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Air Navigation Service Providers and Environmental Performance

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Discussion Questions:

1. To what extent can ANSPs contribute to climate change mitigation?
2. What are the trade-offs of KPA of sustainability?
3. How does the market environment and structure affect the environmental performance of ANSPs?

Abstract

Environmental performance is a significant aspect of aviation. Apart from reducing the emissions of the ANSP, it is important to consider the airspace structure. The Single European Sky (SES) aims to organize the airspace uniformly, with air traffic control areas based on operational efficiency rather than national borders. One of the main aspects of SES is performance evaluation in four areas: cost efficiency, capacity, safety, and environment. In the Key Performance Area (KPA) of environmental, targets aiming at climate change mitigation have been set for flight efficiency and airspace structure. This chapter discusses the various measures and considers some challenges for improved environmental performance.

Keywords: flight efficiency, airspace, Performance; environment, Key performance indicators, KPAs trade-offs

1 Introduction

Air transportation contributes to economic prosperity, facilitating growth, particularly in developing countries. Aviation facilitates the transportation of people and goods, improves living standards, alleviates poverty and increases revenues from taxes. Nevertheless, the rapid air transport growth has created a series of environmental problems, from noise pollution to climate change. Aviation's environmental efficiency remains a concern despite improvements in fuel efficiency, the introduction of Market Based Measures like the Eu Emissions Trading Scheme (Efthymiou and Papatheodorou, 2019) and the Carbon Offsetting Scheme for International Aviation (CORSIA). It is important to coordinate policies and balance stakeholders' interests and actions, according to Efthymiou and Papatheodorou (2020). The focus of environmental policy attention has been on airlines and airports, but environmental policies have been introduced to Air Navigation Service Providers (ANSPs) in the last decade.

European ANSPs are estimated to consume 1,140 GWh of electricity annually, roughly equivalent to 55% of the annual electricity consumption of Malta. We estimate that switching to renewable energy and making energy-efficient investments could save ANSPs over 311K tonnes of CO_2 every year. Decarbonising this ground infrastructure by switching to and investing in renewable energy over the next decade could save 311K tonnes of CO2 equivalent emissions annually, summing up to almost 6.2M tonnes overall by 2050, according to Eurocontrol (2021). Apart from reducing the emissions of the ANSP, it is important to consider the airspace structure.

The European sky is one of the busiest skies globally, with 33,000 flights a day. Yet, its air traffic management is organised in a fragmented way. The European airspace system covers an area of 10.8 million km² managed by 37 ANSPs and 63 Area Control Centres (ACCs). The estimated cost of this airspace fragmentation amounts to 4 billion EUR a year (Efthymiou and Papatheodorou, 2018), and an average flight is 42 Km longer due to fragmentation inefficiencies: this results in longer delays, higher fuel consumption, higher level of emissions and increased burden on users. This fragmentation adversely impacts flight safety, limits capacity, increases costs and slows down decision-making. Thus, better coordination for transferring the responsibility of an aircraft among Air Traffic Control (ATC) sectors in Europe is needed. Such an initiative to reform the architecture of the Air Traffic Management (ATM), known as Single European Sky (SES), was first launched by the European Commission in 1999.

Airspace not limited by national borders allows the complete unification of European airspace and more direct flight paths (Kantareva et al., 2016). EC anticipates that with the implementation of the SES, safety will improve ten times, airspace capacity will triple, the cost of air traffic management will fall by 50%, and the adverse impact on the environment will fall by 10%. The first package of the legislative framework introduced in 2004 establishes the EC as the regulator for the civil sector and the Single Sky Committee to assist it in its regulatory activities, the provision of ANS, the organisation and use of airspace and the interoperability of the European Air Traffic Management Network (EATMN). The SES II Package approved in 2009 introduced the Performance Scheme, a refocus of the Functional Airspace Blocks (FABs) and a Network Manager (NM) to coordinate certain actions at a network level.

Regulation 390/2013 (known as the Performance Regulation) identifies four Key Performance Areas (KPAs) in SES, namely a) Safety, b) Capacity, c) Cost-Efficiency and d) Environment. The Performance Scheme is developed for different periods, called Reference Periods (RP). An essential point in Performance Regulation (PR) is monitoring, including data collection and dissemination. If there is evidence that the targets will not be reached, then the introduction of corrective measures becomes necessary. Regulation 390/2013 considers Key Performance Indicators (KPIs) necessary to monitor, benchmark and review performance schemes for ANS and network functions.

2 Performance

Performance is a complex concept that describes the capability of generating results. Performance can be expressed as a set of variables or indicators that are complementary or occasionally contradictory. Performance measures can be classified as follows (Parmenter, 2015):

1. Performance Indicators (PIs) express what needs to be achieved.
2. Key Performance Indicators (KPIs) express what needs to be achieved to improve performance drastically.
3. Result Indicators (RIs) express what has already been achieved in general.
4. Key Result Indicators (KRIs) express what has been achieved according to a certain perspective or critical success factor.

In general, a Performance Indicator (PI) can be described as an additional metric that partially reflects the performance of an organizational unit. Regulation 390/2013 considers performance indicators as indicators used for performance monitoring, benchmarking and reviewing of performance schemes for air navigation services and network functions. Dobruszkes and Efthymiou (2020) suggest that environmental reporting is fundamental to environmental policy; thus, environmental indicators play a crucial role in achieving key policy objectives.

The performance in Single European Sky focuses on four Key Performance Areas (KPAs) a) Safety, b) Capacity, c) Cost-Efficiency and d) Environment. The 4 KPAs are part of the wider set of 11 ICAO KPAs, including efficiency, flexibility, predictability, security, access & equity, interoperability and participation. The implementation as of 1 January 2012 of the performance scheme aims to set and implement binding targets for the EU Member States through the adoption of European-Union wide performance targets and approval of consistent National or Functional Airspace Blocks (FAB) performance plans.

Commercial aircraft operate at cruise altitudes of 8 to 13 km, where they release gases and particulates that alter the atmospheric composition and contribute to climate change. The effects of non-CO_2 emissions (which have no Kyoto Protocol equivalent values) are still scientifically less well understood, although there are indications that certain non-CO_2 emissions could have effects in some cases. In the case of contrails, the impact could be significant, but scientific understanding of the direction and magnitude of the impact is not currently well consolidated. To control the CO_2 emissions, environment is included in the Key Performance Areas.

The Air Navigation System should contribute to protecting the environment by considering noise, gaseous emissions, and other environmental issues in implementing and operating the global Air Navigation System. According to Regulation 691/2010 "the Performance Scheme", the main objective is to reduce ANS related CO_2 emissions and Local Air Quality (LAQ) through flight efficiency improvements, both in the air and on the ground.

The **first Reference Period (RP1)** focused on improvements on average horizontal en route flight efficiency of last filed flight plan (KEP) in European Network level (reduction of -0.75% of the route extension in 2014 compared to the 2009 baseline equal to 5.42%) only and not mandatory to national/FAB level and monitoring on Effective use of Civil/Military airspace structures. The other objectives of RP1 are:

1. Develop and support the deployment of 500 airspace changes in 2012 – 2014.
2. Support the implementation of Free Route Airspace (FRA) in 25 ACCs by 2014.
3. Increase the number of Conditional Routes (CDR) annually by 5% according to the Flexible Use of Airspace Concept (FUAC).

4. Increase the CDR1/2 availability and usage annually by an average of 5% (FUA).
5. Reduce the route unavailability (in time and quantity) by 10% in 2013 and 2014 (FUA).
6. Reduction of vertical flight inefficiency by 5% in 2014.

The FUA indicators (bullet 3-5) are reported quarterly. Flight efficiency (bullet 6) is reported only twice per year.

The main objective for the **second Reference Period (RP2)** is at the EU wide level and the national/FAB level. The focus of RP2 is on:

1. Average horizontal en route flight efficiency of last filed flight plan (target is set at European Network level (KEP=4.1%);
2. Horizontal flight efficiency of the actual trajectory (KEA) (target is set at EU wide level (KEA=2.6%) and FAB level-different for every FAB);
3. Effectiveness of booking procedures for Free Use of Airspace (only monitoring at EU wide level and national/FAB level);
4. Rate of planning of CDRs (only monitoring at EU wide level and national/FAB level);
5. Effective use of CDRs (only monitoring at EU wide level and national/FAB level);
6. Additional time in taxi-out phase (only monitoring at National/FAB level and airport level);
7. Additional time in terminal airspace (ASMA) (only monitoring at the national / FAB level and the airport level).

Monitoring of the ASMA and Additional taxi-out time indicators has started during RP1, under the Capacity KPA. The rationale for monitoring is to gain experience with the indicator and ensure an acceptable level of quality, both from a data and algorithmic perspective.

Reference Period 3 (RP3) covers the years 2020-2024. The only KPI in RP3 is the average horizontal en route flight efficiency of the actual trajectory. In contrast, the average horizontal en route flight efficiency of the last filed flight plan trajectory, the average horizontal en route flight efficiency of the shortest constrained trajectory, the additional time in the taxi-out phase, the additional time in terminal airspace, the share of arrivals applying Continuous Descent Operation (CDO) and local airspace structures are set as indicators for monitoring.

EUROCONTROL conducted environmental impact assessment studies to evaluate the impact of the FABs creation on the environmental performance of SES. For instance, the DANUBE FAB Environmental Impact Assessment Study was carried out using the System for traffic Assignment and Analysis at a Macroscopic level (SAAM) fast-time simulation tool to calculate the changes in fuel use and CO2 emissions n the Danube FAB airspace above FL09 (Kantareva et al., 2016). The study concluded that the annual fuel saving due to the FAB implementation will be 45,000 tonnes by 2020 and 80,000 tonnes by 2030. The annual CO2 savings are expected to be 143,000 tonnes by 2020 and 255,000 by 2030 (Kantareva et al., 2016).

Significant focus has been placed on flight efficiency, as inefficient flight trajectory contributes significantly to CO2 emissions. According to Eurocontrol (2021), ANS can influence approximately 6% (11.6 Mt) of the total gate-to-gate fuel burn. Most of this (39%) is related to en route airspace horizontal inefficiencies (Table 1).

Phase of flight	**Estimated ANS-related benefit pool (CO2 emissions in Mtonnes)**
En-route airspace horizontal inefficiency	4.5

Terminal airspace: arrival path extension	2.4
Enroute airspace vertical inefficiency	2.1
Descent: inefficiency due to intermediate level off	1.1
Surface: Taxi-out	1.02
Surface: Taxi in	0.47
Climb: inefficiency due to intermediate level off	0.1
Terminal airspace departure path extension	0.0

Table 1: Estimated ANS-related benefit pool by phase of flight (Eurocontrol, 2021)

3 Efficiency improvements

A higher increase in capacity than traffic growth was achieved during the last decade while maintaining safety standards. At the same time, more efficient routes were implemented. The European ATS route network distances are 3.6% longer than the Great Circle distances (for intra-European flights). An initial assessment of the European ATS route network design, availability and utilisation indicate that flight efficiency could improve further by enhancing route availability and utilisation. The restrictions imposed on utilising the European ATS route network contribute approximately 0.4% to the airspace utilisation inefficiency. In 2018, FABEC area control centres coordinated seasonal improvements concerning 117 different flows, saving 4.3 million kg of fuel and 13.4 million kg of CO2.

EUROCONTROL developed a Flight Efficiency Plan (FEP) containing 5 Action Points that required immediate attention:

1. Enhancing European en-route airspace design
2. Improving airspace utilization and route network availability
3. Efficient TMA design and utilization
4. Optimizing airport operations
5. Improving awareness of performance

These action points could save the airlines 470,000 tons of fuel each year – the equivalent of 390 million euros and 1.5 million tons of CO_2 emissions (EUROCONTROL.int, 2016d). Airframe design, weight, weather conditions and the airspace they are flying in influence the optimum cruise conditions. Flight Management Systems at an aircraft can determine the most efficient cruise altitude and speed to optimise fuel burn. ATM can assist in this process by enabling capacity in the en-route phase of flight to offer aircraft the cruise levels and speeds they request to burn less fuel. Furthermore, taking advantage of the wind can offer efficiency gains.

3.1 En-route flight efficiency

Flight efficiency can be measured horizontally or vertically. The KPI average horizontal en route flight efficiency of the actual trajectory is calculated as follows (EC Reg (EU) 2019/317):

(a) this indicator is the comparison between the length of the en-route part of the actual trajectory derived from surveillance data and the achieved distance, summed over IFR flights within or traversing the local airspace;

(b) ‘en route part’ refers to the distance flown outside a circle of 40NM around the origin and destination airports;

(c) where a flight departs from or arrives at an airport outside the local airspace, the entry or exit points of the local airspace are used for the calculation of this indicator;

(d) where a flight departs from and arrives at an airport inside the local airspace and crosses a non-local airspace, only the part inside the local airspace is used for the calculation of this indicator;

(e) ‘achieved distance’ is a function of the position of the entry and exit points of the flight into and out of the local airspace. Achieved distance represents the contribution that those points make to the great circle distance between origin and destination of the flight;

(f) for the purposes of this indicator, ‘local’ means at national level or at the level of functional airspace blocks, depending on the level at which the performance plan is established;

(g) the indicator is calculated for the whole calendar year and each year of the reference period as an average. The ten highest daily values and the ten lowest daily values are excluded from the calculation when calculating this average.

The average horizontal en-route flight efficiency (indicator) is the difference between the distance of the en-route part of the trajectory and the optimum trajectory, which is, on average, the great circle distance. Thereby, “en-route” is defined as the distance flown outside a circle of 40 NM around the airport. The flights considered for this indicator are:

- all commercial IFR flights within European airspace;
- where a flight departs or arrives outside the European airspace, only that part inside the European airspace is considered;
- circular flights and flights with a great circle distance shorter than 80NM between terminal areas are excluded.

The factors influencing horizontal flight efficiency are illustrated in Figure 7.1. The figure also describes the planning process of an optimized Flight Plan Routing. States that do not have a central archive of surveillance data use indicator option A based on the last filed flight plan trajectory. If surveillance data are available (radar data, ADS-B data or other), States use the actual trajectory (indicator option B).

<Insert Figure 7.1 here>

Figure 7.1: The planning process of an optimized Flight Plan Routing

Furthermore, the desired outcome is not to achieve zero extra distance, creating operational and economic problems. The user-preferred trajectory rarely corresponds to the direct route. Computing the indicator for wind-optimum trajectories (assuming such data are available), for example, can produce an extra distance compared to the direct route. This is because more favourable wind situations (e.g. high wind speed bands over the Northern Atlantic Ocean) can increase the ground speed of an aeroplane and so reduce flight time-based costs (e.g. aircraft or fuel). Hence, reducing the horizontal en route flight efficiency indicator towards its theoretical limit (zero) is not advised.

NATS has developed a flight efficiency metric called 3Di inefficiency score 3Di. The 3Di is an average efficiency rating for vertical and horizontal trajectories. It applies to domestic airspace for the airborne portion of flight only. It must be highlighted that because aircraft performance and fuel flow rates vary across the different phases of flight, the metric applies different weightings for level flight occurring in climb, cruise, and descent phases of flight. Combining those two factors (i.e. deviation from the optimal trajectory and flight phase related rating) gives the inefficiency score for each flight in the considered airspace. Scores run from 0, representing zero inefficiencies to over 100, with most flights typically having a score between 15 and 35. The score can be improved by better airspace design, controllers' tools, flow management techniques, changes to procedures, awareness training, flexible use of airspace and optimised coordination across sectors. The score is also affected by the number of flights, the traffic demand on sectors, the weather, any unusual events (e.g. runway closure) and changes in the runway capacity.

The horizontal plane compares the actual radar ground track against the (most direct) great circle track – between the first and last radar point. Horizontal inefficiency is defined by the difference between these two distances, which describes the 'additional miles flown'. In the vertical plane, it compares the actual vertical profile from radar data against a modelled ideal flight, defined as a continuous climb to the aircraft's Requested Flight Level (for cruise), and followed by a continuous descent approach. Inefficiency is the difference between the 'actual' and 'ideal' flight profile. The vertical inefficiency is defined by the amount of flight time spent in level flight and the deviation from its requested cruise level. Level portions of flight at low altitude are more fuel penalising than higher levels.

By providing the most direct possible routes, smooth continuous climbs and descents and optimum flight levels during the cruise phase, air traffic controllers aim to help reduce aircraft fuel burn and carbon emissions, earning a low 3Di score. Combining the 3Di airspace efficiency metric with the Flight Optimisation System or 'FLOSYS' enables the Air traffic controllers to analyse the environmental efficiency of flights in near real-time. By having access to this granularity of data for the first time, controllers and airspace managers will identify better opportunities for operational improvements that will save airlines fuel and cut carbon emissions.

3.2 Continuous Descent Operation and Continuous Climb Operations

During normal approaches, Air Traffic Control often requires aircraft to descend early and level off at intermediate altitudes (Figure 7.2). The flight phases at these lower altitudes are more fuel-inefficient than flights in higher altitudes. It aims to keep aircraft as long as possible at the cruising level and perform the succeeding descent with idle engine power to increase fuel and noise efficiency. Therefore. Continuous Descent Operations (CDO) describes a descent technique whereby engines are as far as possible operated at idle thrust to reduce engine noise, fuel burn and exhaust gas emission during descent (Efthymiou et al., 2019).

In ICAO Document 9931 (2010), the 'Continuous Descent Operations Manual', CDO is defined as "an aircraft operating technique aided by appropriate airspace and procedure design and appropriate ATC clearances enabling the execution of a flight profile optimized to the operating capability of the aircraft, with low engine thrust settings and, where possible, a low drag configuration, thereby reducing fuel burn and emissions during descent. The optimum vertical profile takes the form of a continuously descending path, with a minimum of level flight segments only as needed to decelerate and configure the aircraft or to establish on a landing guidance system (e.g. ILS)."

<Insert Figure 7.2 here>

Figure 7.2: General CDO concept (Efthymiou et al., 2019)

To achieve the maximum possible benefits of CDO in terms of fuel savings and noise reduction, the descent should be flown from the Top-of-Descent (TOD) to the Final Approach Fix (FAF) close to the airport (ICAO Doc 9931, 2010). CDOs create measurable benefits concerning fuel burn and emission reductions even if they are not introduced or flown to the full extent starting at the TOD. Establishing some parts of continuous descent and removing only some level offs during descent can also create measurable benefits. The resulting of such optimised descents according to the ICAO CDO manual can provide the following advantages (ICAO Doc 9931, 2010):

- more efficient use of airspace and arrival route placement
- more consistent flight paths and stabilised approach paths
- reduction in both pilot and controller workload
- reduction in the number of required radio transmissions
- cost savings and environmental benefits caused by reduced fuel burn
- reduction in the incidence of controlled flight into terrain (CFIT)
- authorisation of operations where noise limitations would otherwise result in operations being curtailed or restricted.

Also, if the actual focus is on the descent phase of a flight, the principle of avoiding level offs at lower altitudes can be applied conversely to the climb phase of a flight. This method is called Continuous Climb Operations (CCO). ICAO Document 9993 (2013) defines CCO as "An operation, enabled by airspace design, procedure design and ATC, in which a departing aircraft climbs without interruption, to the greatest possible extent, by employing optimum climb engine thrust, at climb speeds until reaching the cruise flight level".

3.3 Conditional Routes

Another aspect contributing to the environment's improvement is Conditional Routes (CDRs). A Conditional Route (CDR) is an ATS route that is only available for flight planning and is used under specified conditions. A Conditional Route may have more than one category, and those categories may change at specified times:

- Category One - Permanently Plannable CDR: CDR1 routes are generally available for flight planning during times published in the relevant national Aeronautical Information Publication (AIP). Updated information on the availability following conditions published daily in EAUP/EUUPs. CDRs1 can either be established on an H 24 basis, fixed time periods, or fixed flight level bands.
- Category Two - Non-Permanently Plannable CDR: CDR2 routes may be available for flight planning. Flights may only be planned on a CDR2 following conditions published daily in the EAUP/EUUPs, and
- Category Three - Not Plannable CDR: CDR3 routes are not available for flight planning; however, ATC Units may issue tactical clearances on such route segments. CDR3 are not subject to allocation the day before by Airspace Management Cell (AMCs).

For instance, improving flight plan quality and utilising civil/military airspace structures can reduce emissions. If all the available routes were used at their full potential, annual savings of 30.000 tons of fuel/year or reduced emissions of 100.000 tons of CO_2/year could be achieved. Apart from improving airspace utilisation and route network availability, enhancing European airspace design and introducing a more efficient Terminal Airspace, by improving Terminal Airspace design and implementing Continuous

Descent Approaches (CDAs), or optimising airport operations, by Implementing Airport Collaborative Decision Making (A-CDM) can lead to carbon offsetting.

Through Collaborative Decision Making (CDM) procedures, airport and aircraft operators, ground handlers and air traffic control share information, creating a common situational awareness for all actors. CDM is a concept to be implemented in an airport environment by introducing operational procedures and automated processes.

3.4 Free Route Airspace

Free Route Airspace (FRA) is a specific airspace within which users can freely plan their routes between an entry point and an exit point without reference to the ATS route network. In this airspace, flights will remain subject to air traffic control. Although FRA aims for permanent implementation, it is used during specific time periods. In complicated airspaces like MUAC[1], FRA plays an important role in its capacity.

The main benefit of FRA implementation is straighter routes and the consequent reductions in the total flown distance, carried and burned fuel, and emissions. This will reduce the aircraft's weight during flight and give a further benefit of reduced fuel burn and CO_2 emissions during the whole flight. Additionally, FRA will significantly reduce the route structure and flight planning complexity. Therefore, there are also opportunities to rationalise some legacy inefficiencies in the network.

FRA is based on full trajectory operations. Thus, the FRA concept brings increased flight predictability and reduced uncertainty for the Network, leading to capacity increases for ATM, which will also benefit the user. Several ACCs and ANSPs have already implemented fully or partially Free Route Airspace with further phased implementations planned by all FABs/ANSPs, including cross-border operations and full free route implementation. Free Route operations are already operational in Portugal (24hrs), Maastricht (24hrs, night and weekend in parts of the Area of Responsibility- AoR), Karlsruhe (24hrs in parts of the AoR), Ireland (24 hrs), Austria - night, Finland - night and weekend, Zagreb, Belgrade, the Former Yugoslav Republic of Macedonia and joint Free Route in Denmark and Sweden. The implementation is coordinated through the NM European Route Network Improvement Plan (ERNIP) and the Network Operations Plan following the Strategic Objectives and Targets set in the Network Strategic Plan and the Network Manager Performance Plan.

In Europe, there are many initiatives to implement free route airspace. The first states in which the FRA was implemented were Sweden, Portugal and Ireland. The introduction of the FRA is easier for Portugal and Ireland because their airspace extends above the Atlantic Ocean, which leads the transit flight paths Europe - America thus to almost zero climbing/descent to/from the defined FRA area.

In 2011, 142 'direct routes' became available to the airspace controlled by MUAC. Those routes contributed to the reduction of flight time and engine use, reduction of fuel use, CO2 emissions, and the costs occurring from the high traffic density in the European airspace. Those routes were conducted during the night and the weekend for safety reasons. They are also the first step to the «Free Route Airspace Maastricht (FRAM) programme» that aims to implement those routes daily and 24hours scale. The benefit of this change is 1.16 million Km less per year, meaning 3,700 tonnes of fuel less, 12,000 tonnes of CO_2 and 37 tonnes less

[1] Operated by EUROCONTROL on behalf of four States, EUROCONTROL's Maastricht Upper Area Control Centre (MUAC) provides civil and military cross-border air traffic control in the upper airspace of Belgium, Luxembourg, the Netherlands and north-west Germany (from 7.5 km or 24,500 feet).

NOX compared to the previous routes. In 2019, MUAC successfully transitioned to 24/7 free route airspace. The environmental benefits in MUAC airspace alone can be significant – an estimated 40,000 kg of fuel and 150,000 kg of CO2 emissions saved per day if all flights make the best use of FRA (EUROCONTROL, 2022).

Eurocontrol estimates that implementing pan-European free route airspace will reduce flight distances by 7.5 million nm annually. The main problem is an insufficient ATC system, which cannot cope with the requirements of the FRAs. For example, it can be expected that free-selected trajectories of a given number of aircraft will create a higher workload to Air Traffic Controller compared to adherence of predefined airways serving for the same amount of aircraft. Another example is that dynamic Flight Data Processing (FDP) makes ordering sectors for flights more difficult. Therefore, today's ATC systems only support FRAs to a limited extent.

3.5 Flexible Use of Airspace Concept

The Flexible Use of Airspace Concept (FUAC) uses airspace structures and procedures that are particularly suited for temporary allocation and/or utilisation, such as Conditional Routes (CDRs), Temporary Reserved Areas (TRAs), Temporary Segregated areas (TSAs), Cross-Border Areas (CBAs), Reduced Coordination Airspace (RCA) and Prior Coordination Airspace (PCA). To improve the airspace utilisation in both a fixed route network and a free route environment, these airspace structures will be implemented according to the specific requirements.

According to Commission Regulation 2150/2005, Flexible Use of Airspace is "an airspace management concept, according to which airspace should not be designated as either purely civil or purely military airspace but should rather be considered as one continuum in which all users' requirements have to be accommodated to the maximum extent possible." Airspace management cell (AMC) means a cell responsible for the day-to-day management of the airspace under the responsibility of one or more Member States. Airspace restriction is defined as the volume of airspace within which, variously, activities dangerous to the flight of aircraft may be conducted at specified times (a 'Danger Area'); or such airspace situated above the land areas or territorial waters of a State, within which the flight of aircraft is restricted following certain specified conditions (a 'Restricted Area'); or airspace situated above the land areas or territorial waters of a State, within which the flight of aircraft is prohibited (a 'Prohibited Area')".

According to the Commission Regulation 2150/2005, the following principles shall be applied for the FUAC:

(a) coordination between civil and military authorities shall be organised at the strategic, pre-tactical and tactical levels of airspace management through the establishment of agreements and procedures to increase safety and airspace capacity and to improve the efficiency and flexibility of aircraft operations;

(b) consistency between airspace management, air traffic flow management and air traffic services shall be established and maintained at the three levels of airspace management enumerated in point (a) to ensure, for the benefit of all users, efficiency in airspace planning, allocation and use;

(c) the airspace reservation for the exclusive or specific use of categories of users shall be of a temporary nature, applied only during limited periods of time based on actual use and released as soon as the activity having caused its establishment ceases;

(d) Member States shall develop cooperation for the efficient and consistent application of the concept of flexible use of airspace across national borders and/or the boundaries of flight information regions, and shall in particular address cross-border activities; this cooperation shall cover all relevant legal, operational and technical issues;

(e) air traffic services units and users shall make the best use of the available airspace.

4 Some considerations

4.1 Incentive Scheme

The EC gives Air Navigation Service Providers incentives to enhance their compliance and efficiency to the Performance Regulation. The risk-sharing mechanism of the charging scheme, i.e. the sharing of the financial risk between Member States/ANSPs and airspace users, is seen as a meaningful economic incentive for ANSPs to be more cost-efficient, taking advantage of good management, economies of scale and productivity gains. This creates a regime close to a cost capping in a multi-annual framework. According to article 12 of Reg. 390/2013 with a link to Commission Implementing Regulation (EU) No. 391/2013, all stakeholders' incentives shall be part of the regulatory environment known ex-ante and be applicable during the entire reference period. Moreover, the incentives on environment and capacity shall be financial, and the NSA should enforce corrective actions if necessary. Safety is a KPA that does not have any incentives mechanisms due to its uncompromising nature. The maximum number of aggregate bonuses and the maximum amount of aggregate penalties shall not exceed 1% of the revenue from air navigation services in year n.

4.2 Trade-offs between the KPAs

Flight efficiency always involves trade-offs between the different areas, for instance, safety versus capacity, fuel cost versus time cost, ground versus airborne delay, noise versus emissions, etc. Excess fuel burn in the Air Traffic Management system is primarily characterized by flight delay costs and flight efficiency costs. Flight delays occur when an airport or airspace resource (runway, gate, taxiway, or airspace sector) has greater demand than the available capacity. Flight delays tend to grow exponentially with increased levels of traffic. Flight efficiency is measured by increased flight time, distance, and fuel compared to an “ideal” flight trajectory.

As per the DANUBE FAB Performance Plan section 3.3 - Description of KPAs interdependencies and trade-offs:

> *"Safety*
>
> *Safety KPA establishes mandatory requirements in ATM operations and represents the key element of ANS. No safety compromises should be made to improve other KPAs, especially the cost-efficiency. The Performance Scheme Regulation and corresponding targets for RP2 are more oriented on cost-effectiveness while focusing less on the safety key performance area. Thus, for the second reference period and the next to come, the biggest challenge for States and FABs will be to keep focusing on safety while trying to achieve the targets in different KPAs.*
>
> *Capacity*
>
> *The very good performance of ATFM delays recorded by the DANUBE FAB in the last five years and for RP2 implies extra cost through investments, staff and corresponding procedures. DANUBE FAB RP2 capacity targets followed the PRB expectations and indicative figures while contributing to the very challenging cost-efficiency objectives. We appreciate that having one of the most reduced FAB determined unit cost and ATFM delays represent a very challenging objective and should be carefully assessed.*

Environment

Similarly to the capacity targets, flight efficiency requires extra cost through investments, staff, and corresponding procedures for reaching the targets. "

4.2.1 Example of Environment Vs Unit Rate Cost

The flight Milano- Brindisi can follow different routes. In Figure 7.3, two different routes are given. The green flight path is sorely within Italy, whereas the red path passes through Croatia. The Great Distance Cycle (GDC) are the dashed lines in the map. For the red flight path, i.e. the one passing from Croatia, the GDC is calculated firstly from Milano to the border of the FIR and then within Croatia for the other intersections of the flight plan with the charging zone and then to Brindisi. Compared to the flight plan contained entirely within Italy, the route through Croatia implies a reduction of 430 km in Italy and an increase of 477 km in Croatia.

For an aircraft weighing 80 metric tonnes, the price (for the unit rate) per kilometre (July 2013) is €1.00 in Italy and €0.53 in Croatia. Therefore, the longer route (through Croatia) is €177.19 cheaper (430km x €1.00 – 477km x €0.53). This significant difference in cost is the different Unit Rates in the two charging zones. The aeroplane might burn additional fuel by a longer distance, but the total savings are higher if the plane flies through Croatian airspace. In this specific example, the additional distance is 47km for the plan through Croatia. It is cheaper for the airspace user to file (and fly) the longer flight plan as long as its operating costs per kilometre are less than €3.77 (€177.19 / 47km). This constitutes an incentive for airspace users to file longer routes with a detrimental effect on the horizontal flight efficiency indicator (KEP).

<Insert Figure 7.3 here>

Figure 7.3: Two alternative routes between Milan and Brindisi (Efthymiou and Papatheodorou, 2018)

Avoiding expensive unit rates and asking for direct routing may negatively impact safety due to sector overload and capacity due to ACC under and overload. This is the argument used to implement a single unit rate per FAB, which is quite complex given the diverse local financial arrangements.

5 Conclusions

The SES general target is to reduce flights' environmental effects by 10%. SES brought many changes in how various countries collaborate in ATC management. The KPA of Environment in the Performance Regulation is not exactly a separate target, but someone could argue that it benefits from improvements in the other areas. Moreover, the restructuring of the airspace and the creation of FABs contributed to the ATC management improvements in several areas. Despite these improvements, the SES has not delivered to the desired level environment-wise, mainly due to the lack of effective economic incentives for the ANSPs. Despite the societal pressure for improved environmental performance, there is a low prioritization in the Environment KPA.

Significant focus has been placed on flight efficiency and airspace structure to mitigate climate change. Other environmental parameters are also of significant importance. More initiatives focusing on Local Air

Quality and Noise pollution should be considered due to their high impact on local environmental issues. The trade-off between the different KPAs and the various environmental issues should be better balanced.

Finally, it is of fundamental importance to increase the environmental literacy of airspace users, ATCOs and all the stakeholders. The most effective action to increase environmental awareness is to change the mentality of ATCOs and ANSPs employees via training. In addition, airspace users are not making the best from SES. There are conditional routes available that the airlines do not use either due to the short notice or due to the difficulty from the AOC to change the flight plans as a system. The airlines should also be informed about the implemented solutions regarding the CDRs, and a better communication channel should be developed to make the change of routes a reality.

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