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RESOLUTION OF OPERATIONAL CONSTRAINTS IMPOSED BY FRAGMENTATION OF EUROPEAN AIRSPACE

ABSTRACT

The development of new concepts aiming to increase flight efficiency represents one of the main guidelines for the future European Air Traffic Management (EATM) system development. Future EATM system design is driven by the development and implementation of various technical and operational solutions which are based on collaborative and coordinated airspace and air traffic flow management. European airspace fragmentation is recognized as one of the most prominent problems which limit improvements in terms of flight efficiency. This primarily relates to the fact that EATM system is organized and operated at national scale. This research was carried out with the purpose to signify two concepts which have significantly improved flight efficiency level. Free Route Airspace and Flexible Use of Airspace concepts particularly distinguished as good examples of how it is possible to improve flight efficiency regardless to fragmented European airspace design. Hence, the research resulted by analysis of concepts designs, characteristics and their deployment benefits to airspace users. Also, an issue which limits further flight efficiency improvements at European scale have been identified.

KEY WORDS

Air traffic management; European airspace; fragmentation; Free Route Airspace; Flexible Use of Airspace

1. INTRODUCTION

Nowadays, due to increasing air traffic demand in the Pan-European region, many airspace management problems arise. Hence, air traffic and airspace planning and management functions can no longer be based on meeting of the demand foreseen only for the near future. There is no doubt that the manners in which the European airspace will be organized and managed in the future will play a vital role. Current airspace management design is extremely vulnerable and influenced by different external and internal factors. Hence, different EATM stakeholders are trying to minimize as much as possible both kinds of influential factors so the airspace users do not even notice them. Such an approach is necessary in order to enhance future improvements in terms of flight efficiency.

Fragmented design of European airspace is considered to be one of the hardly overcoming factors which negatively influence flight efficiency. During last two decades various initiatives, regulations and concepts implementations, with greater or smaller effects, tried to reduce negative impacts associated with fragmented airspace design.
The need for implementation of new operational concepts which will be able to overcome fragmented airspace design has been recognized as one of major challenge of future EATM development. Hence, in 2004 the Single European Sky (SES) initiative was formally launched with a goal to improve the overall performances of EATM system. It is supported by a technological modernization programme SESAR (Single European Sky ATM Research) whose purpose is to enable defined goals by modernising and harmonising ATM systems through the definition, development, validation and deployment of innovative technological and operational ATM solutions [1].

This paper presents referent samples of ATM concepts, which on national level maps changes occurring within the ATM system at European and regional level. Therefore, this paper presents a synthesis of effect of two Europe-wide applicable concepts - Free Route Airspace (FRA) and Flexible Use of Airspace (FUA), which managed to overcome operational constraints due to fragmented European airspace design and improve flight efficiency.

2. EUROPEAN AIRSPACE FRAGMENTATION STATUS

It can be defined that current fragmented design of European airspace is result of historical relationship between Air Navigation Service Providers (ANSPs) and European states. Over the last twenty years, as the most obvious EATM system’s weakness was recognized problem of decision-making at national levels [2]. Considering that still nowadays European airspace is highly fragmentary designed with regard to the existing number of ANSPs, it can be concluded that this problem continues to exist. Figure 1 shows airspace of 19,507,200 km² divided between 37 ANSPs.

There is no doubt that fragmented design of European airspace negatively influences safety and environment, reduces airspace capacities and increases operational costs. The European Commission, various representatives’ bodies, as well as many experts and scientists recognize fragmentation as one of the causes of EATM system’s inefficiency and dysfunctionality. For example, EUROCONTROL, the European Organisation for the Safety of Air Navigation, considers that it is difficult to overcome fragmentation due to the existence of different interest groups in Europe. They expect that the European airspace will be fragmented as long as Europe does not have an integrated European defence
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system. otherwise, their opinion is that, the states will continue to oversee and operate airspace through its ANSPs to protect their national sovereignty [3].

undoubtedly, inefficiency has its cost and since fragmentation represents a quite significant issue, then, the size of the inefficiency related cost is even higher. by reviewing the literature, it can be concluded that there is no consensus about what is the real cost of airspace fragmentation. even the European commission itself lists different information within its publications. in 2015 within “an aviation strategy for Europe” it estimated that the cost of the EU's fragmented airspace design represent at least EUR 5 billion a year [4], while in 2017 it defined that the European airspace fragmentation costs at least EUR 3 billion a year [5].

an analysis of consequences of fragmented design of European airspace is precisely specified within European Court of Auditors’ (ECA) report titled “Single European Sky: a changed culture but not a single sky” [6] which identified that Functional Airspace Blocks (FABs) - by which it have been tried to reduce airspace fragmentation level, eventually only fostered cooperation forums and did not airspace defragmentation. Report also indicates that the SESAR has fostered a common vision but has become detached from its initial schedule and is now open ended, as well as that the charging and performances measurement schemes are affected by different shortcomings. Hence, it is possible to identify several repercussions of fragmented design of European airspace. The most obvious ones are that Area Control Centres (ACCs) operate below optimal economic size, multiplication of systems, unsynchronized adaptation of technologies and infrastructure, higher maintenance, training, research and development (R&D) and administrative costs etc. [7]. Furthermore, even though the planning of the SES initiative is based on the collaborative implementation of ATM Master-plan defined concepts and projects, the real implementation is fragmented and based on national levels thus aggravating European airspace unification [8].

3. European Airspace Management Design

In general, airspace management function can be described as a process by which the airspace is being organized and managed in accordance with airspace users’ requirements. Although European airspace management function does not represent an exception in this regard, during past decades the existence of certain deficiencies has been noticed. Hence, in order to achieve further improvements of flight efficiency, it was necessary to harmonize different EATM system’s operational units. This primarily refers to the need of strengthening the link between interconnected operational units and procedures of airspace management (ASM), Air Traffic Control (ATC) and Air Traffic Flow Management (ATFM) functions. Figure 2 depicts the current interdependent design of operational units affecting flight efficiency level.

Figure 2 - Overview of operational units affecting flight efficiency level [9]

European airspace management design is based on a model that includes three functional levels: strategic, pre-tactical and tactical level where each level has a direct impact on other levels. Strategic level consists of definition of the national airspace policy and establishment of pre-determined airspace structures. Pre-tactical level includes day-to-day allocation of airspace structures according to
airspace user requirements while third (tactical) level is characterised by a real-time use of airspace structures simultaneously ensuring safe Operational Air Traffic (OAT) and General Air Traffic (GAT) operations.

Strategic level starts one year and lasts up to one month before planned event occur. Pre-tactical level starts just after strategic level ends and lasts up to one day before planned event occurs. Final, tactical level includes time gap lasting from one day before and ends up with few hours before planned event occur. Hence, although they are separated, specified levels are closely interdependent management phases which need to be performed coherently to ensure efficient use of airspace and booster flight efficiency level.

Such a systematic design aims to improve European airspace management performances and consequently EATM system’s efficiency, i.e. to reduce flight inefficiency. By reviewing literature, it can be found that there are several different definitions referring flight inefficiency. In such a status quo different stakeholders involved in strategic air traffic planning and management have various perceptions of flight inefficiency. Reynolds [10] defines that flight inefficiency can be defined as anything that causes an aircraft to fly a path different to its optimum trajectory. Furthermore, it is well known that the potential causes of flight inefficiency significantly differ in accordance with different flight phases. According to Mihetec et al. [11], it is possible to express flight inefficiency by the agreed performance indicators including distance difference (NM), duration difference (min), fuel combustion difference (kg) and CO₂ emission (t). Bearing that in mind and in addition to many European ATM Master Plan-defined projects, two concepts have particularly distinguished and managed to overcome operational constraints due to fragmented European airspace design. Therefore following two subsections put a focus and defines how FRA and FUA concepts did improved flight efficiency on a Europe-wide level.

3.1 Flexible Use of Airspace concept

According to Huang [12], the issue of civil and military coordination in the context of airspace management have been discussed since 1996. Cook [13] concludes that such a situation was imposed by the need to better accommodate the changing needs of the military and markedly increased traffic congestion. FUA represents an airspace management concept described by the International Civil Aviation Organisation (ICAO), developed by EUROCONTROL and regulatory supported by the European Commission. European Commission (EC) Regulation No 2150/2005 defined that within FUA concept airspace should not be designated as either purely civil or military airspace, but should rather be considered as one continuum in which all airspace users’ requirements have to be accommodated to the maximum extent possible [14]. The FUA concept implementation enabled the maximum shared use of airspace through enhanced civil/military co-ordination. It is based on dynamic airspace management design from which the most distinguished elements are Temporary Reserved Area (TRAs)/Temporarily Segregated Areas (TSAs) and Conditional Routes (CDRs). On the one side, TRAs/TSAs represent a manageable structures established in response to the need for civil, military, R&D, training, test-flights or activities of a temporary nature [15]. On the other side, it is necessary to emphasize that there are more applicable CDR types. Considering foreseen availability, flight planning possibilities and the expected TRA/TSA activity time, it is possible to divide CDRs into the three categories: CDR1 (permanently plannable CDRs), CDR2 (non-permanently plannable CDRs) and CDR3 (not plannable CDRs). Their spatial distribution is shown by Figure 3.
Unlike to the TRAs/TSAs - which are defined within national Aeronautical Information Publications (AIPs), CDRs are non-permanent parts of the published ATS route network. The CDR activation is published by an Airspace Management Cells (AMC) in a form of Airspace Use Plan (AUP) and Update Use Plan (UUP). Furthermore FUA concept is also defined by Reduced Coordination Airspace (RCA) and Prior Coordination Airspace (PCA) procedures used for flexible airspace management and few more airspace structures, e.g. Cross-Border Areas (CBAs), Danger (D) and Restricted (R) areas which are subject to pre-tactical or tactical allocation under the Temporary Airspace Allocation (TAA) process.

The concept of Flexible Use of Airspace is more detail explained in EUROCONTROL’s ASM Handbook [15]. Its purpose is to provide additional descriptions of the ASM functions and EATM system related processes and procedures referring FUA concept. In general, it can be defined that an idea behind FUA concept is that CDRs supplement the existing ATS route network and lead aircraft through TSAs. In such way FUA concept allows GAT to fly shorter, to use more direct routes and so save time, fuel and money. Thereby, a shift from permanent airspace structures into dynamically manageable military airspace structures significantly reduced operational constraints due to fragmented European airspace design.

### 3.2 Free Route Airspace concept

Second important concept which managed to operationally overcome constraints due to fragmented European airspace design is Free Route Airspace. The idea of Free Route Airspace concept originates from 1998 and creation of “Eight-State Free Route Airspace Project” involving following eight countries: Belgium, the Netherlands, Luxembourg, Germany, Denmark, Norway, Sweden and Finland. Ten years later EUROCONTROL actualized coordinated development of new and comprehensive FRA concept Europe-wide. New concept development and later on implementation was also politically supported by European Commission, i.e. by Commission implementing Regulation (EU) 2019/123 of 24 January 2019 laying down detailed rules for the implementation of air traffic management (ATM) network functions.

According to definition, Free Route Airspace concept includes an specified airspace within which users can freely plan a route between a defined entry point and a defined exit point with the possibility of routeing via intermediate (published or unpublished) waypoints, without reference to the air traffic services (ATS) route network, subject of course to availability. Within such airspace, flights remain subject to air traffic control [16]. Figure 4 shows an example of how FRA concept implementation in form of South East Common Sky Initiative Free Route Airspace (SECSI FRA) reduced number of required cross-border waypoints. Consequently such an approach made flying more direct and increased flight efficiency.
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Figure 4 – Spatial overview of South East Common Sky Initiative Free Route Airspace (SECSI FRA)

Nowadays, FRA concept implementation is still underway and is scheduled to be Europe-wide completed above Flight Level (FL) 310 by Jan 1, 2022. Considering that EUROCONTROL has initiated FRA concept deployment, as the Network Manager (NM) - it is responsible for further coordination, development and concept implementation. In addition, involvement of a large number of different stakeholders, such as civil and military experts in airspace design, European Civil Aviation Conference (ECAC) Member States, ANSPs, airspace users, flight planning organisations and other relevant international bodies, witnesses comprehensiveness and significance of FRA concept in European ATM development.

In the regions where FRA concept is already deployed, airspace users can fly any preferred trajectory between a defined entry and exit points. Unlike conventional Air Traffic Service (ATS) routes, FRA concept implementation enables a reduction in route length (NM), flight time (min) and consequently fuel consumption (kg) as well as carbon dioxide (CO₂) and nitrogen oxide (NOx) emissions reduction. According to EUROCONTROL, since 2014, due to deployment of FRA concept airspace users have saved of around EUR 500 million of additional fuel costs [17].

4. DISCUSSION

Due to the increasing density of air traffic in Europe, the availability of airspace capacities becomes more important issue. The anticipated growth of air traffic over the next twenty years requires the implementation of innovative methods, solutions and procedures with an aim to improve the current flight efficiency level. In an ideal world, aircraft would fly directly from point of departure to point of arrival. Between these two points ATM system would manage flight operation, continuously trying to minimize any potential constraints influencing flight efficiency level. Taking into account the current state of the European ATM system, it can be concluded that it is still far away from ideal design.

Undoubtedly, it is possible to single out European airspace fragmentation as one of the most apparent causes jeopardizing improvements in terms of flight efficiency. European airspace fragmentation represents a condition which disables complete European air traffic market’s development potentials. It limits airspace capacity, adversely affects the environment, increases operational costs and above all, potentially affects safety.

Nowadays different development strategies, initiatives and projects within European ATM system aim towards creation of more efficient system. SESAR, as the technological pillar of the SES initiative, seeks to harmonise and modernise ATM systems and procedures across Europe. Since its establishment, it has been gradually releasing technological and operational improvements which
usually had to pass “three steps approach” including definition phase (drawing up the plan for modernisation), development phase (the establishment of the necessary technological bases) and deployment phase (installation of the new systems and procedures). Although different concepts are frequently defined as the main driving forces for the realization of the Single European Sky, in terms of improvements achieved by operational harmonization of EATM system, it is undisputed that FUA and FRA concept are the most distinguished examples.

SESAR Joint Undertaking (JU), which is responsible for managing the development phase of SESAR, proposes a new initiative to reorganize the European airspace. Within its document titled “Proposal for the future architecture of the European airspace” [18] as the key element of the proposal it highlighted airspace optimisation process that includes both, further extension of Free Route Airspace and Flexible Use of Airspace, as well a progressive re-sectorisation based on dominant traffic flows. Although it hasn’t been yet Europe-wide applied, the effects of the FRA concept implementation can already be noticed. As it can be seen by Figure 5, in past few years, NM and ANSPs efforts have led to the successful FRA concept implementation in a large part of North, South-East and Central South-East Europe. By the end of 2017, 51 ACCs have either fully or partially implemented Free Route Airspace concept, which exceeds the target of 35 ACCs set by the Network Manager Performance plan [19]. Hence, airspace users are already adapting their flight planning systems to fully exploit potentials enabled by FRA concept. The shift from fixed ATS routes to free airspace offered significant opportunities to airspace users in terms of flying time and distances reductions. Consequently, less fuel is burnt what enables financial savings to airspace users and reduces amount of emitted emissions. To be more precise, EUROCONTROL defines that by implementation of FRA concept flying distances could be reduced by approximately 7.5 million NM that represents the equivalent of 45,000 tonnes of fuel saved, or a emissions reduction of 150,000 tonnes of CO₂ or EUR 37 million [15].

![Figure 5 – Temporal and spatial overview Free Route Airspace concept implementation [20]](image)

Effective and harmonized application of flexible use of airspace includes clear and consistent rules for civil-military coordination which takes into account all airspace users’ requirements. Bearing that in mind, it is important to point out that different airspace users are driven by different objectives and business models. Consequently, they have different requirements for airspace allocation. On the one side, civil aviation (GAT) wants to develop trajectories with the most cost-efficient aircraft routing options. On the other side, military aviation (OAT) wants to use the airspace structures in such way that they enable the most effective aircraft routing with a goal to enhance execution of missions’ objectives. Figure 6 shows an example of flight route between London (ICAO: EGGW) and Naples (ICAO: LIRN) in dependence of spatial allocation of TRAs and TSAs.
Until the introduction of the FUA concept, airspace structures were H24 per day unavailable for commercial air transport [21]. Although military airspace structures were closed for commercial airspace users, frequently they were not H24 operational. Such a situation made European airspace management more complex and civil-military cooperation more difficult. Consequently, it affected increase of en-route delays, lack of airspace capacity and increase of operational costs. The implementation of FUA concept has given a big growth in the general level of flight performances, including efficiency, capacity, reduction in distance and time [22-23]. Also, FUA concept implementation enabled higher utilization level of military airspace structures which could be no longer operational H24 and unevenly used. In such way prerequisites have been made to further increase the flight efficiency. According to EUROCONTROL [24], the implementation of the Flexible Use of Airspace concept delivered benefits to both civil and military aviation. It increased flight efficiency offered through a reduction in distance, time and fuel, enabled more efficient ways to separate OAT and GAT, enhanced real-time civil/military coordination, reduced need for airspace segregation and finally enabled higher airspace utilisation level.

Analysed two concepts’ implementation certainly improved flight efficiency and managed to overcome fragmented European airspace design. In this way operational improvements reduced negative impacts associated with airspace fragmentation. Jointly they enabled higher flight efficiency by facilitating airspace management (less aircraft rerouting and more direct flight routes), financial saving to airspace users (less fuel burnt), better civil-military coordination (higher airspace utilization level) and minimized negative environmental effects (reduction of NOx and CO2 emissions). But despite achieved improvements in terms of flight efficiency, still there is one thing to be considered. If we consider the relation between current flight efficiency in regard to opportunities enabled by implementation of two analysed concepts, it can be concluded that full potentials have not been yet utilized in proper way. Also, it can be frequently seen that opportunities enabled by two concepts implementation are being abused by airspace users. This primarily refers to the fact that certain factors impacting flight efficiency level are outside of a ANSPs’ control and that they do not significantly depend on improvements achieved by optimization of the airspace structures as much as they depend on a current charging scheme for air navigation services. The best examples could be found in flight planning practices of GAT operations, their route choices and used models of routes cost-optimisation. Bearing in mind mentioned, it is important to point out horizontal en-route flight efficiency indicator which reflects flight efficiency elements which are beyond the control of ANSPs, but does not specify their share in overall value. Indicator captures the difference between the planned or actual trajectory against the shortest route. According to Performance Review Body of the Single European Sky [25] for 2018 the average horizontal en-route flight efficiency of the actual trajectory (KEA) was on average 2.81% longer than the great-circle distance while in regard of the last filed flight plan (KEP) it was on average 4.73% longer than the great-circle distance. Figure 7 shows level of flight inefficiency during
2014 and 2018 on the example of Republic of Croatia (ANPS: Croatia Control Ltd; FIR Zagreb) where both analysed concepts were implemented.

From the figure above, except from the fact that horizontal en-route flight efficiency is quite variable indicator, it can be seen that two concepts improved flight efficiency. Also, 2018 data indicates that during pre and post summer time, flight efficiency level was deteriorated. Hence, it can be concluded that although two analysed concept improved flight efficiency level, nowadays there is an issue arising how to further improve flight efficiency by managing the flights in most optimal way.

5. CONCLUSION

The need to improve the airspace management system was yet recognized at the end of the 1990s. Nowadays, it is quite debatable how much really significant work has been done so far. Since the European airspace is as fragmented as 20 years ago, there is a rhetorical question arising what have been done ever since and was it possible to do it better?

Although airspace represents a limited resource, air traffic volume continuously increases over the Europe. Such a situation made airspace management more complex and civil-military cooperation more difficult. To prevent further system’s dysfunctions at the operational level, it was necessary to reduce negative impacts arising from fragmented airspace design. Later on FRA and FUA concept were developed and their implementation phases started. Nowadays benefits from their deployment are notable to airspace users on daily basis. Due to fact that they have possibility to execute flights on more direct routes improved flight efficiency level.

Although different airspace fragmentation types can be found in other areas of EATM system, operational improvements - in terms of implementation of FRA and FUA concepts are seen as a the most distinguished efforts how to overcome fragmented design of European airspace. Hence, it can be concluded that during last two decades the most noticeable effort to overcome airspace fragmentation was made in terms of operational improvements which also led to an improvement in flight efficiency level.

Furthermore, despite opportunities enabled by two analysed concepts, it is recognized that the airspace users continue to execute flights in a way to maximize their financial benefits. This primarily refers to the fact that airspace users choose to utilise benefits of FRA and FUA concepts in way to maximise financial savings by flying on a most economic instead on the shortest routes. Considering that airspace users are primarily driven by business models which will enable them greats cost efficiency, frequently it is achieved at the expense of flight efficiency. Such an approach results in lower utilization possibilities of maximum benefits enabled by FRA and FUA concepts. Hence, it can be concluded that although FRA and FUA concepts already did improve flight efficiency, their maximum
benefits won’t be noted until airspace users start to rather fly on shorter instead of more economical routes.

REFERENCES


