry has been in recent decades. In addition to that, the Helios report does not include several concepts that are nowadays crucial for the European ATM either because they did not exist at that time or because they were considered at that time to be left out of the scope of the study.

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- Virtualization and other technological advances: new technologies will be explained also in chapter 7.
- New studies on fragmentation: as it was mentioned in the introduction, several studies have been carried out since the Helios report was published and will be included in this report. As it was mentioned in chapter 1, once fragmentation has become measurable one can investigate how it impacts performance. As an example, several research regarding economies of scale in the European ATM system will be included in chapter 13.

In addition, some topics that were left out of the Helios study will be included in this report, as they are important to explain the whole spectrum of the European ATM structure. As it was explained in chapter 1, the Helios study does not include a definition of fragmentation or the optimum scale and does not include indicator to measure them. Work has been done on this aspect in chapters 1 and 2. Another vital topic that was not considered is the transition costs. Chapters 5 and 7 will explain in detail this issue, as they can be a determinant factor to decide whether to defragment or not. Another comment that can be made about the Helios report is that there is not a holistic view of fragmentation, as there are also positive impacts of fragmentation that the Helios report does not mention. A few examples will be included in chapter 4.

Finally, the previous report mentions that fragmentation between civil and military provision was excluded of the study. However, in air traffic management terms fragmentation between civil and military air navigation does not make sense. The report called “Military requirements and European airspace – genesis of fragmentation” addresses this issue. This report mentions that with the Chicago Convention of the International Civil Aviation Organization (ICAO), every State has complete and exclusive sovereignty over the airspace above its territory. Therefore, each country is responsible for the security, defence, disaster management and law enforcement obligations in its own airspace. In this manner, it is vital for aircrafts to be provided access to sufficient space, enabling adequate opportunities for the training and execution of security, defence, and law enforcement elements.

In the European Context, the Single European Sky (SES) initiative aims to reform ATM in Europe to cope with sustained air traffic growth and operations under the safest, most cost- and flight-efficient and environmentally friendly conditions. This implies de-fragmenting European airspace, reducing delays, increasing safety standards and flight efficiency to reduce the aviation environmental footprint, and reducing costs related to service provision.

Nevertheless, SES regulation shall not prevent the application of Member States´ measures needed to safeguard essential security or defence policy interests. SES directives aspire for a seamless European airspace by assuring flexible and effective access to all stakeholders (including the military) without prejudice to Member States´ sovereignty and requirements relating to public order, public security, and defence matters.

Since modern military aircraft and weapons require larger volumes of airspace and civil air traffic is expected to increase, airspace utilization must be optimized to satisfy military and civil needs. This can only be achieved with a new flexible approach towards airspace design and management, which will require airspace planners to be aware of the operational needs of all airspace users.

In this context, there are several short-term solutions to European civil-military ATM defragmentation that are included in the Table 2.

Table 2: Short-term civil-military solutions to European ATM defragmentation

| | |
|---|---|
| STATES | Provide new airspace design features with increased ARES vertical and lateral modularity. Enhance civil-military coordination/collaboration participate in cross-border arrangements |
| CIVIL AU | Ensure efficient use of the ATM network information in real time through NOP and effective use of the available airspace resource (Fly as planned) |
| NM | Synchronize ARES allocation and use with traffic flows through DCB Continuously update NOP and ensure consistency of the AU demand through balancing demand of all categories of AU versus available capacity and provision of the real airspace status update |
| MILITARY AU | Share true demand with ATM actors concerned through improved OAT FPL and engage in CDM when possible (Fly as Planned) |
| ANSP | Ensure efficient civil-military co-ordination, provide ATS services to all categories |
| ALL | Collaborate in all phases of the ATM lifecycle to optimize ATM network performance |

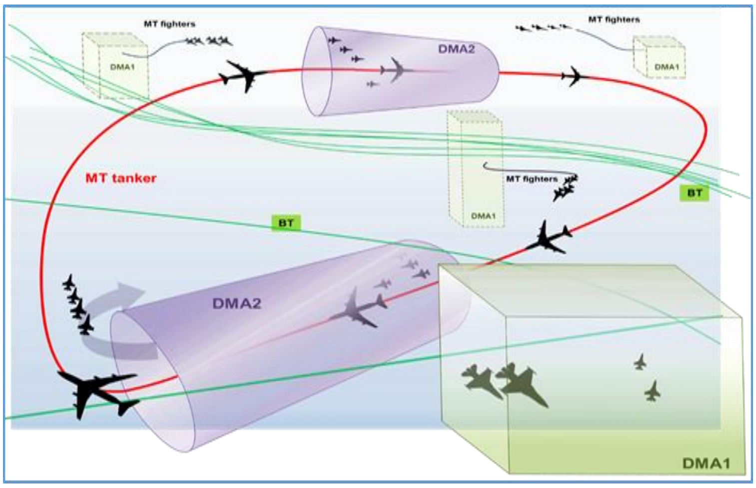
*Source: Military requirements and European airspace – genesis of fragmentation (2019)*

In the long-term, the future Single European Sky relies on a high-performing ATM system enabling airspace users to fly their optimum trajectories. SESAR ATM vision 2035 is trajectory-based free route operations with well-defined navigation performance. The military vision for the future European ATM system is integration of the security and defence dimension to ensure that Military Aviation will continue to execute their task effectively, without prejudice to the safety of civil air traffic. The backbone of the future ATM operations is the sharing of a single, harmonized reference trajectory though a common data set among all ATM stakeholders.

A key evolution expected from the military AU is the sharing of integrated flight profile and airspace reservation/restriction allocated via advanced ASM through solutions as the Improved OAT Flight Plan and its future development. This will enable network-wide optimization of traffic flows within airspace configurations coordinated at ECAC level to balance demand and capacity.

With advanced ASM in place, airspace reservations/restrictions designed according to Variable Profile Area (VPA) and Dynamic Mobile Area (DMA) principles will be allocated though a civil-military CDM process seamless from local to network levels, aiming at fulfilling the military mission requirements whilst minimising the impact on the ATM network performance.

Figure 3: Mission trajectory with DMAs




*Source: Military requirements and European airspace – genesis of fragmentation (2019)*

As a summary, the Helios report does not include some topics that are nowadays relevant in the fragmentation of European ATM/CNS. This includes new technologies, legislations and new research, optimum size, transition costs, positive impacts of fragmentation or civil/military fragmentation.

<u>Sources:</u>

- M. Steinfurth, I. Kuren, R. Lacatus, A. Paulov, V. Somosi, 2019: Military requirements and European airspace – genesis of fragmentation

# 4 PRINCIPLE OF SUBSIDIARITY

When talking about defragmentation there are several issues to be addressed. Technology has helped reduce fragmentation, but as mentioned in the InterFAB Research Workshop of 2019 called “Fragmentation in Air Traffic and its Impact on ATM performance” key messages: “Technology developments and automation have helped reduce fragmentation in ATM, however as long as human beings are involved, fragmentation is inevitable. Only 100% automation will overcome fragmentation.”

Moreover, the Chicago Convention of the International Civil Aviation Organization puts responsibility of air traffic control on States. As it was seen in the previous chapter, states have sovereignty over its airspace and are responsible of the safety. The subsidiarity principle is intended to ensure that decisions are taken as closely as possible to the citizen and that constant checks are made as to whether action at Community level is justified in the light of the possibilities available at national, regional, or local level. If all ANSPs become one, this principle would not be applied as everything would be centralized.

If there is a total defragmentation of European air traffic control, States will lose that sovereignty, and this would have several negative impacts:

- States will not be able to make decisions in critical situations like pandemics or wars. That is why air traffic control is considered a critical infrastructure and States should always have control of it.
- There would be only one single technology and operational provider, so if there is a problem with this provider everything will stop. A monopoly case will be created, which is not desirable.
- Positive impacts of fragmentation like the cases mentioned in the following section (DNSA and MUAC case studies) would be nullified, as everything would be centralized, and the subsidiarity principle would not be applied.

Moreover, there are positive impacts of fragmentation that would be lost if total centralization is established. The research that was already mentioned in chapter 1 called “Is Fragmentation a sin? Discussion through some case studies” includes some examples where more fragmentation has meant more efficiency.

**Case Study DSNA:** Two cases in relation with French airspace show how fragmentation could be beneficial in terms of flexibility of airspace management and with respect to optimization of en-route capacity. In terms of flexibility, the BALSI project implemented in 2018 has solved safety and capacity issues linked to the operations around Geneva and Lyon airports creating more fragmentation. This area is fragmented between Swiss and French ACCs and BALSI creates more fragmentation inside this ACCs since this solution is only applied to this area. This project means the first implementation of dynamic airspace configuration, that goes further than solutions usually implemented inside one single ACC. The responsibility of airspace volumes is switched in real time between Geneva and Marseille ACCs, depending on the Runway in use at Geneva airport. This change in responsibility allows optimized aircraft trajectories in the airspace of both orientations of runway for take-off (QFU configurations) of Geneva airport, thus generating major gains on safety, capacity, flight time and fuel consumption.

The second case is about the Collaborative Advanced Planning process (CAP) that started in Reims ACC in 2015. The fragmentation and the deep local knowledge enabled the creation of a brand new local en-route Collaborative decision Making (CDM) process. In normal cases when the traffic forecast exceeds a sectors capacity for a few number of flights, a regulation of traffic is set. But due to the uncertainties of real traffic, the regulation generates capacity losses. With the CDM process, DSNA (French ANSP) contacts airlines and proposes route and/or level changes to those flights which are potentially subject to AFTM regulations. With that minor change, the implementation of an ATFCM measure is avoided and the capacity is optimized. This proccess has been so efficient that was extended to other French ACCs and was even integrated in the SESAR PJ24 project (that will be explained in chapter 12). In this case the fragmentation was the sorce of efficient innovation linked to a very local and in-depth knowledge of constraints and of operational actors.

**Case study MUAC:** Multiple factors influence the Operational Efficiency. The main causes can be divided into capacity constrains (as the sector design in Europe is based on national boundaries and its implementation heterogeneous), underutilization of unused military airspace, route changes and unit rate variations. Operational fragmentation requires consideration of the specific local circumstances and the different needs of airspace users. Several actions can mitigate the negative impact of this type of fragmentation:

- Network throughput optimization via optimal flow-based design rather than throughput on ATC sector or ACC level.
- Improved traffic predictions such as Traffic Prediction Improvement Project.
- Network centric planning and execution such as eNM measures (network capacity plan).
- Optimized Flexible Use of Airspace, efficient civil military FUA process.

As a conclusion, fragmentation cannot be easily measured with its different aspects. Its impact on the performance of the ATM system is not necessarily negative. In addition, the transition costs of implementing a more centralized system need also to be considered (this will be analised in the chapters 5 and 7). The different case studies show that with fragmentation the system efficiency can be increased and the negative effects can be mitigated either by means of new technology or new processes. Defragmentation in itself is no asset as there may be a negative performance impact. Therefore, subsidiarity and the evolution of technology that changes the business model of ANS provision should be considered.

Sources:

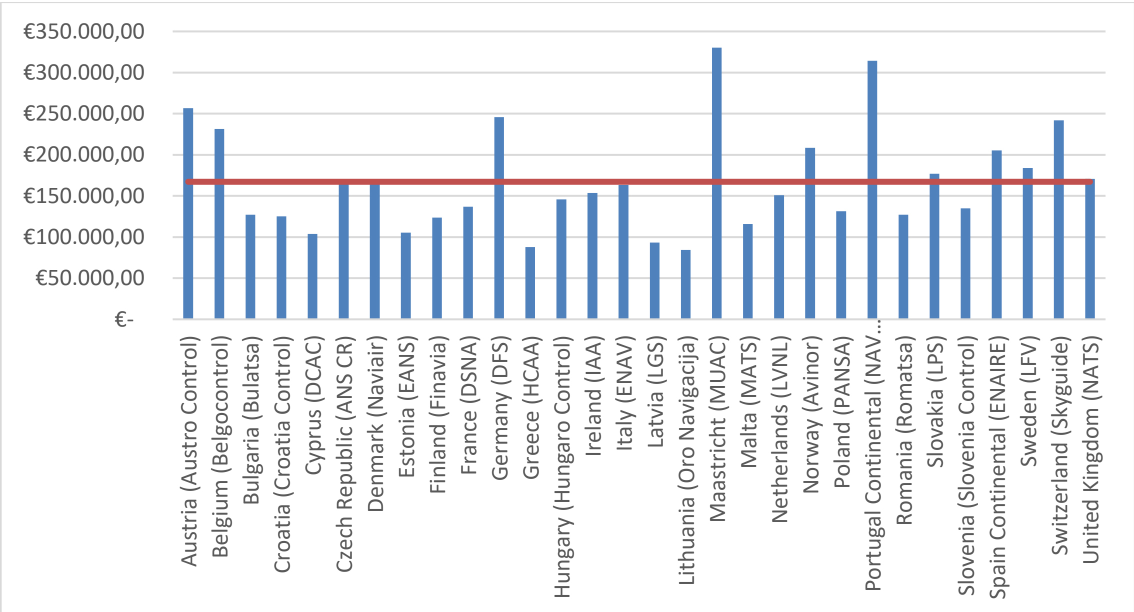
- Fragmentation in Air Traffic and its Impact on ATM performance
- Anton R, Lokman N, Pitton E, Whittome M. Is Fragmentation a sin? Discussion through some case studies. Research Workshop on Fragmentation in Air Traffic and ist impact on ATM Performance.

# 5 WORKING CONDITIONS IN DEFRAGMENTATION

One of the main things that should be considered when talking about fragmentation is that working conditions and costs are different in each country. The defragmentation helps in defragmenting working hours and salary and one may think that the tendency is to go to the average of hours and salary. However, this is not the case, as workers with higher wages and shorter working hours will not accept lower salaries and longer hours. In addition, once the ANSPs have become one, the ATCOs with the worst working conditions will want to match their conditions with their now equal partners. Thus, the tendency is to go highest salaries and lowest working hours.

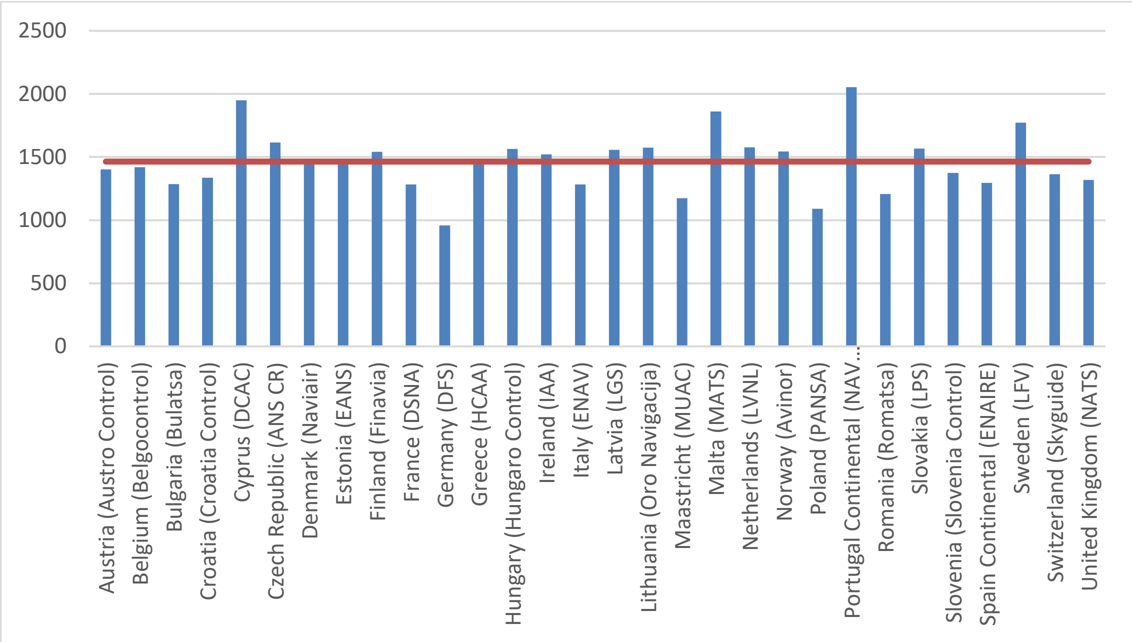
Taking the data of ATCOs of the European Union members in a gate-to-gate perspective, the working hours per year vary from 959 to 2,054. This is a huge variation between European Union countries. The employment-cost gap is even bigger, with the lowest being 84,350€ per year and the highest 330.200€. With this data, it will be challenging to defragment these differences. Note that all European Union countries are included plus Norway and United Kingdom (Maastricht Upper Area Control Centre (MUAC) manages the upper airspace over Belgium, the Netherlands, Luxembourg, and north-west Germany). Figures 3 and 4 show the ATCO salary and working hours p.a. per countries, with the orange line being the average.

Figure 4: ATCO salary p.a.




*Source: own elaboration*

Figure 5: ATCO working hours p.a.




*Source: own elaboration*

Considering the assumptions made above, it seems reasonable that in case of a defragmentation at European level with all ANSPs become one, wages are equalised at the top and working hours at the bottom. Working on the assumption that the same hours are to be monitored but that each ATCO works less hours, it will be necessary to recruit new ATCOs. Table 2 shows the number of new workers that need to be recruited in each country to control the same hours as at present with the shortest working hours (Germany). Countries such as Cyprus or Portugal would have to more than double their current workforce to meet these needs.

Table 2 also shows the employment costs for each country to pay their current employees as the highest in Europe (Maastricht). In this case, there are many countries that would more than double their costs, with countries like Lithuania, Greece and Latvia reaching an increase of costs of 291%, 276% and 254% respectively. Another thing to consider is that the increase in the number of ATCOs' staff brings with it an extra increase in employment costs. In addition, these new workers will also be paid at the highest salary range. The seventh and eighth columns of table 2 show these cost increases due to the hiring of new ATCOs. Finally, the last two columns show the total increase of employment cost, the increase related to the raise of wages for current workers to bring them in line with the highest European wage rate and the increase related to hiring new ATCOs.  As can be seen, practically all countries increase their costs by more than double, with extreme cases such as Cyprus, Greece, Latvia, Lithuania, and Malta where costs are multiplied by 4, 5 or even 6 times.

These data lead to the conclusion that the costs of defragmentation for European ANSPs are unaffordable. Moreover, other issues related to the diversity of working conditions, such as national holidays, work bonuses or the daily subsistence allowance, should also be considered where the tendency will also be to equalise over the best working conditions, increasing costs. Increase in ATCOs and employment costs with defragmentation.

Table 3: Increase in ATCOs and employment costs with defragmentation (case 1)

| Countries/ANSPs | | ∆ ATCOs hired | | ∆ Employment costs | | Cost of hiring new ATCOs | | ∆ Employment costs: old ATCOs + new ones | |
|---|---|---|---|---|---|---|---|---|---|
| | | Workers | % | Million € | % | Million € | % | Million € | % |
| Austria | Austro Control | 136 | 46.15% | 22 | 28.60% | 45 | 59.35% | 67 | 87.96% |
| Belgium | Belgocontrol | 99 | 47.92% | 20 | 42.78% | 33 | 68.42% | 53 | 111.21% |
| Bulgaria | Bulatsa | 95 | 33.88% | 57 | 159.40% | 31 | 87.88% | 88 | 247.28% |
| Croatia | Croatia Control | 98 | 39.17% | 51 | 163.62% | 32 | 103.27% | 83 | 266.88% |
| Cyprus | DCAC | 110 | 103.34% | 24 | 217.79% | 36 | 328.40% | 60 | 546.19% |
| Czech Republic | ANS CR | 140 | 68.33% | 33 | 93.82% | 46 | 132.44% | 79 | 226.26% |
| Denmark | Naviair | 113 | 53.53% | 34 | 96.18% | 37 | 105.01% | 71 | 201.19% |
| Estonia | EANS | 37 | 54.53% | 15 | 213.38% | 12 | 170.89% | 28 | 384.27% |
| Finland | Finavia | 103 | 60.62% | 35 | 167.30% | 34 | 162.05% | 69 | 329.36% |
| France | DSNA | 952 | 33.84% | 543 | 140.97% | 314 | 81.54% | 858 | 222.52% |
| Germany | DFS | 0 | 0.00% | 150 | 34.42% | 0 | 0.00% | 150 | 34.42% |
| Greece | HCAA | 263 | 54.47% | 117 | 275.54% | 87 | 204.57% | 203 | 480.11% |
| Hungary | Hungaro Control | 113 | 63.00% | 33 | 126.61% | 37 | 142.77% | 70 | 269.38% |
| Ireland | IAA | 155 | 58.54% | 47 | 114.73% | 51 | 125.70% | 98 | 240.43% |
| Italy | ENAV | 481 | 33.82% | 237 | 102.20% | 159 | 68.38% | 396 | 170.58% |
| Latvia | LGS | 45 | 62.16% | 17 | 254.31% | 15 | 220.24% | 32 | 474.55% |
| Lithuania | Oro Navigacija | 51 | 64.06% | 20 | 291.46% | 17 | 250.76% | 37 | 542.22% |
| Maastricht | MUAC | 57 | 22.37% | 0 | 0.00% | 19 | 22.37% | 19 | 22.37% |
| Malta | MATS | 47 | 93.97% | 11 | 184.80% | 16 | 267.64% | 26 | 452.45% |
| Netherlands | LVNL | 137 | 64.49% | 38 | 118.61% | 45 | 140.98% | 83 | 259.60% |
| Norway | Avinor | 253 | 60.91% | 50 | 58.29% | 83 | 96.42% | 134 | 154.71% |
| Poland | PANSA | 78 | 13.70% | 114 | 151.23% | 26 | 34.42% | 140 | 185.65% |
| Portugal Continental | NAV Portugal | 225 | 114.11% | 3 | 5.09% | 74 | 119.92% | 77 | 125.02% |
| Romania | Romatsa | 119 | 25.74% | 94 | 159.53% | 39 | 66.82% | 134 | 226.35% |
| Slovakia | LPS | 65 | 63.31% | 16 | 86.72% | 22 | 118.21% | 37 | 204.93% |
| Slovenia | Slovenia Control | 38 | 43.19% | 17 | 144.86% | 13 | 105.77% | 30 | 250.63% |
| Spain Continental | ENAIRE | 580 | 35.12% | 206 | 60.73% | 191 | 56.45% | 397 | 117.18% |
| Sweden | LFV | 363 | 84.81% | 63 | 79.44% | 120 | 152.18% | 182 | 231.62% |
| Switzerland | Skyguide | 147 | 42.13% | 31 | 36.50% | 49 | 57.51% | 80 | 94.01% |
| United Kingdom | NATS | 465 | 37.37% | 198 | 93.30% | 153 | 72.23% | 352 | 165.53% |
| **TOTAL** | | **5,564** | | **2,296** | | **1,837** | | **4,133** | |

*Source: Eurocontrol (2021): own elaboration*

For comparability reasons it can also be useful to do the same exercise but instead of taking the maximum salary and minimum working hours just taking the average for both. Here it is also assumed that the same total working hours should be worked by each ANSP, and table 3 shows the difference in ATCOs and employment costs if hours and salary moved from current state to European average. Note that unlike the previous case in this case there may be negative increments, since in countries that work less than the average, as the number of hours of each ATCO increases, fewer workers are needed. It is the opposite case in salaries, the countries where ATCOs earn more than average will see their employment costs decrease when salaries are equalized on average.

As seen in table 3 there is a huge heterogeneity between European countries. Cases like Germany and Maastricht will decrease their employment costs by 78% and 69% respectively, as Cyprus and Latvia will increase them by 166% and 101%. The total employment costs of European ANSPs will decrease 383 million €. The biggest contributor to that decrease is Germany because it is a country with many ATCOs, the lowest hours worked per ATCO and wages well above average.

Table 4: Increase in ATCOs and employment cost with defragmentation (case 2)

| Countries/ANSPs | | ∆ ATCOs hired | | ∆ Employment costs | | Cost of hiring new ATCOs | | ∆ Employment costs: old ATCOs + new ones | |
|---|---|---|---|---|---|---|---|---|---|
| | | Workers | % | Million € | % | Million € | % | Million € | % |
| Austria | Austro Control | -13 | -4.24% | -26 | -34.89% | -2 | -5.45% | -29 | -40.34% |
| Belgium | Belgocontrol | -6 | -3.08% | -13 | -27.71% | -1 | -4.40% | -14 | -32.10% |
| Bulgaria | Bulatsa | -34 | -12.28% | 11 | 31.34% | -6 | -31.85% | 5 | -0.51% |
| Croatia | Croatia Control | -22 | -8.81% | 10 | 33.47% | -4 | -23.23% | 7 | 10.24% |
| Cyprus | DCAC | 35 | 33.23% | 7 | 60.90% | 6 | 105.61% | 13 | 166.51% |
| Czech Republic | ANS CR | 21 | 10.29% | -1 | -1.86% | 4 | 19.95% | 3 | 18.08% |
| Denmark | Naviair | 1 | 0.60% | 0 | -0.67% | 0 | 1.17% | 0 | 0.50% |
| Estonia | EANS | 1 | 1.25% | 4 | 58.67% | 0 | 3.92% | 4 | 62.59% |
| Finland | Finavia | 9 | 5.24% | 7 | 35.34% | 1 | 14.02% | 9 | 49.36% |
| France | DSNA | -346 | -12.31% | 85 | 22.01% | -58 | -29.65% | 27 | -7.65% |
| Germany | DFS | -611 | -34.48% | -139 | -31.94% | -102 | -46.34% | -241 | -78.29% |
| Greece | HCAA | 6 | 1.21% | 38 | 90.14% | 1 | 4.56% | 39 | 94.70% |
| Hungary | Hungaro Control | 12 | 6.80% | 4 | 14.73% | 2 | 15.42% | 6 | 30.15% |
| Ireland | IAA | 10 | 3.88% | 4 | 8.72% | 2 | 8.33% | 5 | 17.05% |
| Italy | ENAV | -175 | -12.32% | 6 | 2.38% | -29 | -24.91% | -24 | -22.53% |
| Latvia | LGS | 4 | 6.25% | 5 | 79.39% | 1 | 22.14% | 6 | 101.54% |
| Lithuania | Oro Navigacija | 6 | 7.49% | 7 | 98.20% | 1 | 29.33% | 8 | 127.54% |
| Maastricht | MUAC | -51 | -19.82% | -42 | -49.37% | -8 | -19.82% | -50 | -69.19% |
| Malta | MATS | 14 | 27.10% | 3 | 44.20% | 2 | 77.17% | 5 | 121.37% |
| Netherlands | LVNL | 16 | 7.78% | 3 | 10.69% | 3 | 17.00% | 6 | 27.69% |
| Norway | Avinor | 23 | 5.43% | -17 | -19.86% | 4 | 8.60% | -13 | -11.25% |
| Poland | PANSA | -146 | -25.50% | 20 | 27.20% | -24 | -64.07% | -4 | -36.87% |
| Portugal Continental | NAV Portugal | 79 | 40.29% | -29 | -46.79% | 13 | 42.34% | -16 | -4.45% |
| Romania | Romatsa | -82 | -17.61% | 19 | 31.40% | -14 | -45.70% | 5 | -14.30% |
| Slovakia | LPS | 7 | 7.00% | -1 | -5.46% | 1 | 13.08% | 0 | 7.61% |
| Slovenia | Slovenia Control | -5 | -6.18% | 3 | 23.98% | -1 | -15.12% | 2 | 8.85% |
| Spain Continental | ENAIRE | -189 | -11.47% | -63 | -18.62% | -32 | -18.43% | -95 | -37.05% |
| Sweden | LFV | 90 | 21.09% | -7 | -9.15% | 15 | 37.84% | 8 | 28.70% |
| Switzerland | Skyguide | -24 | -6.87% | -26 | -30.89% | -4 | -9.38% | -30 | -40.27% |
| United Kingdom | NATS | -124 | -9.99% | -5 | -2.13% | -21 | -19.32% | -25 | -21.45% |
| **TOTAL** | | **-1,494** | | **-134** | | **-250** | | **-383** | |

*Source: Eurocontrol (2021): own elaboration*

It can also be useful to see the current differences of European ATCOs in the total employment costs and hours. Table 2 shows the current hours of duty and employment cost of European ATCOs in OPS. The other three columns in each category show the difference with the current status in total hours and employment costs if the hours worked and salaries become the European average, minimum or maximum in each country. In the hours ∆ average column, the positive red numbers mean that if that country works average hours, the hours on duty will be higher than current ones and the green negative numbers mean they will reduce. The same applies to the employment costs ∆ average column: red positive meaning costs will increase and green negative meaning they will reduce.

As it can be seen in the table, if all countries worked the average hours of the European ATCOs, the hours on duty would increase in more than two million. Germany is the country that would be the most affected if all ATCOs worked average working hours, increasing its working hours by more than 50%. It makes sense that Germany is such a big part of the overall number, since is the country with the fewest working hours p.a. and one of the highest numbers of air traffic controllers. The country that will reduce most its working hours is Greece, even if Cyprus, Malta and Portugal have higher working hours p.a. If all countries had working hours like Germany, the total number of working hours would reduce by more than five million hours. On the other side, if all countries worked as Malta, the total working hours of European ATCOs would increase by more than 10 million hours. That is a huge gap since a Maltese ATCO works more than twice as many hours per year on average as a German ATCO.

In the case of the employment costs, the table 2 shows that if all European countries pay the European average to their air traffic controllers, the total European employment costs will decrease in 185 million €. The country with the biggest savings will be Germany. Germany is not even in the top five countries with highest salaries, but its high volume of workers makes it the biggest saver. Spain will be the second country that will reduce its employment costs most, also because it has many employees, as the salary is similar to that in Germany. France will be the country with the highest employment costs increase. This case is similar to the previous ones in the sense that France is not only of the lowest-wage countries for air traffic controllers, but the large number of workers makes the costs increase a lot. If all countries had salaries for ATCOs like those of Latvia, the total European employment costs would decrease to 1.7 billion euros (70%). Moreover, if they were paid like in Belgium, the total European costs would raise by 1.5 billion euros (61%).

As a conclusion, when talking about defragmentation usually transition costs are not considered and it can be seen in these chapter, they make the whole process unaffordable. Moreover, other barriers like language, different working calendars, national laws, different costs of living and social standards can complicate defragmentation processes even more.

Table 5: Hours on duty and employment costs for European ATCOs in OPS

| Countries / ANSPs | | ATCOs in OPS thousand hours on duty | | | | Employment costs for ATCOs in OPS (million €) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Actual | Δ Average | Δ Minimum | Δ Maximum | Actual | Δ Average | Δ Minimum | Δ Maximum |
| Austria | Austro Control | 402 | 27 | -126 | 186 | 63 | -19 | -49 | 14 |
| Belgium | Belgocontrol | 300 | 27 | -90 | 148 | 47 | -13 | -36 | 12 |
| Bulgaria | Bulatsa | 340 | 44 | -93 | 186 | 26 | 13 | -13 | 43 |
| Croatia | Croatia Control | 325 | 33 | -95 | 165 | 31 | 6 | -19 | 34 |
| Cyprus | DCAC | 194 | -48 | -101 | 5 | 9 | 6 | -5 | 17 |
| Czech Republic | ANS CR | 288 | -11 | -110 | 91 | 29 | 0 | -20 | 21 |
| Denmark | Naviair | 314 | -5 | -116 | 108 | 32 | -1 | -22 | 23 |
| Estonia | EANS | 88 | -5 | -35 | 25 | 5 | 3 | -3 | 10 |
| Finland | Finavia | 269 | -4 | -99 | 93 | 23 | 4 | -14 | 24 |
| France | DSNA | 3,672 | 487 | -1,001 | 2,019 | 371 | 59 | -232 | 379 |
| Germany | DFS | 1,769 | 986 | 0 | 2,001 | 397 | -113 | -305 | 99 |
| Greece | HCAA | 817 | -119 | -369 | 138 | 41 | 31 | -18 | 85 |
| Hungary | Hungaro Control | 266 | -18 | -107 | 74 | 27 | -1 | -18 | 18 |
| Ireland | IAA | 323 | -16 | -126 | 97 | 32 | 0 | -21 | 24 |
| Italy | ENAV | 1,765 | 333 | -418 | 1,106 | 213 | 4 | -142 | 166 |
| Latvia | LGS | 118 | 15 | -32 | 65 | 4 | 9 | 0 | 20 |
| Lithuania | Oro Navigacija | 134 | -14 | -57 | 29 | 6 | 6 | -2 | 15 |
| Malta | MATS | 104 | -28 | -55 | 0 | 4 | 4 | -1 | 10 |
| Netherlands | LVNL | 409 | -95 | -207 | 21 | 57 | -24 | -46 | 0 |
| Norway | Avinor | 634 | -48 | -257 | 168 | 52 | 8 | -33 | 53 |
| Poland | PANSA | 554 | 188 | -78 | 461 | 54 | 23 | -29 | 80 |
| Portugal Continental | NAV Portugal | 401 | -78 | -194 | 41 | 48 | -15 | -37 | 10 |
| Romania | Romatsa | 533 | 108 | -121 | 345 | 53 | 13 | -31 | 63 |
| Slovakia | LPS | 135 | -5 | -51 | 43 | 14 | 0 | -9 | 10 |
| Slovenia | Slovenia Control | 128 | 3 | -44 | 51 | 11 | 2 | -7 | 12 |
| Spain Continental | ENAIRE | 2,115 | 362 | -525 | 1,274 | 344 | -89 | -261 | 102 |
| Sweden | LFV | 780 | -140 | -369 | 96 | 83 | -17 | -61 | 33 |
| Switzerland | Skyguide | 457 | 65 | -122 | 257 | 84 | -30 | -67 | 10 |
| United Kingdom | NATS | 1,734 | 212 | -484 | 929 | 230 | -29 | -165 | 121 |
| Maastricht | MUAC | 309 | 79 | -60 | 222 | 67 | -27 | -54 | 3 |
| **Total** | | **19,673** | **2,336** | **-5,541** | **10,446** | **2,458** | **-185** | **-1,721** | **1,511** |

*Source: own elaboration*

Sources:

- EUROCONTROL: ATM Cost-Effectiveness (ACE) 2019 Benchmarking Report: https://www.eurocontrol.int/archive_download/all/node/13636
- EUROCONTROL: ATM Cost-Effectiveness Dashboard: https://www.eurocontrol.int/ACE/ACE-Framework.html

# 6 TRANSITION COSTS

The Helios report mentions that the transition costs are not included in the study when talking about defragmentation. Nevertheless, they represent a substantial cost, and they should be addressed. There are different types of transition costs for defragmenting ANSPs, such as:

- **New facilities versus old facilities:** unless using the current facilities in a centralised mode (this implies high costs for the ATM standardisation processes) in the case of transitioning to a new bigger centre, obviously a new centre needs to be built and the old ones will not be used anymore. Nevertheless, selling such a specific facility is difficult.
- **Moving costs:** moving all the equipment and staff to a new centre will be a long and costly process.
- **Costs of new ATM System:** A new ATM system may be needed to harmonize the new defragmented centre.
- **Training costs and Time:** workers will need time to learn to operate with a different system.
- **Cost to harmonize working conditions:** Salary and working hours have been already discussed in chapter 5, but other issues like language, different working calendars, national laws, different costs of living and social standards can be problematic in a defragmentation process. Moreover, the chapter 11 mentions that these issues were the reason why the US did not defragment the centres as the FAA wanted.

Eurocontrol has made a great effort to centralise services in the last decades. However, centralized services have failed due to transition costs because requirements are different for each ANSP as it was mentioned in chapter 4. Analysing the cost structure of ANSPs, the only way to safe costs with centralisation is via technology and it is estimated that 15% of tech costs can be reduced. Nevertheless, as it was mentioned in chapter 5, other costs should be considered and, as it will be developed in chapter 13, negative scale effects exist, overcoming the potential savings generated with centralization. The following are some examples of defragmentation attempts and how transition costs have affected them:

**Border triangle case:** The Director Generals of Civil Aviation from France, Germany and Switzerland decided to launch a feasibility study considering a common control centre in the southern part of FABEC at the border triangle between these 3 states. The activity studied the concept of controlling the entire Swiss airspace and part of German and French airspace. However, this was never materialized due to transition costs. The study estimated that even if 9-19% of the current costs could be saved between 2020 and 2040, the costs of implementing this single centre will be some 500 million € between 2010 and 2040.

**NUAC case:** Sweden and Denmark combined their air navigation services through the jointly owned company Nordic Unified Air Traffic Control (NUAC) replacing Naviair (Denmark) and LFV (Sweden) in the Danish/Swedish FAB. The NUAC Programme developed several scenarios for a FAB within Danish and Swedish airspace including merger, NUAC/SKAANE business case, alliance, and operational alliance scenario (feasibility studies).

Even if the merger was the most efficient scenario, the operational alliance was chosen because it delivers the main airspace benefits of the merger, but without creating the same potential difficulties with employees and trade unions that would arise if employees had to be transferred to a new merged organisation. This means that transition costs overcame the benefits of merging the ANSPs.

Figure 6: Financial results of the three analysed scenarios NUAC

| | Net present value | Internal rate of return | Payback time |
|---|---|---|---|
| Merger | 131.7 million € | 47% | 2011 – 4 years |
| NUAC/SKAANE | -18 million € | - | - |
| Alliance | 52.7 million € | 35% | 2011 – 4.5 years |

*Source: NUAC Programme: Definition Phase Final Report Appendix 1 Business Case OCTOBER 2006 Third Draft*

As it was mentioned in the NUAC 2010 press release, annual LFV & Naviair internal cost reductions were calculated at 13M€. Nevertheless, NUAC does not exist anymore since 2019 and Naviair and LFV are split again. Transition costs and the principle of subsidiarity mentioned in topic 4 seem to make this joint project unbeneficial. In topic 13 the issue of which ACC size is the most efficient will be developed.

Thus, the transition costs are not considered in the Helios report but as shown by these examples, they play a significant role to determine whether a project is benficial or not.

Sources:

- RocketReach: NUAC HB Information: https://rocketreach.co/nuac-hb-profile_b5ddd859f42e5589
- NUAC Programme: Definition Phase Final Report: Appendix 1 Business Case: https://www.naviair.dk/media/Appendix_01_Business_Case_ver_01_00_05102006.pdf
- NUAC Programme: Definition Phase Final Report: Appendix 6 Integration Strategy: https://www.naviair.dk/media/3App06-IntegrationStrategy.pdf
- NUAC: Newsletter 01/2010: https://www.naviair.dk/media/NUAC-newsletter-1-2010-JUNE.pdf
- Flieger Law Office: Nordic Unified Air Traffic Control takes over Danish/Swedish airspace: https://www.fliegerlaw.com/en/nordic-unified-air-traffic-control-takes-over-danishswedish-airspace/
- European Commission: Improving the management of Danish and Swedish skies: https://ec.europa.eu/inea/en/ten-t/ten-t-project-implementation-successes/improving-management-danish-and-swedish-skies
- SFSA Holding KB: DK-SE Functional Airspace Block (DK-SE FAB) HLG (High Level Group): https://www.svenskaflygplatser.com/sfsa/sfsaflightsupport/home/atm/fab/index.html
- Skybrary: DK/SE FAB and NUAC HB - Safety Case and Safety Assesment Process: https://skybrary.aero/bookshelf/dkse-fab-and-nuac-hb-safety-case-and-safety-assesment-process
- Eurocontrol Skyway magazine: CENTRALISED SERVICES: A new era of ATM partnerships: https://www.eurocontrol.int/sites/default/files/publication/files/skyway-Winter-2013-web.pdf

# 7 IMPACT OF TECHNOLOGY ON FRAGMENTATION

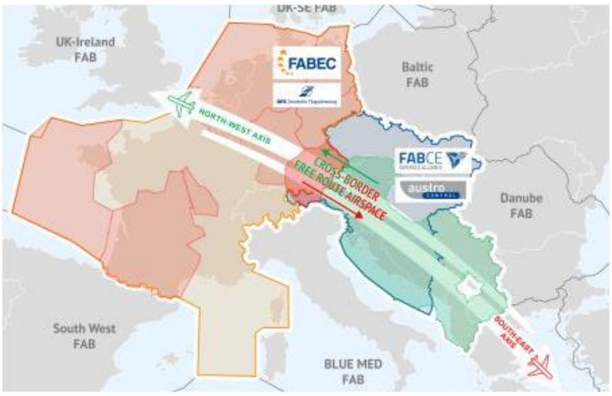
Technology has had a big impact on ATM performance and on fragmentation. Technological advances change the work environment, procedures and the way of working due to new functionalities. In some cases, negative impacts of fragmentation that the Helios report comments have been overtaken by technology. When comparing the situation of 2006 with the situation of nowadays, the technological advances have had an impact on fragmentation. It must be considered that when the 2006 report mentioned the underperformance due to fragmentation, performance took place at sector level but got measured at ANSP level.

The SES-II regulation that was mentioned in the introduction requires all EU members to be part of a FAB by 2012. **Functional Airspace Block (FAB)** means an airspace block based on operational requirements and established regardless of state boundaries, where the provision of air navigation services and related functions are performance-driven and optimized with a view to introducing, in each functional airspace block, enhanced cooperation among air navigation service providers or, where appropriate, an integrated provider. Thus, issues mentioned in the 2006 report like fragmented planning or lack of ATM systems interoperability were overtaken.

Moreover, the **InterFAB** coordination platform was established for a safer and a more efficient sky. It was formally established in 2015 by representatives of the 9 European FABs. It is the first platform that brings together all FABs' stakeholders, an opportunity for extensive control to ensure the implementation of the Single European Sky initiative at European level and to formulate common goals, share experiences and collectively have a strong and cohesive voice in Europe.

In this context, the **Free Route Airspace (FRA)** has been implemented. Free route airspace (FRA) is a specified airspace within which users may freely plan a route between a defined entry point and a defined exit point, without reference to the ATS route network, subject to airspace availability. Within this airspace, flights remain subject to air traffic control. FRA improves the aviation sector's efficiency, capacity and environmental problems and it opens the way for further improvements in airspace design and air traffic management operational concepts.

Figure 7: Cross border free route airspace




*Source: CANSO: FAB CE/FABEC – Expansion of cross-border free route airspace for climate-friendly air traffic*

Related to that concept the two categories of flight should be explained. **VFR** (Visual Flight Route) means that the aircraft is intended to operate in visual meteorological conditions and **IFR** (Instrumental Flight Rute) depends upon flying by reference to instruments in the flight deck, and navigation is accomplished by reference to electronic signals. Operating under VFR means that flying is conditioned by the weather. While IFR provides efficiency, additional safety, and usually consistent contact with air traffic control, it requires that pilots follow an exact pre-determined/pre-planned flight route. IFR flying, however, affords the freedom of flying any route and altitude you choose, barring specific airspace limitations. Thus, the implementation of IFR allows FRA to be implemented.

The Helios report also mentions that the reason of the suboptimal organization is that the air navigation services (ANSs) are organized at state level and in smaller than optimal operation units in national ANSPs. The reports says that “these units may have become sub-optimal, for example, as changes in the technology of service provision have raised the optimum size of a centre upwards”. This may have been the case because operations and technology had to be close together in the same centres. This is no longer the case with the entry of **virtualisation** into air traffic control, both for ACC and Tower. The virtualization allows the operational and technological part of a centre or Tower to be separated, making it possible for the technological part to be outside. It also helps reduce costs and be more efficient in two ways: On the one hand, technological equipment can be installed in cheaper locations. On the other hand, several digital and virtual control towers can be grouped together in the same space thus resulting in fewer and more efficient staff to control the airports (Remote Tower Control).

Moreover, the virtual centre concept is one of the pillars of the European ATM Master Plan. The virtualization of ATMs is made possible primarily through the dissociation of the controller work position (CWP) as a client through the remote provision of ATM data and technical services, such as the distribution and management of flight data, as well as surveillance data. The virtualization of European ATM also solves one of the most important problems in the sector, namely the fragmentation of systems and processes between European countries. Virtual centres provide greater flexibility in organising air traffic control operations within and between air traffic services units (ATSUs) and allow several ATSUs to provide seamless services from the airspace user's perspective.

In addition, virtualization may increase efficiency. The Skyguide Case study ilustrates that. Skyguide adopted a Virtual Centre model consisting of a One Sky by One System approach. Switzerland nowadays has two ACCs with local data centres and different operational procedures. In the future there will be only one Data Centre that will serve both ACCs. The location transparency between geographical operations and ATM systems will improve the service provision and make optimized use of operational ATCO availability (irrespective of the geographical location). It also allows the rationalization of IT means.  A paradox could be conceived to deal with fragmentation with splitting of OPS and TECH systems, which have a significant investment cost. However, positive added value was proven in the specific configuration of Swiss airspace, through an improved and seamless operational service linked to the scale effects of rationalised IT means, via a centralized system. Thus, the principle of Centralization was applied in Technology whilst keeping the principle of Subsidiarity in Operations. Nevertheless, the univocity of only one big data centre poses some (cyber)security problems that need to be coped with, along with redudancy of data and back up facilities. As a conclusion, technological advances play a huge role in the evolution of air traffic control and in recent decades has served to counteract the negative effects of ATM/CNS fragmentation that the Helios report mentioned.

Sources:


- Sky Library: Functional Airspace Block (FAB): https://skybrary.aero/articles/functional-airspace-block-fab
- Sky Library: Single European Sky (SES) II: https://skybrary.aero/articles/single-european-sky-ses-ii
- Eurocontrol: Free route airspace: https://www.eurocontrol.int/concept/free-route-airspace
- Interfab: Cooperation for Single European Sky: https://www.inter-fab.eu/
- SESAR: Towards virtualization in ATM: https://www.sesarju.eu/news/towards%20virtualisation%20in%20ATM
- CANSO: Virtualisation: A reality making its way to ATM in one form or another https://canso.org/virtualisation-a-reality-making-its-way-to-atm-in-one-form-or-another/
- INDRA: Indra wins 173 million euros framework contract to digitalize the management of the european air navigation network: https://www.indracompany.com/en/noticia/indra-wins-173-million-euros-framework-contract-digitalize-management-european-air
- Florence School of Regulation: Special Issue on Defragmentation of the Skies: https://fsr.eui.eu/special-issue-on-defragmentation-of-the-skies/
- FABEC: Initial Information for EU, other Member States and other interested Parties on the Establishment of FABEC: https://www.fabec.eu/images/user-pics/pdf-downloads/ssc36_fabec_information_paper_v2_0.pdf
- FABEC and Eurocontrol: NTM / DIK – SWAP Validation report https://www.eurocontrol.int/sites/default/files/library/011_FABEC_SWAP_validation.pdf
- Skyguide: The Virtual Centre Model: https://silo.tips/download/the-virtual-centre-model
- Eurocontrol: Evaluation of Functional Airspace Block (FAB) Initiatives and their contribution to Performance Improvement https://transport.ec.europa.eu/system/files/2016-09/evaluation_of_fabs_final_report.pdf

# 8 CNS/ATM PHYSICAL INFRASTRUCTURE EVOLUTION

In this chapter, a comparison between the physical infrastructure of 2003 and 2020 is made. The technological advances have created a big restructuring of communications, navigations, and surveillance infrastructure. The Table 6 shows the European ATM/CNS infrastructure in 2003 included in the Helios report.

Table 6: Key European ATM/CNS physical infrastructure (2003 data)

| | | Number |
|---|---|---|
| COM | VHF ground stations | 1123 |
| | Ground-ground voice links | 2246 |
| | ACC links (inter-State) | 160 |
| | ACC links (Intra-State) | 386 |
| NAV | DME | 601 |
| | NDB | 349 |
| | VOR | 617 |
| SUR | En-route primary plus Mode S | 63 |
| | En-route primary plus MSSR | 5 |
| | Approach primary plus MSSR | 92 |
| | Approach primary only | 43 |
| | MSSR only | 140 |
| ATM | ACCs | 69 |
| | Sectors | 792 |

*Source: The impact of fragmentation in European ATM/CNS: Prepared by Helios Economics and Policy Services*

One problem is that there are not many sources for up-to-date data. The report called CNS infrastructure evolution opportunities by EUROCONTROL includes information about the CNS physical infrastructure in 2020. However, they are not comparable because neither of them explains how the counting was made.

In the case of communications infrastructure, in recent decades there have been many changes in the sector which have led to a major restructuring. The 2003 data counts complete systems and that of 2020 counts networks (available in Table 7). Thus, data is not comparable as ground stations do not really matter as e.g., one station can have more than one antenna.

Continuing with the navigation physical infrastructure, the data of 2020 is included in Table 8. These data should be comparable, but according to this data the NDB have increased ∆220% when it is a declining technology, so it is totally counterintuitive. This makes the rest of the data unreliable. Moreover, the 2003 data does not include ILS technology nor corresponding military infrastructure.

Finally, the physical infrastructure of surveillance in 2020 is shown in

Table 9. On the one hand, the data of 2003 is divided into en-route and approach and counts secondary radars separately. On the other hand, the data of 2020 does not make the

differentiation and includes WAM/ADS-B and ADS-B - ADS-B was not used in 2003, so it is not comparable. It needs to be considered that it is currently a time of technological transition where there is an overlap of technology and thus more infrastructure is being utilized.

Table 7: COM infraestructure in 2020

| Domain | Use | Type | ECAC |
|---|---|---|---|
| FMTP | National | X25 | 6 |
| | | National Network | 18 |
| | International | X25 | 41 |
| | | Regional Networks | 72 |
| | | NewPENS | 51 |
| | | Others (leased lines) | 21 |
| | **FMTP Total** | **FMTP Total** | **209** |
| Voice | National | National Networks | 10 |
| | | Leased lines (Analog) | 42 |
| | International | Analog lines | 0 |
| | | Regional Networks | 5 |
| | | Leased lines (Analog) | 40 |
| | **Voice Total** | **Voice Total** | **682** |

*Source: EUROCOTROL: CNS infrastructure evolution opportunities*

Table 8: NAV infraestructure in 2020

| | Area | ECAC |
|---|---|---|
| | **ILS** | **813** |
| | ILS Cat I | 550 |
| | ILS CAT II/III | 263 |
| | DME (ILS) | 807 |
| | GLS | 23 |
| | DME standalone | 189 |
| | TACAN standalone | 102 |
| | VOR standalone | 46 |
| | VOR/DME | 675 |
| | VORTAC | 27 |
| | NDB | 1117 |
| VOR – VOR standalone + VOR/DME + VORTAC | **VOR** | **748** |
| DME – DME standalone + VOR/DME | **DME** | **864** |
| TACAN – TACAN standalone + VORTAC | **TACAN** | **129** |

*Source: EUROCOTROL: CNS infrastructure evolution opportunities*

Table 9: SUR infrastructure in 2020

| | ECAC | | |
|---|---|---|---|
| Type | CIV | MIL | TOTAL |
| PSR | >145 | >120 | >265 |
| Mode AC | 120 | >80 | >200 |
| Mode S | 325 | 210 | 535 |
| WAM/ADS-B | 926 | - | - |
| ADS-B | 133 | - | - |

*Source: EUROCOTROL: CNS infrastructure evolution opportunities*

Comparing the ATM structure, the Helios report mentions that there were 69 ACCs and 792 sectors in the ECAC area in 2003. According to Eurocontrol, there were 70 ACCs in 2020, so the number of ACCs has kept almost the same. Nevertheless, the number of sectors in 2020 is 2245, regarding the maximum number of sectors excluding MIL areas, FRA areas and areas of special interest. Some airspaces may have been created for combined use and may be used in real life as a single sector managed by 2 ATCOs (or two sectors with one executive each who share the same planner ATCO), the two studies measure the sectors in different ways. Thus, the data is not comparable.

As a conclusion, to make a comparison a consistency of data is needed, and it does not exist nowadays. In practical terms, this comparison of 2003 and 2020 data does not give a realistic idea of the evolution of the CNS/ATM physical infrastructure. What can be taken from this comparison is that there is new technology in use today that did not exist in 2003 and that there is a phase of transition with an overlap of different technologies for the same purpose.

Sources:

- EUROCONTROL: Greening European ATM's ground infrastructure: What could ANSPs achieve over the next decade?: https://www.eurocontrol.int/sites/default/files/2021-10/eurocontrol-think-paper-13-green-european-atm.pdf
- EUROCOTROL: CNS infrastructure evolution opportunities: https://www.eurocontrol.int/sites/default/files/2021-06/eurocontrol-cns-infra-evolution-opportunities.pdf

# 9 EVOLUTION OF COSTS IN EUROPEAN ATM/CNS

Another important issue in judging the development of European ATM is the costs, as the 2006 report mentions that costs are higher than they should be due to fragmentation. Thus, the Helios report includes the 2003 en-route ATM/CNS costs table. To be able to compare it with more recent data, inflation until 2019 was applied to this data (as data of 2020 and 2021 may be biased due to the COVID pandemic) and is shown in Table 11.

Table 10: Cost of European en-route ATM/CNS (2003 data)

| | Capital replacement costs (M€) | Annual operating costs (M€) | Total annual costs (M€) |
|---|---|---|---|
| COM | 560 | 60 | 110 |
| NAV | 230 | 10 | 30 |
| SUR | 3,000 | 210 | 500 |
| ACCs & ATM systems | 4,900 | 2,100 | 2,500 |
| Associated support | 1,000 | 1,100 | 1,200 |
| **Total** | **9,690** | **3,480** | **4,340** |

*Source: The impact of fragmentation in European ATM/CNS: Prepared by Helios Economics and Policy Services*

Table 11: Cost for European en-route ATM/CNS (2003 data, inflation to 2019)

| | Capital replacement costs (M€) | Annual operating costs (M€) | Total annual costs (M€) |
|---|---|---|---|
| COM | 727 | 78 | 143 |
| NAV | 299 | 13 | 39 |
| SUR | 3,894 | 273 | 649 |
| ACCs & ATM systems | 6,361 | 2,726 | 3,245 |
| Associated support | 1,298 | 1,428 | 1,558 |
| **Total** | **12,579** | **4,517** | **5,634** |

*Source: Own elaboration*

The Eurocontrol ACE Report of 2019 includes the en-route ATM/CNS costs for 2019. As it can be seen in the table 8, the ATM/CNS costs for 2019 amounts to 4,015 million €. It needs to be considered that in real terms the costs are even lower but is the best estimation with the available data. This means that expenditure is 29% lower compared to 2003 data with inflation up to 2019.

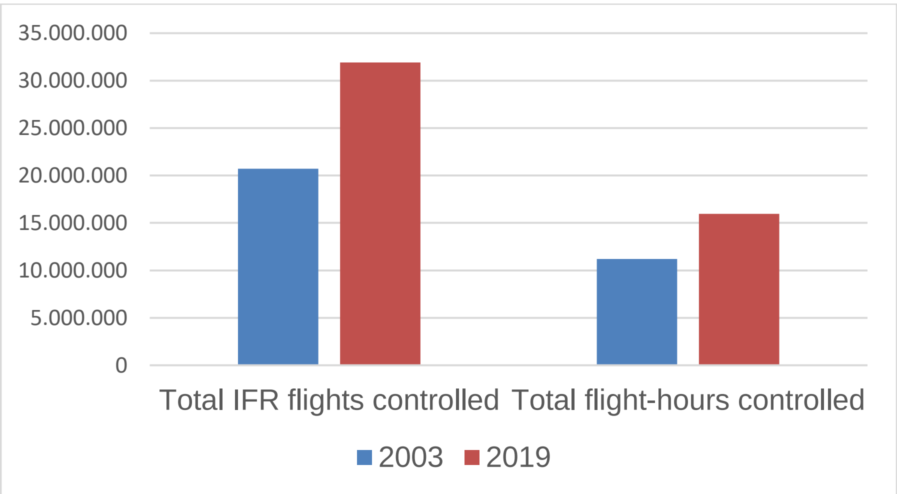
Moreover, the number of total IFR flights and flight hours controlled in Europe have increased 54% and 42% respectively in those years (as can be seen in figure 8). Thus, the en-route ATM/CNS unit cost per IFR flights controlled has decreased 54%, and 50% in the case of the en-route ATM/CNS unit cost per IFR flight-hours controlled.

Table 12: En-route ATM/CNS costs (million €) 2019

| En-route ATM/CNS costs (million €) 2019 | |
|---|---|
| Staff costs (no ATCO in OPS) | 1,650 |
| Non-staff operating costs | 1,089 |
| Depreciation costs | 789 |
| Cost of capital | 395 |
| Exceptional costs | 92 |
| **TOTAL** | **4,015** |

*Source: Eurocontrol ACE Report 2019*

Figure 8: Evolution of flights and flight-hours controlled between 2003-2019




*Source: Own elaboration*

Thus, technological and legislation advances that have been discussed in other chapters like virtualization, FABs, SES or SESAR have led to efficiency gains reducing unit costs as well as total costs even with the high increase of traffic.

Sources:

- Eurocontrol ACE Report 2019: https://www.eurocontrol.int/sites/default/files/2021-06/eurocontrol-ace-2019-benchmarking-report.pdf

# 10 NEGATIVE IMPACTS OF FRAGMENTATION

The Helios report includes a summary of areas where fragmentation was expected to have an adverse impact. In this chapter, it will be reviewed whether these areas remain causes of inefficiency in European ATM/CNS or not. In this way, it will be possible to analyse whether fragmentation, or the different consequences of fragmentation, is still a reason for inefficiency in the European ATM. Table 13 describes the causes of fragmentation included in the Helios report that will be reviewed with today's perspective

Table 13: Causes of fragmentation

| | Cause of fragmentation |
|---|---|
| Common issues | Piecemeal procurement (mainly ATM systems) |
| | Sub-optimal scale in maintenance and in-service development (mainly CNS) |
| | Fragmented planning |
| ACCs | Economies of scale in ACCs (operating costs) |
| | Economies of scale in ACCs (capital cost) |
| | Constrained sector design (flight efficiency benefits) |
| ATM systems | Lack of common systems (operating costs) |
| | Lack of common systems (capital costs) |
| | Increased coordination at interfaces |
| CNS infrastructure | Optimum location of en-route navaids |
| | Overprovision of secondary radar |
| Associated support | Economies of scale in training, administrative costs and R&D |

*Source: The impact of fragmentation in European ATM/CNS: Prepared by Helios Economics and Policy Services*

Starting with the common issues, they have been addressed with the creation of the FABs, since, as seen in chapter 7, they are based on operational needs irrespective of national borders. The FABs have optimized the provision of air navigation services through the cooperation of the ANSPs with a performance-oriented approach and, where appropriate, an integrated provider. Moreover, other more local cases have been solved with agreements, like the ones seen in chapter 4 of DNSA and Skyguide.

Continuing with the ACCs, the report mentions that with larger ACCs there would be economies of scale in operating and capital costs. Thus, having these fragmented structure causes inefficiencies. However, the studies made about economies of scale in the European ATM, that will be discussed in chapter 13, show no evidence of that economies of scale, but that negative economies of scale exist. In addition, the Free Route Airspace as explained in chapter 7 can fix the constrained sector design that is mentioned in the Helios report.

Moreover, the size of ACCs does not matter that much anymore as the concept of virtualization has overcome this (explained also in topic 7).

Regarding the ATM systems, the Helios report says that the lack of common systems generates inefficiencies in operating and capital costs and that increased coordination is need at interfaces because of the fragmented ATM systems. As will be explained in topic 12, the SESAR (Single European Sky ATM Research) program is a project of the European air transport community that is responsible for the development and implementation of the future common ATM system. Thus, nowadays the different ATM systems allow information to be shared between them and there are no interoperability problems between them. In addition, system families like COOPANS and INDRA Itec provide services to different countries, as they have similar requirements. COOPANS is an international partnership between the air navigation service providers of Austria, Croatia, Denmark, Ireland, Portugal, and Sweden. INDRA Itec includes Germany, Spain, UK, Netherlands, Norway, Lithuania, and Poland. Moreover, having different providers is positive for competence and innovation reasons. In addition, as seen in chapter 4, European ATM systems need very different solutions, so is positive to have a variety of providers.

In the case of CNS infrastructure, the causes of inefficiency mentioned in the report are the non-optimum location of en-route navaids and overprovision of secondary radars. FABs have already make some progress in this regard, as data is shared between countries and ANSPs by using jointly the same infrastructure. It needs to be considered that there is a transition from ground stations to space stations and that in this transition period different technologies exist for the same purpose. The overprovision of infrastructure is also needed for contingency in case of failure or maintenance of the equipment.

Finally, the report mentions that there are inefficiencies in associated support as economies of scale in training, administrative costs and R&D exist and are not being exploited. The creation of FABs also address these issues, as in the creation of FABs, the cooperation in training was identified as a measure adding sustainable economic value, becoming effective gradually on a short-term basis. Some FABs have already developed a standard for a basic OPS training course, although total defragmentation is not possible because of language and location barriers, among other issues described in chapter 6. For example, Entry Point North provides a full range of ATS training and services for Sweden, Ireland, Hungary, Denmark, Spain, and Belgium. Administrative costs have also been addressed by common procurement, which is organised with a FAB Common Budget (with costs that are shared according to the corresponding FAB mechanism which may vary from FAB to FAB). The common systems explained in the ATM systems also address R&D fragmentation.

Thus, the reasons mentioned in the report as causes of inefficiency of a fragmented ATM system have been addressed in these decades. As seen in this chapter, different European legislations like the creation of FABs and SESAR have helped addressing this issue. In addition, studies on fragmentation in recent decades dismantle the narrative of economies of scale in the European ATM and therefore the loss of efficiency related to fragmentation.


Sources:

- Eurocontrol "CNS infrastructure evolution opportunities" & "European Navaid Infrastructure Planning Handbook including Minimum Operational Network (MON)": https://www.eurocontrol.int/publication/european-navaid-infrastructure-planning-handbook-including-minimum-operational-network
- FABEC: "Creating the FAB Europe Central": https://www.fabec.eu/images/user-pics/pdf-downloads/final_summary_uk.pdf
- InterFAB: "The added value of FABs: A generic Cost-Benefit Analysis": https://www.inter-fab.eu/images/user-pics/pdf-downloads/20190228_AddedValueofFABs_v1.pdf

# 11 COMPARISON EU-US

The Helios report makes a reference to the comparison between EU and US. It is mentioned that the US performs in a more efficient way, and it is suggested that the fragmentation is an important contributing factor to the performance gap between Europe and the US. The general argument is that the Federal Aviation Administration (FAA) can control more flights in a similar airspace at half the cost compared to Europe.

Stepping out of that thesis, FABEC published a study called “ATM in Europe - It’s all about performance” in 2013 that questioned the underperformance of European ATM. The objective of that research was to expand the fundamental data and facts which the statements on the European ATM were based and to determine if the underperformance existed or not. The study says that FAA controls 67% more flights at similar costs and that the controlled flight in the USA on average is 38% less expensive as in Europe. However, this point of view overlooks many influential factors which could change the assertion:

- **Exchange rate variability:** the total costs of ATM in the USA vary depending on the fluctuating exchange rate. Using the exchange rate from June 2008 ($1.58/EUR 1), the cost of a controlled flight in the USA was even 50% cheaper than in Europe. Nevertheless, a comparison of costs in the USA and Europe attempted to take the fluctuation into account by introducing the value "ATM/CNS Cost in MPPS 2011" to compare the costs of infrastructure. Using that comparison, the controlled flight in USA is only 20% cheaper than in Europe and not 50%.
- **Infrastructure costs:** There is a common believe that the infrastructure costs are more expensive in Europe that in US. This is because the infrastructure costs have been divided equally between those using the services and since the hardware for ATM in the USA is used more frequently by aircraft the costs seem cheaper for everyone. It needs to be considered that the depreciation and maintenance of a radar station does not become less expensive when there is less traffic. Thus, the direct comparison of infrastructure costs (ANSP expenditures for ATM) shows that the costs in the USA are higher than in Europe (Source: FABEC: Benchmarking EU/US – Operational Heterogeneities).
- **Traffic structure:** The major difference between the air transport system in the USA and Europe is the level of traffic numbers of the various of types of traffic. While, in Europe, significantly more than 90% of controlled air traffic consists of IFR commercial traffic, in the US, this amounts to only about 70%. The rest of flights are complimentary and have no significant impact on the workload of a FAA ATCO. Many of these flights operate from aerodromes and in airspace not used to the same extent by commercial aviation. This means that these two types of traffic use separate spatial capacity resources which reduces the load on the airspace and thus the FAA. If one compares flown passenger miles between the two systems, the European value is about 11.7% higher than the American one. This is because, on average, IFR general aviation flights are expected to transport very few passengers: Commercial aviation flights transport about 78 passengers per flight in the USA and about 91 passengers per flight in Europe. If the costs for ATM (PPP) are divided by the passenger kilometre performance parameter, the conclusion can be drawn that the controlled passenger kilometre in Europe is currently about 16% less expensive than in the USA.
- **Working conditions:** The higher level of staff efficiency in the USA (more flights controlled with lower number of controllers) is directly related with the fact that the American ATCOs work about 30% more hours per year on average than the Europeans.
- **Working methods:** While many European ANSPs use the principle of single staffing at times of the day with low traffic density and at night, in the USA it is also quite normal to have a single radar controller control a high level of traffic. In the USA, the coordinator position is frequently not filled. FAA tower locations can decide on their own if they continue to staff a tower when there are fewer than 4 flights per hour. This is not possible in Europe.

- **Charging regime:** In Europe, the costs for ATM are based on flight-related criteria and covered by charges related to the weight of the aircraft. In the USA the system is financed mostly by passenger taxes that every passenger must pay. In addition to that, FAA funding receives financial help from the US treasury – thus leading to the statement, that the FAA does only reimburse parts of its costs by user taxes. If the charging regime applied in US was applied in Germany, the budget of DFS will be 32% higher than in the current situation. Thus, the argument that the public, airlines, and passengers in Europe necessarily must pay more for ATM than in the USA is not true, as the FAA is partly funded by general tax money.

Moreover, a working paper called "Benchmarking EU / US – Operational Heterogeneities" and its update made in 2019, came up with the same ideas regarding the performance gap between ATM in US and Europe. Using data for different years, they confirm that the difference in performance come mainly due to the differences in structure and working conditions. In fact, after homogenization, the costs per flight hour and per pax mile is higher in the US.

Another comment that was made in the 2006 report is that the typical size of European ACC is much smaller than those in the US. It is commented that "FAA is currently examining the possibility of consolidation among its existing 21 centres". Nevertheless, nowadays there are 22 centres according to the Federal Aviation Administration. In any case, the ACC number is not comparable with the one in Europe because the US has also Terminal Radar Approach Control Facilities (TRACON) and Combined Control Facilities (CCF) that would also be ACCs in the European standards.

Table 14: Comparison of ACCs in Europe and US (2019)

| **Europe** | | **USA** | |
|---|---|---|---|
| **ACCs** | 63 | **TRACONs** | 147 |
| | | Stand-Alone | 25 |
| | | Combined ATC Towers | 122 |
| | | **En Route Centres & CCFs** | 25 |
| | | ARTCC | 21 |
| | | CCF | 4 |

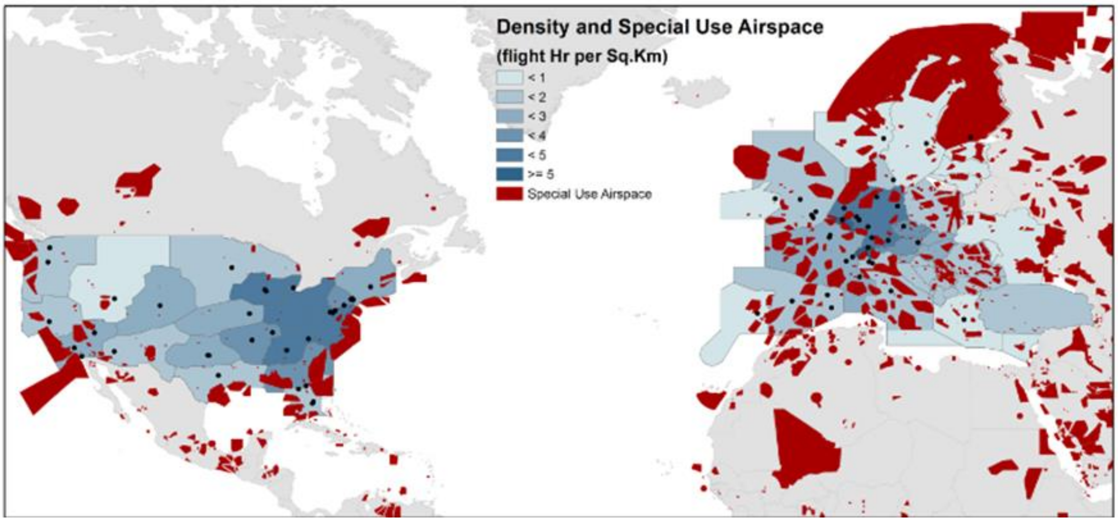
*Source: Eurocontrol ACE 2019 & FAA: Air Traffic by the numbers*

The reports of the U.S. Department of Transportation and Federal Aviation Administration about that topic mention that consolidating the existing centres may be more efficient cost wise. Nevertheless, it has not been done for several reasons. Among the reasons mentioned are the facility's airspace boundaries and total operating positions, the size of the building, the total number of controllers, technicians, and other employees working at the facility, the automation and other equipment to be installed, the transition schedules for existing facilities to move to the new building and workforce-related issues. The addendum of the Federal Aviation Administration includes the federal register comments of different professionals of the aviation sector, such as, ATCOs or pilots. They all agree that there are further disadvantages in the process of consolidation and that they will overcome the advantages. Moreover, the difference in living costs (therefore the wage bonuses) of the different region where mainly the reason why FAA wanted to consolidate in the cheapest states. This was not made because workers rejected it. In the European case it would be even more difficult with big salary differences (as seen in topic 5) and different languages.

Other comments that appear in the study regarding the US/Europe comparison are that with bigger centres economies of scale appear and that Europe should try to do consolidation exercises. Both these topics have been already discussed at chapter 3 and will be more detailed in chapter 13.

Regarding the civil-military fragmentation, the Eurocontrol report called “Comparison of air traffic management-related operational performance: US/Europe” from 2017 mentions the challenge of the integration of military objectives and requirements which need to be fully coordinated within the respective ATM system and compares the situation in Europe and the USA. To meet their national security and training requirements while ensuring the safety of other airspace users, it is occasionally necessary to restrict or segregate airspace for exclusive use which may conflict with civilian objectives to improve flight efficiency as flights must then detour around these areas. To accommodate the increasing needs of both sets of stakeholders, in terms of volume and time, close civil/military cooperation and coordination across all ATM-related activities is a key requirement. Here is a comparative map of Europe and the USA.

Figure 9: Comparison of Special Use Airspaces (SUA) in Europe




*Source: Comparison of air traffic management-related operational performance: US/Europe (2017)*

Looking at the map, the distribution of Special Use Airspaces between Europe and US has a lot of differences, even though in terms of organization of the civil/military cooperation the US and Europe both apply a similar model. In the US, the Department of Defence Policy Board on Federal Aviation is responsible for communicating the Department of Defence position on airspace policy and air traffic management. In Europe the national Ministries of Defence are responsible and albeit there is coordination at European level the Military is out of scope of SES. In the USA, at the operational level, the Federal Aviation Administration headquarter is the final approval authority for all permanent and temporary Special Use Airspace (SUA), and operations are organized according to a common set of rules. In Europe the Single European Sky includes the implementation of the Flexible Use of Airspace (FUA) concept and at the operational level the Network Manager is the coordinator of civil and military requirements and publishes the daily European Airspace Use Plan (AUP) and Updated Airspace Use Plans (UUP) on the day of operations. The FUA concept is further enhanced to A-FUA which is enabled by the use of Local And sub-Regional Airspace management support system (LARA) through the collaborative decision-making between civil and military partners based on the provision of live situational awareness.

Even if the model seems to be similar at a first glance, Europe shows a more fragmented distribution of SUA than the USA thus making long-range direct routes quite hard to be flown. It must be considered that the airspace volumes represented in the maps are not all active at the same time, because they are managed flexibly. Moreover, many SUA are located in the core of Europe potentially affecting the civil air traffic flow, whereas in the US SUA tends to be located along the coastlines allowing for less constrained transcontinental connections. The reason of that is that each state in Europe has its air force and they have separate training areas.

As a conclusion, the main differences of ATM infrastructure costs come from different working conditions and working methods that result in higher number of flights controlled per ATCO, but if this is calculated per pax mile, ATM costs are higher in the US than in Europe. The direct comparison is not viable due to the impact of exchange rate and other major differences. In addition, this comparison is not very helpful to improve European ATM efficiency, since traffic volume and working conditions cannot be matched with the ones in the USA. Also, the SUA differences exist mainly due to legal and geographical differences and are out of scope for SES.

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# 12 IMPORTANCE OF SESAR AND ATM MASTER PLAN

When the Helios report was written, the European air traffic control structure was totally different. This topic mentions the most important legislative changes and how they have affected defragmentation.

Within the framework of SES (that was explained in the introduction), The **European Air Traffic Management (ATM) Master Plan** is the main planning tool for ATM modernisation across Europe. It defines the development and deployment priorities needed to deliver the **Single European Sky ATM Research (SESAR)** vision defined in the Essential Operational Changes. Each Essential Operational Change has an associated set of Deployment Scenarios required to achieve the Change. These Deployment Scenarios create individual Stakeholder Roadmaps that are supported by CNS roadmaps and by Standardisation and Regulatory Needs view.

The SESAR (Single European Sky ATM Research) program is a project of the European air transport community that is responsible for the development and implementation of the future common air traffic management system. Its objective is the implementation of a high-performance European ATM network, born from the need to create an integrated vision of the evolution of the European traffic management system.

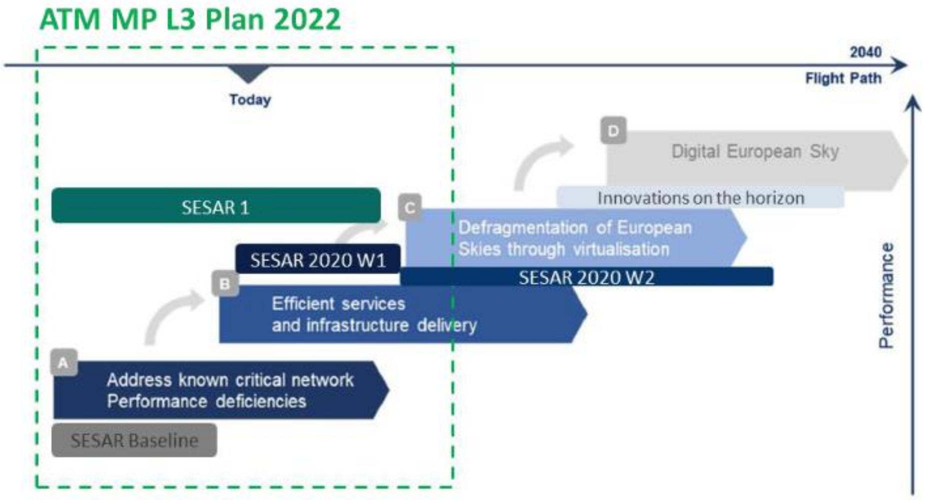
The first SESAR JU programme, known as SESAR 1, ran from 2008 to 2016. In that time, SESAR members ran over 400 projects, conducted some 350 validations, 30,000 flight trials and invested 20 million hours to deliver results that would meet the operational needs of those who must implement them afterwards. Thanks to this intensive work, the SESAR JU partnership delivered more than 90 industrial prototypes as well as over 60 new or improved operational or technical solutions.

SESAR 2020 is a programme for researching the future of air traffic management in Europe. It builds on its predecessor, SESAR 1, to deliver high-performing operational and technological solutions for uptake by the aviation industry. With a budget of 1.6 billion between now and 2024, SESAR 2020 will support projects to deliver solutions in four key areas, namely:

- Airport operations
- Network operations
- Air traffic services
- Technology enablers

However, in 2021 the SESAR program was reorganized in SESAR 3 Joint Undertaking. In 2022, the (ATM) Master Plan has 11 implementation objectives. These objectives serve as a common investment guideline for stakeholders. Thus, these obligations serve to defragment the European ATM, as they all invest with the same objectives and along the same lines which will foster harmonization of ATM/CNS in Europe.

Figure 10: ATM MP L3 Plan 2022




*Source: EUROCONTROL: European ATM Master Plan - implementation plan - level 3*

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# 13 COMPARISON OF ACCS

There is a common belief, especially when comparing European and American ATM (as it was discussed in topic 11), that big ANSPs and ACCs are more efficient. The Helios report elaborates on this idea throughout the report. Nevertheless, some research studies are included that disprove this belief and provide quantitative facts. Thus, data from European ANSPs is taken to measure the correlation between size and productivity.

To see whether size is relevant in performance, the correlation between size and different performance indicators is calculated (data of 2019). Size is measured as total flight hours controlled. The data shows that there is not strong correlation between the performance indicators and ANSP size. The two indicators that are most influenced by size are ATCO hour productivity and ATCO employment costs per ATCO-hour and are both positive, meaning that bigger ANSPs are more productive but also have higher employment costs per hour on average. The negative correlation with the support costs means that bigger ANSPs have lower support costs per composite flight-hour on average.

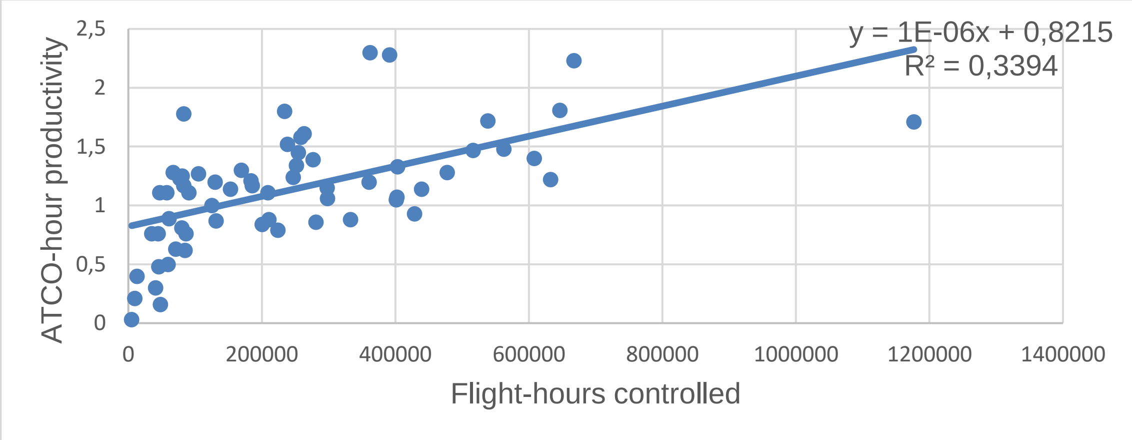
Table 15: Performance indicators at ANSP level (2019)

| Performance indicators | Correlation with size |
|---|---:|
| ATM/CNS provision costs per composite flight-hour | -3.21% |
| ATCO hour productivity | 19.10% |
| ATCO employment costs per ATCO-hour | 17.39% |
| Support costs per composite flight-hour | -13.21% |

*Source: own elaboration*

Then linear regressions of these indicators at ANSP level are calculated. These linear regressions demonstrate weak links between performance indicators and size (all of them have a correlation with size of less than 30%). However, the ACE report provides ATCO hour-productivity data at ACC level. Using these data, the correlation with size increases to 58%. This means that the size of the ACC is more relevant to ATCO hour-productivity than the size of the ANSP on average. The ACC with the most flight hours controlled (1.2 million hours) is Ankara (DHMI) and the ACC with least flight hours controlled (5,058 hours) is Dnipro (UkSATSE). The ACC with the highest ATCO-hour productivity (2.3) is Lisboa (NAV Portugal) and the ACC with the lowest ATCO-hour productivity is Dnipro (UkSATSE).

Figure 11: ACC size and productivity linear regression




*Source: own elaboration*

The linear regression of this ACC size and productivity shows a positive impact of size in productivity, that means that on average the more flight hours controlled the bigger the ATCO-hour productivity is. If the flight hours-controlled increase by 100,000, the productivity will increase by 0.1 on average. Nevertheless, the $R^2$ is 0.3394, meaning that the flight hours-controlled explain only the 33.94% of the increase of productivity. If we consider the flight hours controlled as the best indicator to measure the size of an ACC, that means that the size itself only explains one third of the performance gap between small and big ACCs approximately and that there are other reasons that explain this difference. It must also be considered that there are some small ACCs like the four from Ukraine and the ones from Moldova and Armenia that have extremely low productivity due to the low density of air traffic that distorts the data. Thus, there are other small ACCs like the ones in Croatia, Hungary, or Stavanger (Norway) that are in the top 10 of ATCO-hour productivity. It must be considered that there is one outlier in total flight-hours controlled (Ankara with 1.2 million and the second being less than 0.7 million) and does not reveal a higher productivity than the rest. Moreover, there are ACCs with similar flight-hours controlled with a 3 times difference in efficiency, or with a similar efficiency and 5 times difference in flight-hours controlled.

Thus, the size itself seems not to be a determinant factor of efficiency. The low correlation suggests that there are other factors that have an impact. Therefore, DEA or SFA are more appropriate.

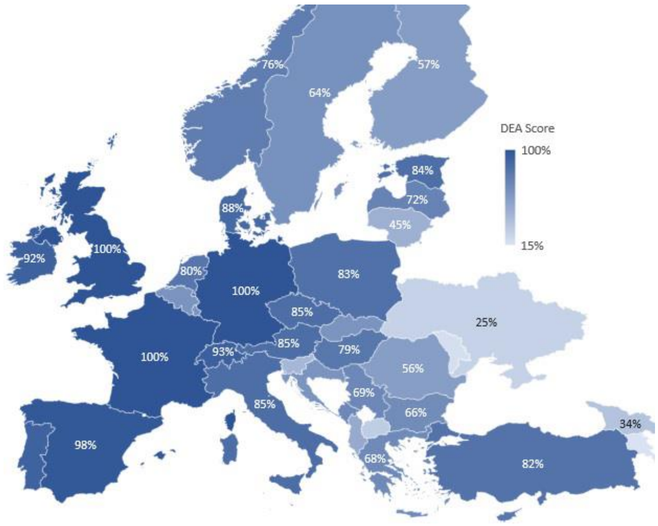
The research called **"Efficiency losses through fragmentation? Scale effects in European ANS provision"** by Standfuss et al. (2019) use the data envelopment analysis (DEA) to measure the economies of scale in European ANS provision and the efficiency in the admittedly complex and highly dynamic environment of European ATM.  The DEA allows the use of multiple inputs/outputs without imposing any functional form on data or making assumptions of inefficiency. Airport movements and total controlled flight hours are used as the two outputs and ATCO hours and operating costs except ATCO costs are used as inputs. Then the comparison of European ANSPs is made. The results demonstrate that reducing the fragmentation could improve efficiency for some ANSPs. However, the study suggests a turning point where decreasing returns to scale appear.  Thus, defragmentation is not always the most efficient way to go, as the optimal level of ATM fragmentation will vary on time depending on the technology and sector´s needs.

A study called **"Cost-efficiency benchmarking of European air navigation service providers"** also uses DEA to assess efficiency of European air navigation service providers between 2002 and 2011.  It is mentioned that "The exploitation of the scale efficiency (due to increasing economies of scale) varies across ANSPs. In the years 2002–2004 the majority of ANSPs were operating under the economies of scale. For the remaining years of the number of providers operating under the economies of scale has been declining."

Another study called **“Measuring the efficiency of air navigation services system by using DEA method”** calculates the efficiency of the European ANSPs in the years 2009, 2010 and 2011 and it ranks the ANSPs. The ranking shows no significant difference between ANSPs by size. It concludes that the efficiency of all ANSPs is improving over the years and that this is due to technological advances and not due to economies of scale. Thus, these studies show that the efficiency of ANSPs has improved due to technical changes (as shown in the topic 6) and not due to defragmentation.

More recent research called **“How to Benchmark Air Navigation Service Providers?”** study some issues that must be solved to define an air traffic control benchmarking system, as the appropriate decision units are examined. It is argued that Air Navigation Service Providers would be a good choice of decision units within the European context.  Thus, candidates for inputs and outputs in a DEA efficiency analysis are discussed and it is emphasized that monetary values should be excluded. When different DEA analysis are compared, it is shown that a maximum of four factors (inputs or outputs) should be used in a DEA model, such as, ATCO hours, Share Non-ATCOs (Inputs), Total Controlled Flight Hours and Airport Movements (Outputs). Some ANSPs achieve efficiency in all years (100%). These ones are large ANSPs in the European core area. East European Countries tend to have lower scores. Nevertheless, as can be seen in the outputs used to make the DEA, this efficiency scores have more to do with the traffic volume that with the size of the ANSP itself.

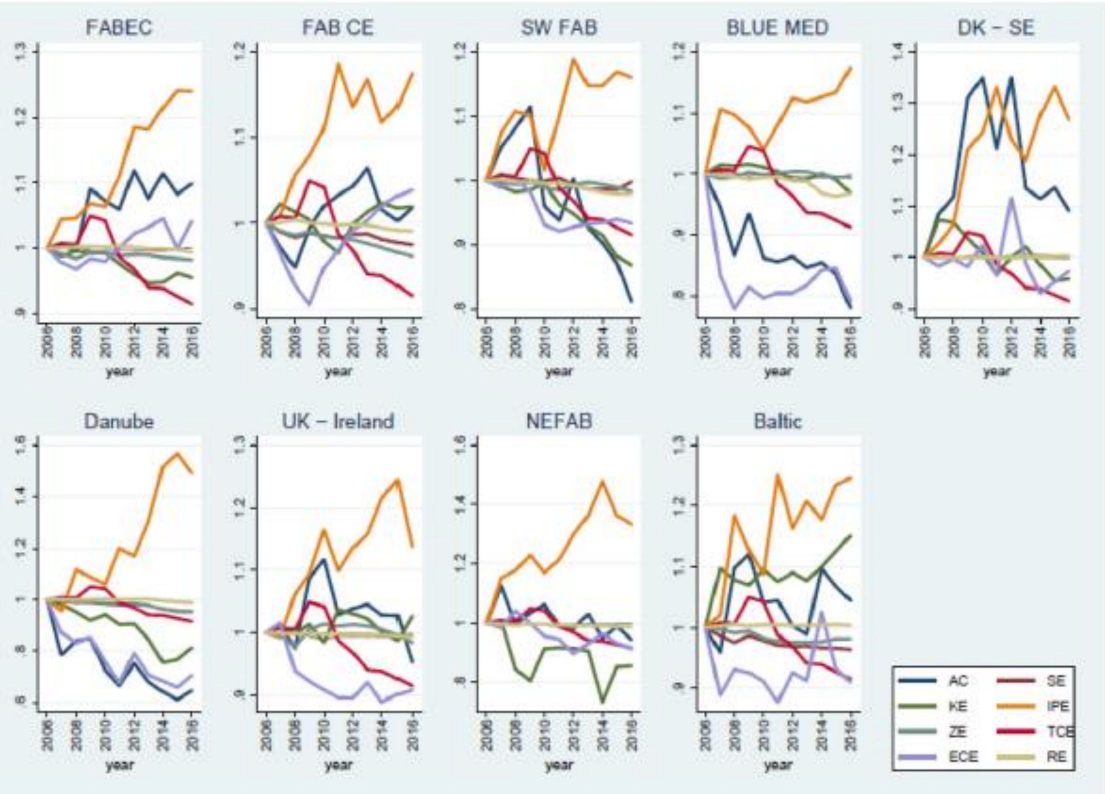
Figure 12: Average Efficiency Scores in Europe: 2008-2018




*Source: How to Benchmark Air Navigation Service Providers?*

Another research called **“Analysis of cost-effectiveness in the provision of air navigation services at functional air blocks”** analyse the evolution of the cost-effectiveness in the provision of ATM/CNS services from 2006 to 2016 at FABs using stochastic frontier analysis techniques. This study shows that the average ATM/CNS provision costs decrease for five of the nine FABs. The improvement in cost-effectiveness is especially high for Danube, BLUE MED, and SW FAB and more modest for UK-Ireland and NEFAB. The average provision costs increase over time for the rest of the FABs. Thus, there is no correlation between the size of the FAB and the efficiency.

Figure 13: Time series decomposition of changes in cost-effectiveness at FAB level (2006-2016)




*Source: Analysis of cost-effectiveness in the provision of air navigation services at functional air blocks*

Different studies, using different methodologies and data, show that the correlation between the size and performance in the European ATM is not strong at all. Thus, there is no evidence of economies of scale in European ATM and that the performance gap between different ACCs or ANSPs has other reasons of being rather than size.

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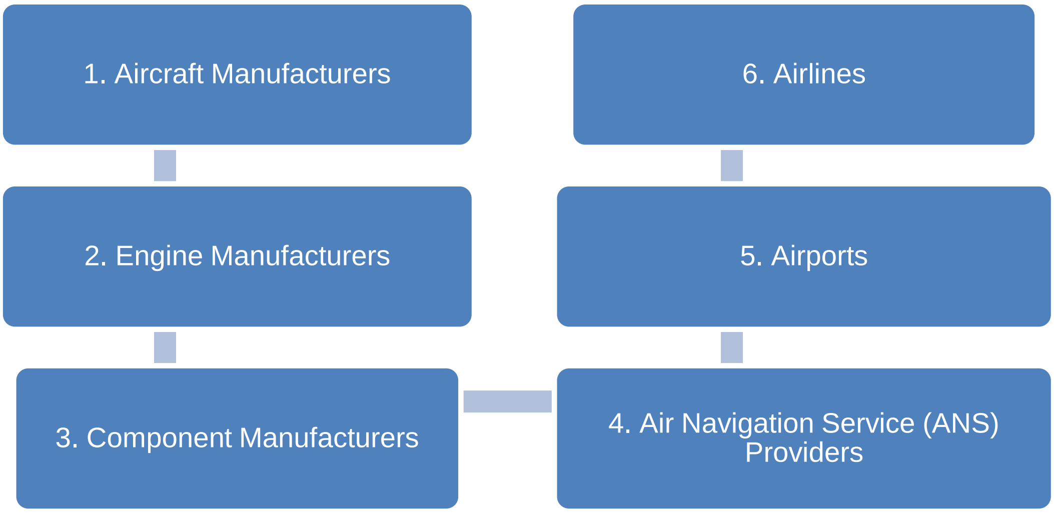
# 14 FRAGMENTATION IN THE WHOLE VALUE CHAIN

When talking about the fragmentation of the European ATM/CNS, it is important to consider the fragmentation of the whole air transportation value chain to understand if the ATM is fragmented or not comparing to the rest. The Helios report does not include information of the other steps in the value chain. Passengers and goods that require air transportation services make up a very broad spectrum, so they are really fragmented. However, the rest of the value chain is not. The article called "Air Transportation Value Chain" includes the value chain shown in the Figure 14.

Figure 14: Air Transportation Value Chain




*Source: Sarosh Bhatti: Air Transportation Value Chain*

Excluding the ANS providers, the following is a description of the fragmentation of each link in the value chain:

- **Airplane Manufacturers:** Boeing and Airbus are the world's only major large passenger aircraft manufacturers. The two companies share almost exclusive control of the worldwide airplane supply business for large commercial jets. Together, they own nearly 90% of the global market.
- **Engine Manufacturers:** There are three dominant players in this market globally: Pratt & Whitney, Rolls Royce, and General Electric, structured as a very narrow oligopoly.
- **Component Manufacturers:** Components in the aircraft are all designed to perform a specific job, such as, avionics, breaks, wheels, navigational computers, electrical generators, etc. For example, in avionics three companies control the market: Honeywell, Rockwell Collins, and Thales.
- **Airports:** They are close to a natural monopoly by design. If an airline plans to serve a city, generally it has no other choice than to use the nearest airport that offers all the required infrastructure and facilities. In the European case, most airports are owned by states. Even if you think about a case like London where 6 airports are available (London City, London Gatwick, London Heathrow, London Luton, London Stansted, and London Southend) a slot is needed to flight to each of those airports, there are certain capacity restrictions, and they have different connections, so in the end the options are limited. Thus, globally it looks like a very fragmented sector as there are a lot of different airports, but if the market is looked locally in most cases, it is a monopoly since there are no other options.
- **Airlines:** Europe currently has 105 airlines offering scheduled flights. In Europe there are 7 big full-service carriers, 7 big low-cost carriers and more than 15 regional airlines. One may think that this means there is a lot of competition, but the competition is not between airlines but between routes. Airlines compete only with other airlines that fly the same route on each flight and in most cases, there is not much choice or if there is, it is between the same group of airlines. The top 10 airlines control over the 60% of the European market (Source: Eurocontrol: Traffic Overview).

Thus, when ANS states designate companies in accordance to SES regulations, they are natural monopolies since only one ANSP can be designated to control each airspace. Thus, the air transportation value chain is not fragmented and monopolies or oligopolies reign throughout the chain. The whole value chain is structured as monopolies or very narrow oligopolies, as the aviation sector does not generate much competition due to its own market characteristics. In the same way, the structure of the market itself determines the level of fragmentation of the ANS.

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