Research Workshop

Single European Sky and Resilience in ATM

15-16 September 2022 in Sofia/Bulgaria

Documentation

danubefab
functional airspace block

GARS
German Aviation Research Society e.V.

FABEC

Editorial

Turbulent times – academics and experts seek solutions for more resilient air traffic management

Around 100 participants from all over Europe and America attended the research workshop Single European Sky and Resilience in ATM in Sofia, Bulgaria, on 15-16 September. Organised by Danube FAB, Functional Airspace Block Europe Central (FABEC) and the German Aviation Research Society (GARS), the workshop brought together senior academics, high-level industry experts and regulators to exchange views on how to manage increasing uncertainty in air traffic management. In response to shocks such as tumbling demand during the pandemic, geopolitical upheaval, unpredictable weather phenomena and changing traffic patterns, delegates identified priority areas to increase resilience during challenging times.

Unpredictable events have become everyday reality and take different forms and range from local loss of traffic or local extreme weather to global shocks such as the pandemic and the war in Ukraine. Rather than dwell on their frequency and cause, the workshop highlighted the importance of preparing for future uncertainties and shocks. For example, shifting traffic flow leads to excess demand and additional income in some states while others experience unused capacity and falling income. Just-in-time resource management is unsuited to these extreme fluctuations, and capacity planning take on greater importance. Disruptive events take different forms and range from local loss of traffic or local extreme weather to global shocks such as the pandemic and the war in Ukraine. There is a balance to be found between operational and financial resilience to withstand such events. Societal concern over climate change and environmental changes have a slow but long-lasting impact, but it is so far attributed minor importance in the regulation defining the mandate of air navigation services.

Among senior speakers, delegates heard from Princeton University Professor of Economics and Director of the Bendheim Center for Finance, Markus Brunnermeier, about managing uncertainty. Industry representatives and academics from more than ten European countries and the United States contributed to in-depth discussions about the challenges and opportunities facing air traffic control and the value of resilient infrastructure. This resulted in key findings that highlight the importance of balanced performance targets, financial and operational buffers, regular stress tests and a collective approach to forecasting to best help manage future uncertainty.

Key Messages

The workshop discussed how the functioning of the air traffic management critical infrastructure can be safeguarded in turbulent times, characterized by growing, diverse and conflicting demands that bring tension and uncertainty to routine operations. It was acknowledged that aviation serves as a catalyst of the European economy air traffic control as its integral part, contributes to safe and efficient air transport thus supporting mobility to the benefit of citizens. The pandemic has demonstrated the importance of keeping the airspace open at all times and thus maintaining deliveries of basic supplies such as goods and medicine and facilitating citizen repatriation.

Exogenous shocks, such as the pandemic and geopolitical conflicts, have led to a high traffic volatility and to a low predictability of air traffic.

While the Green Deal as a European answer to tackle climate change is asking for a reduction to zero emissions by 2050, the issue of national security has gained more importance. For these reasons, the workshop set out to provide insights as to if, and how, the provision of air navigation services needs to be adapted to be equally robust and flexible, and thus to become more resilient.

The key findings of the workshop are:

- We live in a world with recurrent systemic shocks which makes resilience more and more important. Resilience enhancers are e.g. redundancies and buffers, liquidity and flexibility. Resilience enhancers come at a cost whereas the benefits of resilience will only occur when there is a shock. Thus, market forces do not incentivize resilience.
- Whereas traffic demand evolves on a daily, weekly or monthly basis, capacity is determined usually by years or decades ahead. ANSPs need to develop their operational capabilities continuously which is in contradiction to short-term business plans of airlines. Airlines schedule flights based on passenger demand and constraints such as availability of slots, aircraft and staff – constraints of ANSP are not a significant part of this plan and therefore an iterative and collaborative capacity planning could provide benefits for the whole aviation system.
- High uncertainty on future traffic demand due to conflicts, wars, pandemics or social unrest and with possible diametrically opposite scenarios puts ANSPs in a dilemma: Whether to cut costs, investments, and activities to stabilize the current financial situation or to overcome lack of financial means in the short run by continuing to invest in staff and technology to prepare for returning high traffic demand.
- The cost structures of ANSPs are largely fixed with minimal variable costs. Thus, they have

little leverage when a fall in demand leads to harsh revenue decline, causing liquidity and financing issues and unused operational capacity. Similarly, unexpected demand hikes are hard to manage without pre-planned resources, and result in capacity issues that impact the passenger experience and often increase the environmental footprint due to deviations. A more environmentally friendly flight plan could be facilitated by the Network Manager as airlines do not always use full potential of available routes in flight planning.

- The current SES regulation in force since 2004 is based on the assumption of steady air traffic growth without significant changes in demand or disruptions. Its foundation are traffic forecasts with a five-year perspective and it may not sufficiently address interdependencies between the different key performance areas.
- Current performance and charging regulation can balance small changes in traffic demand and manage low levels of traffic volatility. Currently, there is no permanent mechanism to manage strong fluctuations or a significant loss of revenues. In addition, there are neither permanent provisions that ANSPs' costs will be covered in such circumstances nor that the financial liquidity to run the operations will be maintained.
- Limiting ANSPs' potential to generate revenue may endanger the entire air transport system by severely affecting the operational and financial resilience of ANSPs.
- Operational and financial resilience go hand-in-hand. ANSPs should be predominantly operationally resilient when traffic is high and predominantly financially resilient when traffic is low. As infrastructure providers, ANSPs need to invest anti-cyclically, which runs counter to the airlines' short-term business model.
- The first step to improving resilience of air navigation services needs to include both financial and operational buffers to manage increased volatility and traffic shortfalls. Hence monitoring accuracy of traffic forecasts and volatility with meaningful indicators, paired with a sensible risk assessment, is essential to determine the buffers required.
- To ensure the preparedness of ANSPs economic stress tests would provide certainty about the general financial strength of an ANSP. The task will be to determine for each ANSP its tipping point, meaning that after reaching this point a recovery will be lengthy and at a high cost. The stress test can be complimented with a constant monitoring of predicted traffic scenarios. Interdependent operational and financial objectives need to be adjusted depending on the actual traffic evolvement to assure a long-term efficient solution including external environmental costs.
- The concept of the commons in terms of shared infrastructure may support resilience in air traffic management. The same applies for cross-border services which may support ANSPs to provide capacity. However, these concepts may not be helpful in a situation when all areas experience a downturn in traffic as it was the case during COVID-19 or all areas suffer capacity shortages due to unforeseen traffic demand as in 2018/2019 in the core area.

Research Workshop

Single European Sky and Resilience in Air Traffic Management

15-16 September 2022 in Sofia/Bulgaria

Conference venue: Vivacom Art Hall Oborishte 5

First day, September 15th, 2022

Moderation: Mariya Kantareva, DGCAA Bulgaria

12:00-13:00	**Registration, lunch and welcome**		
13:00-13:30	**Opening statements**	Georgi Peev – *BULATSA DG and DANUBE FAB ANSP Board Co-chair* Michael Lokay – *FABEC Presidency, Federal Ministry for Digital and Transport, Germany*	**page 7**
13:30-14:30	**Setting the scene: The resilient society**	Prof Markus Brunnermeier – *Edwards S. Sanford Professor of Economics and Director of the Bendheim Center for Finance, Princeton University*	**page 13**

Coffee break

First step: Understanding aspects of resilience in air traffic management

Moderation: Mariya Kantareva, DGCAA Bulgaria

15:00-16:15	**Operational resilience lessons – an ATCO's view**	Alexander Zarbov, Juraj Jirku – *DANUBE FAB*	**page 20**
	Cyber resilience in aviation	Radu Babiceanu – *Embry-Riddle Aeronautical University, Daytona Beach, Florida, United States*	**page 30**
	Impact of the COVID pandemic on air navigation service providers – European level and case study Bulgaria	Vitan Todorov – *BULATSA, Bulgaria*	**page 38**

Coffee break

16:45-18:00	**Network-oriented planning of cross-border capacity provision to increase resilience and improve performance**	Jan-Rasmus Künnen, WHU – *Otto Beisheim School of Management, Germany*	**page 48**
	Achieving supply chain efficiency and resilience by using multi-level commons	Florian Lücker – *University of London, United Kingdom*	**page 54**
	Conflicting business models: How structural differences threaten aviation resilience, and what potential solutions might exist on the ANSP and airline side	Nuno Simoes – *Nav Portugal* Prof Karsten Benz – *University of Worms, Germany*	**page 56**
18:00-18:15	**Wrap-up**	Mariya Kantareva	

Social Event – Grand Hotel Sofia – 20:00hrs

Research Workshop

Single European Sky and Resilience in Air Traffic Management

15-16 September 2022 in Sofia/Bulgaria

Conference venue: Vivacom Art Hall Oborishte 5

Second day, September 16th, 2022

08:30-09:00	**Welcome coffee**		
09:00-09:15	**Starting the day**	Mariya Kantareva	
Second step: How to integrate resilience in European air traffic management? Moderation: Mariya Kantareva, DGCAA Bulgaria			
09:15-10:45	**How to cope with demand fluctuations – resilience as the solution for volatile traffic?**	Thomas Standfuß – *Technische Universität Dresden*	**page 72**
	Single European Sky and resilience in ATM – can this be a "win-win" for the aviation industry? – The IFATCA input	Frederic Deleau – *IFATCA* Dr. Stathis Malakis – *Hellenic Air Navigation Service Provider*	**page 86**
	Does current performance and charging regulation really facilitate resilience of ATM industry?	Vilma Deltuvaite – *Innovation Agency Lithuania*	**page 96**
Coffee break			
Third step: How to prepare ATM for current and upcoming risks? Moderator: Prof Hartmut Fricke, Technische Universität Dresden			
11:15- 12:30	**Alessio Quaranta, President ECAC Coordinating Committee** **Denis Bouvier, LCol (R), PRB Member** **Jesus Caballero, CEO SOF Connect, Sofia Airport** **John Santurbano, Chairman FABEC CEO Board and Director Eurocontrol MUAC**		**page 111**
12:30-12:45	**Closing remarks**		
Farewell lunch			

Setting the Scene

Opening Statements

Opening statement by Georgi Peev,
BULATSA DG and DANUBE FAB ANSP Board Co-chair

Regular challenges in many different forms

Hello everyone and welcome to the latest InterFAB Research Workshop. On behalf of DANUBE FAB thank you all very much for travelling here. We are delighted to welcome you to Sofia and hope you enjoy your stay. Over the coming two days, I am very excited to hear from our fascinating presenters who have worked hard this summer to deliver their research papers on how ATM can increase or improve its layers of resilience.

We are all of course aware of the relevance of resilience at the present time. April 2020 saw aviation traffic levels fall by more than 80%, with many aviation businesses not prepared for this instantaneous loss in income. This left them in extremely difficult financial and operational positions. While much of the focus at that time was on financial survival, resilience covers a wider range of topics within our industry, with factors such as staffing, extreme weather, cyber-attacks, or technology failures.

Resilience has been very relevant to DANUBE FAB, with challenges regularly showing themselves in many different forms. From the challenges of the 2008 financial crisis, the conflicts in Ukraine in 2014 and now in 2022, and of course COVID, DANUBE FAB has learnt many lessons along the way. The solutions we chose to deal with these challenges will be discussed and presented by my colleagues from the FAB and BULATSA during our first panel today. Today we feel privileged to have globally renowned researchers from the academia as well as practitioners and managers across our industry and we look forward to their insight into how society as a whole can become more resilient. I will be further interested to hear the discussion as to how their ideas can be applied in air traffic management.

I hope you enjoy your time in Sofia and find the presentations our speakers have prepared interesting and insightful. Please do ask as many questions as you want, and I look forward to chatting with you personally throughout the workshop and at our social event this evening!
I will now hand you over to Michael Lokay from the Federal Ministry for Digital and Transport of Germany to provide his welcome.

**Opening statement by Michael Lokay,
Federal Ministry for Digital and Transport,
Germany**

The past is well behind us

Many thanks Georgi; I would like to acknowledge the work you and your colleagues have accomplished in Bulgaria over these last months to ensure the safe and efficient management of air traffic services during a most challenging period of our industry's history.

There is a clear need to work together to find solutions to the common challenge of unprecedented levels of market volatility we are all facing.

On behalf of FABEC I would like to welcome you today to this InterFab Research workshop. I would like to thank the colleagues within DANUBE FAB and the German Aviation Research Society for organising this workshop and everyone here for participating at this important event.

We have six main issues on the table:

- How can aviation partners prepare themselves for the next pandemic or another major shock to the system?
- How does political unrest in and around Europe impact air traffic management predictability?
- How can we combine and maybe more important balance financial resilience with operational resilience?
- What is a "resilient society" described by Professor Brunnermeier in his keynote and how can these characteristics be applied to aviation, especially in terms of integrating climate change and high levels of cyber security into our operations?
- What is needed to ensure resilience in day-to-day air traffic management, what factors need to be considered to make air navigation service provision more adaptable to sudden market changes?
- How can we use or improve the current legislation to make the ATM system more flexible and thus more resilient?

It would be great to believe that the events which have shocked our industry and our continent over the last few years will gradually abate and we will eventually return to the world of 2019 at some stage.

But I fear the past is well behind us. As well as the continuing terrible events unfolding in Ukraine we are now facing a looming energy crisis in many parts of the continent and the macroeconomic challenge of rising inflation. It is too soon to say what the impact of these two phenomena will be on our industry, but we are sure that ATM – as a critical service delivery – have to play a major role to fulfil the needs of the citizens, the markets and states defence interests.

So, as we seek to re-align our planning and management of day-to-day operations to take account of multiple disruptive events it is vital, more than ever, that we share our experiences and gain knowledge from experts and colleagues about the challenges and solutions to building new levels of resilience into our organisations.

After all, the new “normal” might be very different from the old “normal”. We could be at the start of a new age shaped by uncertainty and volatile traffic demand which will require new levels of flexibility from all partners in the aviation chain.

This workshop is a welcome, vital element to better understanding the challenges we face and how we should start preparing for them.

Thank you for your attention and I very much look forward to learning more about this crucial topic.

Setting the Scene

Keynote speaker Prof Markus Brunnermeier

“Redundancies and buffers – the key to building up resilience”

Markus Konrad Brunnermeier is the Edwards S. Sanford Professor of Economics at Princeton University. His book The Resilient Society was recently named “One of the Best Business Books of 2021” by the Financial Times.

Before we look at the lessons to the aviation industry from your research into building resilience into systems, societies and industries, perhaps we could discuss some of the basic principles and conclusions of your book “The Resilient Society.”

We are now living in a world full of shocks – pandemics, a war in Ukraine, financial crises and natural disasters as a result of climate change, food shortages. So we have to ask ourselves: how can we best be prepared for a continuous series of shocks, which appears to be the new norm, especially as they all seem to be coming at the same time? How do we build resilience into our societies? We have to understand what resilience means and how we should prepare ourselves by building in new levels of redundancy. Essentially this means a change of mindset.

Resilience is different from managing risk or avoiding shocks or minimising their amplitude. It is about bouncing back. And to successfully do this we need a shift in mindset so we can plan strategies which take account of risks and identify those from which we can successfully recover.

So robustness and resilience are different.

Robustness is about withstanding shocks, but resilience is about bouncing back from various shocks and external influences. The oak is a strong, robust tree and does not move much in the wind while a reed moves considerably. But in a hurricane an oak can sometimes fall over while the reed bends but does not break – it is more resilient.

But we also need to understand the difference between the shocks which will lift us out of stagnation – once we have learned how to recover from them – and those which could destroy us. Shocks which will undermine or weaken our powers of resilience will need to be identified and avoided.

How can we make our businesses more resilient?

Redundancies and buffers. If we are to become more resilient, we will need to build in more inventory and extra buffers. Particularly important is the need to have sufficient liquidity to deal with shocks. We have to develop systems which allow us to move swiftly from one process to another within a short timescale. For manufacturing industries, for example, this could mean reducing dependence on specialist components and moving towards deploying more generic items, which will allow us to switch more easily between processes.
It is also good to develop a sound infrastructure which will allow us to move from one geographic market to another – and digitalisation of systems is an important part of this. It all helps to build resilience.

We also need diversity. In a forest which is a monoculture all the trees can be hit simultaneously but if different trees are planted it is more protected. And we want to avoid group think – all organisations need people who think out of the box.

Social cohesion is also important, we need everyone to be pushing in the same direction; if there's a shock caused by fundamental imbalances in organisations or societies this impairs resilience.

What are best practices to manage continuous uncertainty which we are facing?

Our research shows that those organisations which are most successful at dealing with volatility are those who continuously build buffers and are adaptable. And the risk is that in a crisis an organisation deletes the buffers it has built up and then is gradually overwhelmed.

The kind of buffers needed here are financial, operational and those that centre around innovation.

Should we avoid crises?

We should not avoid crises at any cost. We can learn a great deal from managing small crises and this can add to our resilience; if you try to avoid the first or second crisis by the time the third crisis hits it will be far more difficult to recover from. For example, societies who had to cope with the SARS 1 pandemic often proved much better at coping with COVID than those who had no experience at dealing with a pandemic. And in 2020, when COVID hit western society and the financial system was on the brink of collapse, we were able to access the toolbox we had developed to cope with the 2008 financial crisis, and this allowed us to employ the right financial instruments.

What are resilience destroyers and how do we avoid them?

There are many potential resilience destroyers, including adverse feedback loops and tipping points. Adverse feedback loops coming from reactions to crises which don't solve the essential problem but make things worse. Often things can get out of control and there is no way back. These often kick in when one reaches a tipping point. In climate terms, for example, this would occur if the Gulf Stream were to stop. Europe would become increasingly cold and there's no way we could switch the Golf Stream back on.

Centralised systems are vulnerable to collapse if the centre is taken out, but decentralised systems and especially distributed networks are far more resilient, so the network structure matters a great deal. In corporate networks you can apply circuit breakers to isolate areas which have been badly affected and even in economies there is always the option of corporate bankruptcies.

But societies cannot apply circuit breakers, which means that communications between all players matter a lot during a time of crisis.

And there is a paradox here unfortunately. Even though it is far more efficient to tackle volatility at a global level, investment in local resilience lowers investment in global resilience – if each country has poured investment into its own resilience, it has less incentive to invest in global resilience, even though it would be much more cost-efficient to do so.

In the highly regulated ATM world we are driven by certification processes, standards and target levels of safety. From an ATM perspective how can we design our systems and operations to add resilience?

Resilience is about how quickly one can bounce back, not about how big the shock is. One way to measure resilience is to measure how quickly the system responds to a shock, putting in plans to reduce the response time. You can still have target performance levels, but they could be based on the speed and effectiveness of response.

It's true that uncertainty is always the norm and recently volatility has become more severe, as mentioned in the first question. In addition, to higher volatility, things are also moving faster. In a fast-moving society, response times are short and one has to make sure that the response stabilizes the society rather leads to destabilizing adverse feedback loops.

We need to make sure societal infrastructure always works well. But there are not always the financial incentives to build in appropriate buffers and this can have a severe impact on the rest of society. If you have a well-functioning infrastructure, you will help society better adapt to shocks, independent of where the shocks are coming from.

Session 1

Understanding aspects of resilience in air traffic management

Operational Resilience Lessons – an ATCO's View

Alexander Zarbov[a] and Juraj Jirku[b]

Introduction

This paper describes the strategies implemented to add layers of resilience in DANUBE FAB that make Air Traffic Management (ATM) agile and prepared to meet crises. These strategies aimed at more efficient use of resources, adaptive training plans, flexible rostering, taking good care of staff, upgrading existing technology, and all that while keeping a permanent focus on Safety.

The paper presents real life operational data, reflecting events which influenced ATM operations in the DANUBE FAB. It will ponder over the resilience in ATM, challenged to overcome the traffic volatility, created by the major global events since 2014.

Setting the scene

In the beginning of Air Traffic Control (ATC), the only technology available to the Air Traffic Control Officers (ATCOs) was a radio, a clock, a sheet of paper and a pen(cil). At that time, aircraft (A/C) had to follow exact routes and lots of expensive ground equipment was needed to allow pilots to detect their position and report it to ATC. All crews had a navigator on board, who was extremely busy. Next, primary (non-cooperative) surveillance was introduced. It uses high-power transmitters and is expensive, prone to clutter and lacks A/C identification and altitude information. The first radar screens were circular, using cathode-ray tubes and the only information presented on them was the (relative) position of the A/C. ATCOs used flight progress paper strips [1] to be able to track the positions and progress of the A/C under control (Figure 1).

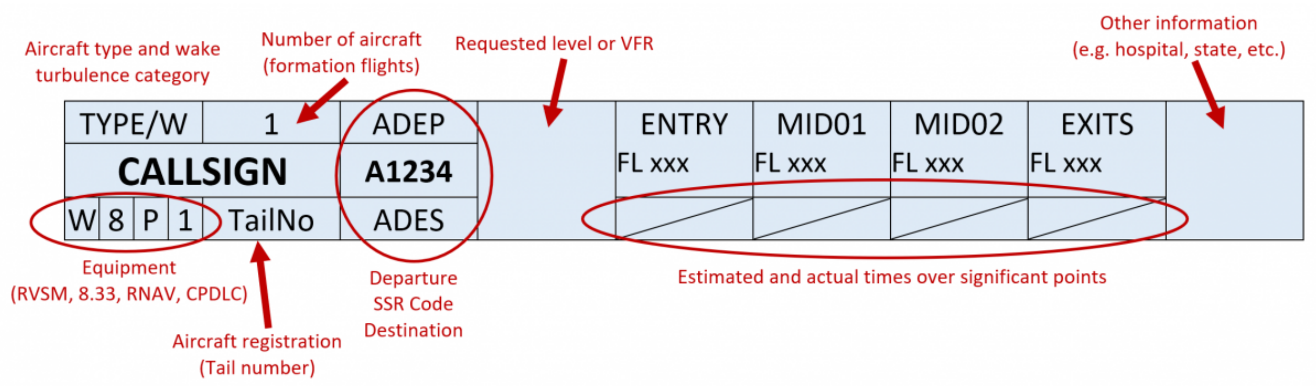

Figure 1: Flight progress strip

[a] BULATSA
[b] Egis

The balance in the system at that time can be illustrated as on Figure 2.

Several decades later, the transponder on board of A/C started to respond to the signals from the ground providing secondary (cooperative) surveillance. It brought improvement in terms of cost, reliability, and performance. The transponder started sending identification information (Mode A code) or pressure altitude information (Mode C code) to the ground. This information could then be presented to the ATCOs on the radar screen, which improved the level of safety, thus accommodating more traffic. The situation then looked like this – traffic increased but ATCOs numbers remained about the same. The implementation of computers in ATM (mid 1990s) was the big turning point. Flight Data Processing (FDP) made paper strips obsolete – all necessary information could be presented in the A/C label or in tables on the radar screen. In the meantime, new A/C entered the scene – faster, lighter and more efficient. Prices of oil remained stable and air travel became cheaper and more affordable – meaning a significant increase in the number of people flying (Figure 3).

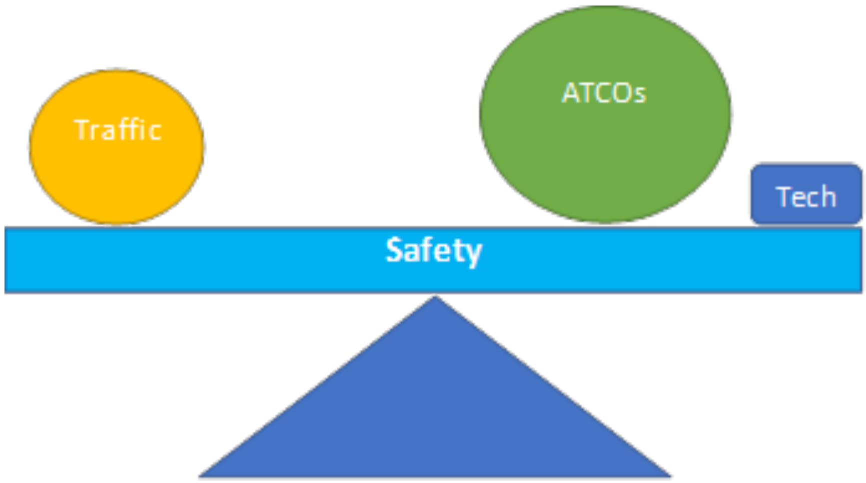

Figure 2: Safety balance in ATM

In 2000, enroute ATCOs at BULATSA handled 279 298 A/C, 2.81 times less than in 2019 – 784 649. At the same time the number of ATCOs in 2019 was only 50% more than in 2000. A similar traffic evolution was observed for ROMATSA with a 149% increase of traffic in 2019 compared to 2000, while the number of ATCOs decreased by 11% following a wave of retirements starting at the end of Single European Sky (SES) Performance Scheme Reference Period 2 (2015-2019) - RP2 and continuing throughout RP3 (2020-2024).

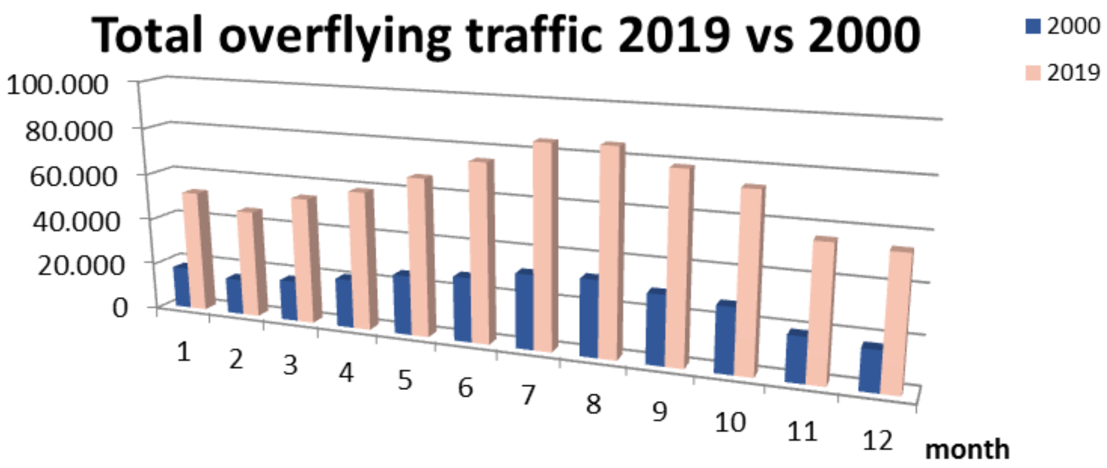

Figure 3: Traffic overflying Bulgaria and Romania in 2019 vs. 2000

The bottom line here is – ATM exists in a constantly evolving and changing environment. It must balance ever increasing traffic with constant pressure to become more efficient by reducing the number of ATCOs. Moreover, the general understanding is that the increase of automation will compensate for the reduced number of human eyes and brains dealing with the increased traffic. Figure 4 shows what we can get if we blindly follow this trend.

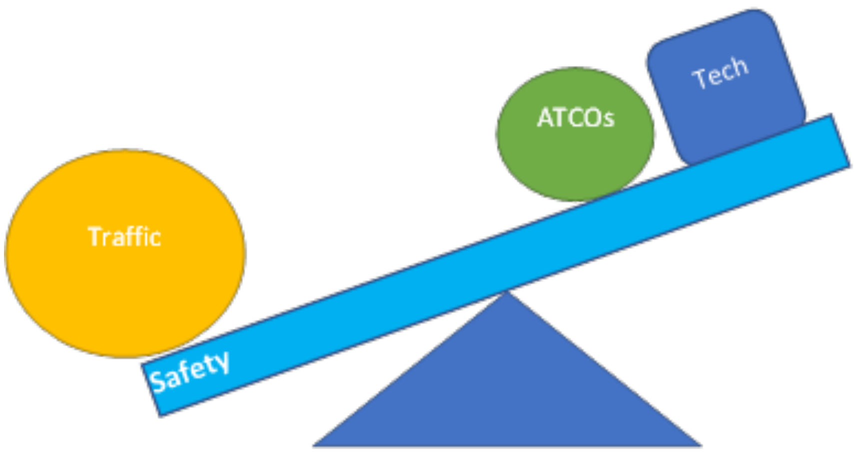

Figure 4: Safety imbalance in ATM

Resilience

There are many definitions of Resilience – all in their own environment. But, in the context of ATM, Resilience is the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions [2].

In another study about Resilience, funded by the EC, the conclusion expresses our sentiments exactly: ***"well-coordinated operations and actions of human operators are essential to maintain resilience in the complex ATM system"*** [3].

Disrupting factors

Traffic volatility

Traffic in DANUBE FAB is seasonally biased - half the number of A/C are flying the skies in winter compared to summer. This places different workload on ATCOs, and therefore, between November and March involvement in testing and training is prevailing, and ATCOs participate in project work to enhance their competence.

Crises

The major crises that struck ATM in DANUBE FAB are listed here:

Year 2014 – Simferopol FIR was closed on 13 March, when Russia took over control at the Simferopol Area Control Centre. ICAO [4] and EASA [5] issued recommendations to avoid the Simferopol FIR until the situation is resolved. The very next day the traffic over Varna family sectors, Sofia FIR, increased by 42%! Before 2014 the annual increase of traffic overflying Bulgaria and Romania was around 30 000 flights (6-7% increase). 2014 ended with an increase of over 27% for Bulgaria and 17% for Romania!

Year 2020 – COVID-19. The coronavirus crisis came without notice and hit the aviation sector abruptly. DANUBE FAB ended 2020 at around 43% of the traffic for 2019, and 2021 at 60% of the same.

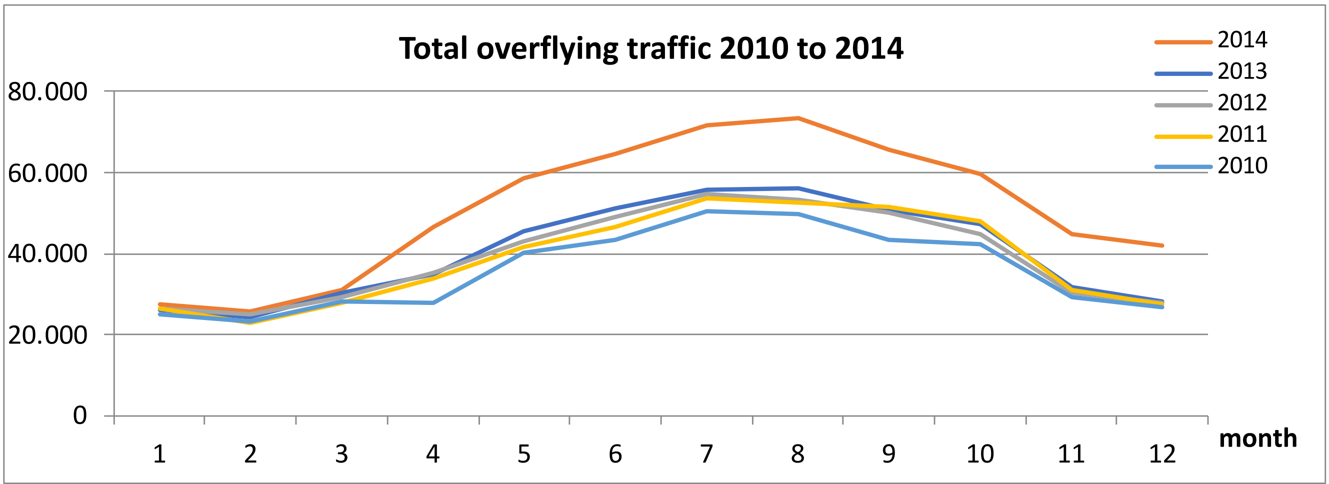

Figure 5: Monthly traffic in 2010-2014 in Bulgaria

Year 2022 – Ukraine Conflict Zone. On 24.02.2022 EASA issued an Information Bulletin [6], practically closing all Ukrainian FIRs and adjacent areas within 200NM surrounding the borders with Ukraine. This forced overflying traffic further south into DANUBE FAB. Compared to the same months in 2021, traffic more than doubled. In the Romanian airspace, not only a traffic increase was observed but also an increase in complexity and of the average distance flown which now surpasses the one for 2019.

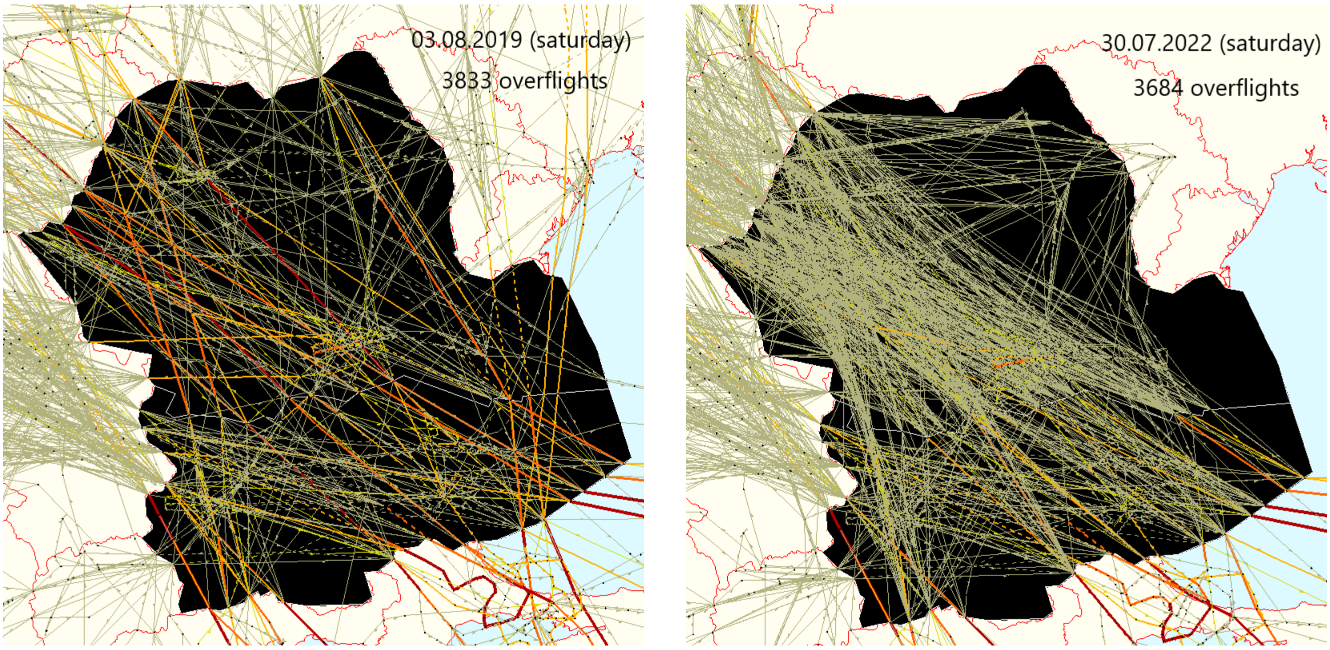

Figure 6A: Traffic across DANUBE FAB in 2019, Figure 6B: Traffic across DANUBE FAB in 2022 – Free Route Airspace

Loss of expertise

The COVID crisis forced Air Navigation Services Providers (ANSPs) to stop recruiting new trainees, and even cut-off jobs, but BULATSA and ROMATSA avoided laying-off ATCOs. The number of ATCOs, planned to man multiple sectors, suddenly became too high. ATCOs worked less hours, controlling less traffic thus becoming prone to skill erosion that might jeopardize Safety.

Strategies

The crises listed above have taught us a lot. With the present-day understanding of the past several strategies have emerged which can help improve the resilience in ATM.

We believe that the efficient use of our ATCOs is the number one enabler for building sufficient resilience into the operations of the ANSPs. A few main items are presented below which make up the frame within which we improve ATCO productivity.

Firstly, it is of major importance to agree on the level of flexibility of available shifts which ATCOs perform. As traffic levels vary significantly during the day or on the various days of the week, it is the natural strive of the ANSP to have the availability of ATCOs move with the variations of the traffic load. That is of course very demanding on the working conditions of the ATCOs. It is a fine balance to be struck, so that ATCOs remain motivated and ready to take the burden of doing dedicated variety of shifts. Another important element to that is what software tools an ANSP uses to manage the rostering of its ATCOs. It should provide the flexibility to accommodate all requirements of the Labour Code as part of the national legislation and to cater for the provision of fatigue management.

ATCOs are usually assigned to control certain volumes of airspace. This is determined by the complexities related to interaction with adjacent large airports, traffic patterns or military restrictions, which require an ATCO to be trained and competent for that specific volume of airspace and its variations in terms of sector shapes. When flexibility of ATCOs must be increased, they can be trained and certified for larger sets of sectors (volumes of airspace). This puts additional burden on ATCOs and only the more experienced ones can achieve it.

DANUBE FAB saw major consolidations of the ACCs in the beginning of this century. Romania had five ACCs and Bulgaria had two, nowadays both countries have just one ACC each. This was surely a well-designed step toward increasing the efficiency of ATCO labour. Within those consolidated ACCs we manage the use of ATCOs on a larger scale, thus making the most of it. This is actually in the true spirit of the Single European Sky principles. As an additional benefit of the consolidation, we see the streamlined implementation of next generation automated ATM systems and early introduction of free route airspace. If we had multiple ACCs that would have been much more complex and achieved slower. As an example, Sofia ACC has two "sector families". Initially, ATCOs are certified on one sector family. But we need certain number of colleagues to maintain competence on both for efficiency reasons. A second sector group training started in 2014 and is still in our toolbox. BULATSA had looked into the possibility of doing such training earlier, but it was discarded as not very practical mainly due to the reason that traffic flows in the two sector groups are completely different. In 2014, forced by the Crimea crisis, we started the so-called cross-training. Some ATCOs from Sofia were trained for Varna sectors within 3 or 4 months, thus providing more resilience. When the traffic went down in 2020, we started the reverse trend – training ATCOs from Varna to Sofia sectors. This proved visionary in the current situation when there is some 60% more traffic in Sofia family sectors compared to Varna ones.

In ROMATSA, ATCOs with 20+ years of experience have been vital in safely handling the increase of traffic in RP2, but wear and tear, and fatigue, have started to show with an increase in loss of licenses and early retirements. That is why a gradual recruitment process was started at the end of RP2, put on hold during the COVID-19 pandemic and restarted as of 2022 in order to have an overlap of new ATCOs and experienced ones that would see the former ones benefitting and learning from their peers.

Automated ATM systems with improved ATCO tools, connectivity and interoperability will always be at the heart of improving ATCOs' productivity, safety of flight and efficiency of the airspace. We have had our stripless systems for more than ten years. Thus, the level of automation and coordination with adjacent sectors and FIRs help ATCOs to save crucial seconds when their sector is busy. That allows for some more aircraft on the frequency before the sector gets saturated. Cumulatively it means a few tens of thousands of additional flights annually being safely serviced. And those additional flights are actually the most impacted ones flying during busy summer days. The CPDLC functionality, introduced recently, helps save seconds even if mostly the "transfer on frequency" instruction is used. Some safety tools on the ATCOs' screens make conflict detection and resolution easier and thus a few more flights can be accommodated without distorting the perception of manageable workload.

Airspace management is an important part of the overall set of resilience actions. Steps to improve the sectorization are a constant effort to accommodate the everchanging traffic flows. Sector shapes can be modified along the traffic flows but again the impact on ATCOs workload must be assessed every time. Changing the shapes and the variety of sectors within which the ATCOs operate involves additional efforts for training and safety assurance which weigh workload of the ANSP but can bring benefits of better utilization and thus – resilience.

A piece of innovative technology is here to help with the more efficient traffic management. BULATSA implemented the so-called Traffic Complexity Assessment Tool which brings proposed solutions to problems of most efficient sector configurations in real time. It constantly processes digital data about aircraft in flight, airspace closures, significant weather, etc. to create a picture of best possible alignment between traffic demand and the available ATC capacity. ROMATSA will also implement this tool in the coming period which proves itself even more necessary in the current situation of increased complexity due to the re-routings induced by the conflict in Ukraine and the subsequent increase in military activity.

Financial Measures

The operational resilience must go however hand in hand with the financial resilience, to make sure that an ANSP can afford to cope with such crises as those described above. This requires an ability to respond to demand as flexibly as possible, while maintaining the financial stability of the company. Financial resilience can be defined as "the ability to cope financially when faced with a sudden fall in income or unavoidable rise in expenditure"[7]. The European performance and charging scheme assumes that ANSPs can cope with the differences in traffic compared to the forecasts of about 10%. The recent shocks have however brought much more significant disturbances to the planning assumptions and made the traffic forecasts in our region in fact invalid. And even though states have an option to re-open their performance plans if the traffic deviates from the assumptions by more than 10% and so called "alert mechanism" is triggered, most of them prefer not to do this due to bureaucratic hurdles and length of this cumbersome process with uncertain result. The only other option is to keep the ability to adjust costs during periods of low traffic while keeping sufficient buffer for coping with higher traffic growth than originally foreseen. This can be achieved through improving "cost base elasticity". This elasticity can be achieved through internal, organizational decisions, or by structural changes imposed by regulatory or market reforms.

Looking at the structure of the ATM/CNS costs in figure 7 [8], it is obvious that the biggest chunk of the costs is represented by the staff costs (around 66%) with around half of this represented by ATCOs. This suggests staff costs is one item where the focus can bring the most results.

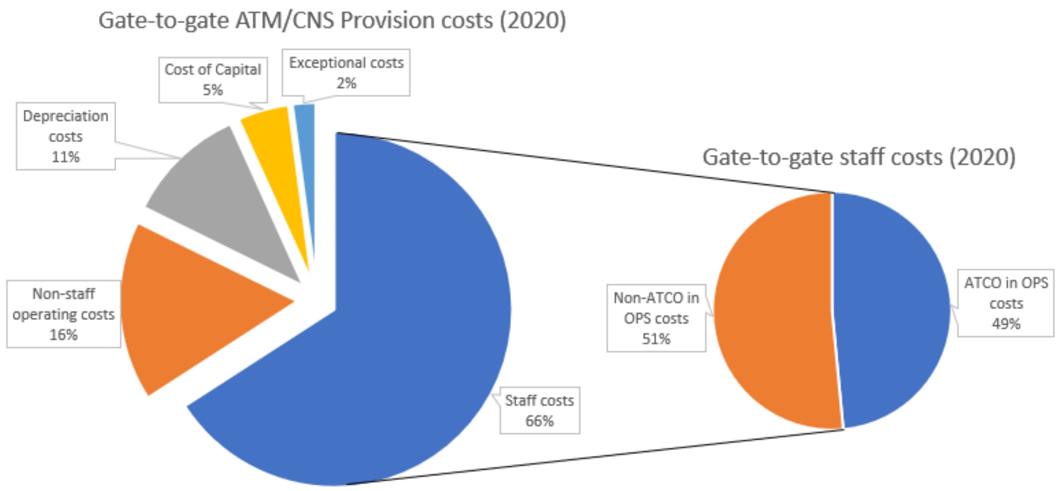

Figure 7: Structure of gate-to-gate ATM/CNS provision costs in 2020 (EUROCONTROL PRU)

In some industries staff costs can be indeed seen as variable costs – they can be flexibly reduced when required, either through redundancies or flexible/part-time employment contracts. However, due to the high level of specialization, qualification and certification of staff employed by air navigation service providers, staff costs in ATM can be seen as "quasi-fixed". While theoretically speaking staff can be made redundant, the cost-benefit of such a move is doubtful. This is because re-employing staff with similar qualifications is very challenging, and re-training new staff is both costly and time-consuming.

As described in the Egis blog on Exploring cost base elasticity for ANSPs [9] and validated by DANUBE FAB experience, ANSPs have some instruments also for improving staff cost elasticity and these include:

- Negotiating flexibility: Subject to national legislation, where there is a lack of staff availability, overtime can be negotiated. Where there is too much staff availability, the concept of "negative-working" can be introduced, where a given number of working hours will be deferred into the future. This ensures staff-hours which cannot be utilized are not wasted.
- Analyze rostering: Rostering patterns of both ATCOs and ATSEPs can be very complex and limited by a series of national and international regulations as well as local practices and union agreements. Nevertheless, lessons are being learnt by analyzing past sectorization requirements and then reflected in future rostering plans. Shift patterns could be staggered, to best align with daily and weekly demand fluctuations.
- Re-deploy for added value: When their usual duties are disrupted, re-deploy staff elsewhere in the company. Lessons can be learnt from DANUBE FAB given our experience with seasonal fluctuations. When traffic is lower, staff can be used to engage in strategic or innovative projects, working on improving future operations. While this does not allow for an immediate cost reduction, it ensures that the ongoing operational costs add value to the service provision, even if the benefits are realized at a later point in time.
- Undertake detailed manpower planning: Taking a longer-term view, ANSPs also engage in detailed

manpower planning activities across all departments. To have a successful recruitment strategy ANSPs must ensure that they have a good understanding of the demographics of their staff. Often, this is limited to only looking at the retirement forecasts combined with a view of traffic growth. It's worth extending this into looking at other demographic factors such as societal trends of wanting to work part-time, gender and age balance with a view to understanding potential longer-term leave (e.g. parental). Additionally, a strategic manpower review can help improve ways of working across the non-operational departments, ensuring organizational efficiency.

It is also important that ANSPs do not stop their CAPEX programmes just to reduce the costs. This would be short-sighted. We need to come out of a crisis stronger, more resilient and better prepared for similar future shocks. A structured review of the investment programmes needs to look at reprioritizing and potentially streamlining investments to make sure that sufficient resources are available where they are really needed. A framework for such review is provided in another Egis blog [10].

ANSPs with highly seasonal traffic, such as BULATSA and ROMATSA, have a great deal of experience with optimization of their staff utilization, also using some of the methods described above. Despite the large increases and decreases seen in traffic in the DANUBE FAB airspace over the years, the capacity has always been appropriately managed, with only very small delays seen in 2015 and 2016, however these delays are extremely small and well below the European average for ATM related delay, and the requirements of the performance scheme at the time. The measures implemented during the sudden increases and decreases in traffic during this period can be considered successful when considering their effects on airspace capacity. This goes hand in hand with an overall positive trend in safety incidents, demonstrating the ATM has become safer and safer within DANUBE FAB. In the years where traffic saw sudden increases or decreases in traffic, the safety incidents do not break this pattern of improved Safety over the years. Given the overall downward trend in safety incidents over time, the measures implemented to improve airspace capacity and efficiency can be considered to have positively impacted the levels of Safety in DANUBE FAB airspace.

Conclusions

Performance conditions in ATM are always challenging. Throughout the years there have been times when we have been either understaffed or using outdated systems, or in the transition phase of learning a new system and/or functionalities. In the meantime, we have been pushing to use ATCOs' time in the best possible way, such as learning new system functionalities, changes in airspace and/or procedures. And all this time Safety has been our number one priority. In order to maintain a safety buffer, we shall always preserve some adaptive capacity which allows flexibility of response to ensure that the stable state persists.

This safety buffer cannot be solely technological, simply because the existing ATM systems can never be upgraded overnight. And ATCOs cannot start using the new functionalities straight on as time for customization and training is always needed. In ATM we shall be prepared for the scary moments when certain functions fail. In that very moment ATCOs must change their mindset to play the redundant role and to take over the lost functionalities. As it has always been ATCO's responsibility to save lives and will always be!

And to put it very shortly – humans are the very centre of the resilient ATM system.

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Cyber Resilience in Aviation

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Abstract
There has been no shortage of attention for cybersecurity challenges that face the aviation community. This trend has been fuelled by a couple of salient facts. The first major contribu¬tor has been the commoditization and wide availability of tools used for cyberattack, and access to industry-specific equipment and knowledge. The second contributor has been the expansive growth of connectivity, software driven functionality, and computing services across all elements of the aviation ecosystem. Meanwhile, demand for greater efficiency continues to increase connectivity and accelerate computerization within aviation systems infrastructure, including aircraft systems. The aviation industry and its stakeholders have taken the cyber-resilience perspective for addressing aviation cybersecurity challenges. This perspective has the benefit of emphasizing safety, more specifically the cyber-safety, and reliability in terms of continuity of systems' operations across the aviation ecosystem framework.

Introduction
There has been no shortage of attention for cybersecurity challenges that face the aviation community. This trend has been fuelled by a couple of salient facts. The first major contributor has been the commoditization and wide availability of tools used for cyberattack, and access to industry-specific equipment and knowledge. Information about systems, avionics, protocols, and technologies such as software-defined radio are now readily available well beyond the industry.

The second contributor has been the expansive growth of connectivity, software driven functionality, and computing services across all elements of the aviation ecosystem. Increased connectivity results in an expansion of the attack surface and potentially creates new vulnerabilities and multiple attack points. This expansion affects all the systems included in the aviation ecosystem, starting with the aircraft, communications (ground- and satellite-based), navigation, surveillance, and air traffic management systems, as well as airline and airport backend operations.

As for all other industries, increased competition and economic performance indicators asks for an increased demand for greater efficiency. This translates into increased new technology adoption in terms of connectivity and computerization within aviation infrastructure, including aircraft systems. More recently, pilot programs were implemented to evaluate the adoption of AI/ML models within aviation ecosystem infrastructure.
The aviation industry and its stakeholders have taken the cyber-resilience perspective for addressing the increased aviation cybersecurity challenges. This perspective has the salient benefit of emphasizing

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safety, more specifically the cyber-safety, and reliability in terms of continuity of systems' operations across the aviation ecosystem framework.

Aviation Ecosystem, Resilience, and Cyber Threats

The need to weigh cyber-threats according to their safety impact, a practice referred to as "cyber-safety," requires a different perspective than IT cybersecurity. Cyber-safety differs from traditional IT cyber-security because of the need for safety certification, which relies on guaranteeing a system's behavior, or "determinism." This unique characteristic of aviation cyber-safety means that solutions widely used across traditional computing systems may create serious certification challenges.

The aviation ecosystem, sketched in Figure 1 below, is a highly connected system-of-systems that includes several actors, every one of them coming with their own cyber safety requirements. Most common actors of the aviation ecosystem include: aircraft and HW/SW component manufacturers, airlines, airports, air navigation service providers (ANSP), air traffic control/management, ground transmission/receiving in-frastructure, satellite systems (position satellites, constellations), and aircraft MRO organizations (main-tenance, repair, overhaul). All these actors are brought together by communication services delivered by IT/OT providers.

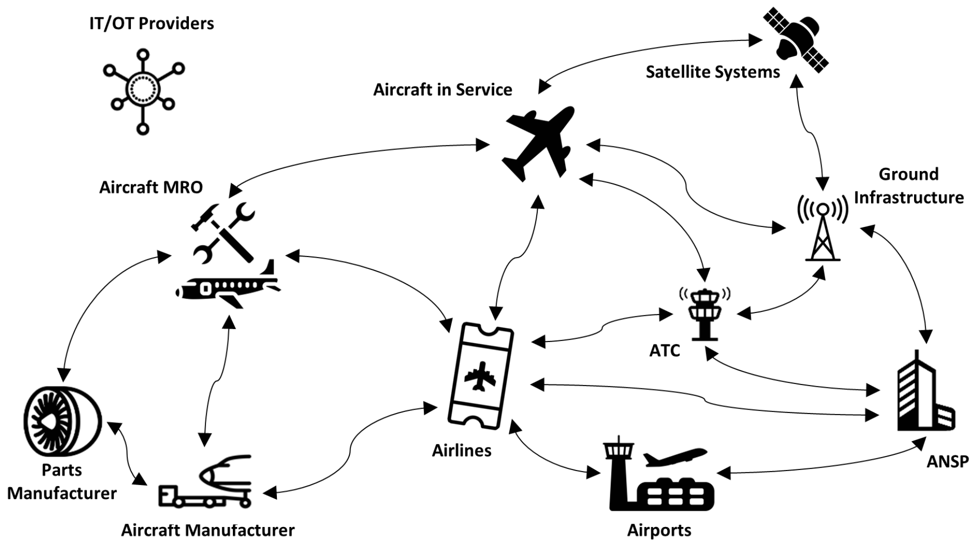

Figure 1: Aviation Ecosystem.

Disruptions in the services provided by any actor across the aviation ecosystem may propa¬gate to other services. Due to the cyber-safety nature of system operations, any disruptions must be eliminated through preventive actions, or mitigated using cyber-safety risk mana¬gement approaches (FAA, 2019). Implementation of cyber resilience approaches across the aviation ecosystem will help in addressing cyber threats and mitigate the resulting cyber risk.

Resilience is a system characteristic defined in natural, organizational, social, and engineered systems that estimates the ability of a system to "prepare for and adapt to changing conditions, and withstand and recover from disruptions” (DHS, 2013). The event could result in temporary and/or permanent changes to the system, so it is better to understand resilience in the context of all possible system operational profiles, as in Figure 2 (Babiceanu and Seker, 2019). It can be observed that, there are only three acceptable profiles (fault-tolerance, robustness, and resilience), whereas all remaining four profiles are unacceptable (recovery to a percentage of the initial output after system performance was reduced to unacceptable levels, survivability of the system but with unacceptable performance, degradation to a very low output resulting in the system becoming unsustainable for use, and system failure), since they result in performance lower than acceptable levels for a significant time period. Fault-tolerant systems have limitations in terms of added redundancy or lack of response to unknown environment conditions, while robust system mechanisms work only if the events can be predicted. In the case, of resilient systems, the performance is reduced after the event, without crossing the minimum acceptable performance level. By employing resilience mechanisms, the system returns to its nominal performance after an acceptable time.

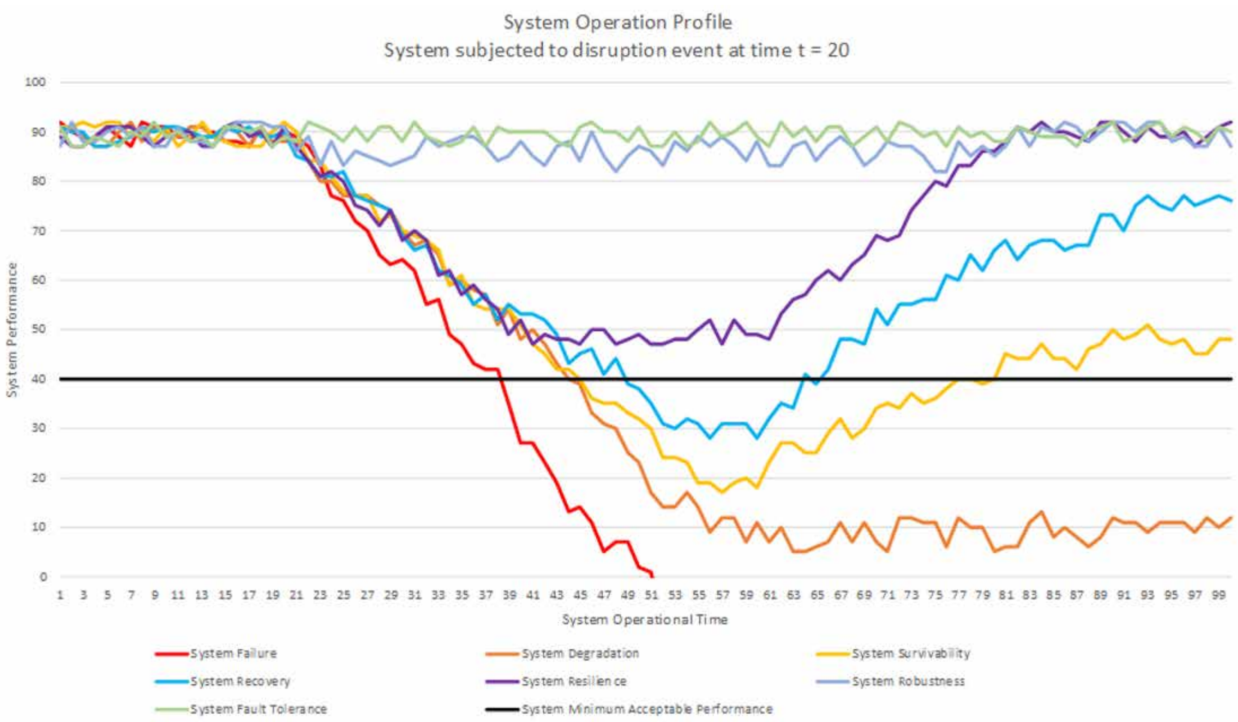

Figure 2: Resilience in the context of system operational profiles (Babiceanu and Seker, 2019).

Traditionally, aviation industry had emphasized safety as the most important operational characteristic. This was accomplished to the extent that cybersecurity in aviation used to be implemented through the practice of security-by-obscurity. No information about aviation systems was used to be made available to the public, thus minimizing the chances of anyone threatening aviation technologies. But as stated in the introductory section, information about aviation systems, transmission protocols, and even retired avionics equipment are now available for the general public, and thus to potential malicious actors.

Reviewing the schematic aviation ecosystem of Figure 1, each of the actors in the overall system could introduce cyber threats during their operations. For example, at aircraft manufacturing operations, security issues could be introduced in the design stage or missed during testing. Customizing the aircraft by the airlines could mean additional software running to the baseline acquisition software. There are a large number of services that airlines use that can be subject to cyber-attacks, though not all of them necessarily result in safety risks: reservation system, passenger information system, airline mobile applications, frequent flyer systems, baggage/cargo screening systems, catering and inflight selling of goods. An aircraft parked at airports, may be subject to attack vectors that could affect its security. Airport services are increasingly connected with many organizations that have businesses on airport premises. Aircraft on-board systems targeted by adverse attacks could include the Electronic Flight Bag, the Flight Management System, certain avionics, and navigation systems dependent on data communication, such as ADS-B or GPS systems.

During flight, aircraft communications are the main risk if data is transmitted in plain text. They also could be subject to jamming, spoofing, or denial of service at ATC/airports from actors using cheap and readily available COTS technology. It must be mentioned here that many ATM systems were developed before cyber threats were accounted for so they may lack the needed cyber vulnerability protection. In addition, satellite communications may have security concerns of their own. Positioning, navigation and timing (PNT) services may be affected by satellite GPS signal interference. Field loadable software during aircraft maintenance or airborne software updates, patches, and new malware not considered during the initial design are significant threats during MRO operations. Aircraft maintenance is increasingly dependent on data transfer between ground systems and aircraft, which can result in unauthorized access of the data feed. From the aircraft perspective during retirement of old aircraft or components, it is essential that critical aircraft parts are not sold to third parties allowing threat actors to reverse engineer them and potentially identify and exploit vulnerabilities. In addition, the data exchange among other actors of the aviation ecosystem that does not include communications to/from the aircraft, made possible by IT/OT providers are subject to known cyber threats that must be addressed through the recommended security practices within the level of cyber-safety risk that allows for certification.

From the organizational perspective, a recent Deloitte Insights report (Deloitte, 2021) developed by surveying a large number of business executive and public-sector leaders identified five attributes of resilient organizations. These attributes, namely preparation, adaptation, collaboration, trustworthiness, and responsibility, facilitate and empower agile strategies and adaptive cultures, and implement and effectively use advanced technologies. Since these five organization attributes often overlap and support one another, to successfully become resilient, or more specific build a cyber resilient aviation ecosystem, organizations should focus not on just one or two of those characteristics, but on all of them to the degree possible. Besides the technical considerations in addressing cyber resilience mentioned in the previous paragraphs, these organizational aspects are as important given the large number of actors involved in the aviation ecosystem.

It is well known that cybersecurity grows fast and becomes more complex every day in both attempting cyberattacks and protection against them. This is also true for the large aviation ecosystem. For example, it was reported that SITA, the organization that provides IT services to approximately 90% of the world's airlines was affected by a data security incident after falling victim to a highly sophisticated attack (ZDNet, 2021). While the aviation safety emphasis has not and will not change, with the adoption of new digital technologies the safety threat environment has grown to include new cyber threats that can pose increased challenges to the safety of operations. The proposed approach to address these challenges is to move to a more resilient type of operations within the aviation ecosystem, by balancing technical and organizational aspects.

Addressing Aviation Cyber Threats and Implementing Cyber Resilience

Tackling cyber-safety challenges requires a coordinated, comprehensive, global effort. Multiple international agencies are cooperating to establish much-needed cyber-safety certification standards. For example, the U.S. Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA) have been working with the RTCA and the European Organization for Civil Aviation Equipment (EUROCAE) to set harmonized cybersecurity standards. From the aircraft security perspective, a series of three security standards are already at their second version. The DO-326 (ED-202) addresses security process considerations during design, development, and acquisition, with cyber threat identification considerations. DO-355 (ED-204) addresses cybersecurity for continuing airworthiness in the aviation ecosystem, including airborne software, digital certificates, and ground and information security. DO-356 (ED-203) addresses the airworthiness security methods, including security architecture and assurance and risk assessment. A framework on how to achieve compliance between these three security standards and other aircraft and component development (SAE ARP, ARINC) and information security (NIST, ISO) standards is presented by Baron et al. (2019).

Just recently, the common work of RTCA and EUROCAE resulted in three more standards addressing aviation cyber-safety. DO-391 (ED-201) addresses Aeronautical Information Systems Security (AISS) and covers most of the actors of the aviation ecosystem: aircraft and components design and manufacturing, aircraft operations, MRO organizations, airports, and ATM. DO-392 (ED-206) covers information security threats and addresses the management of security events across all aviation ecosystem actors. The third document, DO-393 (ED-205) covers the security certification of ground systems (ATM, ANS). All these documents are or will be used as guidelines for cyber-safety certification of systems and components.

Efforts to secure the aviation ecosystem also include dedicated expert committees such as the FAA's Aviation Rulemaking Advisory Committee–Aircraft System Information Security/ Protection (ASISP) Working Group. ASISP provided publicly a series of 30 detailed recommendations covering eight different areas of aviation security (FAA, 2016). Similarly, the Aerospace Industries Association has established the Civil Aviation Cybersecurity Subcommittee. In the United States, the Aviation Cyber Initiative (ACI) was established and is led by an Interagency Task Force, formed of the Department of

Defense (DoD), Department of Homeland Security (DHS), and FAA (DOT, 2020). The ACI includes experts representing government, defense, industry, and academia who collaborate to tackle aviation cybersecurity threats and address the aviation cyber risks. One of the ACI's established objectives is to improve aviation cyber resilience. It includes building sustained mission functions, leverage interdependencies between aviation ecosystem actors, and conduct cyber exercises on threats to aviation ecosystem resiliency. Recently, aviation security was recognized by the U.S. Administration as a national strategy[1]. Also, another recent White House document "Improving the Nation's Cybersecurity[2]" discusses the importance of security measures for critical software, such as airborne software and the need to improve the software supply chain security, all of which are essential for aviation cybersecurity.

Globally, the Aviation Information Sharing and Analysis Center (A-ISAC) shares aviation-specific threat intelligence among aviation community. During their Annual Summit, A-ISAC engages member companies to identify their biggest security challenges, which are then shared with all stakeholders. Novel solutions to secure the aviation ecosystem are part of the summit presentations. During the 2020 A-ISAC Summit, an Embry-Riddle team proposed artificial intelligence models to enhance the cybersecurity of networked aircraft[3]. The International Civil Aviation Organization (ICAO), as the largest international organization focusing on civil aviation, also leads the global aviation security efforts. ICAO identified a series of actions for achieving a cyber-resilient ecosystem, out of which a few are listed next: work towards a common baseline for cybersecurity standards and recommended practices, ensure cybersecurity is included in aviation safety and security systems, identify a mixture of risk assessment methodologies, and develop information sharing platforms to allow for early detection and mitigation of cyber threats. ICAO's Trust Framework Study Group (TFSG) includes experts from the FAA, EASA, commercial industry, and academia and has established three important working groups: operations, digital identity, and networks. The group work aims at improving the resilience of the aviation ecosystem that will enable trusted ground-ground, air-ground and air-air data exchange among all aviation stakeholders.

Aviation Cyber Resilience Efforts at Academic Institutions

Academic institutions also play a crucial role in advancing cybersecurity research and training. For example, Embry-Riddle Aeronautical University (ERAU) develops engineering solutions and provides degree, certification, and training programs in aviation cybersecurity. ERAU is the world leader in aviation and aerospace higher education and positons aero-cybersecurity education and research as one of the signature areas at the forefront its strategic initiatives due to the critical importance to national interests, aviation industry, and public safety. ERAU's cybersecurity research is directed towards the security aspects of aviation and aerospace systems. The faculty have made substantial contributions to the body of knowledge of aviation cybersecurity through direct work with aviation industry stakeholders,

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publications in prestigious venues, and presentations at expert forums. Examples of contributions cover areas such as cyber-resilient avionics systems, aviation datalink security, formal analysis of combined safety and security requirements, blockchain for aircraft maintenance records, aviation cybersecurity framework and risk assessment, and others.

ERAU faculty researchers contribute expertise to the community cyber-defense and preparedness efforts by serving on national and international committees and working groups, and by organizing the annual Aero-Cybersecurity Symposium. The last two editions of the symposium successfully brought together government, industry, and academic cybersecurity experts across commercial and military domains, covering all actor-types of the aviation ecosystem, to discuss solutions to the most challenging cyber-security issues. Given its demonstrated success in bringing together the main players in the aviation and aerospace cybersecurity, ERAU will continue to organize the Aero-Cybersecurity Symposia, the next edition being scheduled in December 2022.

Figure 3: Aviation Cybersecurity Research Opportunities in the ERAU Center for Aerospace Resilience.

The new Center for Aerospace Resilience (CAR), located within ERAU's Research Park, provides access to specialized labs, computational resources, and test facilities to enable state-of-the-art research in the aviation and aerospace cybersecurity domain. An outline of CAR areas of research is shown in Figure 3 and covers to a large extent the entire aviation ecosystem: IT/OT security, aircraft lifecycle security, satellite and navigation security, ground systems security, and datalink communications security. The CAR facilities include hardware and software equipment that supports research engineers and students on a broad range of topics that focus on the design, development, and implementation of models and tools for security assessment and protection of avionics systems and airborne platforms, and the broader aviation ecosystem cyber resilience.

ERAU students are supported in their aviation cybersecurity education journey through prestigious scholarships and internships from federal agencies and well-known aviation companies. As part of their extracurricular activities, students from all ERAU campuses have designed and developed a large number of Capture the Flag (CTF) competitions in the last years. Aviation enthusiasts and expert leaders participate in the ERAU-hosted CTFs, which challenge them to quickly analyze digital systems and capture secret hidden messages, further developing their technical and research abilities. The CTF challenges cover all areas of aviation and aerospace cybersecurity research carried out at ERAU CAR's center. Capita¬lizing on their CTF expertise and through a partnership with A-ISAC, ERAU students created and organized the last four editions of the A-ISAC CTF Competition. Also in the last two years, ERAU students developed and organized CTF competitions at high-level well-known cybersecurity events: DEFCON Aerospace Village, AIAA SCITECH Forum, RSA Confe¬rence, and AIAA Aviation Forum.

Conclusion

Aviation's impeccable safety culture positions it well to combat and defeat cyber-safety risks. In the years ahead, the aviation industry will need to invest in expanded education and training as well as research to ensure high-assurance systems that can be continually updated with minimal impact on certification, thus integrating cyber resilience into the aviation ecosystem. Threats to the aviation ecosystem are dynamic and multifaceted and they can propagate from one actor of the ecosystem to another. Proactively addressing and mitigating threats require complementary security methods, and a collective effort of all aviation ecosystem so that implemented security measures create resilience against both expected and unexpected risk.

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Impact of COVID pandemic on Air Navigation Service Providers – European Level and Case study Bulgaria

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Introduction

According to www.collinsdictionary.com, resilience means the state or quality of being resilient. Something that is resilient is strong and not easily damaged by being hit, stretched, or squeezed. The paper will describe the unique combination of the evolution during the second reference period (2015-2019 RP2) followed by the impact of the pandemic during the third reference period (2020-2024 RP3). It would also look into some key features of the ANSPs and some possible measures they could have undertaken to mitigate the effects. It would further elaborate how uncertainty on traffic evolvement affected and will impact service provision.

Some ongoing legislation changes in the beginning of RP3 and the lack of certainty in respect of legislation development until finalised combined with unclear perspective how traffic would evolve provided for an environment where ANSPs had to make very difficult choices between providing services in pandemics, continuation of investments, preservation of key personnel and cost cutting, given both the existing or under development EU regulatory framework. All such decisions on which way to go have immediate impact on safety and quality of service provision, as well as on their financial situation in the short- and medium-term.

Traditionally ANSPs have been supposed to be resilient in terms of safety and capacity under the application of the full cost recovery mechanism. However, under the determined costs method and the application of SES performance scheme there is no guarantee that ANSPs costs will be covered in all circumstances.

The paper represents an expert opinion and will investigate how various decisions, facts and actions of stakeholders might affect activities and the situation of ANSPs over time. Resilience has different dimensions, and there is strong interdependency between the financial and operational side because the short-term financial effect has a medium- to long-term capacity effect paired with uncertain traffic evolvement.

Resilience – Setting the scene over RP2 (2015-19) and RP3 (2020-24) for EU and non-EU ANSPs (exogenous factors)

From running at full throttle to complete halt

With the start of the Wuhan lung disease in December 2019 and the global spread during the Q1 of

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2020 the aviation and ANS industry were affected most severely as never before in Europe. Only within two weeks, starting from mid-March 2020, passenger flights worldwide were practically ceased and air traffic levels in Europe plummeted by approximately 90%. To make things even more complicated, European ANSPs were highly likely unprepared for such evolution of events, which followed abruptly after several consecutive years over RP2 of ongoing traffic increases and of record delay levels during these years. The available forecasts for the development of flight numbers in 2019 during RP3 planning phase were for further traffic growth meaning that the main focus of ANSPs activity should have been on spending on and investing in human resources and ANS technology for catching up with capacity delivery and coping with delays. An additional detail to this was that all else being equal, because of high traffic and forecasts for additional growth, en-route unit rates, the main source of ANSP financing, were set at relatively low levels at the outbreak of the pandemics.

Unclear way forward what is next

Such evolution has been accompanied by the lack of a reliable perspective when and if this shock will be ended. It has turned out impossible to produce reliable scenarios for traffic recovery in the early days of pandemics development and forecasts at the time could be easily qualified as speculations, as any development could materialise. The first forecast produced by the NM in April 2020 indicated relatively rapid recovery before being replaced some five months later (September 2020) by forecasts of much slower rate of traffic restoration. Developments were also impacted to a large extent by diverse and uncoordinated measures at national level applied by the states regarding passenger flights to limit the spread of the COVID-19 pandemics. A fragile optimism over the summer of 2021 was replaced by new measures in Q4’2021 to contain the spread of Delta and Omicron variants. Nevertheless, the measures taken, lessons learnt, and experience gained during the years of 2020-21 allowed for recovery of traffic over Q2 of 2022. Outlining of the development from today’s perspective could be considered well-known and useless, however it is important mentioning it here, as it is essential to identify the extremely high level of business uncertainty in which ANSPs have had to continuously ensure safety of flights and future performing of state functions. And this turned out to be especially challenging in the SES performance scheme context.

Looking backwards, from the perspective of April 2020, an outcome as of the end of the 2020 where traffic would recover at 75-85% of initially forecasted levels, would have meant that COVID situation is not something so unusual and that all the developments are to be considered short-lived, temporary, and easily to be overcome by ensuring some additional liquidity. While if a forecast existed that the traffic on an annual basis would reach some 40-50% of the forecasted traffic followed by a slow recovery in 2021, and maybe additional contracting of flight numbers, potentially would mean that a scenario for reduction of levels of activity should have been applied, thus having more significant impact on capabilities to ensure service provision over medium- and long-term. Therefore, such level of uncertainty for a diametrically opposite possible evolution results in a dilemma in front of the ANSP – to cut costs, investments and activities in order either to mitigate burning of cash or minimizing the amount of the additional external financing or to ignore lack of financial means in the short-run (not knowing how short it might be) while focusing on medium- and on long-term development of service provision by developing their potential and capabilities for service provision so as to be prepared to provide safe and high quality service when traffic is back to high levels. Either choice and decisions have their strengths and weaknesses, as well as their footprint on current or future ANSP capabilities. It is of essence to bear in mind that all such decisions could not have been and cannot be taken outside the existing legislative framework and where applicable performance scheme.

Legislative and Regulatory framework for charging of air navigation services – ensuring liquidity and preserving capabilities to generate revenue

There are two main methods under which air navigations services in Europe have been charged – the classic one, i.e., full cost recovery method, and the determined cost method under SES performance scheme. The impact of these methods on the ANSP capabilities to generate revenue and generate liquidity varies, as:

- Under full cost recovery method, there is no explicit regulation on operational and financial performance of ANSPs and non-EU states adjusted the en-route unit rates more quickly starting from 2021 and were able to start recovering 2020 losses via the adjustment mechanism from 2022 onwards, based on the existing legislation (EUROCONTROL Principles).
- Under the determined cost method, EU-member states adapted their unit rates starting from 2022 while being allowed to recover (part of) 2020-2021 losses over a period of five to seven years starting from 2023, provided that their RP3 performance plan had been approved in 2022. In case the draft performance plan is approved in 2023, the recovery of 2020-2021 losses would last from 2024 until 2030. To ensure alignment of such course with SES Performance scheme, special EU legislation for the years 2020-2021 was adopted, while there have been debates, if the SES performance scheme should be suspended until a reliable traffic forecast can be produced.

Despite those two methods, a vivid example of handling the situation and of early amendment of the unit rates outside Europe were the actions of the privatised NAV Canada, which have increased charges by 30% starting from September 1, 2020.

It might be summarized that the ANSPs of the EU member states had to ensure additional liquidity and to operate at least 26 months under conditions and unit rates which deviated from the assumptions under which a draft performance plan had been elaborated and submitted for assessment, while the non-EU ANSPs had to that for half of that time. Additional pressure on the liquidity of the ANSPs of EUROCONTROL member states was caused by the decision for deferral of en-route charges for the flight months of February to May 2020 by up to 13 months, accompanied by decisions of some states for a deferral of TNC charges.

Besides the impact of legislative framework on ANSP liquidity, it is more important to outline the impact of the legislative framework on the capabilities of the ANSPs to generate revenues as well as to recover losses, since due to the discussed changes at EU level there was not much certainty to what extent this would be possible. The capabilities of the ANSPs to generate revenue could be achieved only through balanced legislation considering the interests of all stakeholders.

Resilience – ANSPs' features and endogenous characteristics. How ANSP resilience is linked to the operations of airlines

High operational leverage and attributable financial risk

ANSPs perform state functions under Chicago Convention. As such they ensure 24/7 service provision related to the development and maintenance of critical infrastructure. Such activities do not vary significantly in line to fluctuations of traffic volume. As a follow up, the costs of the ANSPs are predominantly fixed, since all requirements and prerequisites for service provision, to ensure safety of flights are to be met irrespectively of traffic volumes (high operational leverage). This means that despite the general perception that ANS provision is a low-risk activity, ANSPs might be vulnerable especially when revenues decrease sharply in periods of significantly lower than planned demand due to the fixed nature of activities and their costs. Thus, the right return on equity has to be properly assessed and reflected when establishing the cost base in both, good and bad, times, as this is crucial for the resilience of ANSPs and is a proper source of financial strength. The latter is an essential requirement for the ANSP to hold a valid certificate. The financial risk related to the activities of ANSP is not so obvious but is existent and implicit. And, if continuously overlooked and underestimated would negatively impact the resilience of the ANSP and therefore jeopardise the financial stability of the ANSP.

Competence scheme for operational staff and complex investment projects. Minimal time horizon of operations

ANSPs follow well defined rules and procedures related to their operational staff and activities, which cannot be overridden, as they are linked directly to safety of flights. Duration of ATCOs training process lasts between 2-4 years in various ANSPs. Successful implementation of key investment projects and commissioning of investments, especially those related to ATM systems, are of complex nature and often are a slow process because of high safety standards to be met. Their length and the resources involved put forward an alphabetical truth related to the minimal planning horizon of ANSP activity – it should be at least five years ahead. To ensure sustainability, plans are to be in place for some seven to ten years ahead. Shorter time horizons simply do not work for the ANSPs, no matter how flexible they are in responding to a changing environment and volume of traffic. Therefore, ANSPs should be responsive to short-term deviations from the forecasts however, strategically they are to be more focused on delivering capacity over the medium- to long-run.

Operational and financial resilience

ANSPs must be prepared to provide services to planned traffic levels, as there is no contract signed between them and airspace users on the exact number of flights to be handled neither in a year nor over a given longer (reference) period. To reflect this situation there are mechanisms to offset the differences between forecasted and actual traffic demand and costs (adjustment mechanism under the full-cost recovery method and traffic risk sharing mechanism under the determined cost method accompanied by article 29 of Regulation (EC) 2019/317 where applicable).

ANSPs are tasked to ensure safety of flights to all traffic, they should maintain flexibility to service higher than planned traffic levels, and be able to cope with traffic demand if it cumulatively exceeds initial forecast. As international and domestic air travel has been growing continuously, despite some short-term crisis and events, the bigger risk from operational point of view for the ANSPs is that are not capable of ensuring safety and zero (or close to zero) delays service especially to high traffic numbers. In view of the implicit duration of ATCOs training processes and implementation of new investments, a conclusion could be made that ANSPs should develop operational capabilities continuously. It is critical from ANSP perspective to properly determine the length of periods when (and if) the development of such capabilities is ceased because later it is often impossible to catch up with the acquisition of the resources needed regardless of the costs spend at a later stage. Traffic ramps up much faster than the speed at which ANSPs generate resources. In support to the continuous development of ANSPs capabilities is the fact that the ANS charges amount to some 5% on average of airline costs, these are 100% variable costs and airlines do not prepay it, i.e., continuous development of ANSP capabilities should not turn out to be a big burden to the airspace users while distortions of service daily due to malfunctioning infrastructure at high traffic levels could turn out to be. Therefore, to be operationally resilient ANSPs should be able to deliver required resources to service traffic, especially when flight numbers are high.

ANSPs, however should be able also to maintain operational resilience in situations where traffic demand is cumulatively below forecast and when financial resources are limited. In such conditions the conduct of ANSPs should not be such that their plans and activities are done regardless of the costs and level of charges (the latter tend to increase when traffic is low due to the highly portion of fixed ANSP costs). ANSPs should take proper and responsive actions within the existing limitations, subject to a situation with low traffic levels and low flights demand and should do their best to limit the financial burden which is to be passed to the users in the future. ANSPs should act and limit costs in such situations but such actions should not be detrimental to their capabilities to provide services. Moreover, ANSPs are mainly autonomous entities, separate from the state, even though they perform state functions. As stand-alone entities good and reasonable financial management and close links between operations and finance should be the rule ensuring resilience, while external help should be an exception.

Therefore, ANSPs should be predominantly operationally resilient when traffic is high and predominantly financially resilient when traffic is low. They have to be able finding ways to ensure safety and elaborate their capabilities in the proper ways until the balance between the outgoing costs for running and development of the operations and the incoming revenues is achieved.

How is the resilience linked to the airspace users?
And is there a mutually beneficial best forward for the ANSPs and for the airlines?
Costs for ANS charges are a very small portion of airlines costs, airlines do not invest in advance in

infrastructure because they pay for the use of critical ATM infrastructure only when they fly some 60 days on average after the flight is being performed. The costs of airlines for charges vary directly in proportion to the volume of their activities. ANSPs are the ones that are being paid one of the last in the queue, and generally, if calculations have been done correctly by the airlines, ANS charges are to be funded either by the money of the passengers who buy tickets or companies ordering cargo flights, not by the airlines' own funds. Thus, it could be concluded that airlines do not effectively bear the costs for the use of infrastructure when they do not fly, but they would be asked to recover the losses of the ANSPs provided that the charges had been low because of non-materialised (high) traffic forecast in times when there is recovery of demand for flights. In the times of crises, the real problem on the airlines side is not the ANS charges costs, which are variable ones, but are their own fixed costs such as the lease of aircraft, insurances, staff costs, etc. Fixed costs of airlines should not be funded either via postponement or savings of variable costs, since such practices would create structural financing and funding problems and increase financial risks within and for the airlines.

On the other side, ANS charges represent maybe in most cases some 100% of ANSPs' funding sources, taking into account the extent of either debt use or on the availability of grants or subsidies to finance activities. Therefore, cutting the capabilities of ANSPs to generate revenue and to recover costs from charges is not of significant importance for the airlines to survive in bad times but would critically impact the operational resilience and capabilities of the ANSPs and would fire back to the airlines and impede their recovery in good times. Even the "financial demise" of the ANSPs (zero charges, no recovery of losses in bad times, etc.), is not equivalent and would not contribute to the salvation of the airlines in times of crises.

Of course, mutual understanding should be always pursued, and air navigation charges shall be such that they encourage the use of air navigation services and facilities. Though safety and capacity are the primary focus of ANSP, these shall be provided in a cost efficient and flexible manner, which considers traffic levels and are not delivered at prohibitive or discouraging charges levels.

Is there a tool that could steer and facilitate ANSPs' Resilience well in advance?

There will always be arguments between airspace users and ANSPs on the delivery of service provision and the lowest possible price. Sometimes, such demands on airlines side are close to unrealistic and even short-sighted, especially in times of crisis. This is completely understandable – airlines have to survive the current year to be able to continue operating in future. Operational and financial resilience of ANSPs cannot be achieved out of the implemented regulatory framework. As there is an implemented performance scheme in the EU where four key performance areas are in the spotlight, it is more than needed to implement a realistic and balanced interdependency model. It would facilitate, based on realistic forecasts, calculations, and simulations, what would be the best and optimised solution for the way forward over a given reference period, taking into the starting point and the recorded historical performance versus system wide targets. It is important not to undermine performance in the key performance areas of safety, capacity, and environment over the coming years for the sake of (excessive) cost-efficiency today.

Interdependencies should be taken into account for the purposes of target setting, and trade-offs are to be assessed as envisaged in the SES legislation. Nevertheless, there are neither commonly adopted methodology nor models for definition and application of the interdependencies concept. This impedes the practical application by the ANSPs and provides for numerous and inconsistent interpretations among ANSPs as well as on regulatory side.

The real issues are coming from the combination of qualitative and quantitative dimensions of interdependencies and the lack of common denominator, i.e., to assess and quantify all/main qualitative parameters and monetise them via their respective values. The absence of official recognition of such approach makes it difficult, if not impossible to meaningfully measure interdependencies. Obviously, cost efficiency is a quantitative dimension, however the quantitative side of capacity and environment key performance areas are being somehow neglected in the assessment of performance plans. Because of the lack of clear methodology for interdependencies, it is not clear when the financial cost effectiveness is applied and when economic cost-effectiveness is applied. Performance planning (and the attributable resilience balance between operational and financial side) is about economic cost effectiveness planning i.e., safety, capacity (costs of prevented delays) and environment (saved emissions due to more efficient trajectories) depending on traffic, are achieved at the respective cost. But somehow these economic costs tend to be overlooked when the draft PP is being assessed because the focus is predominantly on financial cost effectiveness. Therefore, the outcome could be poor quality of performance due to unrealistic planning when total economic costs of a performance plan are not addressed. A key strength of the performance planning and the adoption of a balanced interdependency model would be that the preventive role of the actions of the ANSP would be ultimately recognized and subsequently enhanced. It is much more overly efficient to act in a preventive manner not allowing for a problem to escalate rather than catching up and trying to put out fires once an undesirable situation occurs.

Such model would steer with higher level of confidence the ANSP to the proper activities to be implemented – development of operational capabilities, thus becoming more operationally resilient, or more focus to be given to the financial resilience by limiting costs for the delivery of the optimal operational solution. It would also make it easier for the ANSPs as well as for the airspace users to have better awareness of the strategically correct decisions to be taken in each situation.

Case study – BULATSA

Regardless of the official recognition of the interdependency models in official legislative papers and documents, as part of the performance planning process, BULATSA have applied an interdependency model reflecting interdependencies among the four KPAs being part of the SES performance scheme. An important ingredient of it is the exponential growth of delays when the capacity limits of the system are being approached, as shown in figure 1.

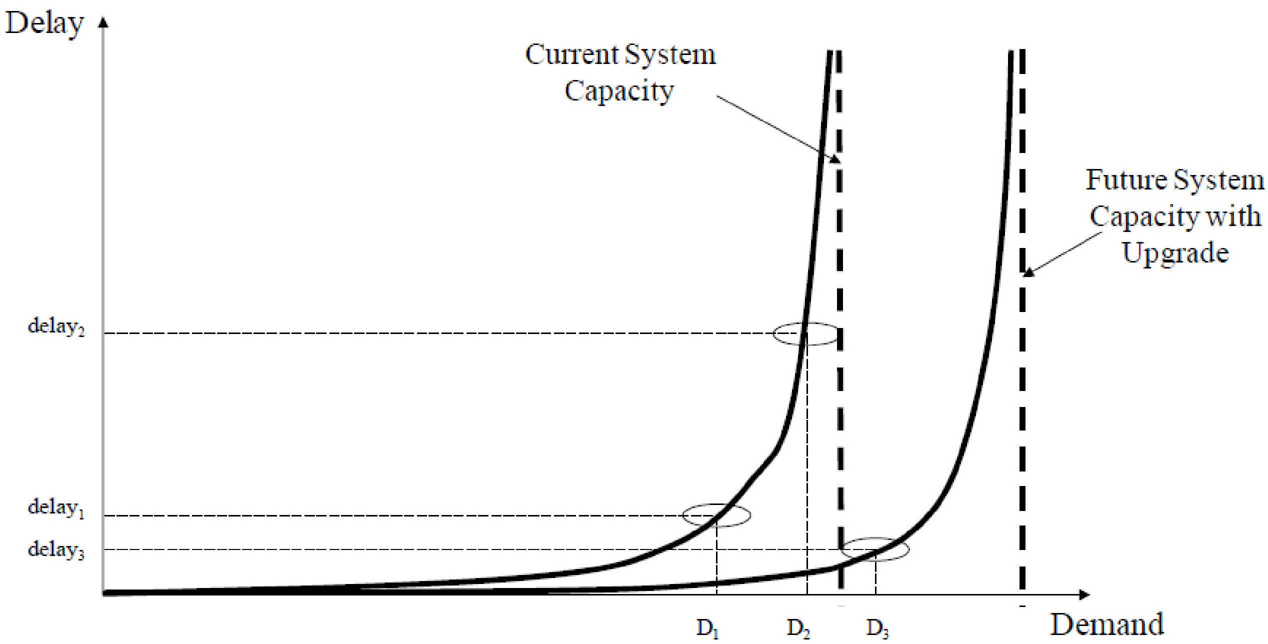

Figure 1: Illustration of the relationship between delay, demand, and system capacity

Source: Hansen, M. and B. Zou (2011). Airport Operational Performance and its Impact on Airline Cost. DOI: 10.1002/9781118535844.ch5

The interdependency model also considers interdependencies with environment KPA where necessary, while safety is being ensured either through direct activities and investments related to safety or through established parameters in other KPAs which shall not be breached, such as sector capacities, maximum ATCOs working hours, duplication of systems, etc.

The application of such model has facilitated the continuous application by BULATSA of a preventive policy, and therefore allowing for lead time to enhance resilience. This requires constant monitoring of traffic scenarios development in the short-, medium- and in the long-term and applying well in advance and in time required measures.

Situation in Ukraine in 2015–19 and impact on BULATSA activities and performance

It has started evolving at the time when RP2 performance plans were about to be drafted and submitted. Taking over of Crimea peninsula in March/April 2014, the non-use of Simferopol FIR airspace overnight followed by MH17 accident in July 2014 and the closure of Dnipropetrovsk FIR airspace resulted in +40% increase of traffic through Sofia FIR airspace in 2014 vs. 2013. Flight numbers continued to grow in 2015-16 without any clear perspective if the use of Simferopol FIR would be resumed by airspace users, as various regulators and EASA stated that it is safe flying there, but airlines have not followed such advice. This has introduced big uncertainty in terms of future traffic levels and imposed significant risks on BULATSA to deliver capacity, which might turn out to be futile. After numerous consultations and analyses, based on the assumption that the resolution of Simferopol FIR situation will not be short-term, actions to revise the submitted RP2 performance plan have been undertaken, to ensure proper level of financing to deliver required number of ATCOs and make necessary investments. In addition to the increased number of flights, in the second half of RP2 BULATSA had to prepare to control more actively arrivals and departures to the new Istanbul airport (LTFM). This would contribute to the increase of complexity of operations due to its closer proximity to the border and the implementation of X-MAN.

To manage traffic levels BULATSA has implemented a set of extensive measures (recruiting and training additional new ATCOs, new investments related to the increase of sector numbers, traffic flows management, proper communication and surveillance equipment, ATM system upgrades, etc.), as well as intensive measures (very flexible roster scheme initially comprising 12 ATCO shifts subsequently increased to 22 shifts) and ATCOs cross training to ensure availability of operational staff in line with traffic demand profiles. In addition to that BULATSA has elaborated numerous sectors configurations, changed up to 20 times a day in response to flights demand, as well as has implemented a new interface at the border between Turkey and Bulgaria allowing for the increase of capacity of airspace.

As an outcome, BULATSA serviced some 900,000 flights annually in 2018-2019 (about 500,000 in 2013) without any delays at an en-route unit rate of 30 Euro.

Developments in 2019 and over RP3

Due to the enormous interest to the airspace of Simferopol FIR, there was further ease on the regulatory side for its use. As a follow up, the main airlines flying there were those of Ukrainian nationality, accompanied shortly by Qatar Airways in September 2019, followed in 2020-21 by some other European (Lufthansa, Swiss, Austrian, Wizz, LOT) and Asian carriers (Geo-sky, Silk Way West. El Al, Flydubai). This has introduced further uncertainty in BULATSA activities, since if the use of this airspace is resumed, the result would be a major outflow of traffic from Sofia FIR., and in view of the developments over RP2 and resources acquired, then the primary focus would need to be changed from operational resilience to financial resilience, at least until unit rates are adapted to the new reality. In 2019, after assessment of the risks a draft performance plan with the assumptions of high traffic scenario and limited use of Simferopol FIR airspace was submitted, with an en-route unit rate of below 30 EUR. 2020 started quite turbulently for BULATSA because of the tension between Iraq and Iran in the beginning of January, which resulted in re-routing of flights to/from the Gulf of numerous and major carriers, followed by COVID-19 pandemics. To manage this situation and to continue financing operations at very low unit rates, BULATSA has:

- elaborated a plan on the preservation of operational and technical capabilities
- immediately cut salaries from March 2020 for all staff by 30% for more than 24 months. All performance related payments under the collective labour agreement were also ceased
- Organised ATCOs in teams to reduce spreading of COVID-19 among operational staff and allocated part of the ATCOs to work on projects
- limited all operating costs to those necessary to maintain operations, only

- prioritised investments to projects which were critical to safety and capacity, and which were well advanced and could not be stopped.

Outcome

The use of the model and the measures applied have worked quite well. BULATSA managed the crisis without neither using any state aid nor loans. Staff and technical capabilities were preserved and ANS services are currently provided at 2019 traffic levels without any delays. According to the submitted and approved RP3 PP, unit rates would be kept at around 35-37 EUR, which is very close to precrisis levels, and are ones of the lowest in Europe.

BULATSA has managed to prioritise successfully its medium- and long-term goals over short-term liquidity crunch in 2020-2021. By the application of a preventive policy and based on sound analysis for the necessary measures, while being facilitated by the adoption of balanced EU legislation (e.g., Regulation 2020/1627, Decision 2021/891) BULATSA managed to avoid pro-cyclical effects of excessive cost cutting in 2020-2021 thus not allowing for weakening of the robustness of its ATM System.

Therefore, as a practical conclusion, significant cost cuttings related to the ANS services should not be put in place, even in bad times, as they would impede the recovery and the development of air traffic industry. ANS provision is a vital state function which is to be delivered in a cost-efficient manner, but it should not be treated as a commercial business activity.

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Network-oriented planning of cross-border capacity provision to increase resilience and improve performance

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Abstract

In this paper, we present the results of a comprehensive simulation and optimization approach to determine the benefits of cross-border capacity provision in a redesigned European air traffic management (ATM) value chain. We create a range of different scenarios for the day of operations (tactical level), which repre¬sent materializations of traffic levels and distributions, to analyse how the availability of cross-border capacity provision affects key performance indicators such as flight delay, additional fuel consumption (from re-routings) and the overall cost of the system. Based on how different capacity decisions perform in these scenarios, at the strategic level we infer the number of air traffic controllers (ATCOs) that might provide cross-border services for each air navigation service provider (ANSP). We apply the modelling approach to a large-scale case study covering traffic on the busiest day in Europe in 2018 across almost the full ECAC-area in order to show the potential effects of different design options for cross-border capacity provision. These design options differ in the extent of cross-border collaboration, e.g., sharing agreements within or across ANSPs. One important result is that cross-border capacity sharing can realize very low remaining levels of displacement cost while requiring only a small portion (less than 3%) of resources to be reserved for capacity sharing. Further¬more, next to reducing overall network cost, having cross-border capacity provision also results in a more stable network performance (in terms of flight delays and re-routings) in the case study.

Introduction

Unanticipated traffic fluctuations as well as unexpected staffing issues or weather phenomena might lead to demand-capacity imbalances in some parts of the European ATM-network, causing disruptions also in other regions and thereby negatively affecting overall network performance. One option for increasing the resilience of the network is capacity-on-demand service, that is, a delegation of the provision of air traffic services to an alternate provider with spare capacity. There are already some examples for this type of cooperation (e.g., FINEST), but there are also several restrictions (e.g., ATCO-licensing and challenges related to costs and charging) that have to be taken into account. Consequently, it is important to understand the potential advantages of such cross-border capacity provision and, in particular, the effects of different design options for cross-border cooperation.

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CADENZA simulation and optimization approach: An overview on methodology and data

Within the SESAR H2020 project CADENZA (Advanced Capacity and Demand Manage¬ment for European Network Performance Optimization) we developed a comprehensive simulation and optimization approach for capacity planning and test it on actual data for en-route airspace across the European network (almost entire ECAC area). The approach, which also builds upon Ivanov et al. (2019), Starita et al. (2016), and Starita et al. (2020), will be briefly summarized here, a more detailed description can be found in Künnen et al. (2022).

The main challenges in capacity planning for the European ATM network are two-fold: 1) the capacities for each ACC need to be decided early in the process (strategic phase) when information on traffic demand and weather is still uncertain, and 2) assessing the potential costs associated with a capacity decision requires solving a hard routing problem. In order to incorporate uncertainty in the decision-making, we evaluate each capacity level on a range of >100 scenarios, each of which reflects a different materialization of traffic volume, weather and ATCO availability. Furthermore, to determine the expected effect of each capacity decision on network performance, we develop an efficient routing heuristic that helps us approximate these cost in reasonable time. In contrast to existing capacity planning models (which decide on 'optimal' capacities deterministically, i.e., one scenario at a time), we determine stochastically-optimal capacity levels. It is this feature that also allows us to apply the procedure to determine the 'optimal' number of ATCOs to be trained for cross-border capacity provision.

We apply the developed optimization approach to a large-scale case study covering 35,000 flights (i.e., one full day of traffic) across Europe. On the capacity side we include 118 area control centres (i.e., airspaces) across 40 ANSPs in the ECAC area, which also includes seven terminal airspaces surrounding slot-coordinated airports. On the demand side, we include all flights in the selected network on September 7, 2018. In order to take into account the significant level of uncertainty on the capacity as well as on the demand side, we use a large number of scenarios. On the capacity side, the different scenarios cover reductions in available capacity (especially due to weather or unexpected staffing issues); the assumed likelihood of these events in different regions is based on historical observations. On the demand side, we combine scheduled traffic (as observed in reality) with a random selection of non-scheduled flights, taken from a pool of actual flights in the respective airspace.

Within our simulation approach we analyse total (variable) cost, in particular the cost of capacity provision (i.e., ATCO hours) and the cost of capacity shortage, causing delays, re-routings and additional CO_2 emissions. Not surprisingly, with respect to the number of sector hours we get a U-shaped total cost function, showing the trade-off between the cost of providing capacity and the cost of lacking capacity.
The CADENZA simulation model can be used to answer a large number of different questions. In particular, we can show that a network-centric capacity management, for example a network manager that decides on capacity provision in different airspaces within predefined limits, combined with a network centric demand management, i.e. the network manager also has some instruments at hand to influence

demand with respect to time and space, leads to lower total cost than a more decentralized decision making on the capacity and demand side (for details see Künnen et al., 2022). Moreover, we can show that the optimum number of sector hours depends on several exogenous variables, such as fuel costs and traffic intensity. In particular, higher fuel cost (e.g., due to CO2 surcharges on fuel consumption) and higher average traffic volumes increase the optimum number of sector hours.

Different options for cross-border capacity provision

The benchmark for analysing the potential advantages of cross-border capacity provision is a situation without capacity sharing (we call this the 'baseline' setting), basically representing the status quo in the industry on the capacity side. The capacity levels in each ACC (in terms of the number of ATCO hours to be provided) are taken from the levels reported by ANSPs for September 7, 2018. However, it should be noted that on the demand side the baseline setting already incorporates some demand management measures, improving the network performance compared to the status quo.

The idea behind cross-border capacity provision is to allow some flexibility between pre¬defined pairs/groups of ACCs ('alliances'). In other words, we assume that a given number of ATCOs in an ACC 'A1' might also control traffic in ACC 'A2', and vice versa. There are several options for forming these pairs of ACCs, e.g., regional proximity, use of the same technology provider, or similarity of traffic patterns. In this paper we consider two different setups or alliances: In the first setup, we allow sharing of resources among ACCs that are part of the same ANSP (a concept we call 'cross-ACC sharing'). In the second setup, we extend the level of flexibility by allowing capacity sharing among all ACCs that are part of the same functional airspace block, or FAB (i.e., truly 'cross-border sharing').

Assumptions for analysing cross-border capacity provision

All else equal, an ATCO that can control traffic in several airspaces will cost more than an ATCO that can 'only' control traffic in one airspace. These costs are basically fixed costs for additional training. In our model we however treat them as variable costs per sector hour, as the aim is to determine the optimum number of ATCOs that should receive the additional training. As there are currently no such ATCOs, assumptions on additional costs are to some degree arbitrary. We assume that flexible ATCOs cost 10% more than the average of the non-flexible ATCOs in the alliance. Of course, a sensitivity analysis is possible, assuming other cost mark-ups for 'flexible' ATCOs.

Our aim is to analyse cross-border capacity provision as a 'hedge' against uncertainty regar¬ding capacity provision and traffic flows. However, if the wage level within an alliance differs between the respective ANSPs, it might also be possible to 'outsource' services, i.e. substi¬tuting own 'expensive' ATCOs with cheaper 'flexible' ATCOs from another ANSP. In order to avoid such incentives, we assume that the number of ATCO hours provided by each ACC in the cross-border setting must not be smaller than the number of ATCO hours in the baseline. This assumption prevents cross-border capacity sharing that is only motivated by different ATCO wage level in different countries.

Results

Table 1 summarizes the results of 100 different scenarios. As mentioned above, we would like to point out that the results for all settings (including the baseline setting) are derived by using the CADENZA network centric demand management approach, i.e., displacement costs are already below the actual values in the European ATM network.

Table 1: Variable ATM cost for different capacity sharing settings (n = 100 scenarios)

Approach	Capacity cost	Displacement cost	Network cost	Savings
Baseline	5,012,019	757,205	5,769,224 ± 81,438	
Cross-ACC sharing	5,027,930	630,314	5,658,244 ± 70,375	-110,980 (-1.9%)
Cross-border sharing	5,026,039	586,300	5,612,339 ± 66,516	-156,885 (-2.7%)

Introducing cross-border capacity provision reduces total costs, as the reduction in displace¬ment costs (i.e., less delays and re-routings) exceeds the additional cost of capacity provision. Although the largest savings of almost 3% are achieved in the cross-border sharing setting, variable cost savings through cross-ACC sharing are still at 1.9%, indicating that capacity sharing within ANSPs is already sufficient for generating large benefits. Moreover, the variation in network cost is reduced in both settings for capacity sharing, showing that flexibility reduces the impact of large distortions in the network. Additional analysis shows that, in fact, total cost in the baseline setting exceeds total cost in the flexible settings in each scenario. Consequently, also from an equity perspective, advantages of providing more flexibility can be observed.

Table 2 highlights another important finding in the case study: In order to reap the benefits from capacity sharing, only a small portion of the total capacity need to be provided 'virtually', or for capacity sharing. Overall, only 595-720 sector-hours (or 2-3%) of flexible capacity were required in the simulation. A detailed analysis of the results shows that in most scenarios, only one ATCO hour is shifted from ACC 'A1' to ACC 'A2' or vice versa. Conse¬quently, the number of ATCOs that would have to be able to perform cross-border services (and that would need to be trained to perform such services) is rather small.

Table 2: Capacity levels (in sector-hours) for the different settings

	Local	Virtual
Baseline	22,097	-
Network-centric	20,871	-
Cross-ACC sharing	21,377	720
Cross-border sharing	21,502	595

Limitations and future work

Apart from legal and practical restrictions with respect to cross-border capacity provision, the additional costs of enabling such kind of flexibility play a crucial role for a potential im-plementation. It is quite obvious that the (monetary) benefits of providing cross-border flexibility decrease with increasing cost of enabling such flexibility. Assuming that the use of the same technology reduces additional training costs, one might rather pair ANSPs based on their technology than based on their location and regional proximity.

Given the large number of flights and options for capacity provision (sector opening schemes), we have to resort to using heuristics and simplifying assumptions in the optimi¬zation in order to obtain a solution within a reasonable timeframe (computation time). For analysing even larger case studies we have to modify the model, which to some degree might also affect the results.

The case study presented in this paper is based on a very busy day in the European airspace. One might argue that for less busy periods there might be smaller gains of cross-border capa¬city provision, as there are lower displacement costs in the local setting. On the other hand, there is still some probability of unexpected capacity shortages (e.g., ATCOs that cannot work due to health reasons). Whereas in the baseline setting each ACC would have to provide its own capacity buffer (e.g., ATCOs on 'standby'), costs for such buffers would be reduced in the cross-ACC and cross-border settings even in periods of low traffic. This effect is not covered by the current CADENZA model which only analyses the number of sector hours and not the number of ATCOs needed to provide theses sector hours. Consequently, the CADENZA team is already working on a model that combines the traffic and capacity provision simulation with an ATCO rostering model (Pavlović et al. 2022).

Conclusions

In this paper we summarize the results from applying the CADENZA simulation and optimization model to decisions on cross-border capacity provision. For a case study representing a busy day in the core European region we show that large benefits can be generated by introducing flexibility with regards to capacity sharing into the network, in which only small share of ATCOs is required to control aircraft also in sectors that belong to a partner ACC. The rationale is quite simple: If an unexpected shift in traffic leads to over¬capacity in one ACC and a lack of capacity in some other ACC, ATCOs that are not needed in one ACC might provide services in the other ACC. Consequently, delays and re-routings (implying additional fuel consumption) can be avoided.

In the model presented in this paper, cross-border capacity provision reduces distortions in the network caused by traffic volatility, which implies some reciprocity between ACCs within an alliance. Even in cases of a longer lasting traffic shift, e.g., caused by longer lasting military activities, cross-border capacity provision might be beneficial. In the case that such longer lasting shifts lead to unidirectional cross-border capacity provision, ANSPs would have to negotiate on compensation payments for service provision. However, if the entire European airspace is simultaneously affected by a large disruption leading either to a boost in traffic or a huge crises (like in the case of the COVID-19-pandemic), cross-border capacity provision cannot solve the resulting issues.

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Achieving supply chain efficiency and resilience by using multi-level commons

Florian Lücker[a]

Abstract

COVID-19 has disrupted the flow of materials, information, and funds in supply chains in many industry sectors. Lockdowns caused disruptions in the flow of material and information resulting in sharp demand declines as well as supply shortages. Fund flows were disrupted when firms refused to offer trade credit to their customers, resulting in sudden increases in working capital needs for many firms. Despite these disruptions, some companies managed their supply chains through the pandemic successfully.
To explain why some firms' supply chains managed to thrive during the pandemic and others did not even survive, we present the concept of "commons" at multiple levels. The notion derives from shared land in an English village where all the people in the village can graze their sheep. In a similar vein, we consider commons for a supply chain to be a set of pooled resources for the flow of information, product, or funds. The resources might be pooled at different levels – within a company, within an industry, or across multiple industries. Regardless of the level, firms can use access to some commons to improve both efficiency and resilience of their supply chains.

Further, having access to a commons lowers the cost of implementing resilience-building strategies such as investing in flexibility or buffers (such as inventory and capacity). This is particularly helpful for smaller firms who would not be able to afford investment in resilience otherwise.
This paper emphasizes government-sponsored commons. In various settings- such as the industrial commons in Western North Carolina- the government plays a central role by providing funds or infrastructure to facilitate the effective functioning of supply chains across companies and geographies. Financial help is sometimes needed from the government because the investment required for the commons at this level is either too large for private companies or the benefits are too broadly shared for any single company to be interested. Government-sponsored commons can range from holding stocks to having domestic manufacturing capacity to creating capability in general. The strategic petroleum reserve is an inventory-based commons sponsored by the US government that provides resilience to competing firms that otherwise could not afford this inventory to mitigate disruption risk.

We conclude the presentation with some ideas how commons could help creating resilience in the Air Navigation Service industry.

Full paper

The full paper has been published in a journal and can be accessed here:
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Conflicting business models: How structural differences threaten aviation resilience – and what potential solutions might exist on the ANSP and airline side

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Introduction and research questions

Since 1945 the European civil aviation industry has developed in more-or-less predictable cycles of peaks and troughs of demand. The link between gross domestic product (GDP) output of European economies and demand for air travel in the continent has been the overriding indicator of high-level forecasts for aviation market evolution.

However new factors, unrelated to national economic performance, began to disrupt the European aviation industry. Although the high-level compound annual growth rate (CAGR) figures for the GDP development remained in their historic 2-3% growth range there started to emerge considerable regional and national variations to the high-level figures. New political disruptions (including the Russian invasion of Ukraine in 2014, the prolonged impact of the Arab Spring revolutions and Brexit), along with climate change (leading to unpredictable severe weather phenomena), environmental re-prioritisation (EU Green Deal etc.), industrial developments (aggressive short term route development strategies) and technology innovations (adoption of automated flight planning tools which quickly change city pair routings based on different airline priorities such as 'cheapest', 'fastest' and 'most environmentally responsible' etc.) began to add new levels of volatility into the European air traffic management system.

From the perspective of airspace users, customer demand has changed fundamentally in times of pandemic, so new routines and predictions for passenger trends have yet to be found. This also applies to the precise and consistent planning of flights in certain air spaces and sectors.

The traditional cameralistic governance model combined with a five- to seven-year planned economy, as laid down in the SES regulation for European air navigation service providers, is in fundamental conflict with the highly flexible operational concepts of airspace users. These are based on business plans that change every 14 days due to the lack of long-term predictability of passenger flows. Under these circumstances, two antagonistic business models confront each other. On one hand, we have the Airspace Users with a great capacity to adapt and to react to the binomial demand supply almost instantly, while on the other hand we have the ANSPs with long planning cycles, based on traffic forecasts, with 'locked' financial envelopes for five years as a result of the current economic regulation model[1] and therefore hardly adaptable to rapid changes in assumptions.

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[1] The performance and charging scheme regulation EU 2019/317

Although the recent pandemic crisis has exposed the differences between both business models and the respective management tools available to both sides to mitigate the effects of a crisis, it should be remembered that already in 2018 and 2019 we were witnessing another ‘quieter’ crisis in the European airspace, a capacity crisis, with delays skyrocketing.

In this respect, it is essential to understand the similarities and differences between both businesses in order to survive the next crises. The authors will address crucial aspects both from the ANSP and the airline perspective, such as:

- How do airlines and ANSPs may converge their levels of flexibility in capacity planning?
- How to generate predictability and stability both within ANSP and airline operations?
- How do we align objectives from both partners to optimize the overall benefit of the aviation industry and hence European economy?

To answer these questions, we will need to understand the dynamics of the current air traffic demand market in much greater detail than currently available. In particular, we need to undertake:

- As a result of the above, an examination of business and regulatory models which will allow for both the generation of short-term capacity enhancement measures during times of peak demand and resilient ATM services at a time of greatly reduced demand.
- Amendments to the ATM performance review system and wider regulations to take account of localised, volatile and unpredicted events which impact capacity demand at ATC centre level, or even on sector or daily level. Further amendments will also be required to make target setting more relevant and resilience performance incentivized.

Europe / Portugal Market Dynamics

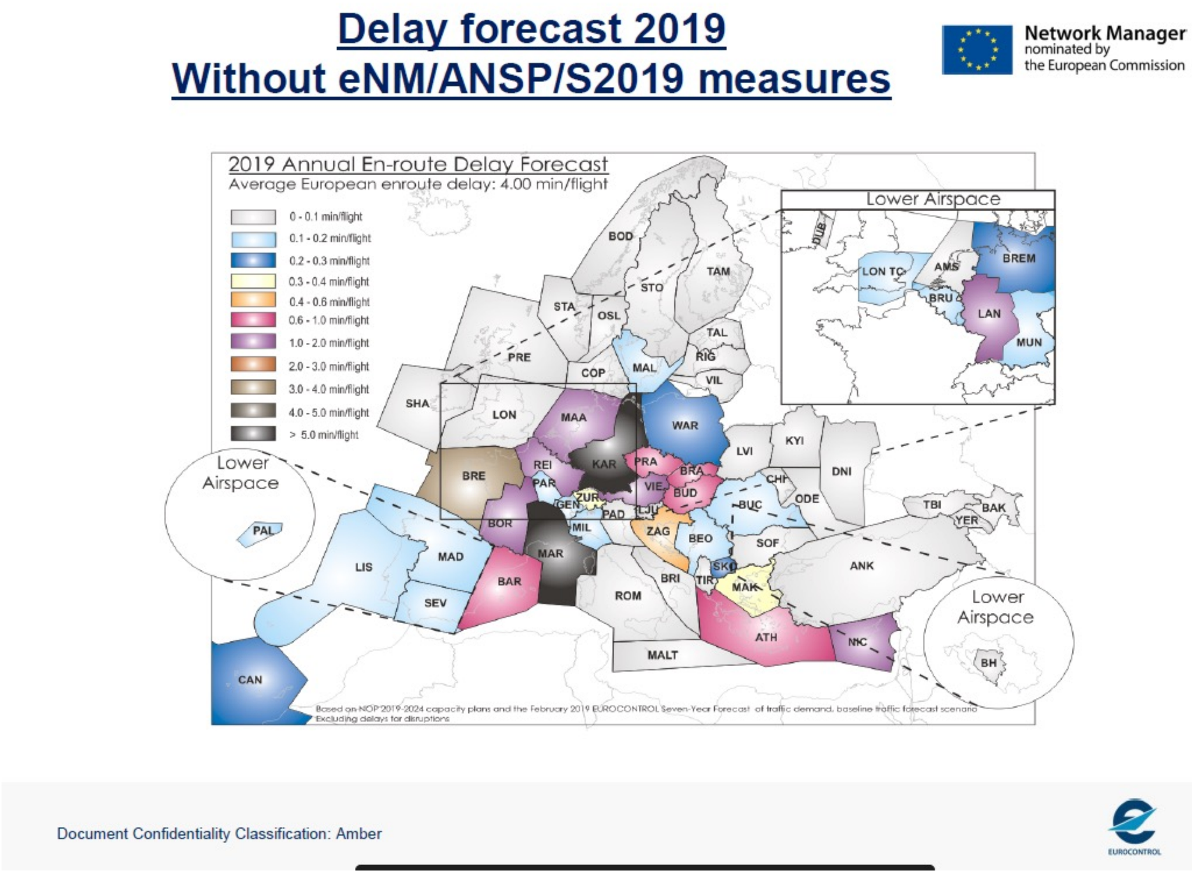
Capacity Crush 2018–2019

In 2019, European skies saw a total of more than 11.1 Mio flights, still a record today. However, by that time, a crisis was already hitting the sector. To be precise a capacity crisis, within several Area Control Centers (ACCs) unable to accommodate the excess traffic demand. This situation even led the Network Manager to reroute over 400 flights daily from various ACCs in Europe[2].

To explain this crisis we need to go back to 2015 (or rather 2014) to understand a little better how the ANSP planning cycle works. 2015 marks the first year of the second reference period (RP2). A reference period usually comprises a five years period and requires the different States and their ANSPs to develop the so-called Performance Plans. In particular, this reference period followed a period of economic contraction due to public debt and banking crisis in 2011. The Eurozone economy contracted, and in some Southern European countries such as Spain, Greece, Italy and Portugal, this decline was even more pronounced.

[2] NMB-19-24-7-Item 2.2 - NM Action Plan_eNM_s19 and Impact

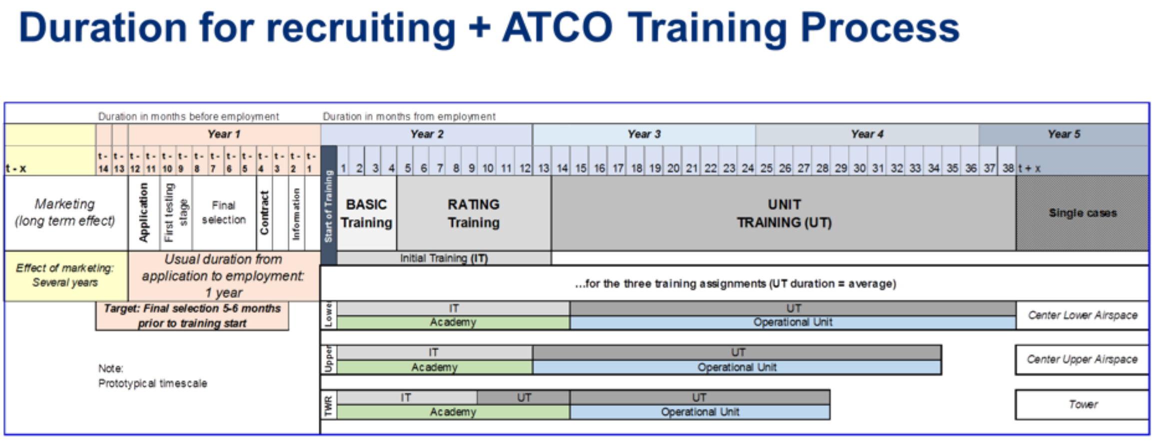
One of the most important influencing factors for air traffic forecasts is a country's economic growth. The higher the economic growth and international trade relations, the larger the increase in air traffic volume. In that sense, RP2 was prepared in a scenario of sustainable economic growth. However, latest in 2017, in some European states it was obvious that the traffic assumptions used in the preparation of the performance plans were completely detached from reality. For some ANSPs, this meant that the plans were undersized, with installed capacity and resources well below the level required to deliver the services, according with the level of performance indicated in the respective performance plans.



The first symptom of this gap was the increase in delays in a large majority of ANSPs, and consequently in the European network. Unable to escalate its services, the Network Manager (NM) was required to intervene in the network to mitigate undesired effects on airspace users with a comprehensive package of measures aimed at reducing some 19 Mio minutes of delay[3]. Moreover, some States have submitted requests to the European Commission to reopen their performance plans in order to revise ANSP's financial envelope, so as to increase the capacity needed to accommodate excess demand. Although this is a process foreseen in the regulation, it is a lengthy, complex and administrative process. In fact, in some cases it can take up to two years to obtain approval, which in practice does not respond to a situation where immediate action is required.

Being a 'human intensive' activity, capacity gains are, most often, directly linked to the number of air traffic control sectors that can be opened in a determined moment and therefore accommodate the expected traffic demand. However, seen from the outside, there are clear limitations to this scalability.

The ATM industry has some specific characteristics that need to be taken into account when managing unpredictability and thus capacity planning. First, the lead times for upgrading or implementing new systems and the time for recruiting and training new ATCOs are considerable and usually take several years. Secondly, it is not possible to store provisioned capacity for later use. The transient nature of capacity provision in air traffic management and the pressure to balance quality of service and cost efficiency influence the decision-making process of air navigation service providers with regard to capacity planning and provision. Thirdly, the financial ones to support 'overtime' costs for an extended period (e.g. summer). In combination with various other factors, this 'crisis' scenario has resulted in massive delays and low punctuality, which translates into an average delay per flight at 14.7 minutes in 2018 and 13.1 minutes per flight in 2019[4].



Pandemic Crisis 2020–2021

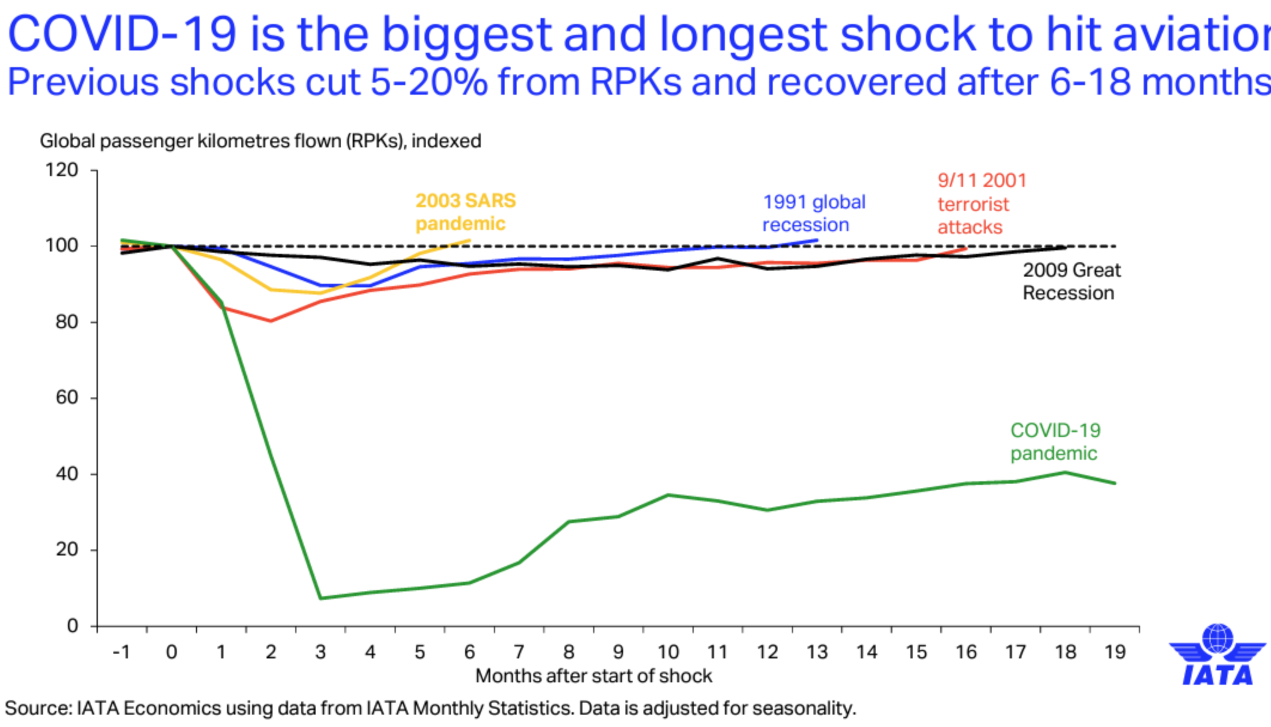
The pandemic has disrupted business operations in all industries. The airline industry was one of the first industries that was affected from the event because the disease is easily passed among people. In the beginning there was no official medical treatment for the disease, triggering an unprecedented panic among the world's citizens. Thus, governments around the world have prohibited cross-country transportation.

It is hard to overstate the degree to which the pandemic has shaken the aviation industry. Since the start of the pandemic in March 2020, a total of 11 million flights have been cancelled, European airports reported a loss of 3.1 billion passengers and IATA estimates the financial loss for European airlines at around €40 billion. The sector is expected to be smaller in the coming years; various studies (e.g. IATA) indicate that passenger volumes will not return to 2019 levels before 2024.

Apart from the financial problems, longer-term effects of the pandemic on aviation are emerging. Hygiene and safety standards are being tightened, and digitalisation will further transform travel experience.
Other impacts, however, are more profound. Unlike the global financial crisis of 2008, which was purely economic in nature and weakened purchasing power, COVID has irrevocably changed consumer behaviour and thus the aviation sector.

[3] NMB-19-24-7-Item 2.2 - NM Action Plan_eNM_s19 and Impact

Airlines are re-evaluating the economics of their operations. Among other things, reduced business travel will require changes in the route network. Airlines have established many flights between hubs and smaller cities in recent years. These flights work because of the high demand in business traffic. With business demand subdued, larger aircraft that fly less frequently are economically more viable. Airlines may find that larger aircraft such as the Airbus A321 become the basis of the short-haul network.



For ANSPs the focus changed entirely from solving the European en route capacity crisis to managing an unprecedented global crisis of the industry affecting the entire value chain. In 2021, traffic increased by a quarter compared to 2020, but still remained just above half the level of 2019.

Since the actual regulation was not prepared to cope with crisis like this one, several pieces of regulation have been produced, in the meantime, to address exceptional circumstances. Slot regulation and performance regulation had to be adjusted to compensate for the sharp decrease of aviation activity. It turns out that ANSPs have limited flexibility to reduce costs in the short term. Firstly, because even during the pandemic crisis air navigation services have been provided to several emergency and rescue flights as well as to cargo flights in order to assure the global logistical chain for vaccines and medical equipment; secondly and most importantly because airspace users expect ANS capacity to be immediately available when traffic demand picks up.

[4] EUROCONTROL, Network Operations Report 2019; all Causes

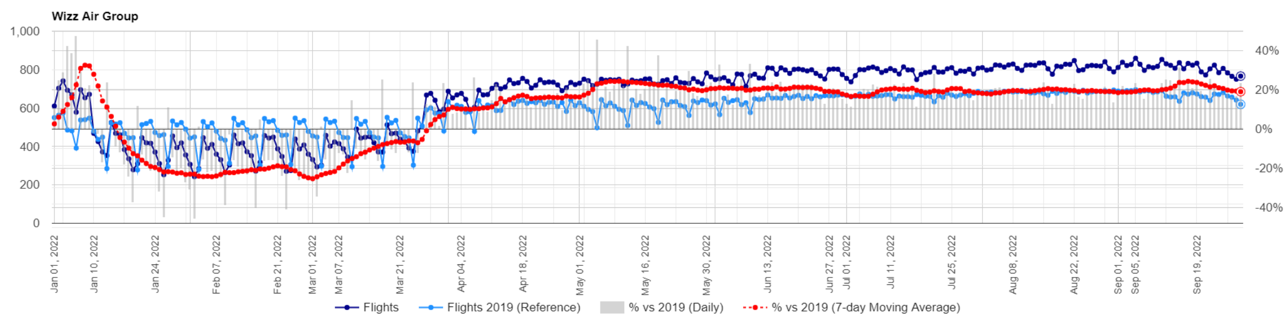
As most ANSP costs are fixed in the short term, the immediate cost containment measures taken were not able to compensate for the massive loss of revenue, and therefore the vast majority of ANSPs had to finance themselves through bank loans. In order to avoid an excessive increase in costs for airspace users, the commission in its exception regulation provides that these costs may be spread over a five to seven years period. However, it will not totally prevent higher user charges for European airspace users in the coming years, which will continue to put the industry under some financial pressure.

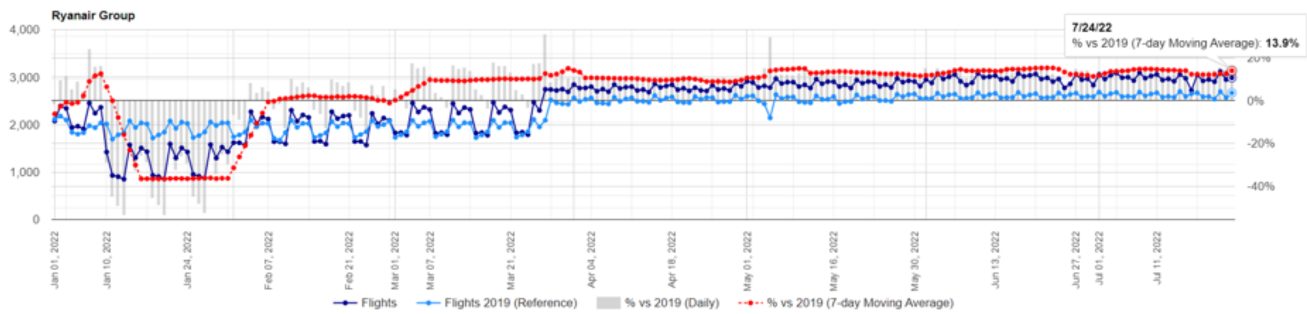
Operational performance has improved across the board in 2021 after the sharp drop in traffic in 2020, but there are early signs of rising inefficiencies and delays, although traffic levels are still well below those of 2019.

Rebound Post-Covid 2022

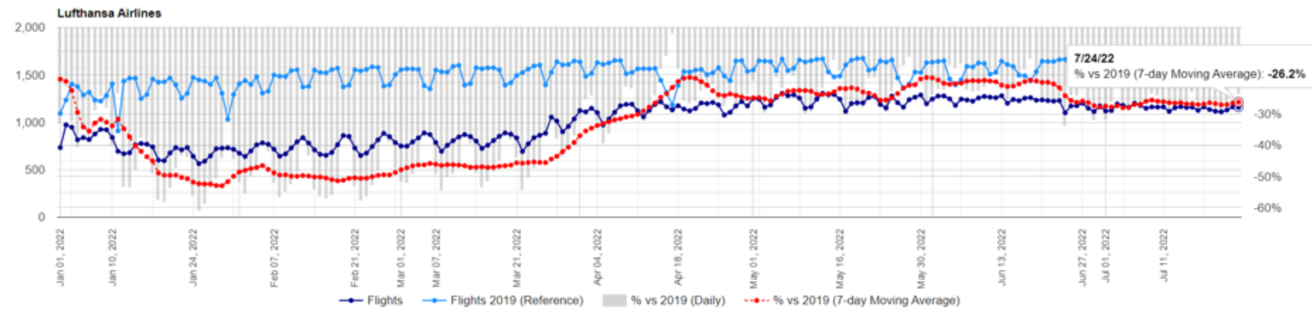
At the beginning of 2022, European air traffic has survived the second year of the pandemic. Increased vaccination rates and the easing of travel restrictions in many European states have led to a steady increase in demand since the second half of 2021. However hope for a complete and sustainable recovery of COVID has been dashed by the war in Ukraine.

It can be seen that in 2022 both flight supply and passenger demand are still significantly below pre-crisis levels[5]. Current traffic figures in Europe also indicate that the number of flight movements is recovering faster than the number of passengers. LCCs such as Ryanair, easyJet, or Wizz Air are better positioned to make the most of the recovery of the travel market. These airlines focus on Europe, do not maintain a complex transfer and long-haul network and are therefore more agile.





[5] See eurocontrol-comprehensive-air-traffic-assessment-20220720.pdf



Source: Aviation Intelligence Eurocontrol - https://www.eurocontrol.int/Economics/DailyTrafficVariation-AOs.html

Many companies have cut the budget for business travel and LCCs feel this less as they mainly transport tourists. In addition, stable liquidity and the point-to-point structure allow LCCs to return to the market more quickly. Full-service carriers, which before the pandemic lived largely on transfer passengers and made their money from the long-haul network, are much more reluctant. They suffer from the fact that large parts of Asia, for example, will probably make it difficult for Europeans to enter the country for a long time to come. The same applies to travel from Asia to Europe.

The pandemic has challenged the airlines' existing market models. The prediction of demand and the corresponding flight planning is much more short-term than before the crisis. The planning times for aircraft and crew rotations are reduced from four weeks to two weeks in advance. The airlines' capacity planning had to reorganise itself accordingly. Long-term, medium-term and short-term decision making on flight operation has become much more agilely.

In recent months, however, it has turned out that the reactivation of aircraft and flight crews is a major and partly underestimated planning and logistical challenge. Since April 2022, this has led to operational shortages, flight cancellations and operational disruptions throughout Europe, which is reflected in a low punctuality of a magnitude previously unknown. As a result, the massive capacity increases announced in April 2022 will be partially reversed. For example, EasyJet is reducing capacity for the key summer months of July, August and September, which will result in a drop from 97% to 90% of 2019 levels.

It is still a long and bumpy flight ahead for airlines to ensure a full recovery, as the post-Covid rebound involves a multitude of risks: geopolitical instability (including Russia's invasion of Ukraine), high inflation (stagflation) and weakening purchasing power, continued lockdowns in China, higher fuel prices and expiring hedging positions, further disruptions to global supply chains, new Covid variants and the already existing staffing problems (airlines, airports, service providers).

For this reason, expectations and pressure on ANSPs in the next years will remain high to find the right balance in adjusting operations and costs in line with demand levels during the recovery phase while at the same time preparing for the future in terms of capacity provision, technological transformation and environmental sustainability.

More specifically, this means average en route ATFM delay per flight were reduced from 1.57 minutes in 2019 to 0.29 minutes in 2021 (0.33 minutes per flight in 2020). With the traffic increase in summer 2021, en route ATFM delays (mainly attributed to capacity and staffing) started to re-appear in some areas. Four ACCs in Europe generated together almost 2/3rds of the total delay reported in 2021. In each case, ATFM delays occurred at significantly lower daily traffic levels than in 2019. This indicates that ACCs did not deploy as much capacity to handle demand as they had been able to deploy prior to the pandemic. Disrupted recruitment and training across the network combined with several ATC system enhancement projects (e.g. Reims ACC) have already caused major disruptions in summer 2022. The Network Manager, together with cooperating ANSPs, has implemented a range of measures to mitigate expected delays. Based on the latest capacity plans, the Network Manager expects a delay of 1.14 minutes per flight in 2022 in a high traffic scenario.

The situation in 2022 illustrates, even more than in previous years, that transparency about the constraints that lead to inefficiencies and delays and an open dialogue involving all stakeholders, especially airlines, are crucial for effective performance improvement.

Business Models ANSPs and Airlines

ANSPs (Performance Model)

ANSP's main source of revenue is the provision of the air navigation services (ATM/CNS) that they provide to flights crossing through their Flight Information Region(s). In this sense, traffic forecasts become the decisive factor in terms of planning, in order to define the necessary capacity to accommodate traffic demand. This will require equipping themselves with the necessary systems, as well as the human resources to be able to provide their services efficiently.

In addition, and because the activity of ANSPs is mostly carried out in a monopoly regime, there is an economic regulation that imposes certain SLAs in terms of service provision, as well as a determined financial envelope for the provision of its services. In short, this is how the Performance scheme / plan works, which is an integral part of EU regulation 2019/317.

As previously mentioned, before the beginning of each reference period (RP) the European Commission publishes a set of European targets for the areas of Safety, Capacity, Environ¬ment and Cost-Efficiency. Each of these European targets is then broken down to the level of each Member State.

Based on the traffic forecasts and the targets that have been set, in particular the maximum delay value and the cost cap, ANSPs start their planning cycle for that reference period, taking into consideration the number of ATCOs (and other staff) they will need, the systems and the investments they will have to make in order to perform their services in line with the efficiency targets that have been defined at local level.

Airlines (Demand Model)

The aircraft type, number of passengers, destinations served, frequencies operated and timings scheduled are some of the elements affected by the Airline's capacity decision. This capacity decision is heavily based on the airline's ability to conduct accurate passenger traffic and aircraft movement forecasts. Passengers forecast based on economic growth (GDP) and passenger yield, while aircraft movement forecast based on future trends in seating capacity and average load factors. Over the last decades all these factors are continuously growing, which increase the importance of a capacity strategy. Capacity decision is one of the most important operational decisions; it is a long-term commitment that selling the airline's output and therefore affects the airline's ability to meet future demand and to maintain its competitiveness. Capacity decision affects most of the operating and capital costs of an airline. Moreover, it encompasses most of the basic operational decisions.

For airlines, a capacity strategy consists of several requirements that a flight planner must take decisions about. These requirements include:

- equipment (aircraft)
- flight range (number of destinations, aircraft productivity)
- employee skills (number of crew members).

Low-cost carriers (LCCs) have grown strongly over the last three decades and have become an alternative to Full-service carriers (FSCs), especially in Europe. Their rise can be attributed to several reasons. First, due to market liberalisation in many countries and air service agreements, LCCs have seized the opportunity to offer innovative services and attract new customers looking for low-cost air services. In 2019, European LCCs claimed 35% of the capacity in Europe. Secondly, LCCs have succeeded in offering what potential airline customers value and in responding to customers' needs, namely flexibility in terms of schedule offering, as well as good quality at lower prices. Third, the LCCs have responded quickly to market conditions and understood that maintaining a competitive advantage requires a ruthless force to minimize costs, increase yields and maximise efficiency. They use a business model based on permanently minimising operating costs, while maintaining a high degree of flexibility in terms of capacity. Destinations are developed, flights established and employees hired without making long-term commitments and without a sustained increase in fixed costs. Low-cost carriers are able to stimulate additional and thus previously non-existent demand on short notice. This makes them independent of passenger demand that can be planned in the long term and thus increases the speed of reaction if travel flows change, e.g. due to pandemic-related travel restrictions.

LCCs have been able to compete with the FSCs because they are skilled at lowering their costs, not offering the same level of amenities, not having the same level of connectivity as the FSCs, and not having to carry legacy costs. Since passengers today do not need network connectivity for all their travel or can do without services, they are willing to replace the FSC product with LCC travel.

In view of the rebound in passenger demand in 2022 and the emerging risks for the European economy, airline capacity management must be flexible and take early demand indicators into account. LCCs (and now also FSCs) make use of the possibilities to identify early changes in traffic flows, e.g. via Google Trends and Google Mobility. Lead times for aircraft and crew rotations are reduced from four weeks to two weeks in advance.

While in the past the duration of marketing incentives at airports was an indicator for the stability of an LCC flight plan for the next 12-24 months, nowadays trends are analysed, market opportunities identified and flight plans changed in a much more short-term manner. An example is Ryanair in Portugal, which – after threatening to close its base in Faro – has now opened a new base in Madeira. In addition to the short-term reaction to changing travellers' demands, Ryanair uses the announcement and sometimes also the execution of the closure of a base as a threat potential against trade unions.

Conclusion / Proposals

As an essential element of the modern air transport system, ANSPs make a significant contribution to safe and efficient flight operations. From a holistic perspective, this corresponds to conflict- and delay-free commercial air traffic on a low-emission course.

Prior to COVID-19, air traffic was characterised by almost steady growth. The experience of recent years also shows that civil aviation recovers very quickly from external shocks like 9/11. However, air navigation service providers report increasing volatility in flight patterns. Some of the possible causes include:

1. External shocks, such as the closing of Ukrainian and Russian airspace
2. Seasonality
3. Weather phenomena
4. Changes in ATC service charges.

Traffic volatility is a growing problem in Europe. Predictability of traffic volumes not only at network level but also at local level, together with data accuracy, is crucial to maintain a high performing ATM system[6].

Although at first sight, the performance scheme may seem a straightforward process, it carries in itself a high degree of uncertainty and complexity.

[6] Hellbach, T.; Edard, J.M.: Volatility in air traffic and its impact on ATM Performance (https://www.fabec.eu/images/user-pics/pdf-downloads/volatility-workshop_2018-05/Panel%201%20J-M.%20Edard,%20T.%20Hellbach_Towards%20more%20predictability.pdf)

Firstly, the ever-present resolution of the equation of increasing capacity with decreasing costs (always present in all RPs). Secondly, the fact that once submitted and approved by the European Commission, the Performance Plan is closed and the respective financial envelope is also locked. Therefore, traffic volatility introduces instability into the system and severely affect both strategic planning and daily operations in the various key areas of safety, capacity, environment and cost efficiency. What often happens is that airline planning does not consider that the ANSP planning cycle is already closed and with little flexibility to accommodate sudden changes in both passenger and airline patterns, for example with the unanticipated increase of frequencies or new connections (city-pairs).

As we understand, traffic forecasts vary year after year, which leaves ANSPs in an uncomfortable position having to continue to provide their services as efficiently as possible and, at the same time, without infringing their financial envelope. This creates several types of tensions, because as happened in 2017, there is a limit to being able to continue to accommodate the increase in traffic and once that limit is exceeded, delays start to skyrocket.

In a situation where traffic grows more than estimated, and in the absence of a sufficient number of ATCOs, the solution most often involves more overtime to maintain capacity levels according to the desired levels of efficiency included in the Performance Plan. However, here too, there is a limit, which is the financial envelope itself. If this is exceeded it means that these costs cannot be recovered in the next financial year. Added to this is the fact that if the limits of delays are exceeded, ANSPs have to compensate airspace users for not meeting the efficiency levels included in the Performance Plan.

Although volatility is generally regarded as an important factor influencing air navigation services, its measurement and actual impact has hardly been investigated to date. Previous studies have primarily proven that seasonal deviations have a significant influence on ANSP productivity. However, volatility has additional multiple spatial and temporal aspects. Subsequently, traffic fluctuations and deviations from the planned air space usage are not taken into account in performance evaluation and target setting. Resilience is a fundamental property of the natural ecosystem that enables rapid recovery after disturbances[7]. We consider resilience in Air Traffic Management as ability of the respective ANSP to retain a certain level of the regular performance during the impact of a crisis and fully reach the performance level relatively fast afterwards. Consideration of air traffic service resilience began with the reactive management of disruption – how quickly can contingency plans be put in place to restore service, even at reduced capacity, when a major disruption occurs? In the past, technical resilience meant a redundant emergency centre in an additional facility that duplicated the functions of the main operations centre. Often this was too costly and still could not prevent the most common continuity failures. However, resilience risk controls can be more than just reactive. When done well, they are proactive and predictive, collecting data on changes and potential disruptions that affect ATC performance and carefully analysing performance data to derive changes in the design and operation of services and systems that prevent or control risks. In our point of view resilience is more than just about disruption and response. It is about flexibility and scalability in the face of demand changes by air space users, helping to ensure the service disruption does not happen in the first place.

However, the fact is that ANSPs are subject to a model that is very inflexible and unable to respond in a practical way to sudden changes in traffic demand. As such it is necessary that the information that feeds the traffic forecasts are the most accurate so that ANSPs, can become more resilient, by planning better and in a more proactive way.

So how can we create a more resilient system capable of converging the planning flexibility of airlines with the performance model of ANSPs? We consider several options to be useful, which are outlined below:

In daily operations, it is common for AUs to communicate a flight plan in advance that needs to be changed shortly before or during the flight operation. Examples include aircraft changes that involve a change in technical capability (e.g. flight level). Other factors that contribute to deviations are yo-yo flights and flying around restrictions. From the airlines' point of view, these changes are justified economically in most cases. Similarly the same applies, when airlines reschedule aircraft and flights a few weeks in advance due to changes in passenger demand. If predictability is to be improved and thus volatility reduced, airspace users must become an integral part of the equation. The current lack of consideration of overall system performance should become a binding agreement between AUs and the ATFM system. Analogies can be found in slot rules (take-off and landing rights at slot-coordinated airports). And even at non-coordinated airports, there is a decision-relevant exchange of information about available terminal and apron positions for aircraft. In case of unavailability of such (on-block) positions, experience indicates that capacity expansions by the airlines are re-examined and, if necessary, adjusted in order to avoid operational disruptions at the respective airport.

Another option could be to provide for a mechanism that allows ANSPs to incorporate some kind of buffer in terms of capacity and costs able to accommodate sudden changes in traffic volume, without undergoing through a substantial revision of the performance plan, or an alert mechanism that only allows revisions with a threshold of 10% deviation, as it currently happens. After ten years of applying the performance model we know today that variations of more than 3 to 5% already put a lot of ANSPs in critical situations to accommodate these traffic variations, without having found throughout this time a format capable of responding to these variations in an agile way.

[7] Our view on resilience is based on Gluchshenko, O.: Definitions of Disturbance, Resilience and Robustness in ATM Context; DLR 2012. See also Gargiulo, F. et al.: Resilience management problem in ATM systems as a shortest path problem, Journal of Air Transport Management, September 2016.

On the other hand, as already mentioned, the traffic forecast we use to draw up our performance plans is less reliable the further away we get from year 0 of the beginning of the reference period. This means in practice that unlike the NOP which is carried out in a sliding window format, with revisions and adjustments on an annual basis according to the most recent traffic figures, the performance plans do not contemplate such a degree of flexibility, which from the outset creates a misalignment between capacity and costs, since the former allows for an update on an annual basis while the latter is closed until the end of the reference period. Taking advantage of the fact that the European Commission requires States to hold annual meetings with Airspace users to monitor the Performance Plans, this moment could be used to make (small) adjustments to the performance plans, incorporating the most recent traffic values and subjecting these adjustments to a public consultation process.

Finally, with regard to traffic volatility, it would be beneficial to find a model whereby information, often of a confidential nature, could be shared in advance with ANSPs so that they could anticipate future capacity needs in a timely manner. The fact is that there is no crystal ball that allows having the correct traffic figures, and it is no less true that STATFOR does a great job with the data it receives, but this work will be of no use if it does not incorporate the most accurate information at each moment.

Session 2

How to integrate resilience in European air traffic management?

How to cope with Demand Fluctuations – Resilience as the Solution for Volatile Traffic?

Thomas Standfuß[a] and Matthias Whittome[b]

Abstract

The resilience of European air transport has become an important issue recently, not only, but especially since the corona pandemic. Further, ANSPs experienced increasing unpredictability of traffic demand, as well as higher volatility in traffic movements. In our study, we will show that traffic prediction, as well as traffic volatility, are important indicators for measuring the required resilience of an air navigation service system, and how external shocks hamper its efficiency. We use regression analysis to quantify the effects of volatility on resilience. Finally, we address aspects of granularity and show that the observation is strongly influenced by the operational level considered.

Background

Although air traffic is characterized by general growth worldwide, the long-term demand curves repeatedly show downturns. These are usually caused by external shocks, which lead to a sudden increase or decrease in traffic movements. For Air Navigation Service Providers (ANSPs), these effects are either direct, e.g., flying around a certain area, or indirect, e.g., by an increase or decrease in passenger/freight demand and subsequent change in movements as observed in times of COVID 19.

Resilience, by definition, is the ability of a complex system to return to its initial state despite massive external or internal disturbances. In Air Traffic Management (ATM), resilience is primarily seen as an ability to cope with capacity disturbances [1], climate change [2], or safety issues [3]. The experience of recent years (e.g., the financial crisis in 2008) shows that civil aviation recovers very quickly from external shocks. In consequence, it might be assumed, that the air transport system is characterized by high resiliency.

In contrast, the COVID 19 pandemic has shown and still shows that some effects will have tremendous consequences, even for resilient systems. In fact, air traffic still struggles with the impacts of the COVID-induced collapse of demand. However, the paradigm of the capacity shortage has been changed: Given the low demand for air traffic movements, the main issue shifts to the financing of the whole system. This 'financial resilience' should be supported by the traffic risk-sharing mechanism of Single European Sky [4]. In consequence, ANSPs would have the chance to (partially) compensate for the lack of revenue through higher fees. However, supporting the airline industry, the charges mechanisms were limited by policy decision-makers [5,6].

The situation is further deteriorated by uncertainties about how traffic demand will develop over the next years. Even in pre-pandemic times, forecast quality was limited [7], hampering efficient resource planning for the ANSPs. To elicit the historical significance, a useful comparison is missing: Since air transport is a very young discipline, there is no equivalent event. Nevertheless, it is possible to apply a comparison on a spatial level. One may observe how regional areas and individual states (or ANSPs) react or reacted to external shocks and how quickly the system adapted to the new situation. Examples are manifold, especially at the local level: Traffic shifts due to the Russian aggression against Ukraine, Malta after the shutdown of Libyan airspace, or north-western Europe during the eruption of Eyjafjallajökull in Iceland are just a few examples. The inherent traffic fluctuations can be measured by volatility scores suggested in [8].

The paper will show how volatility and predictability are one side of the medal of resilience. The frequency and/or intensity of external shocks increases, which on the one hand affects predictability and on the other hand increases traffic volatility. Subsequently, there is a need for a more resilient industry. To demonstrate the significance of volatility as an indicator of a need for resilience, the paper is structured as follows: section 2 is setting the scene by providing an overview of the differences between forecasts and actual traffic over time. Section 3 deals with the definition and measurement of volatility, considering different time periods. In section 4, we show how volatility affects the performance of ANSPs. We emphasize the necessity to distinguish the operational level in section 4, and section 5 summarizes our findings.

Predictability in European Air Transport

In order to ensure safe and efficient air traffic management, Air Navigation Service Providers (ANSPs) make surveillance capacity available (measured e.g., flight entries into the sector per hour) which can be adjusted according to demand. This capacity is built upon human resources and as such incurs costs. In other words, ANSP's responsibility also comprises the efficient deployment of resources to ensure service provision at minimum costs to stakeholders. Therefore, resource planning relies on expected demand for a pre-set horizon. The most scarce and expensive resources are the air traffic control officers (ATCOs).

In medium-term forecast reports, such as [9] and [10], predictions consist of a baseline scenario as well as a high- and low-level scenario. Since the resulting difference between the predicted number of flights in the high- and low-level scenario can be seen as the most probable range of the predicted data, we associate it in this paper with the induced "confidence interval" (CI). STATFOR aims at granting at least 50% of the past observations to lay in that range.

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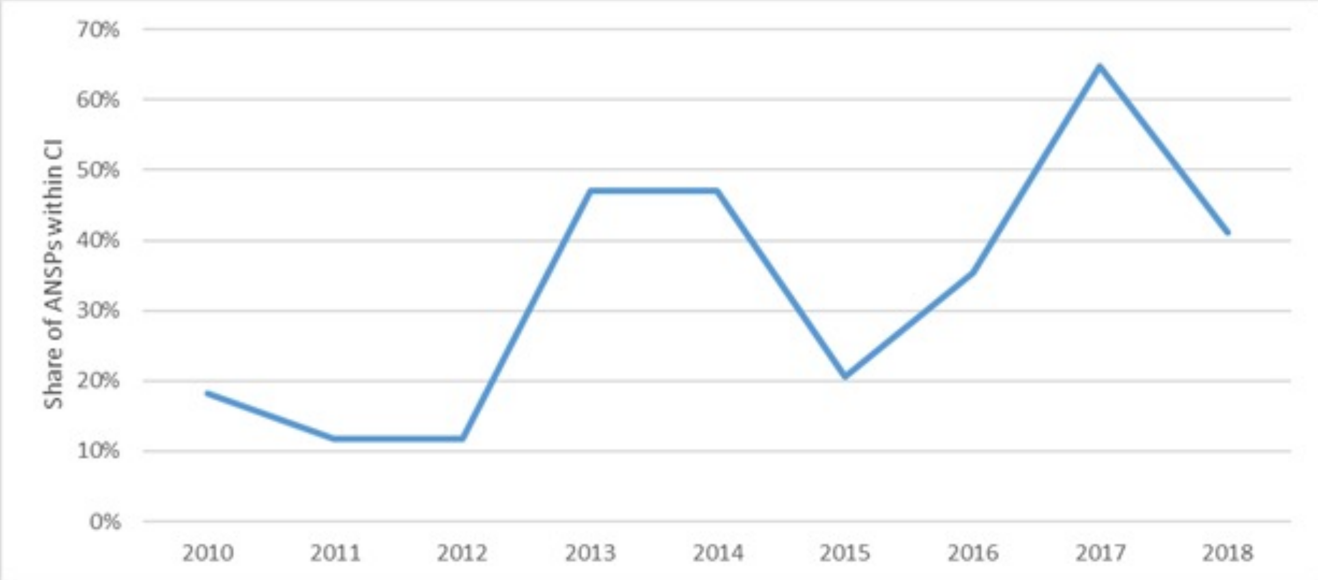

Figure 1: Forecast Quality of STATFOR Predictions in a five-year time horizon

It goes without saying that forecast quality directly affects the need for resiliency. In a perfect world, forecasted demand would be equal to the actual one for all units. In this case, resiliency will not play a role at all. However, as experienced over the past years, external shocks grew and forecast quality was very low, leading to sufficient scores for the minority of ANSPs (e.g., expressed by the MAPE score) [7]. Further, despite the CI induced by STATFOR being quite large and partly extended over the years, it was matched by actual traffic figures in the minority of cases (Figure 1). Further, external shocks lead to increased traffic volatility, since local and global events not only disrupt traffic but also shift flows (see section 3).

It has already been proven that a low forecast quality impacts the performance of an ANSP negatively [7,11]. While demand for goods and passenger mobility and thus air traffic may be a rather dynamic figure changing on an hourly, daily, or weekly basis, the provision of capacity has lengthy circles. Usually, the training of an ATCO takes approximately five years [11]. In consequence, capacity will not be able to scale with the volatility of demand as the provision of human resources cannot keep up with volatile demand. Significant under- or overutilization of resources thus may be an indicator of missing resilience of the system and may have a medium to long-term impact. The effect is amplified by the licensing. Since ATCOs are only licensed for a specific number of sectors, a change in traffic flows may lead to sever inefficiency.

Traffic Volatility in European ATM

Definition and Metrics

Originally, volatility is a term of finance and describes fluctuations in share prices [12,13]. However, fluctuations can also cause problems in air transport, especially in saturated or congested airspaces.

Although the problem is well known, traffic volatility is still not taken into account for economic benchmarking yet. Due to the growing importance of volatility as a research question in transport economics, several studies also dealt with the measurement and effects from an academic point of view. They also address the question of how to deal with increasing volatility [14–16].

In the context of air traffic and the provision of air navigation services, we define volatility as the variability of traffic flow along a specific unit (ANSP, ACC, sector group, or sector) within a given period (e.g., week). In accordance with financial metrics, the volatility σ denotes the (short-term) fluctuation of a time series by its mean or trend [17]. It is measured by the sum of the standard deviation of change rates Ri between two or more periods (1). The arithmetic mean is indicated as μ, and n represents the number of observations. Changes might be defined as absolute, relative, or logarithmic terms. As elaborated in [18], in ATM it is more beneficial to calculate the standard deviation based on the observed values, respectively flights. Subsequently, the underlying metric changes from % (change rates) to a number. However, it must be taken into account that standard deviation as a measure is scale-dependent: A higher input value (e.g., flights) most probably leads to a higher volatility score, although this is not a general rule. As an example, the standard deviation of daily flights in DFS will always be higher than e.g., in Slovenia, simply because the absolute differences in the number of flights are much higher due to size. Therefore, these measures are only useful for the analysis of individual ANSPs, e.g., when comparing annual values of one unit. The metric should not be used when comparing different units, e.g., large and small ANSPs.

$$\sigma = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} (R_i - \mu)^2} \tag{1}$$

A spatial comparison of volatility requires a scale-independent measure due to the pan-European heterogeneity. In scientific research, the most common economic metric is the GINI coefficient, which is often used as an indicator of income inequality [19]. Some sources also use Herfindahl-Hirschman-Index (HHI) [20], however, it has been shown that GINI leads to more valuable results [21]. GINI is a measure of unequal distribution, e.g., of traffic demand over the week. It is based on the number of observations n, the observation index (e.g., hour) i, and the corresponding demand xi, as shown in (2). In other words, it indicates the relative traffic fluctuations in comparison to the overall demand, not the absolute variation like in (1).

$$GINI = \frac{2 \cdot \sum_{i=1}^{n} i \cdot x_i}{n \cdot \sum_{i=1}^{n} x_i} - \frac{n+1}{n} \tag{2}$$

In the current study, volatility means a fluctuation of the output, not resources. In terms of ANSPs, output means e.g., flight hours, flights, movements at airports, or the flight distance. EUROCONTROL offers a variety of public and semi-public data sources, e.g. the ACE data [22] or other PRU data [23]. However, each of these data sets captures different temporal and operational levels. They also differ regarding the available years. Therefore, it is important to first define the temporal aspects of the study.

Time Horizons

Although there are traffic cycles that take multiple years, the seasonality is considered to be **long-term volatility** in this study. However, as [24] has pointed out, volatility acts on multiple time scopes. Thus, one key element of this study is to also investigate volatility on a short- and medium-term basis.

Medium-term volatility addresses daily fluctuations within a week. As an example, traffic tends to be lower at weekends. EUROCONTROL's Performance Review Unit (PRU) publishes the number of movements on a daily basis [25].

We define **short-term volatility** as traffic fluctuations over one day (hourly basis). It is mainly caused by a (relatively) low demand during nighttime. Since the airspace has to be controlled (at least on a sector group level), there is a loss of productivity when traffic volumes are low. The more traffic, the greater the productivity, until the capacity limit is reached. If the sector is split, productivity drops again and increases with higher traffic volumes. This continuous effect is also described as the sawtooth model [26]. The initial idea was to calculate the short-term volatility by comparing day- and nighttime traffic. However, since there are significant differences across Europe with regard to the time zones and the application of daylight-saving time, the adjustment of data to local times is time-consuming. In fact, volatility might not be an issue of day and night, but the general fluctuation over the day. In other words: We assume that consequences for the ANSP are similar when shifting the daily curve (representing the traffic per hour) arbitrarily to left or right. In this case, measures of unequal distribution might be applied and should perform better.

Volatility in European Airspace

The used dataset for short-term volatility was provided by DFS, using a NEST evaluation [27]. We calculated the GINI for all airspaces and days, leading to 15,330 observations per year. Figure 2 (left side) shows the scores for 2019. The higher the score, the darker the blue shade, and the more uneven the distribution of traffic. The highest scores are assigned to the airspaces of Iceland (not illustrated), Norway, and Moldova. Iceland and Norway also have the highest GINI in the case of the maxima: The most volatile day causes a score of 49%/47%. Lower values can be observed for airspaces in southeastern Europe. An exception represents the Caucasian states of Armenia, Georgia, and Azerbaijan.

The investigation of medium-term volatility is based on daily data. For this purpose, we use the database of daily flights, provided by the Performance Review Unit [28]. Daily volatility is particularly high for states/ANSPs located in the European periphery, especially in the southeastern part. In contrast, ANSPs situated in the European core area are characterized by relatively low volatility scores, e.g., German DFS or Belgian skeyes.

Long-term volatility was not part of the study but has already been investigated and published in [8]. For the purpose of completeness and comparability, Figure 2 (right) shows the average seasonality in Europe for the year 2019. The map shows that particularly the southeastern Mediterranean region is characterized by high seasonal volatility. Overall, the scores are comparable to medium-term volatility, although the values are slightly lower. The highest fluctuation is visible for Macedonia, the lowest for Finland.

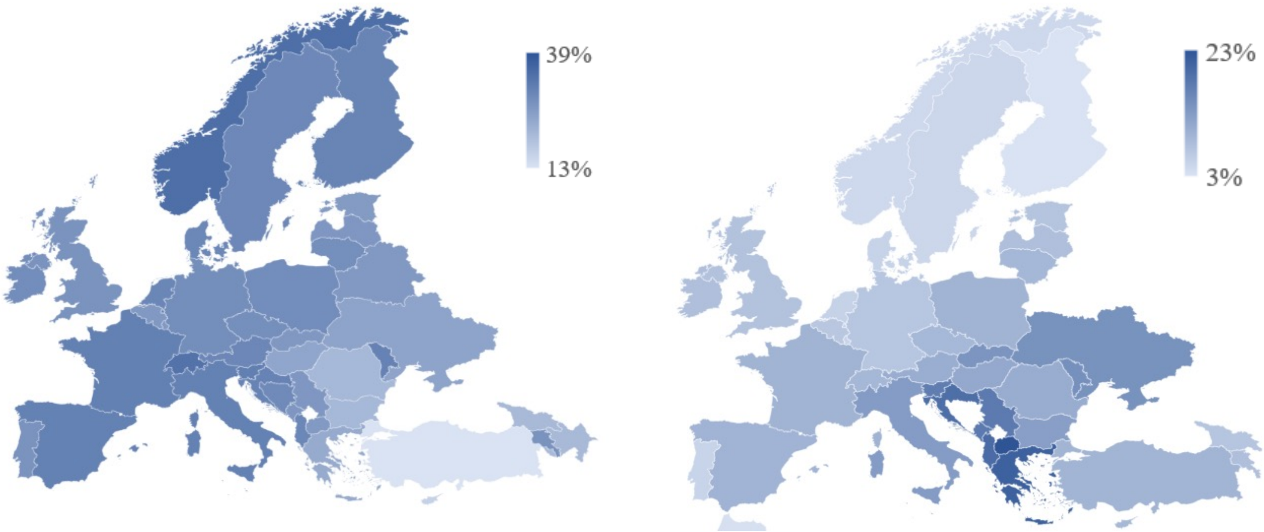

Figure 2: Average short-term (left) and long-term (right) volatility in 2019

Since we see volatility as an indicator of the required resiliency, high-scored ANSPs face an increased necessity to provide or develop strategies to compensate for the fluctuations, e.g., with regards to resource buffering and the flexibilization of staff scheduling. Also achieving economies of scale may increase resiliency. Those measures will become more important since we can observe increased volatility in the past years. Further, extreme values (high peaks in traffic fluctuation) became more common recently.

Influence on Productivity

Method

In the previous section, we distinguish three volatility scores, covering different time periods. However, it is not yet clear whether the three scores affect the necessity to be resilient in the same manner, or if there are differences. Since there is no metric for resilience, we approximate the influence by using productivity. As an example, due to the covid pandemic, traffic (output) went down significantly. On the other side, inputs stayed nearly constant, such as the number of ATCOs or facilities. The more resilient the system, the faster productivity increases after the shock to the initial scores. Thus, we will check if and how the scores influence productivity.

The interdependency between volatility and performance (in our investigation ATCO-productivity) cannot be determined using two-dimensional methods. In this case, the dispersion of the observation leads to an insufficiently established interdependence. This is because performance depends on many factors that must be taken into account.

Regression analysis allows the quantification of one or more independent variables (factors) on one or more dependent variables. As an example, the speed of an athlete may depend on multiple factors, such as age, muscles, training, food, etc. These factors may or may not be measurable (e.g., due to qualitative nature or missing determinability). The regression calculates how to weight the measurable factors ("coefficients") in order to estimate the speed of the athlete as precisely as possible.

The accuracy of the regression model is evaluated by model quality criteria. Good model quality is e.g., expressed by a high coefficient of determination (R^2): The closer the indicator is to 100%, the more variance is resolved by the considered factors. In other words, the higher the quality, the more our regression model reflects the observed values. More detailed explanations can be found in [8,29,30]

Model

The regression model represents an extension of the analyses of [29]. The cited study examined various endogenous and exogenous factors. It determined relevant factors and quantified their influence on performance. Thus, it has already served as a basis for other analyses, e.g., concerning forecast quality [31]. The referenced dataset already included long-term volatility and is now supplemented by the factors of short- and medium-term volatility. Table 1 provides an overview of all considered factors as well as the expected sign. The sign means whether the coefficient is expected to be positive or negative. A positive coefficient increases the value of the dependent variable, a negative one decreases the value. As an example, it might be expected that all volatility scores decrease the performance. Thus, the expected sign is negative ("-"). In contrast, a high share of overflights might increase performance and thus the factor gets a positive sign.

In the discussion of results, we will focus on the three Volatility factors VOL_LT, VOL_MT, and VOL_ST. The indexes stand for long-, medium- and short-term. Older models already included the long-term volatility. We calculated different models, using either GINI or σ as the corresponding score. Factors with large expressions were logarithmized in advance (size, time, wealth), indicated by an "l_" in the results. However, this is just a transformation to cope with large factor values. Using cross-sectional data, we can apply regression models based on 37 observations. Data has been checked in advance on the correlation between the variables.

Table 1: Factors considered in Regression Analysis

Factor	Meaning	Expected Sign
AIRP	Airport Ownership	+
COORD	Coordination – Number of neighboring airspaces	-
COSTS	Employment costs per ATCO	+
DELATM	Delegated ATM	-
DENSITY	Traffic Density	-
DOM	Share of domestic flights	-

Factor	Meaning	Expected Sign
HI	Horizontal Interactions	+
JSC	Joint Stock Company	-
L_AIRP	The number of hubs (>200.000 movements p.a.)	-
MET	MET Services	+
NOFAB	ANSP is no member of a Functional Airspace Block	-
NONA	Share of Non-ATCOs	-
OCEAN	Oceanic Airspace	-
OVER	Share of overflights	+
RES	Technology proxy	+
SI	Speed Interactions	-
SIZE	Airspace Size	+
STATE	State-Owned	-
TIME	Working time per ATCO	+
VI	Vertical Interactions	-
VOL_LT	Seasonality	-
VOL_MT	Weekly Volatility	-
VOL_ST	Daily Volatility	-
WEALTH	Wealth of the country, GDP per Capita	+

Results

As described in the previous subsection, we performed multiple regression analyses. In this section, we focus on two examples using 2016 data. First, we consider a model with the original variables, which was also used in the cited studies. The results show some plausible and some implausible results. For example, the share of domestic flights (DOM), seasonality (VOL_LT), and the number of speed interactions (SI, part of the complexity measure of EUROCONTROL) have negative connotations, while the working time per controller (l_time), the airspace size (l_size) and a joint-stock company as the organizational form (JSC) have a positive influence on productivity, which could be expected. However, short- and medium-term volatility has a positive effect on performance, the latter statistically significant, which is rather unexpected (see also [8]). The counter-intuitive signs of the initial model (not shown in this paper) may have several causes. First, the variance inflation factor (VIF) test (a statistical test on multicollinearity in regression models) shows that particularly medium-term volatility could exhibit collinearity. These collinearity problems are exacerbated using standard deviation instead of GINI. Another problem could be the number of variables used, and the inclusion of insufficient metrics of EUROCONTROL e.g., discussed in [32,33].

Based on these findings, we have reduced the considered variables of the initial model. It includes i.e., volatility, traffic density, costs, and working time per ATCO. Table 2 shows the result for the regression model after variable reduction. In Model 1, volatility is expressed by the GINI score, model 2 uses the standard deviation.

The results for model 1 are plausible with regards to positive or negative signs of the variables. Further, all variables are statistically significant. Although the medium-term volatility was removed (p-value greater than 0.33), both the hourly and seasonal fluctuations are significant and have a negative impact on productivity as expected.

Table 2: Adjusted Regression Model after Variable Reduction

Variable	Model 1	Model 2
const	-0.36 (0.493)***	-1.317 (0.407)
l_size	0.219 (0.064)***	0.316 (0.066)***
OVER	0.592 (0.141)***	0.559 (0.145)***
VOL_LT	-2.142 (0.621)***	-2.287 (0.674)***
VOL_ST	-1.548 (0.727)*	-0.002 (0.001)**
MAPE	-0.145 (0.082)*	-0.143 (0.083)*
COSTS	0.003 (0.001)***	0.003 (0.001)***
JSC	0.158 (0.058)**	0.143 (0.056)**
DENSITY		0.026 (0.013)
Adj. R^2	***0.79***	***0.79***
Log-Likelihood	***21.20***	***20.51***

Standard Errors in brackets. Significance on 10% (*), 5% (**), 1% (***) level

Using standard deviation (Model 2) hardly changes results. The variable DENSITY is included in this case. All variables are statistically significant, except the constant and DENSITY. Further, DENSITY has a positive sign, which is unexpected (see table 1), however, since it is statistically not significant, it does not hamper model quality significantly as expressed by log-likelihood which is marginally lower. The lower coefficient of the short-term volatility is due to the values of standard deviations, which are always higher than the GINI (%).

For neither model 1 nor model 2, the VIF test indicates collinearity. The model quality is slightly below the one shown in Table 2, however, the coefficient of determination indicates that about 79% of the variance in productivity can be resolved by using one of the models.

Indicating Demand for Resilience

Since we see productivity as an approximation for demanded resilience of the system, the results of the regression might be used to decide which indicators are used and how. As an example, the regression shows that short-term volatility has a higher impact than seasonality. In this respect, the observation of daily and yearly fluctuations is important. In contrast, weekly fluctuation is not a valid indicator of required resilience.

To account for the differences in the level of influence, an aggregate score is useful for monitoring purposes. However, it does not make sense to simply add or multiply both scores, since the components have different influences on the performance. The necessity of distinction leads to a weighting of the individual scores. The results of the regression analysis might be used to calculate the weighting. The proposed aggregated volatility score consists of short- and long-term volatility only. Using GINI for both indicators, the overall score (OVS) might be calculated as shown in formula (3). The weighting factors u

$$OVS = u \cdot VOL_{LT} + v \cdot VOL_{ST} \ = \ 0.58 \cdot VOL_{LT} + 0.42 \cdot VOL_S \tag{3}$$

$$u = \frac{2{,}142}{2{,}142 + 1{,}548} = 0{,}58 \tag{4}$$

$$v = \frac{1{,}548}{2{,}142 + 1{,}548} = 0{,}42 \tag{5}$$

(4) and v (5) represent the influence, derived from the regression coefficients.

The highest aggregated volatility can be observed in North Macedonia, Croatia, and Albania. The lowest score was measured for Turkey, Cyprus, and Finland. In general, ANSPs with a low demand seem to have a higher OVS. The potential reason might be, that low absolute changes in demand of a small ANSP might result in high relative changes and thus lead to high volatility scores. However, the main message remains: these states face a high necessity for a resilient system.

Disaggregation

We have observed that volatility has increased in recent years (before 2020). Further, extreme values have increased as well. However, the analyses at the ANSP level only depict average values. Volatility can also increase by the pure allocation of traffic, depending on routes or traffic flows. Therefore, we assume that volatility increases when lower operating levels are analyzed.

In a purely temporal analysis of one operational unit, scalar effects no longer play a role. In this case, it is useful applying the standard deviation (formula 1). Based on data provided by DFS, we were able to demonstrate that volatility increased in most units, both at the ACC and at the sector group level.

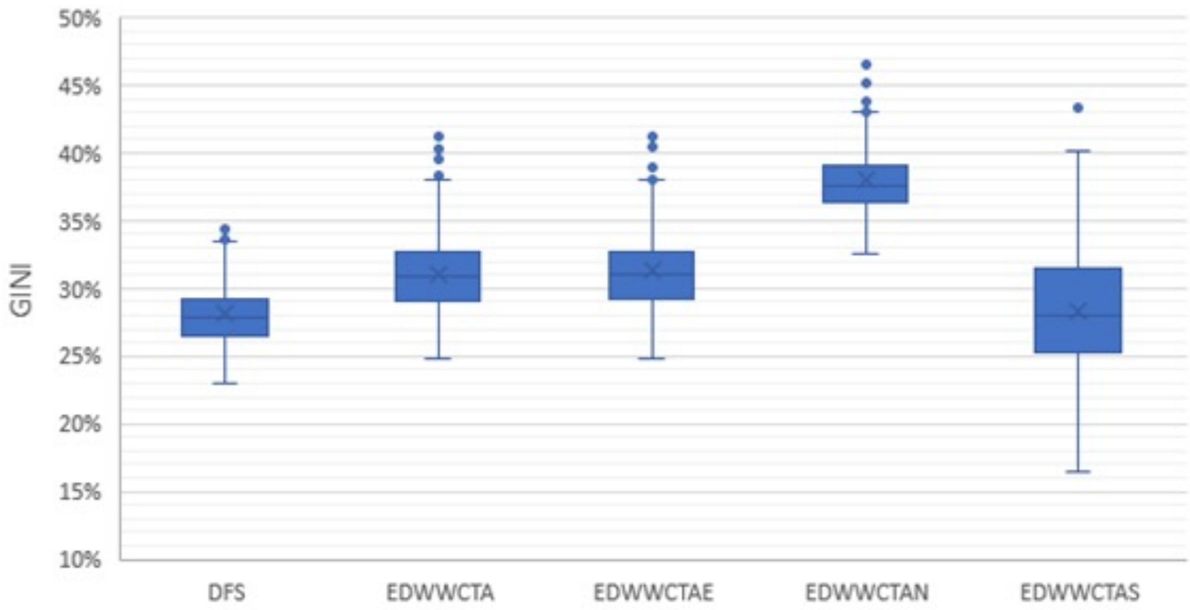

Figure 3: Volatility on different operational levels, DFS, 2019

When comparing volatility between operating levels, only scale-independent metrics are applicable. Accordingly, we applied the GINI score to all available operating levels. Using boxplots (Figure 3), we can observe two effects. First, the GINI score increases when the operating level under consideration is lowered. In other words, sector groups have higher volatility than the corresponding ACC and ANSP. This is in line with our expectations. Second, lower operational levels partly show more extreme values, respectively a higher scattering. Thus, at low operating levels, the high and low peaks are more pronounced.

Conclusions

The resilience of the European air transport system is an important issue in transport economics and policy. Air traffic has always been characterized by periodic and aperiodic fluctuations. In recent years, air traffic demand was becoming less predictable, especially due to the number and magnitude of external shocks. The resulting increase in volatility makes planning more difficult for European ANSPs in terms of resources and allocations.

Since capacity cannot be adjusted as quickly as demand, changes in demand and/or flows can be costly for both airspace users and ANSPs. This effect is exacerbated at lower levels of operation, where the relative variation can be higher: When there is a shift in flow, one sector/group of sectors unexpectedly has more traffic, the other less. These abrupt changes can only be cushioned at the expense of buffers, especially at the staff level. However, this again generates costs. Monitoring volatility is therefore intrinsically important in order to derive efficient buffers.

This paper investigated which metrics can be used to evaluate different temporal forms of volatility. We showed the spatial distribution of volatility scores across Europe. Furthermore, it was shown how the fluctuation of traffic developed over the last years. By applying regression analysis, we were able to show how short- and long-term volatility influences productivity. The used model reflects the observed data with high quality.

Therefore, our paper contributed to a better understanding of how volatility acts on different operational levels, providing a quantified confirmation of experts' assumptions concerning growing volatility. By adjusting the formerly used regression model, we were able to prove that not only seasonality but also daily fluctuations lower productivity significantly. Based on the regression, we introduced a metric for monitoring volatility. This helps to assess the need for resilience for different countries or ANSPs.

We recommend monitoring volatility during different time periods and all operational levels. This will lead to an increased awareness of the required measures to ensure resiliency. Units with high volatility will have a higher need for countermeasures, in particular resource buffers. Of course, this comes with a price since an increase in resources reduces the cost-effectiveness indicator of the ANSP. This makes buffering inefficient in the short term, but efficient in the long term as the system becomes more resilient.

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Single European Sky and Resilience in ATM – Can this be a 'Win-Win' for the Aviation Industry? – The IFATCA Input

IFATCA Joint Cognitive Human Machine Systems Team

Introduction

Resilience is defined as the ability to succeed under varying conditions, so that the number of intended and acceptable outcomes is as high as possible (Hollnagel, 2018). In the context of resilience, Sustained adaptability refers to the ability to continue to adapt to changing environments, stakeholders, demands, contexts, and constraints (in effect, to adapt how the system in question adapts) (Woods, 2018). The EU's Single European Sky (SES) legislation has introduced a Performance Scheme which defines mandatory performance targets for the Air Navigation Service Providers (ANSPs) of EU Member States. The Performance Review Body (PRB) advises and supports the Commission in setting up binding performance targets and thereby, in a way, acts as the regulator for ATM at the European level. In this sense, in the European ATM system, resilience and sustained adaptability are considered to be defined by the scope of the SES Performance Scheme.

The Covid-19 crisis demonstrated that forecasting and charging scheme deficiencies can produce results that provide a false reassurance about the degree of financial stability of the ANSPs. Undoubtedly, the SES has a large share of responsibility in institutionalizing the financial and performance fragility of the European ANSPs. Furthermore, by considering the unanticipated synergy between the effects of the pandemic of Covid-19 and the continuing war in Ukraine we argue that volatility in air traffic and consequently in financial results may be the norm and not the exception anymore.

For the ATM system to sustain resilient performance it needs the capabilities to respond to varying conditions typically through adaptation and coordination and to be able to sustain this adaptability. Traditionally, ANSPs, and the wider context of ICAO, EASA, EUROCONTROL, local CAAs and many more have built systems with resilient performance that have rarely led to fatal accidents. PRC (2022) and EASA (2022) argue that historical evidence shows that overall safety levels in the EUROCONTROL and EASA member states area are high, however there is no room for complacency. Whereas in terms of safety we are performing well, the ATM system has had bigger problems when it comes to efficiency. The SES is the 'dark' side of resilience and has reduced the ANSPs ability to adapt to disturbances and crisis. Focusing on the SES's influence on the ATM systems ability to adjust it functions, configurations and sources of adaptive capacity mainly operational capacity, to the changes that have influenced the system for last two decades IFATCA contends that:

1. the performance scheme has been proven to reduce the ANSPs ability to maintain resilient performance because:
    a. When faced with a crisis e.g., financial crisis, political upheaval, or a pandemic as Covid-19 the performance scheme leads to operational capacity deficiencies.

b. The performance scheme leads to short term fixes rather than sustaining long term resilient performance.
c. The Reference Period (RP) 3 performance scheme lasting only 5 years, needed to be redesigned when confronted with a crisis.

2. the charging system has reduced the ANSPs ability to sustain resilient performance:
a. Because the airlines are paying for the ATM system, there is a tendency to react to airline problems by putting pressure on the ATM system instead of looking at the pragmatic needs of the ATM system.
b. The ATM system, being a critical transportation infrastructure, needs to run 24/7 no matter the traffic demand.
c. Essentially, all ANSPs went bankrupt in 2020/2021, when there were no aircraft flying in the air.

3. That the philosophy of Single European Sky ATM Research (SESAR) and SES has reduced the ANSPs ability to maintain resilient performance.
a. The SESAR philosophy cause brittleness through reducing adaptive capacity.

As a viable way to improve the SES, we suggest investing time and resources in reframing the SES Environment performance indicator to embrace the interdependencies between: Safety, Capacity and Cost Efficiency. Such an indicator needs to be a mix of future expected capacity (a minimum of 10 years), a pragmatic expectation of the promise of technological innovations and how to build in system margins, both financial and staff, to cope with upcoming crises. With such an indicator it could be possible to change the short-term financial focus of the performance scheme to focus on the environment and ANSPs margins to cope with the actual fluctuation of traffic. In a fragile operational and financial context, we also argue that there is an urgent need for a pragmatic definition of a unified framework of resilient performance that includes the joint cognitive human machine ensemble, organizational, financial, and environmental perspectives. To realize this objective, in this paper, we present an initial description of a proposed framework of pragmatic solutions based on the tenets and philosophy of resilience engineering.

Resilient performance is the key to future ATM development

Crisis preparedness, response and recovery remain amongst the most challenging problems facing organizations because of their (a) large social and economic costs in their management and (b) limited organizational learning from previous crisis. Much of the history of the Covid-19 crisis in the aviation domain can be interpreted broadly as an underestimation of risks, not only of the probability of Black Swans category events – events that are unpredictable, result in severe and widespread consequences and after their occurrence, people rationalize the event as having been predictable (Taleb, 2009) – but also, of the distinctive ANSPs' financial fragility to them. The Covid-19 crisis demonstrated that forecasting and charging schemes based on poorly designed traffic growth scenarios, focus on short time-period contingency scenarios, omitted shocks, excessive reliance on flawed financial and economic models, in-appropriate methods and narrow coverage can produce results that provide a false reassurance about the degree of the financial stability of the ANSPs in a crisis like the Covid-19 pandemic. Undeniably SES has promoted these deficiencies with the net result of institutionalizing financial and performance fragility to the European ANSPs.

The resilience engineering perspective looks into the capabilities of the system to cope with increasing demands and surprise events – both fundamental and situational and compensate by adapting its performance. Consequently, the focus shifts from individuals to teams and organizations who have to cope with multiple goals, organizational pressures, uncertainty and complexity. Resilience engineering is about understanding and anticipating what sustains and what erodes adaptive capacity. The definition implies four potentials of resilience, each representing an essential system capability (Hollnagel, 2018). The four essential capabilities are:

1. **Knowing what to do:** That is, how to respond to regular and irregular disruptions by adjusting normal functioning.
2. **Knowing what to look for:** That is, how to monitor events and actions that could become threats in the near term as well as monitor one's own performance.
3. **Knowing what to expect:** That is, how to anticipate developments and threats further into the future, such as potential disruptions, pressures, and consequences.
4. **Knowing what has happened:** That is, the ability to learn the right lessons from experience.

We argue that the Covid-19 crisis exposed that all three of the essential potentials were flawed and now it is time to not let the fourth one fail as well. Drawing on the fourth potential we argue that there is strong need for the re-introduction of the appropriate ability to adapt within the system so that it supports more resilient performance operations-wise and financial-wise after the Covid-19 crisis.

In the Resilience Engineering paradigm Woods and Branlat (2010, 2011) proposed three patterns of adaptive breakdown which represent patterns of maladaptive behavior:

1. **Complexities in time – Decompensation:** This pattern corresponds to an escalation of demands while the system is not capable of adapting and acting fast enough upon the set of disturbances. Under such circumstances, components are stretched to their performance limits and the system's overall control of the situation collapses abruptly.
2. **Complexities over scales – Working at cross-purposes.** System's behavior, which exist in the context of networks of interdependencies (functional, structural, temporal) and cross-scale interactions, have implications at a larger scale than simply at the level of elements producing the behaviors.
3. **Complexities in learning – Getting stuck in outdated behaviors.** This pattern emerges when a system gets stuck in implementing behaviors that were successful in the past and fails to recognize that the conditions for their implementation are no longer met. The pattern relates to breakdowns in how systems learn, either from past experience or dynamically, as situations unfold.

It is evident, in the authors view, that Covid-19 crisis uncovered all three patterns of adaptive breakdown in the European ATM system. In this line of reasoning, we propose a framework of possible solutions to counteract both financial and performance fragility:

1. **Increased Personnel Redundancy:** Hiring and training of new Air Traffic Controllers. Normalizing lean hiring and rostering personnel strategies is a certain path to performance deficiencies. A large share of delays this summer and the last 15 years is directly attributed to ATC staffing (PRC, 2022). This is a textbook example of exhausting capacity to adapt as disturbances/challenges cascade (Decompensation).
2. **Introduction of Stress Tests.** A stress test, in financial terminology, is an analysis or simulation designed to determine the ability of a given institution to deal with an economic crisis. Economic and financial models have limitations and constraints, including misspecification, estimation using assumed and sometimes inaccurate probability distributions, etc. Therefore, using such models to estimate the potential impact of shocks may lead to increasingly inaccurate estimates. Instead of doing financial projection on a "best estimate" basis, an ANSP and its regulators may do stress testing where they look at how robust an organization is in certain crashes. Useful performance indicators can emerge if these stress tests are properly designed and executed. Exploring the utilization of other criteria for the charging scheme than the ones based solely on traffic numbers may emerge as a consequence of these stress test. This is a textbook example of the world changes but the system remains stuck in what were previously adaptive strategies (Getting stuck in outdated behaviors).
3. **Moving Away from Uninformative Safety, Financial and Performance Indicators.** Current performance indicators belong to the 'lagging category' with minimal predictive value that may mislead from the complexities of the actual operational context. For instance, measuring an ANSP performance in terms of delay minutes accumulated is incorrect and highly misleading. It could have been a very busy day with adverse weather, lots of CBs (Cumulonimbus cells) and circumnavigation and controllers performing above standard to ensure separation and yet – delay minutes indicate low performance levels. A statistical analysis of performance-related information may be indicative of emerging threats from many sources. However, a resilient performance intelligence function requires a combination of reactive, proactive, and predictive indicators that will detect emerging threat patterns. The information published by PRC can only be used to assess how frequently organizations come close to the performance, financial and safety margins. Performance indicators are complemented with trends in the last decades and some elementary descriptive statistics. Therefore, stakeholders cannot discern anything more that some well-established but highly uninformative trends (Getting stuck in outdated behaviors).
4. **Restructuring of the Air Traffic Flow and Capacity Management (ATFCM) system.** ATFCM systems needs to move towards a more command and control system and consider rectifying the inefficiencies of the Computer Assisted Slot Allocation (CASA) algorithms. Slot allocation algorithms rely mostly on physical factors (e.g., prevailing winds estimated many hours earlier than the actual flight) but fail to account of actual aircraft performance, flight profile preferences by airlines and direct routings given by controllers in the en-route phase of flight. Hence, some ATC units may be

stretched above their capacity or others may be underutilized because of under-specifications in the ATFCM algorithms. PRC (2022) acknowledged these deficiencies and provided some remedies. This is a textbook example of behavior that is locally adaptive, but globally maladaptive as it to coordinate different groups at different echelons as goals conflict (Working at cross-purposes).

5. **Cultivating Adaptive Diversity.** In the European ATM there are several micro-cultures of controllers. These are controllers' communities exercising and promoting operations based on their local practices and local affordances. For instance, in a major ACC there are three different sector groups, and each group has a different working style/culture. These differences happen because the sector size, crossing points, traffic flows and hence needs vary. An adaptive way of working would increase the overall resilience. Institutionalizing a know-your-neighboring-units-work-practices awareness program would be beneficial to ATCOs during their basic or rating training with (familiarization visits to various ANSPs). Getting to know the working styles of your neighbors could help the ATCO understand them better, thus easier to adapt (Working at cross-purposes).
6. **Tap local knowledge.** Controllers at the sharp end of each unit know best the causes of safety and performance deficiencies. They rely on "localized performance and safety intelligence" at the individual and team level and respond accordingly. Likewise, parent ANSPs organizations may need to drive more of their sense making to local levels and exploit these more these localized performance and safety intelligence to detect and respond to weak signals of performance and safety deficiencies (Decompensation).

Environmental performance as the overarching SES target

The SES political initiative was introduced in 2004 (Finger and Baumgartner, 2014). In 2011 the SES performance scheme was adopted and is moving toward the end of the third Reporting Period. Currently RP4 is being drafted by the Commission and EASA amongst other agencies. Following the impact of Covid-19 travel restrictions, the SES performance scheme needed to be adjusted in order to cope for future crises. The European Union has adopted its Fit for 55 agenda (that is achieving climate neutrality by 2050) which shall provide the political impetus to meet the required contribution to the decarbonization of all the human activities including aviation. In IFATCA's view this is a unique opportunity to adjust the ATM sector's performance to the environmental challenges. This can be achieved by establishing an RP4 performance scheme which puts the environmental performance as the interdependency performance target which is currently lacking in the performance scheme.

Various studies (PRC, 2021; 2022) have highlighted the potential benefit pools of 8-12% ATM can manage as a contribution to the decarbonization of aviation. By creating a systemic approach to manage the ATM contribution to decarbonization IFATCA claims that this could be a win-win situation. To achieve such a win-win situation a systemic approach to managing the European Network needs to be created. This will provide a network-centric approach and the ATM sector under the central coordination of the NM, could start to work to a commonly agreed and shared vision (IFATCA, 2007) of SES. In order to achieve such a network centric approach several currently established operational and institutional set-ups will have to evolve and include an improved virtualized infrastructure. Synchronization and Orchestration needs to be organized (IFATCA, 2007).

SESAR 3 should focus on delivering such a netcentric approach by focusing on the needs of a common virtual Flight Data Processing Systems (FDPS) for the whole Network Management area and provide the ANSP planning tools which assist them to create the needed capacity when required. As the proposed change will have an impact on safety, the safety Key Performance Areas will need to focus on resilient performance while maintaining or extending the current level of safety. New technology will have to be introduced to ATM with a focus on supporting and sustain resilient performance and in particular focus on the principles of Human Machine Teaming. The ATM system can be defined as a “Joint Cognitive System” of people, teams, and artifacts that adapts to the challenges and demands posed by familiar and unfamiliar situations in a dynamically evolving operational context. In this context IFATCA has created the concept of Joint Cognitive Human Machine System (JCHMS) and wishes to influence ICAO and standardization bodies such as EUROCAE and EASA by researching and publishing (IFATCA JCHMS Group, 2022a; 2022b).

With benefits from aircraft technology and Sustainable Aviation Fuels (SAF) only taking real effect beyond 2030, ATM can help reduce emissions by addressing operational inefficiencies in the ATM system in the short to medium term. For every ton of fuel saved, an equivalent amount of 3.15t of CO2 can be avoided. In political discussions, ATM is frequently mentioned to be able to improve fuel efficiency by 10% or more. In reality, it is often not clear what measures are involved and how the results need to be interpreted. There are many different studies aimed at quantifying fuel and flight efficiency. While those studies provide useful and valuable insights, the differences in scope and methodologies make direct comparisons often difficult if not impossible. Previous PRC work (PRC, 2019) has estimated that the benefit pool that can be influenced by ANS is approximately 6-8% of the total gate-to-gate fuel burn (emissions) in the ECAC area. However, most studies apply similar methodologies which compute efficiency gains compared to a theoretical reference which in reality cannot be achieved at system level. There is clearly scope for further improvement in ANS resilient performance (organizational, system and network performance in financial and business terms). However, it is important to stress that the often-quoted benefit pools cannot be fully recovered, nor can the inefficiencies be entirely attributed to ANS. Full efficiency as envisaged is impossible due to technical and safety aspects (separation minima, adverse weather, avoidance of ‘Danger Areas’ and temporarily segregated areas) or tactical decisions (trade-offs). In fact, environmental objectives for ANS can even be conflicting; for example, noise abatement procedures at airports might lead to longer trajectories and hence additional emissions.

ANS performance can help reducing the environmental impact of aviation which can be broadly divided into the impact on (i) global climate, (ii) local air quality (LAQ), and (iii) noise. Generally, the management of noise is considered to be a local issue which is best addressed through local airport-specific agreements developed in coordination and cooperation with all relevant parties including ANS. Due to the complexity of those local agreements, there are presently no commonly agreed Europe-wide indicators specifically addressing ANS performance in the noise context.

Apart from the active support in noise management decisions, the areas where ANS can contribute to the reduction of aircraft noise are mainly related to operational procedures. Continuous climb (CCO) and descent operations (CDO), noise preferential routes and runways are all in the ANS portfolio and help to avoid unnecessary exposure to aircraft noise. The ATM-related impact on climate is closely linked to operational performance (fuel efficiency) which is largely driven by inefficiencies in the flight trajectory and associated fuel burn (and emissions). Hence, the focus has been traditionally on the monitoring of ANS-related operational efficiency by flight phase which served as a proxy for environmental performance since the distance or time saved by operational measures can be converted into estimated fuel and CO2 savings. Using the theoretical upper ceiling, the ANS contribution to reduce emissions is limited to some 0.3-0.4% of the total CO2 emissions in Europe (SAF ≈ 3.8%).

So, what can ATM do to help?

Increased operational efficiency leads to increased fuel efficiency, a subsequent reduction in emissions and network benefits. Ground infrastructure as a contributor to the Greening of Operations through efficiency improvement. ICAO, with the support of its Committee on Aviation Environmental Protection (CAEP), actively pursues its technical work on measures to reduce the environmental effects of aviation. As it is stated in ICAO document 10013 (2014) "significant fuel and emissions savings can be realized by an efficient ATM system. New and established technologies and concepts of operations in CNS can provide opportunities to improve the efficiency of ATM. CNS/ATM can permit more direct routings and the use of more efficient flight conditions such as optimum altitude and speed." Furthermore, in the same document it is stated "New and established technologies and concepts of operations in CNS, such as data link communications, PBN, ADS, FUA and A-CDM can provide opportunities to improve the efficiency of ATM". However, degraded, or low Availability and Continuity of CNS Systems and services (e.g., at airports) can lead to alternative routes flown thus more fuel burn and lower capacity or even total lack of service delivery. So, a new study of a new concept that analyzes the relation between CNS outages or systems unavailability with the impact on the environment and safety issues could help to arrive in the future at the elaboration of new useful metrics or KPIs as requested by Strategic Research and Innovation Agenda (SRIA).

When balancing the requirements of safety, efficiency, capacity and the environment, the level of safety shall always be maintained or improved at all stages of the ATM system (operation, maintenance, and development). In other words, respect for the environment dimension should not undermine or respect for safety. In case environmentally driven procedures are introduced in the ATM System, these must take into consideration the increased complexity for the front-end users, namely controllers and pilots. A trade-off between environment and capacity must be considered as part of this management of complexity, as safety is paramount. Any environmentally driven procedure shall not expose the ATCOs and Pilots to undue liability issues.

Individual environmental aspects shall be considered by an ATM environmental management system and documented in an ATM environment case as part of an overall performance case. Provisions for an

ATM environment management system should comprise at least the following requirements:

- Ensure that the level of safety shall be maintained or improved when environmentally driven procedures are introduced.
- Ensure that all individual environmental factors are identified and considered while establishing procedures.
- The actual values (noise levels, fuel consumption and the level of emissions) of the various individual environmental contributors of new or existing procedures should be established in detail for transparency purpose.
- The interrelation of the various individual environmental factors should be identified and addressed.
- Provisions for an environment case should comprise at least the following requirements:
  • An environment case is a documented body of evidence that provides argument that a certain procedure is optimized for all individual environmental factors as prioritized by the appropriate authorities.
  • An environment case should provide a detailed overview to the appropriate authorities for the determination of priorities of the individual environmental factors on a strategic level.

Program and measures of emission reductions should take into account:

- Safe production has the highest priority and might require additional resources.
- Balancing of emission reduction with competing factors (e.g., noise reduction) needs to be finalized at organizational (strategical level) level and be transparent. However, adjustments need to be possible in the tactical phase with the appropriate training of the concerned staff.
- New procedures and tasks need to be in range of the capability to adapt and system changes need to enhance the assistance of the staff, including the handling of congested situations.
- Information about emission reduction measures and training of the staff members involved is required to achieve optimal support.
- SJU is also requested to evaluate the recommendation for the development of a new Metric on CNS Availability and its' impact on Environment within the context of SRIA.

Conclusions

In this paper we argued that SES has a large share of responsibility in institutionalizing financial and performance fragility to the European ANSPs, we provided a framework of possible solutions to counteract both financial and performance fragility and we stressed the importance of reframing the SES Environment performance indicator to embrace the interdependencies between several performance areas. Thus, by creating a systemic approach to manage the ATM contribution to decarbonization IFATCA claims that this could be a win- win situation. The research and development of the SESAR projects will have to focus on considering the aspects that we have highlighted so far. Although we are aware of the need to aim for an ATM system that is increasingly attentive to emissions and environmental issues, it is necessary to ensure that these objectives do not conflict with the highest safety standards. Furthermore, it is necessary that any new procedures studied are not going to provide additional burdens to the personnel involved with new tasks that could, in an already particularly congested situation, further aggravate the work of the operating personnel.

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Does current Performance and Charging Regulation really facilitate Resilience of ATM Industry?

Vilma Deltuvaite[a, b]

Abstract

Recently increasing air traffic volatility creates new challenges for all aviation industry players, especially for ANSPs. Today, many ANSPs have to cope with unpredicted high volatility in air traffic flows resulted by unexpected external shocks and factors (e.g., military conflicts in different regions and, consequently, opening and closing of airspace, etc.) and local domestic factors (e.g., adverse weather conditions, etc.). The impact of external and internal factors on air traffic flows volatility makes a serious challenge for many ANSPs. Despite significant recent changes in external environment, does current performance and charging regulation of ATM industry provides the legal framework to facilitate resilience of ATM industry to different external shocks and factors?

This paper investigates the main trends and developments of ATM industry's external environment in the recent decade, the developments of performance and charging regulation of ATM industry, and resilience of ATM industry from performance and charging perspective. In addition, main recommendations for improving of ATM industry's resilience from performance and charging perspective following "best practice" approaches in other industries are provided in the paper. The main research questions investigated in the study are the following: what are the main limitations of current performance and charging regulation resulting in limited resilience of ATM industry and what are the main recommendations for improvement of ATM industry's resilience from performance and charging perspective? The following research methods were used in this study: systemic, logical, and comparative analysis of the scientific literature and legal regulations, structured interview, analysis of statistical data. The preliminary results of the study suggest that current performance and charging regulation facilitates resilience of ATM industry to a limited extend and a significant potential for improvement of ATM industry's resilience from performance and charging perspective exists.

Introduction

Recently increasing air traffic volatility creates new challenges for all aviation industry players. The volatile nature of the aviation recovery in Europe is challenging the fundamental airlines' business model. Over the years, airlines have outsourced as many parts of the business as possible. Recent problems in aviation industry are instead largely related to airlines' supply chains, which are vulnerable to disruptions beyond their immediate control. Due to the fierce competition in aviation industry and regulatory cons-

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traints many aviation industry actors have to operate with very low margins resulting limited financial capabilities to withstand different shocks. When a single part of the aviation ecosystem wobbles it leads to cascading disruption through the aviation value chain. The challenge of climate change potentially means slower air traffic growth in the future questioning sustainability of the current airlines' economic model implying unavoidable transformation with the focus on resilience of the aviation value chain.
Recent disruptions in air traffic management (ATM) industry are caused mainly by the airlines' business models being faster to react to unexpected external shocks and factors than the traditional air navigation service providers' (ANSPs) business model. Airlines' business model can adjust to any scale changes very quickly while due to the limited tactical flexibility ANSPs have only a limited number of measures to respond to changes in a short time. This raises the question does the current Single European Sky (SES) Performance and Charging Regulation allow ANSPs to respond flexibly to unexpected large-scale developments?

Recent Developments Challenging ATM Industry: Main Drivers and Their Transmission Mechanisms

Aviation industry's players are now exposed to many of the same risks they faced prior to the pandemic with liquidity risk, climate risk and geo-political risk becoming increasingly important. In addition to the challenging macroeconomic environment, all aviation industry's actors continue to battle the aftereffects of the pandemic, with staff shortages and strikes causing flight cancellations, bottlenecks, and delays across Europe. Recent macroeconomic and industry related developments including increasing air traffic volatility and changing traffic patterns are especially relevant for ATM industry's actors.

The global outlook faces significant downside risks, including intensifying geopolitical tensions, an extended period of stagflation, widespread financial stress caused by rising borrowing costs. In this challenging context global growth is projected to slow sharply in the next two years, consequently, euro area's GDP growth in near future is revised down as well (WB (2022), IMF (2022)). Inflation has accelerated in European Union (EU), reflecting firming demand, persistent supply disruptions, tight labour markets in some EU countries, and, especially, surging commodity prices, which have been pushed up further by the intensifying geopolitical tensions while euro area annual inflation is reaching multidecade highs this year (WB (2021, 2022)). Rising inflation has led to expectations of faster monetary policy tightening across the world. Consequently, anticipated interest rate hikes in response to high inflation by several major central banks will increase the global cost of borrowing. Because of the unprecedented nature of the dual shocks, IMF (2022) notes that the uncertainty is considerable and growth could slow significantly more while inflation could turn out higher than expected.
Widespread labour shortages in a number of EU countries have slowed the recovery and put significant upward pressure on wages. According to OECD (2021), this reflects a combination of declining labour supply and mismatches between available jobs and worker preferences. Recently aviation industry has become less attractive for jobseekers because of huge uncertainty of the industry's further development including negative headlines and large-scale redundancies during last years. Many airlines, airports, ground-handling companies, ANSPs had no choice but to sharply reduce headcounts during the

pandemic and they are now finding it very difficult to bring back former employees because they have found other jobs and the labour market has become extremely tight. In addition, potential employees have seen aviation industry's companies laying off staff in large numbers resulting lost confidence in these companies and aviation industry.

Recently increasing traffic volatility creates new challenges for all aviation industry players, especially for ANSPs. Today, many ANSPs have to cope with unpredicted high volatility in traffic flows (in terms of number of IFR flights[1] and traffic service units (TSUs)) resulted by unexpected external shocks and factors (e.g., military conflicts in different regions, etc.) and local domestic factors. The impact of external and internal factors on traffic flows volatility makes a serious operational and financial challenge for many ANSPs. The last two years mark a new era of volatility with a significant increase in traffic variability in the SES area[2] where monthly traffic variability[3] rose to 37 percent in 2021 compared to 11 percent in 2011 reaching multidecade highs in 2020 (49 percent). Recent macroeconomic and industry related developments pose many risks to ATM industry's resilience and have different potential consequences to industry's further development (see Table 1).

Category of developments	Main developments	Main developments and their transmission mechanisms
Macro-economic developments	Increasing macro-economic uncertainty and economic slowdown in EU	Despite the challenging macroeconomic environment, airlines retain a rather positive outlook. According to IATA (2022), the geopolitical situation in Europe had only a limited impact on passenger demand in 2022. The outlook is positive with aircraft deliveries set to increase in Europe, which should accommodate the expected growth in demand. However, passenger demand could wane somewhat in 2023 when some of the passenger "travel deficit" has been filled, and inflation might take a greater toll on household income. This would have a negative effect on traffic flows (in terms of number of IFR flights and TSUs) deteriorating ANSPs' financial situation
	Rising inflation and increasing labour market tension	In the light of rising prices of goods and services and increasing labour market tension ANSPs can experience pressure from trade unions to raise staff salaries resulting an increase in actual ANSPs' staff costs. Consequently, an increase in actual ANSPs staff costs could deteriorate the financial situation of ANSPs while inflation adjustment mechanism may be applied and unit rates may be amended only after two years
	Rising inflation and increasing cost of borrowing	Increasing cost of borrowing could constrain ANSPs' investments in new technologies limiting the technological progress of ATM industry and deteriorate ANSPs' financial situation due to the increasing interest expenses and limited availability of additional financial resources
ATM industry related developments	Increasing traffic volatility and changing traffic patterns	Recently increasing traffic volatility and changing traffic patterns when traffic flows differences between summer and winter seasons disappear create additional operational and financial challenges for many ANSPs. Traffic patterns have changed and traffic is very much concentrated on peak periods those are higher than before the pandemic. Scaling resources to accommodate traffic peaks is not easy because many ANSPs faced with significant staffing problems. A significant variation in traffic flows (in terms of number of IFR flights and TSUs) ensuring necessary number of operational staff (especially ATCOs) and balancing net cash flows (CFs) in a short-term as well as in the medium-term

Table 1: Recent Macroeconomic and Industry Related Developments Challenging ATM Industry

Source: OECD (2021), IATA (2022)

[1] IFR flight is a flight conducted in accordance with the Instrument Flight Rules (IFR)
[2] The SES area comprises the States included in the SES Performance Scheme: EU Member States plus Norway and Switzerland
[3] Traffic variability is expressed as a relative standard deviation of IFR flights and calculated dividing the standard deviation by the mean

Recent macroeconomic and industry related developments challenge ATM industry creating risks for ANSPs as organizations potentially having both income and cost side effects. While traditional ANSPs business model is fixed cost model where many of the costs related to air navigation services (ANS) provision (e.g., maintenance of ATM/CNS infrastructure) are fixed costs limiting ANSPs financial capabilities to withstand different shocks, the current performance and charging regulatory framework of ATM industry could minimise the impact of these challenges by supporting financial and operational capacity of ANSPs.

Performance and Charging Regulation of ATM Industry: Regulatory Developments and Challenges

Recently increasing air traffic volatility creates new challenges for all aviation industry players, especially for ANSPs. Today, many ANSPs have to cope with unpredicted high volatility in air traffic flows resulted by unexpected external shocks and factors as well as local domestic factors. Nowadays, the resilient ANS provision system is essential to cope with high traffic volatility supported by the SES performance and charging regulatory framework. This raises the question does the current SES Performance and Charging Regulation ensure the resilience of the ANS provision system and allow ANSPs to respond flexibly to different shocks?

The SES Performance and Charging Schemes for the provision of ANS are established on the basis of Article 11 of Regulation (EC) No 549/2004[4] and Articles 14-16 of Regulation (EC) No 550/2004[5] amended both in 2009 by Regulation (EC) No 1070/2009[6]. The SES Performance Scheme sets targets in the key performance areas (KPAs) of safety, environment, airspace capacity and cost efficiency through the adoption of EU-wide performance targets and approval of consistent national or functional airspace blocks performance plans. The targets in the KPA of cost efficiency are the basis for the calculation of user en-route and terminal charges under the SES Charging Scheme containing incentive mechanisms, including the sharing of some economic risks between ANSPs and airspace users (AUs) (see Table 2).

The SES Charging Scheme was established in 2007 on the basis of Commission Regulation (EC) No 1794/2006[7]. According to Commission Regulation (EC) No 1794/2006, in case of unexpected major changes of traffic or costs related to provision of ANS, unit rates might have been amended during the course of the year implying that traffic and cost risks have been passed in full to AUs. A new SES Charging Scheme including the move from a full cost recovery to the determined costs regime, the setting up of traffic and cost risks sharing between ANSPs and AUs mechanisms as well as the SES Performance Scheme containing the EU-wide and local performance targets revision mechanism were

[4] Regulation (EC) No 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the single European sky (the Framework Regulation) as amended by Regulation (EC) No 1070/2009

[5] Regulation (EC) No 550/2004 of the European Parliament and of the Council of 10 March 2004 on the provision of air navigation services in the single European sky (the Service Provision Regulation) as amended by Regulation (EC) No 1070/2009

[6] Regulation (EC) No 1070/2009 of the European Parliament and of the Council of 21 October 2009 amending Regulations (EC) No 549/2004, (EC) No 550/2004, (EC) No 551/2004 and (EC) No 552/2004 in order to improve the performance and sustainability of the European aviation system

[7] Commission Regulation (EC) No 1794/2006 of 6 December 2006 laying down a common charging scheme for air navigation services

introduced in 2012 (see Table 2). However, risk sharing mechanisms of the current SES Performance and Charging Schemes have both their benefits and limitations (see Table 3). In addition, exchange rate adjustment mechanism[8] is also applied to the unit rates and tariffs for ANS charges.

SES scheme	Risk sharing mechanism	Main principles of risk sharing mechanism		
		First reference period (RP1)[9, 10], 2012-2014	Second reference period (RP2)[10, 11], 2015-2019	Third reference period (RP3)[13, 14], 2020-2024
SES Performance Scheme	Local performance targets revision mechanism	During the reference period EU Member State may revise one or more local performance targets contained in the performance plans and adopt performance plans which are amended accordingly, only where both of the following conditions are met: EU Member State provided a reasoned request to the European Commission (EC) to revise local performance targets, and the EC has decided that it agrees that the intended revision is necessary and the intended revised performance targets are consistent with the EU-wide performance targets		
SES Charging Scheme	Traffic risk sharing mechanism	Under traffic risk sharing mechanism, the risk of revenue changes due to deviations from the TSUs forecast set out in the performance plan shall be shared between ANSPs and AUs. Traffic risk sharing mechanism is applied where, over a given year n, the actual number of TSUs exceeds the forecast established at the beginning of the reference period by more than +2 % and no more than +10 % or falls below -2 % and no more than -10 %, 70 % of the resulting additional revenue obtained (revenue loss incurred) by ANSPs concerned in excess of 2 % of the difference between the actual TSUs and that forecast shall be passed on to AUs (recovered from AUs) through adjustments of the unit rates in year n+2. Where, over a given year n, the actual number of TSUs deviates from the forecast included in the performance plan for that year n by no more than ±2 %, the resulting additional revenue or the resulting revenue loss shall be borne in full by ANSPs. Where, over a given year n, the actual number of TSUs is lower than 90 % (exceeds 110 %) of the TSUs forecast included in the performance plan for that year n, the amount of the revenue loss incurred by ANSPs (the additional revenue obtained by ANSPs) concerned in excess of 10 % of the difference between the actual TSUs and forecast shall be recovered (passed) in full, from AUs (to AUs), through adjustments of the unit rates in year n+2		
	Cost risk sharing mechanism	ANSPs should bear the cost risk with regard to differences between determined and actual costs, except for a limited number of cost items subject to specific requirements[15]		
	Inflation adjustment mechanism	Inflation adjustment mechanism[16] is applied due to differences between forecasted and actual inflation. The difference in percentage between the actual inflation index and the forecast inflation index for that given year n is included as an adjustment for the calculation of the unit rate for year n+2		

Table 2. Risk Sharing Mechanisms of the SES Performance and Charging Schemes. *Source: compiled by author*

[8] The unit rates and tariffs for en-route and terminal charges are established by each EUROCONTROL Member State and adjusted every month by applying an exchange rate between the euro and the national currency (EUROCONTROL (2020))

[9] Commission Regulation (EU) No 691/2010 of 29 July 2010 laying down a performance scheme for air navigation services and network functions and amending Regulation (EC) No 2096/2005 laying down common requirements for the provision of air navigation services

[10] Commission Regulation (EU) No 1191/2010 of 16 December 2010 amending Regulation (EC) No 1794/2006 laying down a common charging scheme for air navigation services

[11] Commission Implementing Regulation (EU) No 390/2013 of 3 May 2013 laying down a performance scheme for air navigation services and network functions

[12] Commission Implementing Regulation (EU) No 391/2013 of 3 May 2013 laying down a common charging scheme for air navigation services

[13] Commission Implementing Regulation (EU) 2019/317 of 11 February 2019 laying down a performance and charging scheme in the single European sky and repealing Implementing Regulations (EU) No 390/2013 and (EU) No 391/2013

[14] Commission Implementing Regulation (EU) 2020/1627 of 3 November 2020 on exceptional measures for the third reference period (2020-2024) of the single European sky performance and charging scheme due to the COVID-19 pandemic

[15] Unforeseen and significant changes in costs of new and existing investments (only for RP3), pension costs, costs resulting from unforeseeable changes in interest rates on loans, costs resulting from unforeseeable changes in national taxation law, new cost items not covered in the performance plan, but required by law (only for RP1-RP2), costs or revenues stemming from international agreements (only for RP1-RP2)

[16] The determined costs incurred by competent authorities, depreciation costs and cost of capital shall not be subject to any inflation adjustment (only for RP3)

SES scheme	Risk sharing mechanism	Benefits of risk sharing mechanism	Limitations of risk sharing mechanism
SES Performance Scheme	Local performance targets revision mechanism	Revision of local performance targets and adoption of new performance plan of EU Member State at the beginning of the reference period could improve financial and operational performance of ANSPs during the course of the reference period	Revision of local performance targets and adoption of new performance plan of EU Member State is a long political and legal procedure limiting the impact of revised performance targets and adopted new performance plan on financial and operational performance of ANSPs in a short-term (especially in a revision of a local cost-efficiency target) Revision of local performance targets and adoption of new performance plan of EU Member State in the middle of the reference period or later does not contribute to improvement of financial and liquidity situation of ANSPs
SES Charging Scheme	Traffic risk sharing mechanism	Moderate fluctuations in traffic flows (in terms of TSUs) and traffic's forecasts deviations can be covered by traffic risk sharing mechanism and sharing additional revenue (or revenue loss) between ANSPs and AUs	In case of unexpected major fall in traffic (in terms of TSUs), negative net cash flows from operating activities during the course of the year could deteriorate the financial and liquidity situation of ANSPs while traffic risk sharing mechanism may be applied and unit rates may be amended only after two years In case of unexpected major fall in traffic flows (in terms of TSUs) loss affects AUs in a disproportionate manner
	Cost risk sharing mechanism	Cost risk sharing mechanism strengthens financial discipline of ANSPs while only unforeseen and significant changes in costs related to provision of ANS can be recovered from AUs	Cost risk sharing mechanism is applied only during one reference period while planning and deployment of major investments projects usually takes more than one reference period
	Inflation adjustment mechanism	Moderate fluctuations in the rate of inflation and inflation's forecasts deviations can be compensated by inflation adjustment mechanism Inflation adjustment mechanism as a risk management measure is beneficial for ANSPs and is applied in many industries as a usual risk management practice	In case of unexpected major rise in the rate of inflation, an increase in actual ANSPs staff and other operating costs during the course of the year could deteriorate the financial and liquidity situation of ANSPs while inflation adjustment mechanism may be applied and unit rates may be amended only after two years[19]

Table 3. Summary of Benefits and Limitations of Risk Sharing Mechanisms of the SES Performance and Charging Schemes for RP3

Source: compiled by author

[17] The EC shall adopt the decision regarding revision of local performance targets of EU Member States within seven months from the date of the submission of the complete request submitted by EU Member State

[18] Cost risk sharing mechanism is not applied if the differences between determined costs and actual costs result from unforeseen and significant changes in costs, on the condition that such changes in costs are outside the control of ANSPs and, in the case of cost increases, that ANSPs have taken reasonable measures to manage cost increases during the reference period

[19] In case of unexpected major rise in the rate of inflation, ANSPs can experience pressure from trade unions to raise staff salaries as a response to increasing prices of goods and services resulting an increase in actual ANSPs' staff costs. Consequently, an increase in actual ANSPs staff costs and other operating costs during the course of the year could deteriorate the financial situation of ANSPs while inflation adjustment mechanism may be applied and unit rates may be amended only after two years

Because of the significant, unprecedented impact of the COVID-19 pandemic on the aviation industry, and in particular on the provision of ANS, certain exceptional liquidity support measures had been provided to ANSPs[20] and AUs[21] in 2020 implying limitations of the current SES Performance and Charging Regulation to address large-scale disruptions in aviation industry. Russia's invasion of Ukraine has led to significant changes in flight patterns in Europe. The unprovoked invasion of Ukraine has brought commercial flying there to a standstill and stopped overflights of neighbouring Moldova. Elsewhere around the borders of Ukraine, Russia, and Belarus, overflights are also much disrupted. Consequently, some additional liquidity support measures for ANSPs have been proposed in 2022[22].

The current SES Performance and Charging Schemes are designed assuming steady air traffic flows growth without significant external shocks resulting that the risk sharing mechanisms have both their benefits and limitations. Moderate fluctuations and forecasts deviations of traffic flows and changing macroeconomic conditions can be covered by traffic risk sharing and inflation adjustment mechanisms, while cost risk sharing mechanism strengthen financial discipline of ANSPs. However, risk sharing mechanisms do not allow ANSPs to respond more flexibly to unexpected developments in the external environment and to become more resilient to large-scale disruptions. The primary goal of the SES Performance Scheme is improvement of the performance of ANS in the SES, while the complementing SES Charging Scheme is instrumental to the successful implementation of the SES Performance Scheme. Both schemes should foster long-term improvements in the performance of ANS, and only implicitly implying the focus on sustainable operational and financial capability of ANSPs in a long-term.

Impact of Macroeconomic and ATM Industry Developments on ANSPs Financial Performance and Management Decisions: Research Results

The last two years were the most devastating years for the aviation industry during the last decades while the aviation industry has been hit harder than many other industries as a result of the protective travel restrictions implemented by many EU Member States to contain the COVID-19 pandemic

[20] Complementary to initiatives at country level, EUROCONTROL put in place a loan facility in 2020 to support the ANSPs whose revenues have been decimated by the traffic collapse and ten countries opted into the loan facility (FAA/ATO and EUROCONTROL (2021))

[21] The 41 Member States of EUROCONTROL approved in early April 2020 the temporary deferment of route charges bills in the EUROCONTROL Multilateral Route Charges System due in April, May, June, and July 2020, with payments beginning in November 2020. Given the sizable drop in traffic in 2020 and despite the measures implemented by SES ANSPs to respond to this crisis, the SES performance and charging regulatory framework was expected to result in a massive increase of ANS charges from 2022. To address this, in 2020 the EC put in place exceptional measures (Commission Implementing Regulation (EU) 2020/1627) which required the performance plans to be revised and ANSPs' revenue loss of the years 2020 and 2021 to be recovered over a period of 5 to 7 years. These measures were designed to make sure both, that ANSPs adjust their operations to the new realities and that AUs are shielded from a sudden increase of ANS charges during recovery from the COVID-19 pandemic (FAA/ATO and EUROCONTROL (2021))

[22] The proposals to create a European ATM special solidarity Fund to support Ukraine and Moldova in sustaining the costs of the operational and maintenance staff of their ANSPs for 2022 and a Voluntary Temporary Solidarity Fund to support Estonia, Latvia, Lithuania, and Poland in sustaining the costs of the operational and maintenance staff of their ANSPs for 2022 were discussed in the ad hoc Standing Committee on Finance of the Provisional Council meeting held on 20 June 2022 and presented at the 57th session of the Provisional Council on 29 June 2022. Both proposals have been sent to the EUROCONTROL's Member States for approval by 9 September 2022

leading to unprecedented drop in demand for air travel. This raises the question how recent developments have impacted ANSPs financial performance and management decisions related to financial and human resources management, investments projects' implementation as a response to a sharp drop in air traffic flows in the last two years?

Research methodology. This study focuses on the following research questions: financial capability of ANSPs to withstand large-scale external shocks and ANSPs management decisions regarding financial and human resources management as a response to large-scale disruptions. The impact of macroeconomic and ATM industry developments on ANSPs financial performance and management decisions was examined using statistical data analysis. In addition, structural interviews with six ATM industry's economic regulation experts from five EU Member States representing different stakeholders (ministries, NSAs, ANSPs) have been conducted in June-July of 2022.

Data. Annual operational and financial data for 24 ANSPs providing ANS in the SES area (the SES area's ANSPs[23]) for the years 2017 to 2021 had been used in this research with some data limitations for year 2021[24].

Research results. With the SES area's ANSPs primarily funded through en-route and terminal ANS charges of flights in controlled airspace applying "user pay principle", the dramatic drop in demand[25] as a result of the COVID-19 pandemic had also a major impact on ANSPs revenues and cash flows. A drop of this magnitude has never been seen, even in previous shock events greatly affecting the aviation industry at regional and global scale. In response to the sizable drop in traffic in 2020, a number of ANSPs undertook a range of measures[26] to mitigate the impact of the traffic reduction on their activity but also to address potential cash shortages. Given the sizable drop in traffic in 2020 and despite the measures implemented by ANSPs to respond to this crisis, on average, cash reserves held by the SES area's ANSPs have covered only slightly more than half of the reduction in ANS charges in 2020 suggesting that in the short and medium terms, these ANSPs might face significant liquidity issues (shortage of cash to finance operations). The liquidity and financial leverage of the SES area's ANSPs deteriorated significantly in 2020[27], although the situation might be very different when looking at ANSPs individually. The ANSPs providing ANS in controlled airspace of Denmark, Portugal, Slovenia, and Romania experienced the

[23] Due to the specific organisational and financial set up in HCAA (Greece), DCAC (Cyprus), DSNA (France), IAA (Ireland), LVNL (Netherlands) and MUAC, these six ANSPs are excluded from the research scope
[24] Annual operational data was available only for the years 2017-2020, while financial data for year 2021 covers only 11 ANSPs
[25] Compared to 2019, the number of IFR flights in the SES area decreased by 55.4 % and amounted to 4.4 million IFR flights in 2020
[26] Broadly, all the measures introduced by the SES area's ANSPs can be grouped into three categories: aid from National Governments, loans, and cost-containment measures. An overview of the cost containment measures reported by the SES area's ANSPs is provided in a number of sources: FAA/ATO and EUROCONTROL (2021), PRC (2021, 2022c)
[27] In 2020, the average current ratio at the SES area level amounted to 2.1, which is down by -32 % compared to the 2019 average of 3.1, while the average cash-on-hand days at the SES area level amounted to 149 days, which is 41 days (or -22 %) lower than the 2019 average of 190. The average equity ratio at the SES area level amounted to 0.4 in 2020, down by -16 % compared to the 2019 average of 0.48

most significant liquidity deterioration in 2020. However, the liquidity of the SES area's ANSPs started to improve in 2021 implying immediate measures taken by ANSPs to stabilize their financial situation.

With a large part of the ANS provision costs being fixed in the short term, the measures taken by the SES area ANSPs could only reduce the costs by 5.0 % in 2020, notwithstanding the dramatic drop in traffic in 2020. With the SES area's ANSPs being primarily funded through route charges, their immediate focus was on cost-containment initiatives, loans, and other measures to ensure cash flows and business continuity. Staff costs were by far the main source of the SES area ANSPs savings in 2020, due to the implementation of cost mitigation measures[28]. Majority of ANSPs also reduced non-staff operating costs by completing only essential maintenance, reducing utilities costs and non-essential training activities. Finally, the cancellation or deferral of non-essential investments resulted in lower depreciation costs and lower cost of capital. Although many ANSPs in the SES area adopted a range of cost mitigation measures, the impact of these measures was not sufficiently large to completely offset the substantial reduction in revenue, resulting in negative net cash flows (CFs) from operating activities for almost all the SES area's ANSPs. Overall, almost all the SES area's ANSPs had negative free CFs in 2020, highlighting the need to rely on financial reserves to ensure ongoing ANS provision and/or other liquidity measures, such as loans or state aid, where reserves were not sufficient. In addition, many the SES area's ANSPs reduced CAPEX[29] by -24 % as most of them postponed non-essential investments to future years in order to preserve cash in 2020. However, ANSPs' investments postponement or cancellation can have a long-term consequence as technological progress of ANS provision can slowdown. Taking a long-term perspective, only the SES area's ANSPs having high liquidity reserves and positive net financing activities CFs were capable to continue investment projects implying their capability to focus on long-term sustainable provision of ANS instead of short-term liquidity management.

All the SES area's ANSPs were not able to remain the same level of operational efficiency and to adapt to extremely low traffic levels in the same manner in 2020. Some ANSPs where overtime was allowed and used in the previous years could immediately reduce, to a limited extent, the level of ATCO-hours on duty in operations rooms. In some organisations, a larger proportion of ATCOs in OPS was allocated to non-operational duties. When short-time work could be applied, the time spent by ATCOs on duty in operations rooms could also be reduced. Similarly, ANSPs where overtime was allowed and used in the previous years could more easily reduce (to a limited extent) the level of ATCO-hours on duty than ANSPs where overtime for ATCOs in OPS is not allowed. Finally, the possibility to apply short-time work for some ANSPs brought more flexibility in adapting the ATCO workforce in response to extremely low traffic levels. In 2020, a moderate reduction in the total number of ATM/CNS staff, mainly reflecting

[28] Staff costs were by far the main source of savings in 2020 due to the implementation of the following measures: short-time work/furlough schemes, where applicable, with part of employees' salaries paid by the State either directly to the employees or reducing ANSPs wage bill, reduced staff numbers, and reduced level of remuneration through reduction or freeze of base salaries, reduction, or suspension of variable part of salaries such as overtime payments and performance bonuses (PRC (2022a, 2022b))
[29] Capital expenditure (CAPEX) – a component of cash flows from investing activities that represents the funds used to acquire capital non-current assets

decreases in some staff categories[30], was observed. On the other hand, increases are observed for ATCOs on other duties and on the-job trainees, reflecting a reallocation of some ATCOs from operational to non-operational duties due to the traffic reduction in 2020, and the fact that newly recruited ATCOs had to complete their on the-job training. Due to the applied measures, the total number of ATCOs except to some Nordic countries (Finland, Norway) remains the same in all the SES area's ANSPs in 2020.

The COVID-19 pandemic has led to a sharp drop in air traffic as a result of a significant fall in demand and direct measures taken by the EU Member States as well as third countries to contain the outbreak of the pandemic. The magnitude and persistence of this global crisis is unprecedented and there is still great uncertainty about the shape and form of the recovery over the coming years. This combination of high severity and high persistence also means that in the SES Performance and Charging Regulation existing absorption mechanisms designed to cope with unexpected traffic variations (e.g., risk sharing mechanisms, legally mandated reserves) might not be sufficient for ensuring the resilience of ANSPs. Recent extreme disturbances showed that the current ANS funding scheme in the SES area was not designed to cope with shocks of this magnitude. In the ATM network – a very dynamic and interconnected system – the ANSPs ability to adapt to changing conditions (flexibility/ scalability) and to mitigate effects of unexpected events (resilience) becomes more and more important.

Performance and Charging Regulation of ATM Industry: Recommendations for Further Developments

Recent macroeconomic and industry related developments challenging ATM industry revealed limitations of the current SES Performance and Charging Regulation to address large-scale disruptions in aviation industry implying necessary further regulatory developments of the SES Performance and Charging Schemes as well as transformation of ANS provision/business model allowing ANSPs to respond more flexibly to unexpected developments in the external and internal environment and to become more resilient to large-scale disruptions.

Most recent political debates and scientific discussions on performance and charging regulation of ATM industry in Europe, interviews with ATM industry's economic regulation experts and research results provided many different perspectives regarding benefits and limitations of the current SES Performance and Charging Regulation addressing large-scale disruptions. Considering recent developments challenging ATM industry, progress in development and deployment of ATM and communication, navigation, and surveillance (CNS) technologies, different proposals reinforcing resilience of ATM industry, recommendations focus on further regulatory developments of the SES Performance and Charging Schemes more particularly on transformation of ANS provision/business model (see Table 4). The future ATM industry will progressively evolve into a data ecosystem supported by a service-oriented architecture enabling the virtual defragmentation of European skies as highlighted in the latest European ATM Master Plan and European Airspace Architecture Study (SJU (2019, 2020)). The ATM system infrastructure will progressively evolve with the adoption of advanced digital technologies, allowing civil and military ANSPs and the Network Manager (NM) to provide their services in a cost-efficient and effective way irrespective of national borders, supported by secure information services. Supported by

[30] Other staff, ATCOs in OPS, technical support for operational maintenance, administrative staff, and staff for ancillary services (PRC (2022a, 2022b))

progressively higher levels of automation and common ATM data services, the ATM system will be able to use resources more efficiently, responding to disruptions and changing demand with greater flexibility and resilience. The introduction of service-oriented architectures – relying on vertical and geographical decoupling of services along with new technologies, such as virtual centres associated with a sector-independent air traffic services (ATS) framework – will enable dynamic and shared management of airspace and remote provision of ATS, meaning that sectors can be dynamically modified based on demand and airspace available and managed by the most appropriate area control centre (ACC). Moreover, flight-centric operations may mean that ATS methods gradually evolve from the management of pieces of airspace (sectors) to the management of the trajectory of flights across a larger portion of airspace, thus enabling increased flexibility (SJU (2019, 2020)). The new service-oriented architecture can be implemented gradually whenever for any subset of ANSPs a layer is sufficiently harmonised to be vertically decoupled and consequently services of that layer can be horizontally re-integrated. The current SES Performance and Charging Regulation allows more flexibility and differentiation with respect to the provision of ATM/ANS and explicitly allows submitting ATM data service provision to decoupling and market conditions. However, Ravenhill (2022) highlights that while making some ATM/ANS provided under market conditions may drive economic benefit for the AUs, the lesson to be learned from the recent upheavals in aviation industry is more about how different strategic business risks are shared between different ATM industry's stakeholders and priced into the ATM/ANS. One of the most relevant traffic risk can be shared using dynamic airspace sharing as a part of the Demand Capacity Balancing solution set allowing traffic risk to be shared between different ANSPs when NM collaboratively agreeing the sector opening plan to even out traffic across the ANSPs, leading to more stable ATCOs workload and reducing local traffic risks. While cost risk more particularly ATM system development/deployment cost risk can be taken by both the ATM system's manufacturer/supplier and the purchaser (ANSP) and shared between different ANSPs and ATM system's manufacturer(s)/supplier(s) establishing technological alliances (e.g., iTEC) and implementing common procurement and deployment of ATM system(s). Sharing operational cost between different ANSPs is possible through a range of technological solutions such as virtual centres, remote towers, etc. Many different perspectives regarding strategic ATM business risks sharing are foreseen in the latest European ATM Master Plan and European Airspace Architecture Study including the vision that national ANSPs are becoming ATSPs providing flexible and scalable ATS based on consuming ATM data and CNS services rather than taking the entire risk of ATM business ownership (SJU (2019, 2020)).

However, full implementation of the SES and reinforcing the resilience of the whole aviation industry must involve all aviation industry's stakeholders – ANSPs, airlines, airports, ground-handling companies, and other actors – focusing on a collaborative decision-making, data and information sharing across the entire aviation value chain. At strategic level all aviation industry's actors have to agree on future traffic level they have to accommodate while at tactical level make timely decisions solving any arising operational problems and challenges. Facing the challenges of volatility in demand for ANS services the SES Performance and Charging Regulation should provide the necessary flexibility to ANSPs and AUs to respond to large-scale external shocks, however, more and more decisions between EU Member

States, ANSPs and AUs should be made during consultations involving all stakeholders in collaborative decision-making process supported by the SES performance and charging regulatory framework. New technological developments in ATM industry and transformation of traditional ATM/ANS provision/ business model will allow to introduce new strategic business risks management practices in ATM industry resulting a more sustainable and resilient ATM industry.

Recommendations for further regulatory developments of the SES Performance Scheme	Recommendations for further regulatory developments of the SES Charging Scheme	Recommendations for further transformations of ANS provision/business model
Short-term and medium-term recommendations		
Rethinking of KPAs and key performance indicators (KPIs) of the current SES Performance Scheme and setting performance targets for some KPIs only at EU level (e.g., environment KPI) Focusing on operational efficiency fostering technological progress of ATM industry instead of cost efficiency and defining more relevant operational efficiency's KPIs and PIs Introduction of dynamic KPIs targets setting system[31] relating performance targets to traffic level and allowing more flexibility in adjustment of performance targets during the course of the year as well as reference period Introduction of additional metrics and indicators reflecting traffic patterns and local conditions of the EU Members States Introduction of prospective approach to the revision of EU-wide and national performance targets and adoption EU Member(s) State(s) performance plan(s) instead of retrospective approach and retroactive adjustments of performance targets implying restart of the new reference period	Complementing risk sharing mechanisms by introducing some additional measures dealing with extraordinary situations where initial data, assumptions, and rationales underpinning the performance targets are to a significant and lasting extent no longer accurate due to the extraordinary circumstances Ensuring efficient allocation of risks between different stakeholders (EU Member States, ANSPs, and AUs) addressing the underlying issue of misalignment of inadequate management of risks Building the liquidity reserves to ensure ANSPs are well prepared to face the risks that could arise and capable of withstanding shocks Strengthening the role and responsibility of the EU Member States as the main ANSPs shareholders in strategic business risk management process ensuring the provision of essential services vital for the society and the economy and reinforcing the resilience of critical infrastructure[32]	Fostering deployment of technological solutions increasing digitalisation, automatization, scalability, and reinforcing the resilience of ATM/ANS provision at individual ANSP level Increasing outsourcing of business support functions and focusing on their main activities – air traffic services (ATS) provision
Long-term recommendations		
Involvement of different ATM industry's stakeholders (airports, AUs, and other aviation stakeholders) into the SES Performance Scheme defining their contribution to the achievement of the SES goals including KPAs and KPIs		Supporting the progressive shift from a current fully vertically integrated ATM/ANS provision model to a new ATM/ANS provision model where ANSPs focus on their core capability of ATS delivery and acquire other ATM/ANS services from one or more separate providers

Table 4: Recommendations for Further Regulatory Developments of the SES Performance and Charging Schemes and Transformation of ANS Provision/Business Model. *Source: compiled by author*

[31] According to the ICAO Annex 11 – Air Traffic Services, ICAO Safety Management Manual (SMM) (Doc 9859), EUROCONTROL's ESARR 2 and ESARR 4, each Member State shall establish a State Safety Programme, including safety performance indicators system. The targets for the safety performance indicators for ATS operators are defined as targets values per flight movements or per flight hours allowing more flexibility in targets setting in respect to the traffic level

[32] Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection

Conclusions

Recent unexpected external shocks continue to have a huge impact on the aviation industry, not just the airlines and the airports but also the ANSPs keeping the skies safe. The current SES Performance and Charging Schemes are designed assuming steady air traffic flows growth without significant external shocks resulting that the risk sharing mechanisms have both their benefits and limitations. Moderate fluctuations in air traffic flows and changing macroeconomic conditions can be covered by traffic risk sharing and inflation adjustment mechanisms, while cost risk sharing mechanism strengthen financial discipline of ANSPs. However, risk sharing mechanisms do not allow ANSPs to respond more flexibly to unexpected developments in the external environment and to become more resilient to large-scale disruptions. Recent macroeconomic, financial and industry related developments challenging ATM industry revealed limitations of the current SES Performance and Charging Regulation to address large-scale disruptions in aviation industry implying necessary further regulatory developments of the SES Performance and Charging Schemes as well as transformation of ANS provision/business model allowing ANSPs to respond more flexibly to unexpected developments and to become more resilient to large-scale disruptions. Implementation of the SES and reinforcing the resilience of the whole aviation industry must involve all aviation industry's stakeholders – ANSPs, airlines, airports, ground-handling companies, and other actors – focusing on a collaborative decision-making, data and information sharing across the entire aviation value chain.

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Session 3

How to prepare ATM for current and upcoming risks?

How to prepare ATM for current and upcoming risks? The expert panel view.

In the final panel of the event, and under the direction of Moderator Professor Hartmut Fricke of Dresden Technical University, four senior experts representing different stakeholder groups within the European air traffic management (ATM) value chain, gave their views on how ATM in Europe can be made more resilient, taking into account the views and analysis of expert speakers at the research workshop.

Alessio Quaranta (Director General of the Italian Civil Aviation Authority ENAC), John Santurbano (Chairman FABEC CEO Board and Director of the EUROCONTROL Maastricht Upper Area Control Centre, MUAC), Denis Bouvier (Member of Single European Sky Performance Review Body and formerly Head International Affairs/Directorate for safety of State aeronautics in the French Air Force) and Jesus Caballero (Chief Executive Officer of the SOF Connect consortium which runs the Sofia Airport) outlined their visions for a more resilient future for European ATM. The following extracts are edited summaries of their presentations and answers to question from delegates.

Alessio Quaranta: "We need to think about resilience in a new way"

The Single European Sky (SES) regulation worked quite well until 2020 but then the COVID shock completely changed everything. I think we should try to think about resilience in a new way, as referenced in the recent ICAO conference on the subject. This means not just analysing what we did in the past but learning the lessons and planning for future. Air navigation service providers (ANSPs) are business enablers and they must continue their operations in all circumstances. So this means that we may have to envisage a new criteria of financial fitness before we grant them a licence, as we do with commercial airlines.

We also have a persistent lack of automation so we need to maintain staffing levels, even if it this means maintaining a rigidity in ANSP costs. A new kind of flexibility may be required in the performance rules to balance these needs, including flexibility in staff salaries, unpopular though this may be among ANSPs.

We may also need to consider other interventions, including new forecasting inputs. This is in no way a criticism of STATFOR but perhaps we could also include alongside average levels of traffic demand more localised variations.

It's time take advantage of the crisis to make changes to the regulatory regime. But we will have to think very carefully about some of the proposed changes, such as a single charging system throughout ECAC states to encourage airlines to take the shortest and most environmentally responsible route between origin and destination airports. This will need very careful consideration.

We need to optimise the system - there is a wide gap between high level planning at the European level and operational experiences at the local level and this gap will need to be closed somehow. But we might be able to do this flexibly, adding more resilience into the system without having to draft new legislation at the EU level.

John Santurbano: "The best technologies, investing in the right competences and being agile"

The reality is that you will never get the regulation that will totally please everybody and you will never get precise traffic forecasts as some variables can simply not be predicted. But regulation is not necessarily wrong. Sometimes, it's more about our inability to adapt to the regulation. This means investing in the right competencies and being flexible and agile. We have managed the crisis – we have gone from managing 10 per cent of 2019 traffic levels to 90 per cent without too many issues. We haven't lost staff or ANSPs and there have been no safety issues, therefore we should be optimistic and positive.

With shared ATM systems, as we have seen with our Dutch and Belgian military partners, with Slovenia Control and soon with the Karlsruhe UAC, we can harmonise systems and hence increase efficiency and reduce costs. Shared systems are the way ahead. But for that we need to intensify cooperation and to share a vision.

Common use of airspace, shared between civil and miliary colleagues, is based on trust. The crisis in Ukraine has shown that in some circumstances the military need airspace capacity, so I think investing in the right technologies, developing trust, sharing systems and avoiding finger-pointing is a good way ahead.

In terms of ensuring the balance between managing the fixed costs of staff and the peaks and troughs of demand we have developed solutions to this - flexible rostering tools which use artificial intelligence to optimise air traffic controller rosters with regard to traffic demand and traffic peaks in particular and optimising sector occupancy. Most importantly, for this to work you also need good social dialogue. Flexibility and agility are only possible if there is a buy-on from the workforce.

Denis Bouvier: "Civil/military collaboration means cross-fertilising our knowledge, reducing costs and using the same tools"

What is the relevance of the Professor Brunnermeier's presentation to military activities? First, the mindset. From the soldier to the general we must first accept the shock and the potential defeat but then react as soon as possible to regain control. A plan must be prepared. What is the end state? What do we want to achieve? This takes a lot of thinking through the scenarios, including the maverick scenarios which perhaps is something we don't do enough of in ATM.

But it is clear we must deploy a network of connected cyber-resilient systems. This is very important for ATM. Do we want a harmonised system which is less costly but will be more vulnerable to a specific threat? It would be better to have different systems but interoperable and cyber resilient.

With the flexible use of airspace concept we have implemented tools in many places but the problem is they are not always interoperable, so that means at the end you need humans to re-arrange the flow of data. We need a system which is fully interoperable so in case of a shock you can send the date via different nodes.

We are all working for the pilots. The role of the NM is crucial - it has to inform airspace users of the activation and deactivation of military airspace, but this is linked to ACC systems, and it is the ANSPs' responsibility to send real-time data on activation and deactivation of these areas to the NM, who will send to airspace users.

You have to associate the military. I recall the conclusion of Air Navigation Conference 13 of the general assembly of ICAO which said we have to move from civil/military "cooperation" to more "collaboration" and that means doing things together. We need to cross-fertilise our knowledge, reduce costs and use the same tools. We need to be closer together in the cyber dimension.

Jesus Caballero: "We have learnt lessons from this crisis – mainly, we need to prepare for the next crisis."

Airports are an essential part of the full aviation value chain. During 2022 traffic has been picking up more than expected and Bulgaria has performed very well despite the increase in traffic following the war in Ukraine.

Airport Collaborative Decision Making (A-CDM) is the concept we are using to help the network in real time understand what is happening here on the ground. The next five to ten years will see Sofia growing as we become more connected to the Middle East, Scandinavia, and our neighbours in Eastern Europe. We have already started to connect operational data with Eurocontrol and we are building an airport operations centre to coordinate traffic management between the tower, the ground and in the airspace; we expect to have A-CDM implemented in the next five years here in Sofia.

We have learnt lessons from this crisis – mainly, we need to expect next crisis well prepared. We will add in automation so ground operations can be prepared automatically to avoid sudden staff shortages, especially now that environmental considerations are back on the top of our agenda.

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