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# THE NEW AIRSPACE MODEL FOR FLIGHT PLANNING AT FREE ROUTE AIRSPACE

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***Abstract***

*The continuous increase in the world's population, which according to the United Nations (UN) forecasts, will peak at 10 billion people in 2064, translates into increased demand for transportation services, including air transport*[1]*. EUROCONTROL estimates a 96% increase in the number of flights, which will cause airspace capacity inconveniences*[2]*. This entails a number of undesirable consequences, namely delays in the arrival and departure sector, increased costs for carriers, declining safety levels and a growing dissatisfaction among passengers. Flight planning systems which use airways in the airspace of the International Civil Aviation Organization (ICAO) member states do not provide effective optimization. Planned routes are longer in comparison to optimal trajectories, which translates into fuel consumption and negative impact that the aviation sector has on the environment. This work aims to examine the possibility of improving the efficiency of air route planning in the Free Route Airspace (FRA), using a graph-based airspace model.*

*In the study, the thesis was adopted that it is possible to distribute graph node points at the vertices of zones not available for planning at a given time. Verification of the test results was carried out by comparing flight routes planned in the developed airspace model with those obtained in the validation of the SESAR 2020 PJ06 ToBeFREE project. An Alsim AL200 MCC class flight simulator was used for the validation work.*

***Keywords***: *free-flight space, flight planning, space model*

**NOWY MODEL PRZESTRZENI POWIETRZNEJ ZE SWOBODĄ PLANOWANIA TRAS**

***Streszczenie***

*Ciągły wzrost populacji świata, który według prognoz ONZ osiągnie szczyt w 2064 r., wynosząc 10 miliardów ludzi, przekłada się na wzrost zapotrzebowania na usługi transportowe, w tym transport lotniczy. EUROCONTROL szacuje 96% wzrost liczby lotów, który spowoduje niedogodności związane z przepustowością przestrzeni powietrznej. Pociąga to za sobą wiele niepożądanych konsekwencji, jakimi są: opóźnienia w sektorze przylotów i odlotów, wzrost kosztów ponoszonych przez przewoźników, spadek poziomu bezpieczeństwa oraz rosnące niezadowolenie klientów. Systemy planowania lotów, wykorzystujące drogi lotnicze w przestrzeniach powietrznych państw należących do ICAO, nie zapewniają skutecznej optymalizacji. Planowane trasy są dłuższe w porównaniu do trajektorii optymalnych, co przekłada się na zużycie paliwa i negatywny wpływ sektora lotniczego na środowisko. Praca ma na celu sprawdzenie możliwości poprawy efektywności planowania tras lotniczych w przestrzeni FRA, wykorzystując w tym celu model przestrzeni oparty na grafie. Przyjęto tezę, iż istnieje możliwość rozłożenia punktów węzłowych grafu w wierzchołkach stref niedostępnych do planowania w danym czasie. Weryfikacja wyników badań została przeprowadzona przez porównanie tras lotniczych zaplanowanych w opracowanym modelu przestrzeni z trasami uzyskanymi w ramach walidacji projektu SESAR2020 PJ06 ToBeFREE. Do prac walidacyjnych wykorzystano symulator lotów klasy Alsim AL200 MCC.*

***Słowa kluczowe***: *przestrzeń swobodnego lotu, planowanie lotu, model przestrzeni*

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[1] UN DESA, *World Population Prospects 2022. Summary of Results*, https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022 _s ummary_of_results.pdf [access: 14.06.2023].

[2] *EUROCONTROL predicts growth in aviation traffic over next 8 months*, https://www.eurocontrol.int/news/eurocontrol-predicts-growth-aviation-traffic-over-next-8-months [access: 14.06.2023].

## 1. Introduction

The continuous increase in the world's population has been witnessed since the mid-1800s, and according to the UN, it will peak in 2064 at nearly 10 billion people[3]. With the population growth, the demand for goods increases, which is closely related to transportation services, including air transport[4]. Air transport is a rapidly growing industry and is a pillar and foundation of globalization. The overwhelming advantage of this type of transport over others is the speed of movement, as well as high level of safety.

The highest volume of air traffic is observed in Europe and the United States. In its forecasts, EUROCONTROL estimates that the European Union territories will see an increase in the number of flights by about 96% over the next 20 years[5]. Airspace capacity is defined as the level of traffic that can be efficiently served at a satisfactory qualitative level[6]. Given these forecasts, air traffic may reach the limit of airspace capacity, with undesirable consequences, such as[7]:

- delays in the aircraft departure and arrival sector, causing increased costs and financial losses for carriers, and leading to continued passenger dissatisfaction;
- a decrease in the level of safety in air traffic, resulting from the increased workload of air traffic controllers during the resolution of conflict situations;
- increased environmental pollution and negative impact on climate, due to the increased fuel consumption as well as increased emissions of harmful substances, which are components of exhaust fumes and noise, which are generated.

Modern and innovative ideas, concepts and initiatives, such as the Free Route Airspace and the SESAR program, are being developed in response to the challenges posed by the continuous growth of air traffic and airway capacity constraints. Their main goal is to create and implement a system that will enable increased airspace capacity, improve economic indicators, increase safety and reduce the harmful impact of air operations on the environment.

## 2. Methodology

Determining optimal routes for aircraft flights in the FRA airspace is a significant challenge to manage air traffic effectively. The FRA airspace, with its flexibility and free choice of routes, provides opportunities to optimize flight time, fuel consumption and $CO_2$ emissions. However, due to the increasing complexity of the airspace structure, it is necessary to develop a suitable model that reflects its features and takes into account existing constraints, as well as to determine the optimal flight route with a relatively small computational effort. The purpose of this work is to develop an airspace model that will enable to determine optimal aircraft flight routes, regardless of the complexity of the FRA space.

In order to achieve the stated goal, an appropriate research methodology will be applied. First of all, the analysis of the existing data on the structure of the FRA airspace, such as flight paths, navigation points, sectors and operational constraints, will be conducted. Then, based on the

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[3] UN DESA, *World Population Prospects 2022. Summary of Results*, https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022 _summary_of_results.pdf [access: 14.06.2023].
[4] P. Gołda, D. Pyza, *Transport Cargo Handling Shipments in Air Transport in the Aspect of Supply Chains*, International Conference on Systems Engineering (ICSEng), Las Vegas 2011.
[5] *EUROCONTROL predicts growth in aviation traffic over next 8 months*, https://www.eurocontrol.int/news/eurocontrol-predicts-growth-aviation-traffic-over-next-8-months [access: 14.06.2023].
[6] EUROCONTROL, European Aviation in 2040. Challenges of growth. Annex 1. Flight Forecast to 2040, Brussels 2018.
[7] Sprawozdanie Kancelarii Senatu nr 56/2013 na temat jednolitej europejskiej przestrzeni powietrznej, Bruksela 2013.

collected data, an airspace model will be developed that takes into account relevant features and constraints.

This work will seek answers to the following research questions:

- What are the relevant airspace features and constraints to be considered in the FRA space model?
- How to formulate the problem of determining optimal aircraft flight routes in the FRA airspace as an optimization task?
- What optimization criteria should be considered to find the best flight routes that minimize flight time, fuel consumption and $CO_2$ emissions?
- What optimization methods can be used to solve the formulated problem?
- What are the differences and benefits of using the developed airspace model compared to the existing solutions?
- Is it possible to improve the efficiency of air routes planned in the FRA airspace, planned using the new airspace model?
- Are the routes planned in the model feasible under conditions similar to a real flight?

The answers to the above-mentioned research questions will help to achieve the goal of the work, which is to develop an airspace model to determine optimal aircraft flight paths in the FRA airspace, regardless of its complexity and taking into account relevant optimization factors and operational constraints.

As part of the research work, a research plan was developed in which the use of adequate research tools and methods was planned:

- Literature analysis: a review of the existing literature on types of airspace, air route planning in the FRA airspace and graph-based space models.
- Development of a graph-based space model: use of tools such as computer, graphics programs, AutoCAD and Microsoft Excel to develop a graph-based space model.
- Implementation of optimization algorithms in the developed model.
- Computer simulation: using computer programs to simulate air route planning in the developed model.
- Generating statement data such as route length, flight time and $CO_2$ emissions.
- Flight simulator experiment: the use of the Alsim AL200 MCC class flight simulator to validate the feasibility of the simulation-determined routes in the airspace modeling graph.
- Verification and validation of the developed space model by comparing the air routes planned in the model with those obtained in the validation of the SESAR 2020 PJ06 ToBeFREE project.
- Collection of data and analysis of the results: the analysis of route lengths, flight times and $CO_2$ emissions for the routes planned in the airspace model.
- Interpretation of the results and conclusions: the analysis of the collected data and comparison of the effectiveness of the developed space model with traditional flight planning methods. Comparison of simulation results and the results obtained using a flight simulator.
- Formulation of conclusions based on the results analysis and their interpretation.

Research tools used in the research work include a computer, graphical and Microsoft Excel programs, and the Alsim AL200 MCC flight simulator. The research methods are literature analysis, airspace model development, computer simulation, flight simulator experiment, analysis of data sets, the results analysis, and interpretation of the results and formulation of conclusions.

## 3. The Free Route Airspace (FRA)

Currently, air spaces of the countries that belong to the International Civil Aviation Organization (ICAO) are divided into zones and levels, characterized by different degrees of accessibility and handling of air traffic. European civil airspace has been divided into controlled space, in which a controller is responsible for the separation between aircraft, and uncontrolled space, in which this responsibility rests with the pilot-in-command. Air traffic in a controlled airspace is carried out in an orderly manner by using one of the elements of its airspace, the airways[8]. However, the system of an extensive network of air corridors is complex, and current flight planning regulations do not allow for efficient route optimization early in the flight planning process.

Air routes in Europe are longer than optimal solutions, leading to increased delays, costs, carbon emissions and dissatisfaction of air carriers as well as passengers. The current situation and the increase in air traffic are forcing the search for new airspace management solutions[9]. The answer to the problems is the Free Route Airspace (FRA) concept, established in 2008. The FRA project was launched by EUROCONTROL, in cooperation with civilian and military air traffic management organizations, members of the Air Navigation Services Providers (ANSP), the European Civil Aviation Conference (ECAC), and flight planning support institutions[10].

In accordance with the definition, the Free Route Airspace is:

> a defined airspace in which users are free to plan routes between a specified entry point and a specified exit point, with the ability to plan a route through intermediate (published or unpublished) waypoints, without reference to the ATS route network, subject to airspace availability. Within this airspace, flights remain under air traffic control[11].

The FRA concept is key in overcoming the aviation sector's challenges related to airspace efficiency and capacity, as well as pollution. The project achieves its goals by reducing fuel consumption, carbon emissions and improving flight efficiency. The FRA initiative is a milestone in developing more advanced airspace design methods and ATM operational concepts.

Full implementation of the FRA concept throughout Europe will bring a number of benefits, its originators assume[12]:
- shortening of air routes by 1 trillion nautical miles;
- reducing fuel consumption by 6 million tons;
- reducing carbon dioxide emissions by 20 million tons;
- savings of 5 trillion euros.

### 3.1. POLFRA and its limitations

In Poland, air operations based on free route planning were introduced by the Polish Air Navigation Agency in the form of an airspace called POLFRA, under the EU Executive Order No. 716/2014, which is a pilot program of the SESAR Pilot Common Project (PCP). The operational implementation of the airspace with freedom of flight planning in Polish airspace took place on 28th February 2019.

[8] H. Jafernik, R. Fellner, *Prawo i procedury lotnicze*, Gliwice 2015.
[9] M. Zieja, H. Smoliński, P. Gołda, *Estimating the system efficiency to ensure aircraft flight safety*, "Journal of KONBiN" 2015, vol. 36, no. 4.
[10] G. Drupka, T. Rogalski, *Free Route Airspace – nowe regulacje przestrzeni powietrznej*, [in:] *Prawo lotnicze i kosmiczne oraz technologie – nowe wyzwania,* eds. E. Dynia, M. Pączek, Rzeszów 2019.
[11] T. Todorov, *Free Route Airspace (FRA) in ICAO EUR Region – FRA Concept*, https://www.icao.int/MID/Documents/2018/ATM%20SG4/PPT11.pdf [access: 14.06.2023].
[12] *Free route airspace*, https://www.eurocontrol.int/concept/free-route-airspace [access: 14.06.2023].

The implementation of POLFRA airspace allows users to select their preferred flight path at the planning stage (Fig. 1), resulting in greater consistency between the planned and actual flight trajectory. As a result, flight predictability increases and safety is improved[13].

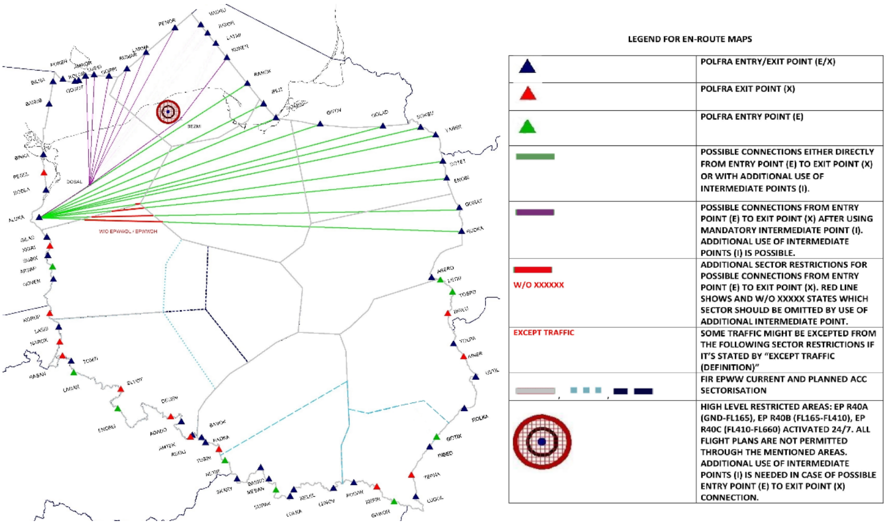


Fig. 1. POLFRA en-route
*Source: https://www.pansa.pl/polfra/maps/ [access: 14.06.2023].*

When planning flights in POLFRA airspace, users should take into account bypassing areas inaccessible to civil operations in accordance with EAUP/EUUP and NOTAM dispatches. For this purpose, when planning, one should use the FRA (I) waypoints published in AIP Poland ENR 4.4 or the radio navigation aids contained in EN 4.1. Planning of flight trajectories through active restricted air spaces is prohibited unless otherwise specified in the Flexible Use of Airspace (FUA) Concept.

The European Airspace Use Plan (EAUP) and The European Updated Airspace Use Plan (EUUP) are the main sources of information on current and planned activities of airspace structures in Europe. They are automatically updated in the EUROCONTROL European Airspace Traffic Management System (Network Manager – NM). This information is used to verify the correctness of flight plans by the Initial Integrated Flight Plan Processing System (IFPS).

Restricted areas that occur in POLFRA airspace above FL095 are associated with Flight Plan Buffer Zones (FBZs) or FUA restrictions. FBZs are virtual buffers of a certain width, imposed on active zones and published in AIP Poland. The buffer spaces were introduced for the purpose of correct validation of IFR flight plans in the FIR EPWW, that is checking their collision status with active zones during the planned flight. Flight trajectories passing through active FBZs are automatically rejected (Fig. 2). FBZ spaces are described by geographic coordinates and altitude ranges. There is a characteristic letter "Z" at the end of the designator of such a zone.

[13] M. Zieja, H. Smoliński, P. Gołda, *Information systems as a tool for supporting the management of aircraft flight safety*, "Archives of Transport" 2015, vol. 36, no. 4, p. 67–68.

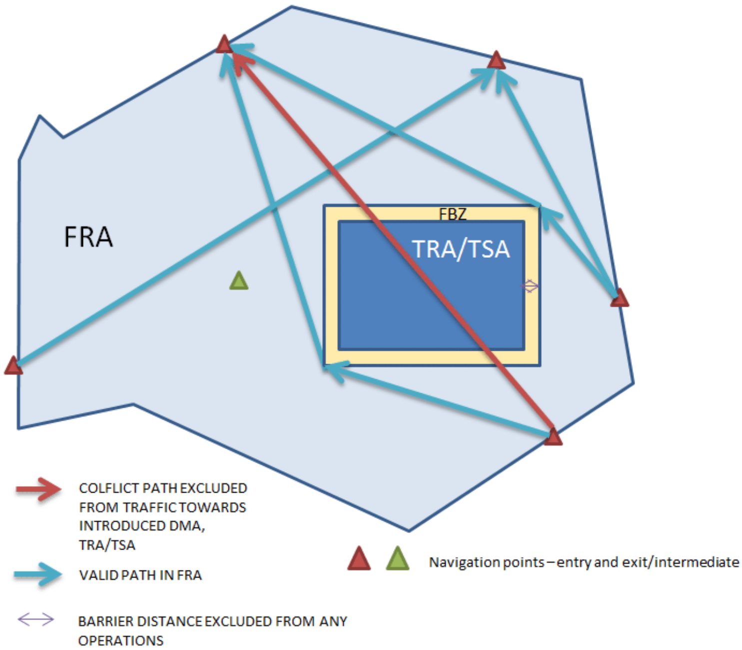


Fig. 2. FBZ in the FRA airspace

*Source: G. Drupka, T. Rogalski, Computational geometry draft to avoid Dynamic Mobile Area in Advanced Airspace Management service, [in:] Poszerzamy Horyzonty, vol. 5, eds. A. Piotrowska-Puchała, M. Bogusz, M. Wojcieszak, P. Rachwał, Słupsk 2017.*

## 4. The FRA airspace model

Addressing the difficulty of not being able to effectively optimize the flight path at the planning stage (taking into account any space constraints) is the Single European Sky ATM Research program (SESAR)[14]. SESAR is a key technological component of the Single European Sky (SES) initiative. The main intention of the SESAR 2020 program is to carry out a comprehensive modernization of the Air Traffic Management (ATM) system in order to create a next-generation system that will be highly efficient and ensure the safe development of air transport throughout Europe.

The Polish Air Navigation Services Agency, representing the B4 Consortium in the governing bodies of the SESAR Joint Undertaking, in cooperation with the Rzeszow University of Technology, implemented the PJ06 ToBeFREE "Trajectory Based Free Routing" project. The result of the project was the creation of an algorithm to optimize air routes in the FRA. The algorithm is based on an airspace model, which is a graph[15]. This model reflects relevant features, restrictions and limitations of the airspace applicable at a given time.

The flight trajectory in the model is represented as a set of graph node points, described by geographic coordinates, along which the aircraft moves. The solution to the problem described by

[14] G. Drupka, A. Majka, T. Rogalski, L. Trela, *An airspace model aplicable for automatic flight route planning inside free route airspace*, "Scientific Letters of Rzeszow University of Technology, Mechanics" 2018, vol. 35, no. 298.
[15] A. Majka, *Weryfikacja i walidacja nowego algorytmu planowania tras w przestrzeni FRA*, [in:] *Mechanika w Lotnictwie ML-XIX 2020*, eds. K. Sibilski, P. Lichota, Warszawa 2020, p. 169–170.

the graph model is the classic methods of searching for an extreme trajectory, by using the Dijkstra algorithm[16] (Fig. 3).

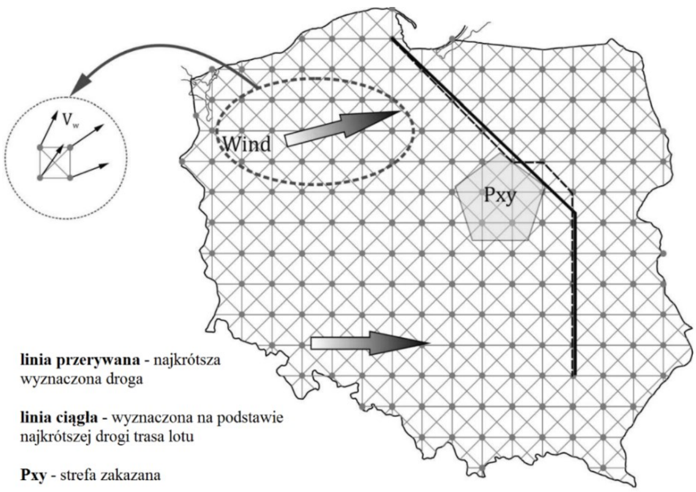


Fig. 3. Flight trajectory in a graph-based airspace model
*Source: A. Majka, Weryfikacja i walidacja nowego algorytmu planowania tras w przestrzeni FRA, [in:] Mechanika w Lotnictwie ML-XIX 2020, eds. K. Sibilski, P. Lichota, Warszawa 2020, p. 170.*

The result of the V2 validation of the SESAR 2020 PJ06 ToBeFREE project was three flight routes (Limited FRA): Rzeszow–Szczecin, Krakow–Slupsk and Wroclaw–Gdansk (all of them within Polish airspace), determined on the airspace model in the form of a graph. The model assumed the highest level of space complexity, which took into account the activity of military zones. The use of this method of flight planning, compared to the classic use of airways, showed a reduction in distance and, consequently, flight time.

The efficiency of the calculations performed by an algorithm using a graph-based model largely depends on the placement of node points and the distances between them. Choosing the right distances and node locations is important for the optimization and the increase in the efficiency of the flight path.

## 5. The new graph-based airspace model

The main objective of the research work was to analyze the possibility of improving the efficiency of flight planning in the FRA airspace based on the optimization of the graph-based airspace model. The research assumed the possibility of a different arrangement of graph node points[17].

The airspace model was taken as a graph, the structure of which mapped the airspace of Poland (FIR EPWW), with active military zones (Fig. 4).

[16] Ibidem, p. 170.
[17] I. Lugo-Cárdenas, G. Flores, S. Salazar, R. Lozano, *Dubins path generation for a fixed wing UAV*, International Conference on Unmanned Aircraft Systems (ICUAS), Orlando 2014; A. Tsourdos, B. White, M. Shanmugavel, *Cooperative Path Planning of Unmanned Aerial Vehicles*, Wiley 2011.

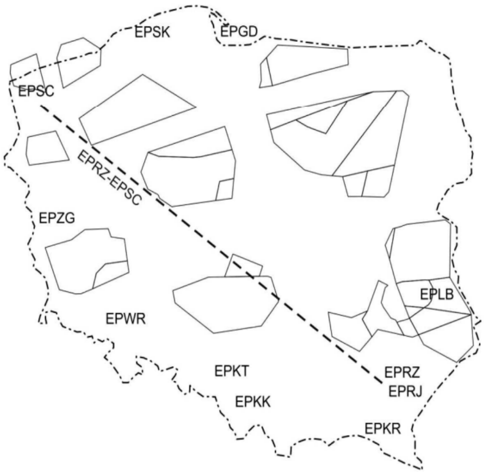


Fig. 4. Model of airspace with active military zones
*Source: A. Majka, Weryfikacja i walidacja..., p. 170.*

Military zones were assumed to be the areas inaccessible to civilian air operations, thus they had to be avoided (Fig. 5). Zones adjacent to each other were considered to be one area. These areas were then described with a convex figure in order to minimize the number of node points and optimally shorten the flight path (Fig. 6). A buffer with a radius of 5 NM was imposed along the boundaries of the zones. The buffer was imposed for safety reasons. Guiding and planning a flight trajectory that violates the buffer was assumed to be illegal.

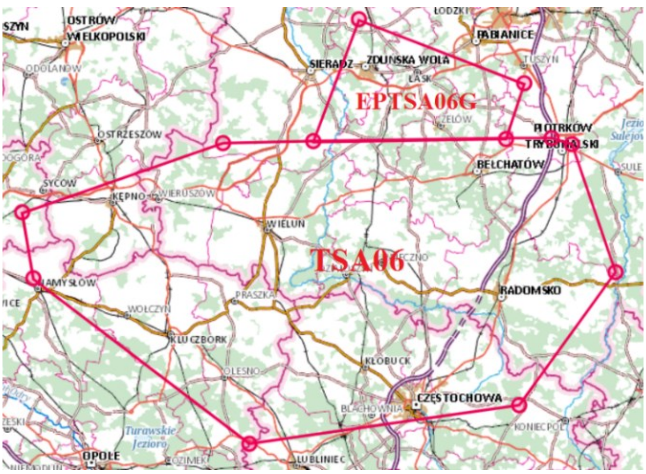


Fig. 5. Active military zones TSA06 and EPTSA06G
*Source: own work.*

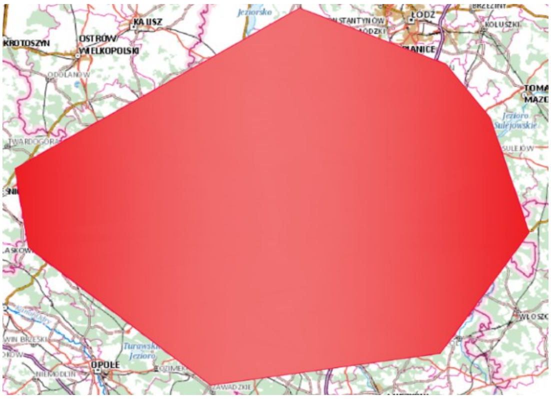


Fig. 6. Prohibited zone for civilian flights, described by new node points
*Source: own work.*

The result of the study is an airspace model described by a set of points representing the vertices of the graph, which are the boundary points of zones inaccessible to civil air operations at a given time (Fig. 7). The vertex points were described by geographic coordinates and constitute navigation points (WayPoint – WP) for flight planning. The aircraft trajectory in the adopted airspace model will be a broken line, described by the graph's node points.


Fig. 7. Resulting airspace model (prohibited zones – red color)
*Source: own work.*

The developed airspace model was used to find the optimal aircraft route, taking into account flight time and distance. The extreme route was called the route directly connecting the Top of Climb (TOC) and the Top of Descent (TOD) points, not taking into account forbidden zones. The search for the optimal route deviated as little as possible from the ideal route in such a way as not to violate the buffers of zones not available for planning. The vertices of forbidden zones, described by geographic coordinates, were taken as the optimal points of the route. The determined optimal route was compared with the route determined in the V2 validation of the SESAR 2020 PJ06 ToBeFREE project (Fig. 8). The results of the calculations are shown in Table 1.

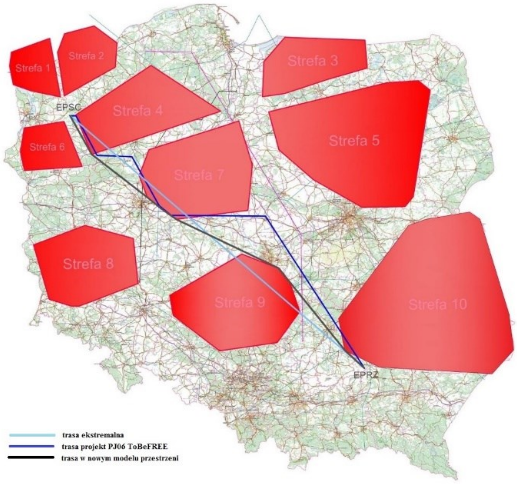


Fig. 8. The new space model and the determined optimal route Rzeszow (EPRZ) – Szczecin (EPSC), following node points of the graph

*Source: own work.*

Table 1. Covered flight distances for the routes planned in the two models

| EPRZ–EPSC | Route length [km] |
|---|---|
| PJ06 | 584,33 |
| New model | 534,75 |

*Source: own work.*

## 6. Validation of test results using a flight simulator

In order to verify and validate the feasibility of a flight along the route that was determined in the model, a simulated flight was carried out, assuming the appropriate aircraft type and flight parameters. For the validation work, the Alsim AL200 MCC flight simulator (Fig. 9) was used, courtesy of the Department of Avionics and Control at Rzeszow University of Technology.

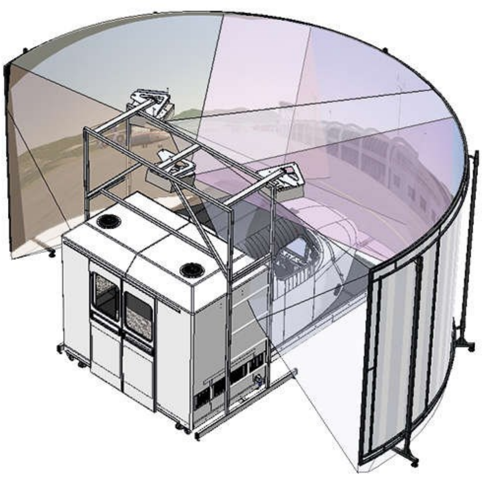

Fig. 9. Schematic of the Alsim AL200 MCC simulator

*Source: https://www.alsim.com/simulators/alx-fnpt-ii-mcc-mpl-flight-training-device/ [access: 14.06.2023].*

The aircraft model adopted in the simulation was a Beechcraft King Air B200[18]. In order to compare, the two flight paths were entered into the on-board computer and flight simulation was carried out using the autopilot. The obtained simulation results are shown in Table 2.

Table 2. Times and distances traveled during the simulated flight

| | EPRZ–EPSC (optimal route) | EPRZ–EPSC (limited FRA) |
|---|---|---|
| **Route length [NM]** | 287,50 | 316,50 |
| **Route length [km]** | 532,45 | 586,16 |
| **Time [min]** | 77 | 87 |

*Source: own work.*

The results obtained from the simulated flights (Table 2) show high consistency in the calculations (Table 1). The collected data confirm that the route planned in the model is feasible under conditions similar to a real flight. The distance and thus the flight time have been shortened compared to the space model from the PJ06 ToBeFREE project.

On the basis of the data from the flight simulator, fuel consumption was calculated (Fig. 10), assuming the price of JET A-1 fuel equal to 3430 PLN/m3[19], after conversion of 4.32 PLN/kg[20]. The reduction in fuel costs compared to the route determined during the validation of the PJ06 ToBeFREE project was PLN 232.10 one way.

An analysis of the environmental impact of the designated routes was also carried out. The calculations assumed the use of JET A-1 aviation kerosene, which has a density of 0.8 kg/l. Assuming that burning one kilogram of kerosene results in the emission of 3.16 kilograms of CO2, carbon footprint of the validated flights was calculated. The amount of carbon dioxide emitted by aircraft engines during the simulated flights is shown in Table 3 The study showed a 7% reduction in $CO_2$ emissions (Fig. 11), which clearly demonstrates that the developed airspace model contributes significantly to reducing the negative environmental impact of air transport.

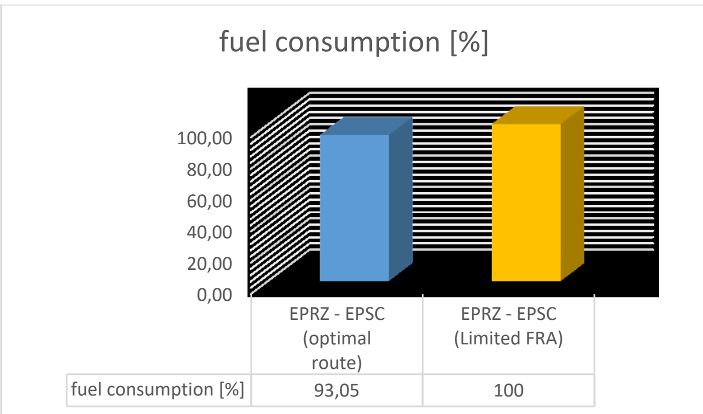


Fig. 10. Comparison of fuel consumption of two validated air routes

*Source: own work.*

[18] https://www.flyingmag.com/aircraft/turboprops/beechcraft-king-air-200-transformation [access: 14.06.2023].
[19] Orlen, *Hurtowe ceny paliw*, https://www.orlen.pl/pl/dla-biznesu/hurtowe-ceny-paliw#jet-a-1 [access: 14.06.2023].
[20] http://2008.raportroczny.lotos.pl/pdf/dane_tabela.pdf [access: 14.06.2023].

Table 3. Total amount of $CO_2$ emitted during the simulated flight

| | EPRZ–EPSC (optimal route) | EPRZ–EPSC (PJ06) |
|---|---|---|
| **$CO_2$ emission [kg]** | 1775,92 | 1908,64 |

*Source: own work.*

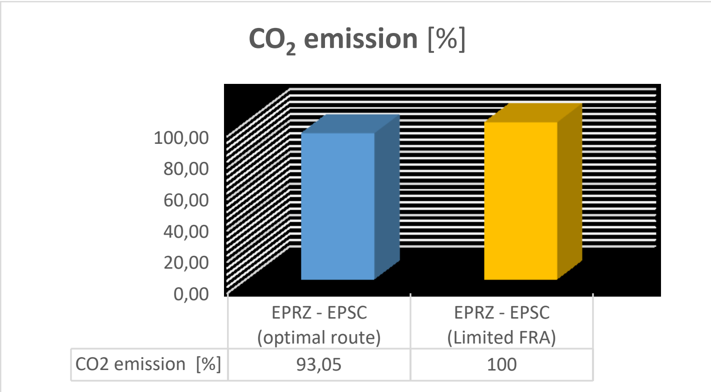


Fig. 11. Comparison of $CO_2$ emissions during validation of air routes
*Source: own work.*

The results of the study clearly indicate that the research hypotheses have been confirmed. The adopted airspace model allows to achieve the goals of shortening the distance and flight time of aircraft, reducing fuel consumption and reducing the negative impact of air transport on the environment. In addition, it should be noted that shorter distance of air routes translates into a reduction in aircraft operation, and thus a reduction in maintenance frequency. This leads to a reduction in costs for air carriers, and may even lead to higher earnings given the ability to use reduced fuel demand for the ability to transport a larger load. Reduced travel time will also have a positive impact on customer satisfaction.

## 7. Summary

Due to the continued growth of the world's population and technological advances, work and research projects on increasing airspace capacity is an extremely important topic. The solution to the problems of increasing traffic in the aviation sector may be modern flight planning systems in the FRA airspace. These systems require the development of an airspace model that takes into account the complexity of this space and the activity of dangerous and prohibited zones for civil operations at any given time.

The developed airspace model, which is a graph, assumes the use of navigational coordinates of the vertices of forbidden zones as node points. These zones, which are areas inaccessible for planning, are described as convex polygons, including a safety buffer. The research clearly shows that the routes planned in the new space model are shorter in terms of distance and travel time compared to other graph models. The calculations also showed a reduction in carbon dioxide emissions, which have a negative impact on the environment. A comparative analysis of the data from simulator sessions proved the correctness of the proposed airspace model, demonstrating an improvement in the efficiency of the air routes planned as part of the SESAR 2020 project validation. The collected data confirms that the route planned in the model is feasible under conditions similar to a real flight.

A solution that takes into account a different distribution of the node points of the airspace modeling graph opens the door for further research. This is yet another step in order to succeed in an efficient system for planning air operations. Research on the model will, in all likelihood, bring us closer to achieving a satisfactory level of air traffic management that will comprehensively solve the problems of airspace capacity and the negative impact of the aviation sector on the environment, as well as provide its users with the highest level of flight safety.

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