Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 45 (2020) 676–683

Transportation Research Procedia

www.elsevier.com/locate/procedia

AIIT 2nd International Congress on Transport Infrastructure and Systems in a changing world (TIS ROMA 2019), 23rd-24th September 2019, Rome, Italy

South East Common Sky Initiative Free Route Airspace - implementation aftermath

Zvonimir Rezo*[a], Sanja Steiner[a]

[a]*Croatian Academy of Sciences and Arts, Traffic Institute, Kušlanova 2, 10000 Zagreb, Croatia*

Abstract

In a short period since South-East Axis Free Route Airspace (SEAFRA) and Slovenian Austrian Cross-Border Free Route Airspace (SAXFRA) were established, during 2018 these two Free Route Airspace (FRA) areas operationally merged into South East Common Sky Initiative Free Route Airspace (SECSI FRA). Nowadays, SECSI FRA represents a joint venture with the aim of sustainable future development of European Air Traffic Management (ATM). It's a good example of regional cooperation since it includes stakeholders from six adjacent states and four Air Navigation Service Providers (ANSPs). Also, successful deployment of SECSI FRA have led to the creation of one of the largest areas with applicable FRA concept. Therefore, that represent a major step towards achieving a 2022 plan - implementation of FRA concept across whole Europe. This research aims to assess deployment effects of SEAFRA, SAXFRA and SECSI FRA and based on quantitative research it provides information on hypothetical question how did implementation of South East Common Sky Initiative Free Route Airspace (SECSI FRA), and its earlier versions - SEAFRA and SAXFRA, reflected on the performances at South East Axis in terms of airspace complexity. In addition, this research is based on the computation of real data obtained from Performance Review Unit (PRU) and it covers period from 2014 till end of 2018. Lastly, deployment impacts have been analysed and compared in relation to other European ATM network's performances and presented throughout this research paper.

Keywords: Air Traffic Management; Free Route Airspace; South East Common Sky Initiative Free Route Airspace; Airspace complexity

* Corresponding author. Tel.: +385-976421029
E-mail address: zvonimir.rezo@gmail.com

2352-1465
10.1016/j.trpro.2020.02.111

1. Introduction

In addition to many other projects associated with Single European Sky (SES) initiative, the Free Route Airspace (FRA) concept is particularly distinguished. The idea behind the FRA concept was created in 1998 within an Eight-State Free Route Airspace Project involving following eight countries: Belgium, the Netherlands, Luxembourg, Germany, Denmark, Norway, Sweden and Finland. In 2008, EUROCONTROL together with International Air Transport Association (IATA) and Civil Air Navigation Services Organization (CANSO) actualized development of FRA concept as part of its Flight efficiency plan. Nowadays, FRA concept implementation is still underway, and it's scheduled to be completed by 2022 Europe-wide. In addition, EUROCONTROL states that "FRA will make it possible to meet the demands of future airspace users over the next 50 years, such as civil and military Remotely Piloted Aircraft Systems (RPAS), hypersonic transport, spaceplane operations to sub-orbit, wireless network balloons and airships" (EUROCONTROL, 2018). Such an optimistic statement ignores the fact that nowadays strategic air traffic planning highly depends on a complex set of many influential factors whose effects won't vanish with implementation of FRA concept. Moreover, strategic air traffic planning implies a systematic study of broader issues, from geospatial analysis and dynamics of air traffic flows to elements of transport policies. Thus, FRA concept needs to be seen as only one of many projects whose aim is to increase efficiency of European ATM network. Reason for mentioned above arises also from the fact that although FRA concept implementation brings improvements in terms of environment (to society) and cost-efficiency (to airspace users), it doesn't resolve other problems related with airspace management, especially in terms of airspace capacity and complexity. Moreover, present forecasts predict a further increase of air traffic within European ATM network what will be even more a challenging situation for airspace management functions in terms of capacity and complexity. Hence it can be stated that among many other elements which affect efficiency of European ATM network, airspace complexity has an important role. In that context it can be stated that the choice of a research topic is based on a growing importance to capture on-going changes occurring within the whole European ATM network since they also reflect on the national ATM development and management strategies. Thus, research aims to answer hypothetical question how did implementation of South East Common Sky Initiative Free Route Airspace (SECSI FRA), and its earlier versions - South-East Axis Free Route Airspace (SEAFRA) and Slovenian Austrian Cross-Border Free Route Airspace (SAXFRA), reflected on airspace complexity at South East Axis. In addition, this research was carried with a task to separately assess changes of airspace complexity at intra-regional and inter-regional level. Thereby, it was possible to obtain more detailed information about effects of latest significant changes at South East Axis, its position within European ATM network and lastly to better understand if there were some discrepancies of effects between ANSPs.

2. Free Route Airspace concept

2.1. Concept development overview

One of concepts that have managed to operationally overcome constraints due to fragmented European airspace design is FRA concept (Steiner et al., 2019). FRA concept is an operational concept for the modernization of the airspace, addressed to improving the efficiency of the flights (Nava Gaxiola et al., 2018). According to its definition, it represents a specified airspace within which users may freely plan a route between a defined entry point and a defined exit point, with the possibility to route via intermediate (published or unpublished) way points, without reference to the ATS route network, subject to airspace availability. Within this airspace flights remain subject to air traffic control (Network Manager, 2016). In such a way, unlike conventional Air Traffic Service (ATS) routes, FRA concept enables a reduction in route length, flight time and consequently fuel consumption as well as carbon dioxide (CO_2) and nitrogen oxide (NOx) emissions reduction (Aneeka and Zhong, 2016). Also, FRA concept development and implementation is supported by European Commission, i.e. by Commission implementing regulation (EU) No 716/2014. It has defined Jan 1, 2022 as a deadline for Europe-wide deployment of FRA concept at and above Flight Level (FL) 310 (European Commission, 2004). Thereby, in past few years Network Manager (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. More specifically, by the end of 2017, 51 Area Control Centres (ACCs) have fully or partially implemented FRA concept thus exceeding the original target of 35 ACCs (EUROCONTROL, 2018).

2.2. South East Common Sky Initiative Free Route Airspace development overview

On Feb 1, 2018 SECSI FRA became H24 operational thus offering significant benefits to airspace users along the South East Axis. Successful deployment of SECSI FRA have led to the creation of one of the largest areas with applicable FRA concept. It was formed by merging two existing FRA areas: South-East Axis Free Route Airspace (SEAFRA) and Slovenian Austrian Cross-Border Free Route Airspace (SAXFRA). Three ANSPs - Croatia Control Ltd (CCL), Serbia and Montenegro Air Traffic Services (SMATSA) LLC and Bosnia and Herzegovina Air Navigation Services Agency (BHANSA) firstly on Apr 30, 2015 implemented cross-border Free Route Airspace Night concept above FL325. Thereby, SEAFRA became a singular area including airspace under the sovereignty of the four states and a first cross-border "beyond Functional Airspace Block (FAB) level" (Serbia and Montenegro are not FAB Central Europe (CE) Member States). From Dec 8, 2016 SEAFRA became operational H24 from FL 325 up to FL 660. By route length reductions, SEAFRA ensured daily savings up to 9,300 kg of fuel and up to 30,000 kg of CO_2 emissions reduction (Croatia Control, 2016). Simultaneously with SEAFRA development, Slovenia Control Ltd and Austro Control GmbH have on Oct 10, 2016 merged into SAXFRA. Thus, SAXFRA became the first European FRA H24 operational area which included cross-border coordination between two countries. Since SAXFRA stretches from the ground (GND) to FL 660, all previously used fixed ATS routes have been deleted. That enabled savings of 13 tons of fuel on the daily basis and consequently reduction of CO_2 emissions in amount of 43 tones daily (FAB CE, 2019). The main changes introduced by merging two areas into SECSI FRA were that ex-SEAFRA area has vertically extended from earlier defined FL 325 to FL 205 - thus satisfying the provisions defined by Regulation (EU) No 716/2014. Second significant change was that entry and exit points between SAXFRA and SEAFRA became intermediate points. Except mentioned operational modifications, environmental and cost-efficiency gains of airspace users also became more substantial. Lastly, it's expected that SECSI FRA should annually deliver potential savings from 600,000 up to 700,000 Nautical Miles in flight distance, daily enable reduction in fuel consumption of 8,000 kg and a reduction in CO_2 emissions of 25,500 kg (Croatia Control, 2018).

3. European airspace complexity assessment methodology

European ATM network represents one of the most regulatory defined and operationally coordinated networks, however, with many different constraints, dysfunctions and disparities. Hence, in Europe strategic air traffic planning is much more requirable than simple demand and supply management. It represents a broader set of activities that needs to be organized, managed and coordinated at multiple operational levels and with participation of different international stakeholders and business entities. In that context, after establishment of Single European Sky initiative, consideration of airspace complexity as one of the representative indicators became more acceptable and used within studies of strategic air traffic planning and development. Although years before it was used in different variations, term of airspace complexity was properly addressed in the middle of the last decade by establishment of *ATM Cost-effectiveness (ACE) Working Group on Complexity* which was set up from representatives of ANSPs, EURCONTROL's Performance Review Unite, Civil Air Navigation Services Organisation (CANSO) and representatives of airspace users and European Commission (Rezo and Steiner, 2019a). Result of their work is still nowadays applicable European airspace complexity assessment methodology that was also applied within this research. In addition, within EUROCONTROL's document titled *Complexity Metrics for ANSP Benchmarking Analysis* airspace complexity was defined as "the external factors that impacts the controller workload and/or the level of difficulty of the ATC task, without (considering) the internal, ATC procedures-related factors" (ACE Working Group on Complexity, 2006). Beside a general definition, this document has also defined a methodological framework how to measure airspace complexity throughout four complexity dimensions, i.e. indicators. Thus, following airspace complexity dimensions and their indicators were individually analysed within this research; traffic density dimension (articulated by adjusted density indicator), traffic in evolution dimension (articulated by potential vertical interactions indicator), flow structure dimension (articulated by potential horizontal interactions indicator) and traffic mix dimension (articulated by potential speed interactions indicator). Lastly, the result of the combination of the specified four indicators are airspace structural index and complexity score which have been also applied as two aggregate indicators and analysed within this quantitative research.

3.1. Intra-regional assessment methodology

The objective of intra-regional assessment methodology is to determine changes of airspace complexity within SECSI FRA area in relation to FRA implementation sequences. Within both, intra-regional and inter-regional assessment methodologies, six earlier specified airspace complexity indicators have been applied as a reference criterion. Their values have been collected, published by Performance Review Unit (PRU) and applied within this research. PRU, as part of the EUROCONTROL, is responsible for a public reporting of different key performance indicators describing European ATM network performances (EUROCONTROL, 2019). Applied intra-regional assessment methodology is based on a comparative trend analysis and it follows FRA implementation timeline at South East Axis. Based on five years data analysis (from January 2014 till December 2018) it was possible to identify variability of applied indicators and conduct comparison of impacts. Main goal of intra-regional assessment is to determine ANSPs' airspace complexity status before FRA implementation (2014-2015/2014-2016), during separate FRA concept implementation at SEAFRA (2015-2018), i.e. SAXFRA (2016-2018) areas and airspace complexity status after merging into SECSI FRA (2018). Such an approach made possible to follow dynamics of air traffic flows' variability and to capture equalities, similarities or differences between ANSPs in terms of different airspace complexity indicators and in relation to FRA implementation sequences.

3.2. Inter-regional assessment methodology

Unlike to the intra-regional assessment (which focus is to capture changes at SECSI FRA area), inter-regional assessment considers values of the entire European ATM network. In addition, it's important to point out that this assessment methodology does not treat air traffic flows' variability dynamics in relation to FRA implementation sequences. Moreover, the focus of this assessment is to define the status of SECSI FRA area within European ATM network. Hence, this assessment methodology as the reference data uses only PRU's 2018 data which captures values of airspace complexity indicators of 37 ANSPs and spatially covers airspace of 11,200,157 km^2. The main goal of applied inter-regional assessment methodology is to capture cohesion level in terms of airspace complexity. This assessment is based on the spatial statistics, i.e. on the application of spatial autocorrelation methodology. Spatial autocorrelation determines the dependence of a given variable's value on the values of the same variable recorded at neighbouring locations (Cliff and Ord 1973). In order to measure spatial autocorrelation, Moran's index (I) have been applied. Among various measures of spatial autocorrelation, it's the most significant one (Das and Ghosh, 2016). In that context, based on the application of Moran's I scatter plot it was possible to identify local spatial associations. Moran's I scatter plot is a useful tool for conducting research as it allows to estimate the similarity of observed value to adjacent values (Anselin, 1996). In this case, values of complexity indicators of one ANSP have been compared with values of adjacent ANSPs. To determine their similarities or differences four indicators (arising from four quadrants of the scatter plot) were used, whereby high value area surrounded by similarly high values is specified by HH indicator. Conversely, low value area with low neighbouring values by LL indicator, low value area surrounded by high neighbouring values by LH indicator and vice versa for HL indicator.

4. Results

4.1. Intra-regional assessment results

Since in the most cases individual ANSPs' performance analysis provides partial findings it was necessary to define functional integration of adjacent ANSPs within the context of FRA implementation at intra-regional level. Such analysis involved synthesis of 704,850 complexity indicators (covering period from 2014 till end of 2018) in a form of average annual values per indicator - as it's shown by Figure 1. In that context comparative trend analysis results indicate that FRA implementation had different impacts on ANSPs, i.e. it had differently reflected on ANSPs' airspace complexity indicators. Regarding time before, during and after FRA concept implementation, at intra-regional level it's notable an increase of horizontal scores and consequently structural indexes and complexity scores. Furthermore, obtained results shows a downfall of speed score indicators at intra-regional level. Based on that, it can be concluded that FRA concept implementation had positive impact on traffic mix dimension.

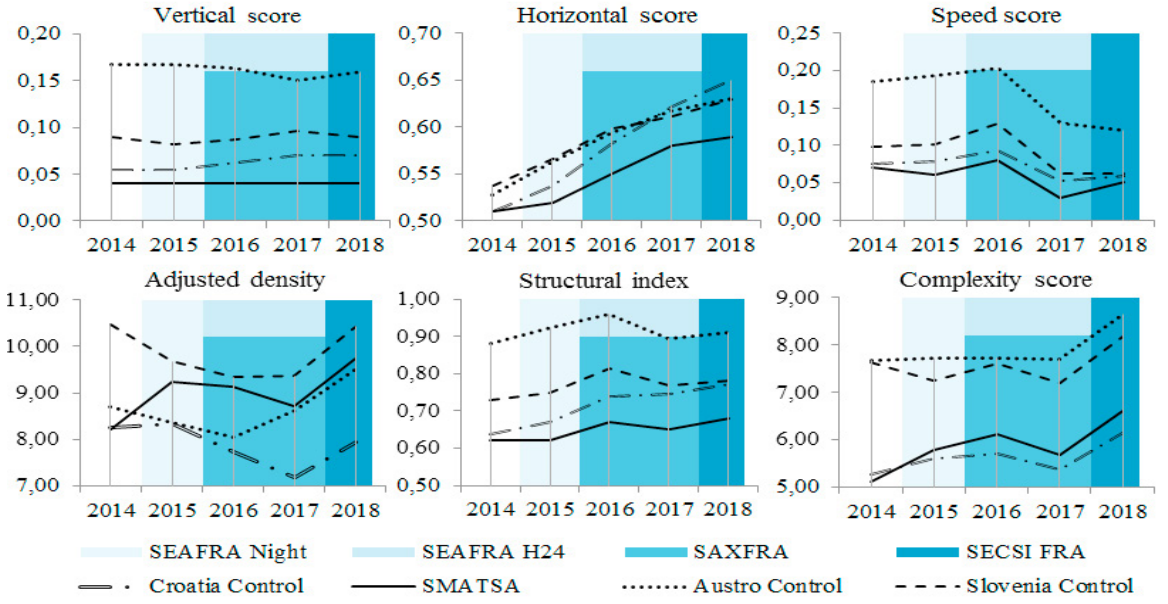

Fig. 1. Intra-regional airspace complexity indicators' trend analysis comparison

4.2. Inter-regional assessment results

Strategically, it was also important to valorise SECSI FRA geo-traffic position in the context of its territorial and functional affiliation to the European ATM network. The results of inter-regional assessment were obtained through performance simulations and they are presented by Figure 2. This assessment included conduction of 1,914 mathematical operations processing 222 complexity indicators expressed as 2018 indicators' averaged values.

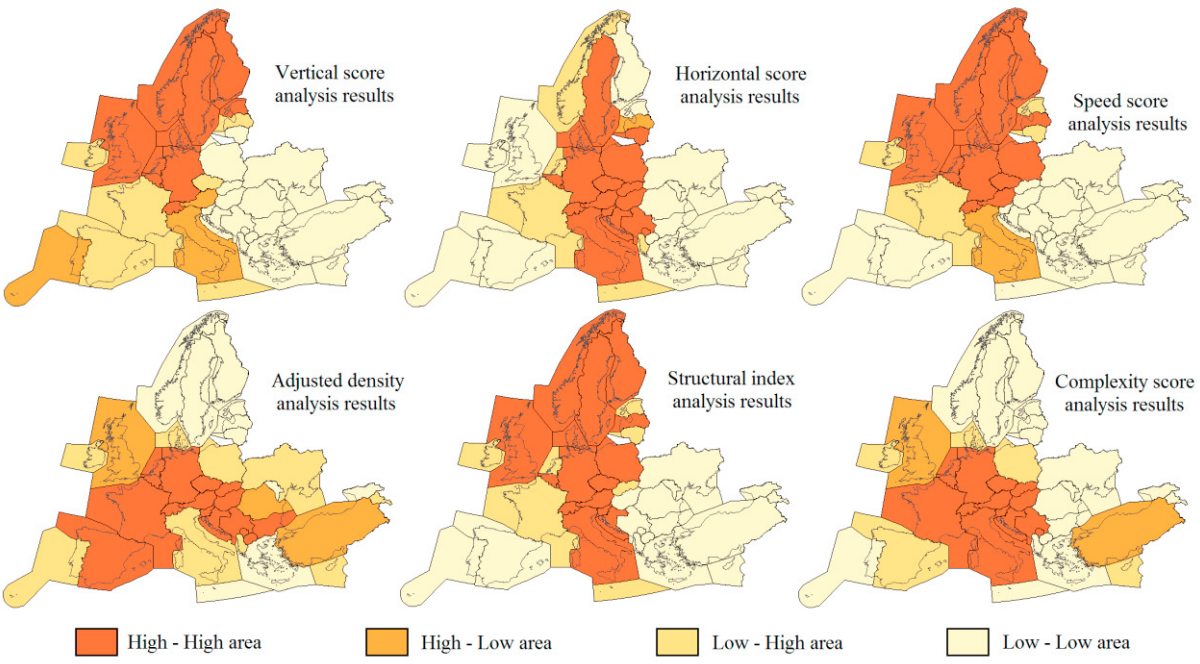

Fig. 2. Spatial overview of SESCI FRA geo-traffic position in relation to European ATM network

5. Discussion

Since FRA concept is designed for Europe-wide application, benefits of its implementation have to be recognised in creation of future sustainable European ATM network. Although FRA represents a complex concept, it can be simplified and considered from two main aspects - from airspace users and environmental aspect and from ANSPs' aspect. On the one side, FRA concept aims to reduce operational costs of airspace users and it has been proven to be very efficient for them (Antulov-Fantulin et al., 2018). Moreover, it is expected that they will reach a cost reduction of up to 3.8% after 2022 when FRA will be Europe-wide applicable (Bentrup and Hoffmann, 2016). FRA concept enables to fly on the shorter routes what consequently leads to reduction of fuel consumption and the harmful emissions. According to ATM Master Plan Level 3 Report, flying distances could be reduced by approximately 7.5 million Nautical Miles what represents the equivalent of 45,000 tonnes of fuel saved, or an emissions reduction of 150,000 tonnes of CO_2 or EUR 37 million (SESAR Joint Undertaking, 2018). Likewise, transition from fixed ATS routes to FRA concept reduces airspace users' exposure to fuel prices variability and offers them significant opportunities in the terms of aircraft route management and flight planning. On the other side, ANSPs by utilising additional operational, financial and human resources need to create a functional FRA environment.

Nowadays, many successful aviation businesses manage to grow simply because they understand their business environment (Rezo and Steiner, 2019b). In that context, establishment of SECSI FRA is representative example of a joint undertaking in line with the development goals of future European ATM network. It's a good example of regional cooperation that has included stakeholders from six adjacent states and four ANSPs. PRU's data (Performance Review Unit, 2018) indicate that during 2018 those ANSPs together handled 2,751,080 IFR flights. That represents an 8.58% traffic increase compared with 2017 data when SAXFRA and SEAFRA areas were operational, i.e. 18.87% increase compared with 2015 data when FRA concept implementation was on its beginnings. That clearly points out that traffic demand at South East Axis has increased during past few years. However, it's indisputable that traffic increase has influenced a certain increase share of airspace complexity. But, at the sample of reduction of speed score indicator, it would be wrong to conclude that traffic increase is the single reason for overall increase of airspace complexity. It's therefore clear that FRA concept implementation effects did reflected on airspace complexity indicators thus making them credible research indicators.

According to Steiner et al. (Steiner et al., 2014), efficiency of European ATM network shouldn't be indicated only by transport network's technical elements, nor the handled transport volume, but rather by terms of connectivity and availability. It that context European ATM network's performances should be articulated throughout capacitive, cost-effective, safety related and environmentally oriented spatial cohesion. Therefore, the spatial cohesion of European airspace and its main corridors needs to be strategically planned within multiregional integrations framework. In that context within this retrospective research, the effects of FRA concept implementation at South East Axis have been studied at two levels - intra-regional level and inter-regional level. The major difference between these two levels is that intra-regional level, no matter how clear the difference between the indicators were, can't give a comprehensive interpretation of a wider regional functional and operational integration. Therefore, this research was carried by a complementary combination of analytical and graphical methods thus providing outcomes answering how did FRA concept implementation reflected on South East Axis and about its position within European ATM network in terms of airspace complexity.

According to Renner et al., FRA concept implementation can impact former flow of traffic so that it becomes disarranged (Renner et al. 2018). Consequently, in areas with low level of traffic homogeneity that can have a high impact on workload level and the airspace capacity. Hence, the intra-regional assessment has included indicators' trend analysis from the initial FRA concept implementation to SECSI FRA deployment. They indicate that during observed period (from 2014 till end of 2018) there were no notable changes in terms of vertical score variability. To some extent, the reason for such a situation could be found within the fact that air traffic overflying South East Axis is mostly characterized as transit traffic. Compared to the period prior to the FRA concept implementation, it can be concluded that the adjusted density indicator increased at Austro Control's and SMATSA's Area of Responsibility (AoR), decreased at CCL's AoR while at Slovenia Control's AoR it remained the same as when FRA concept implementation have started. For the rest of the observed indicators trend analysis points out increase of horizontal scores, structural indexes and complexity scores as well as speed scores decrease at entire SECSI FRA area.

Although SECSI FRA area represents only 3.19% of a totally observed airspace area, its position is quite important. In addition, considering that on Feb 1, 2018 SECSI FRA went operational, airspace complexity indicators capturing performances during 2018 represent a reliable data source for conclusions writing. So, based on obtained results of inter-regional assessment it was possible to draw out conclusions about SECSI FRA geo-traffic position within European ATM network. Results comparisons indicate that SECSI FRA area partially joins to the different spatial patterns since there are value variations from one to another indicator. For example, vertical and speed score analysis results, with an exception of Austro Control's AoR, indicate that the most of SECSI FRA area falls under area of a lower values with neighbourhood of also lower values. That primarily refers to area of eastern and south-eastern European airspace. In the case of traffic density dimension articulated through adjusted density indicator, results clearly points out that high value area surrounded by similarly high values covers central and south eastern parts of European airspace as well as SECSI FRA area. From the other indicators' analysis results, it can be concluded that SECSI FRA area represents an area with high values of indicators that spatially associates with neighbourhood of same high values so covering mostly a central part of European airspace.

6. Conclusion

Nowadays, it's a matter of time (years) until FRA concept will operationally unify differently fragmented European ATM network. Considering that FRA concept is planned to extend within FAB CE in the period 2019-2021, it was important to conduct a research aiming to answer how did FRA implementation affected airspace complexity at South East Axis. Within this paper, FRA concept implementation effects have been studied on intra-regional and inter-regional level. Intra-regional level assessment has provided results which are based on a comparative trend analysis while inter-regional level assessment has provided findings defining the SECSI FRA position within European ATM network. According to obtained results it's possible to conclude that FRA concept implementation had differently affected airspace complexity and its indicators. Research findings of an intra-regional level assessment indisputably show a recognizable consecutive reduction of speed score indicator as well as the increase of horizontal score indicator. Consequently, that have led to a slight increase of structural and complexity score indicators. So, it's undeniable that the FRA concept affected traffic increase, routes reconfiguration and changes in routes utilization levels, that have jointly led to increase of airspace complexity. However, it's notable that joint venture of implementation of FRA concept didn't bring equal benefits to all participating ANSPs. For example, Austro Control, unlike other ANSPs within SECSI FRA area, have recorded the highest improvements in terms of reduction of traffic mix dimension (decrease of 36.84% in comparison to 2014 data when FRA concept wasn't yet started). As compared to time before and after implementation of FRA concept, Croatia Control went from being ANSP with lowest flow structure complexity to being ANSP with highest flow structure complexity. Moreover, it's also an only ANSP within SECSI FRA area whose traffic density has decreased in comparison to its value before FRA concept implementation has started. On the other side, SMATSA recorded increase of 18.37% of same indicator compared to its value before FRA concept implementation. Hence, it can be defined that implementation of FRA concept, in comparison with other participating ANSPs within SECSI FRA, affected the mostly traffic flows in AoR of Croatia Control. Traffic flows in that AoR with implementation of FRA concept started to be more scattered and less concentrated than before (since flow structure has changed). Furthermore, obtained results from inter-regional level assessment lead to the conclusion that SECSI FRA area in terms of airspace complexity mainly represents a border area between Central and Eastern Europe which in dependence of observed airspace complexity indicator spatially associates with different areas.

To sum up, this research has proven how difficult it's to create and implement a comprehensive and sustain European ATM network development plan that evenly comply all stakeholders' interests. In that context, it can be concluded that in forthcoming period some ANSPs will face with such a development scenario where their staff's workload level will be highly increased, where more complex traffic will be needed to be handled and where at the same time ANSPs will have to respect the policy requirement of continuous unit rate decrease, thus neglecting own interests in favour of environmental and airspace users benefits. Additionally, it's possible to conclude that research carried on the example of the FRA implementation has confirmed the "unspoken rule" that within complex European ATM network, unfortunately, it's difficult to improve one performance segment without compromising other segment(s).

Acknowledgement

This targeted research was performed by the Traffic Institute of Croatian Academy of Sciences and Arts and it's a part of a broader research in the domain of strategic air traffic planning and development.

References

ACE Working Group on Complexity. Complexity Metrics for ANSP Benchmarking Analysis. EUROCONTROL, April 2006

Aneeka, S., Zhong, ZW., 2016. NOx and CO_2 emissions from current air traffic in ASEAN region and benefits of free route airspace implementation. Journal of Applied and Physical Sciences 2.2, 32-36.

Anselin, L., 1996. The Moran Scatterplot as an ESDA Tool to Assess Local Instability in Spatial Association: Spatial Analytical Perspectives on GIS. Taylor and Francis, London, England

Antulov-Fantulin, B., Rogošić, T., Juričić B., Andraši P., 2018. Air Traffic Controller Assessment of the Free Route Airspace Implementation within Zagreb Area Control Centre. In: Bajor, I., Vidović, A. (Eds.). Proceedings of the International Scientific Conference: Science and Traffic Development (ZIRP 2018). Opatija, Croatia. pp. 1-10.

Bentrup, L., Hoffmann, M., 2016. Free Routing Airspace in Europe Implementation Concepts and Benefits for Airspace Users. International conference for Research in Air Transportation (ICART). Philadelphia, USA. pp. 1-3.

Cliff, AD., Ord, JK., 1973. Spatial autocorrelation. Pion, London, England

Croatia Control, 2016. SEAFRA H24 [WWW document]. URL http://www.crocontrol.hr/default.aspx?id=3625 (accessed 1.12.2019)

Croatia Control, 2018. South East Common Sky Initiative Free Route Airspace (SECSI FRA) Successfully Implemented [WWW document]. URL http://www.crocontrol.hr/default.aspx?id=3780 (accessed 2.1.2019)

Das, M., Ghosh, S., 2016. A cost-efficient approach for measuring Moran's index of spatial autocorrelation in geostationary satellite data. International Geoscience and Remote Sensing Symposium (IGARSS). Beijing, China. pp. 5913-5916.

EUROCONTROL, 2018. Free route airspace (FRA) [WWW document]. URL https://www.eurocontrol.int/articles/free-route-airspace (accessed 12.18.2018).

EUROCONTROL, 2019. Air navigation services performance review [WWW document]. URL https://www.eurocontrol.int/air-navigation-services-performance-review (accessed 07.12.2018)

European Commission. 2014. Commission implementing regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan. Brussels, Belgium

FAB CE, 2019. Free Route Airspace [WWW document]. URL https://www.fab-ce.eu/airspace/free-route (accessed 2.16.2019)

Nava Gaxiola, CA., Barrado, C., Royo, P., Pastor, E., 2018. Assessment of the North European free route airspace deployment. Journal of Air Transport Management 73, 113-119.

Network Manager. 2016. Free Route Airspace developments. EUROCONTROL, Brussels, Belgium

Performance Review Unit, 2018. Pan-European ANS Performance Data Portal [WW document]. URL https://5c95e9a890bf82000b43636e--pru-portal.netlify.com/# (accessed 1.15.2019).

Renner, P., Rohács, D., Papp, G., Kling, F., 2018. The Effects of the Introduction of Free Route (HUFRA, Hungarian Free Route Airspace) in the Hungarian Airspace. 8th SESAR Innovation Days. Salzburg, Austria. pp. 1-8.

SESAR Joint Undertaking. European ATM Master Plan Level 3: Implementation View: Progress Report 2018. SESAR Joint Undertaking, March 2018

Rezo, Z., Steiner, S. 2019a. European airspace complexity and fragmentation correlation research. Proceedings of Research Workshop Fragmentation in Air Traffic and its Impact on ATM Performance, Budapest, Hungary. pp. 1-8.

Rezo, Z., Steiner, S. 2019b. European air traffic market segmentation model: A cost-efficiency based assessment. German Aviation Research Society: 16th Aviation Student Research Workshop, Amsterdam, Netherlands. pp. 1-12.

Steiner, S., Feletar, P., Šimecki, A., 2014. Transport and spatial correlation of regional development. In: Vidan, P., Twrdy, E., Leder, N., Mulić, R. (Eds.). 6th International Maritime Science Conference. Solin, Croatia. pp. 505-517.

Steiner, S., Mihetec, T., Rezo, Z. 2019. Resolution of Operational Constraints Imposed by Fragmentation of European Airspace. In: Grgurević, I., Rožić, T. (Eds.). Proceedings of the International Scientific Conference: Science and Traffic Development (ZIRP 2019). Opatija, Croatia. pp. 385-395.