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Education in Traffic and Transport
Original Scientific Paper
Submitted: 2 May 2022
Accepted: 8 July 2022

FLIGHT TRAINING SYLLABUS STRUCTURE IMPACT ON PROACTIVE PLANNING OF HIGH-PERFORMANCE MILITARY AIRCRAFT PILOT TRAINING OPERATIONS IN FLEXIBLE AIRSPACE STRUCTURES

ABSTRACT

European airspace is marked by fragmentation, and from fragmentation originated congestion. As an answer to congestion, flexible use of airspace is created to fulfil all users' requirements optimally, and at its very core lies civil-military cooperation and the coordination of airspace use. Such an approach is enabled by collaborative decision-making, which presumes timely and complete exchange of complete relevant information between airspace users. To participate in the process, the military should be transparent regarding its restrictions and capabilities of adaptation to other airspace users' demands. Flight training syllabus structure and its specific impact on proactive planning of high-performance military aircraft pilot training operations in flexible airspace structures is the subject of this research. Significant diversity in the hourly distribution of civil traffic demand in flexible airspace structures in Zagreb FIR proves them applicable for a proactive approach to high-performance aircraft pilot training operations planning and management. Noticeable reduction in the number of civil aircraft affected by high-performance aircraft pilot training operations in flexible airspace structures at congested flight levels is corroborated. Simulations of proactive planning of high-performance aircraft pilot training operations reveal indications of flight syllabus structure's impact on pilot flight training duration, as well as the possibility to manage its restrictions.

KEYWORDS

flexible airspace structure; flight training syllabus; high performance military airplanes; proactive planning.

1. INTRODUCTION

European airspace congestion and air traffic service inefficiency rests on fragmentation caused by national service providers identified with national airspace borders. The fragmentation of European airspace creates non-optimal functioning of European service providers compared to the similar-sized but non-fragmented US airspace [1]. There are military airspace structures in European airspace in greater number and size compared to USA airspace. Most of these are positioned in the central part of European airspace [2]. Further airspace capacity increase is not likely to be achieved by continuation of airspace compartmentalisation. Fragmentation is not expected to cease until the creation of the integrated European defence system [3].

National airspace management is the reality and necessity of national sovereignty protection. Restricted predictability of traffic demand is supported by military airspace reservations non-harmonised with civil users and void of information exchange and interoperability. Flexible use of airspace enables improvement of air traffic management and airspace management despite airspace fragmentation. The need for a collaborative civil-military approach to capacity and best practices adjustment has been indicated to reduce national airspace borders' limiting influence on network capacity [4, 5].

Flexible use of airspace tends to fulfil all users' requirements optimally by establishing coordination of airspace use planning process, rules and procedures of civil-military cooperation. A prerequisite for collaborative decision-making is timely and complete exchange between airspace users concerned with respect to complete targeted information regarding all relevant air traffic [6, 7]. Airspace users' coordination performed daily as a minimum implies after-action analysis to clarify the effectiveness of the process itself and the feedback regarding participants' performance in a process.

Degradation of the sovereignty of member states over their airspace or degradation of military forces' readiness is not an option, even though certain additional expenses could arise, as well as the military component's loss of influence. On the other hand, there are underused available resources and presumed legal implications in case of accidents involving civilian and military participants. Therefore, civil-military cooperation does not derogate from the responsibility of states for national defence and supports the protection of military operations and training [8–10].

There are three levels of airspace management: strategic (Level 1), pre-tactical (Level 2) and tactical (Level 3). The strategic level plans and recommends flexible airspace structures, their rules of priority and coordinates civil and military operational requirements without privilege. The pre-tactical level operates through a joint civil-military airspace management cell embedded in the designated service provider. The tactical level implies real-time cooperation of civilian and military sectors regarding activation, deactivation and re-allocation of airspace structures executed throughout the airspace management cell [11, 12].

Flexible airspace structures can be restructured depending on their dimensions, and civil traffic can be performed through them. Restructuring follows the idea that a part of airspace with less traffic demand is to be used for military operations. The dimensions and location of the airspace have to fulfil military users' operational requirements. Modular approach to the flexible use of airspace structures presumes its vertical and horizontal structuring based on smaller components that can be activated in accordance with military users' requirements and civil traffic demands. Vertical adjustment of operational spans of altitudes or flight levels can be applied in accordance with military aircraft mission requirements. Timing of military operations could be adjusted so as not to affect daily peaks of civil traffic demand in targeted flexible airspace structures. Every flexible airspace structure is defined by peculiar dimensions and position related to airways and airports in a specific civil traffic demand. Airspace structure is another feature that influences the possibility of flexible use of airspace, as intervention in one sector can significantly influence not only its operations but the neighbouring sectors as well [13].

Military flight training planning is a part of military flight management procedures performed in such manner that provides a targeted capability level of both personnel and the unit. Flight training planning manages material and resources as well as manpower over a definite planning period. Availability and adequate capacity of air traffic services, flight intercept guidance and adequate training areas are mandatory for flight training planning under flight training syllabus requirements [14, 15].

Flight training syllabus impacts military flight training planning in a manner divergent from other military flight training process components. Availability of flight crews, aircraft and airspace structures defines the feasibility and extent of training operations. Flight crews' impact is shaped by the total number of pilots, individual pilots' level of experience and targeted level of training. Aircraft availability for planning is defined by the number of operating hours as well as the number of aircraft over a defined period [16, 17]. Maintenance, both preventive and corrective, requires aircraft unavailability for flight tasks over a certain period. Maintenance operations can be arranged in such manner as to enable either an increased or reduced rate of resource consumption [16, 18]. Flight training syllabus sets operating criteria for flight training planning regarding aircraft and manning requirements, as well as airspace management. Flight training syllabus places the sequence of all flights in a flow diagram that can be either without branching or a branching one [16, 19].

This paper discusses flight training syllabus structure and the impact it creates on the planning of high-performance military aircraft pilot training operations in flexible airspace structures. The planning process is performed proactively in a collaborative manner to reduce the degradation of civil traffic volume in a flexible airspace structure.

2. METHODOLOGY

The flight training syllabus prescribes for each exercise of high-performance aircraft pilot training the following parameters: exercise designation; exercise flight time; number and type of aircraft in formation; role in formation; previously accomplished exercise; airspace required; altitude or flight level required; and day or night flying. A flow diagram of the original flight training syllabus used for this research [20] is shown in *Figure 1*. A generic flight training syllabus preview is shown in *Table 1*.

Based on the original flight training syllabus, single-path flight training syllabus, two-path flight training syllabus and segregated flight training syllabus have been developed for the purposes of this research.

There are two types of markings in the diagram shown in *Figure 1*. White rectangles describe day flying exercises, and black rectangles represent night flying exercises. The data regarding previously accomplished exercise(s) from *Table 1* match the connecting lines between exercises in *Figure 1*. There are exercises that are prerequisite for more than one following exercise. Respectively, there are more than one exercise with the same previously accomplished exercise as prerequisite. That creates the branching of the syllabus flow diagram.

To enable fluent planning and management of flight training in the unit, all students are guided by the same pathway through the syllabus. Thus, the flow diagram of the original flight training syllabus

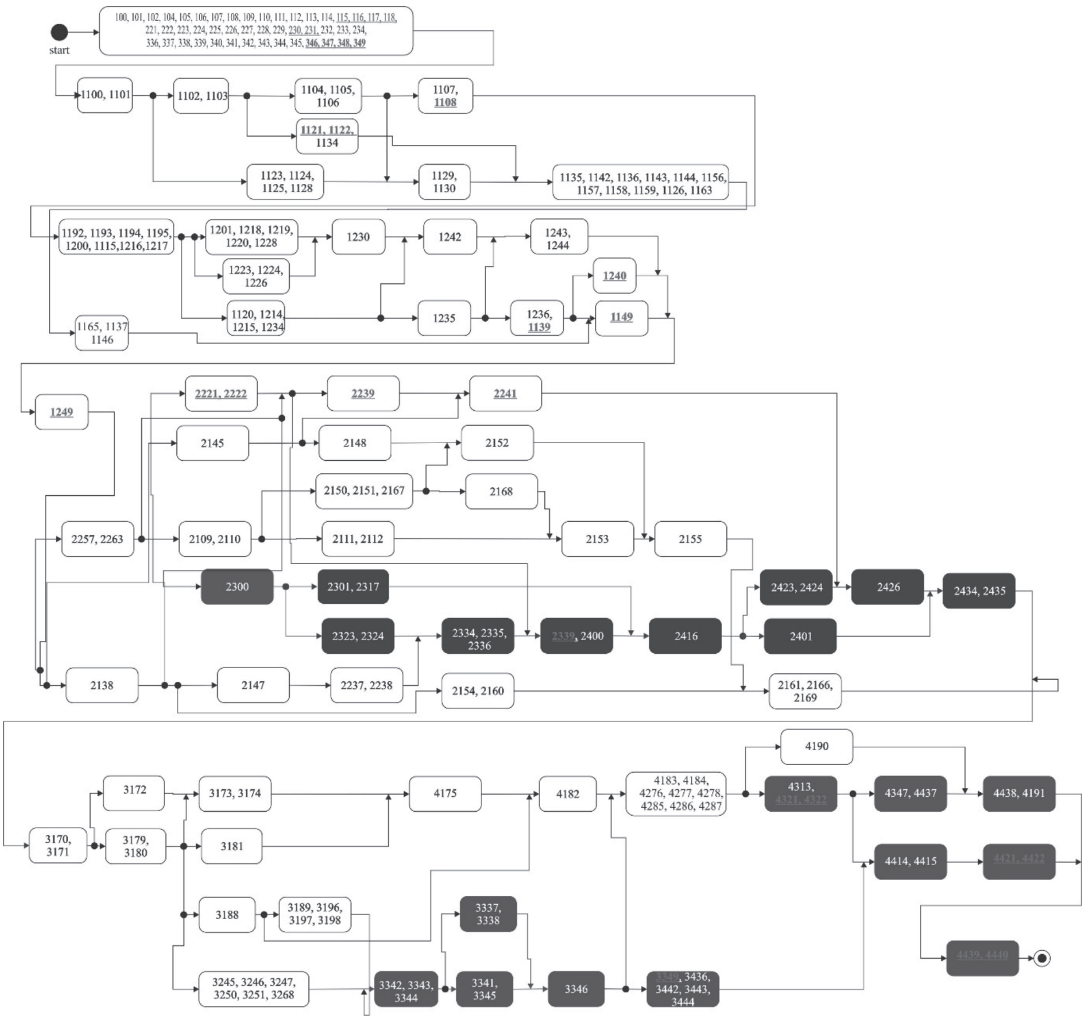

Figure 1 – Flow diagram of original flight training syllabus

Table 1 – Preview of generic flight training syllabus

Designation	Flight time	Number and type of aircraft	Role in formation	Previously accomplished exercise(s)	Airspace required	Altitude/FL	Day/ night
1143	55 min	2 single seaters + 2 double seaters	flight lead	1139	Zone	FL300–450	Day
1146	45 min	2 single seaters + 2 double seaters	second wingman	1142, 1143	Zone	FL300–450	Day
1149	55 min	2 single seaters	wingman	1146	Route	FL060–300	Day

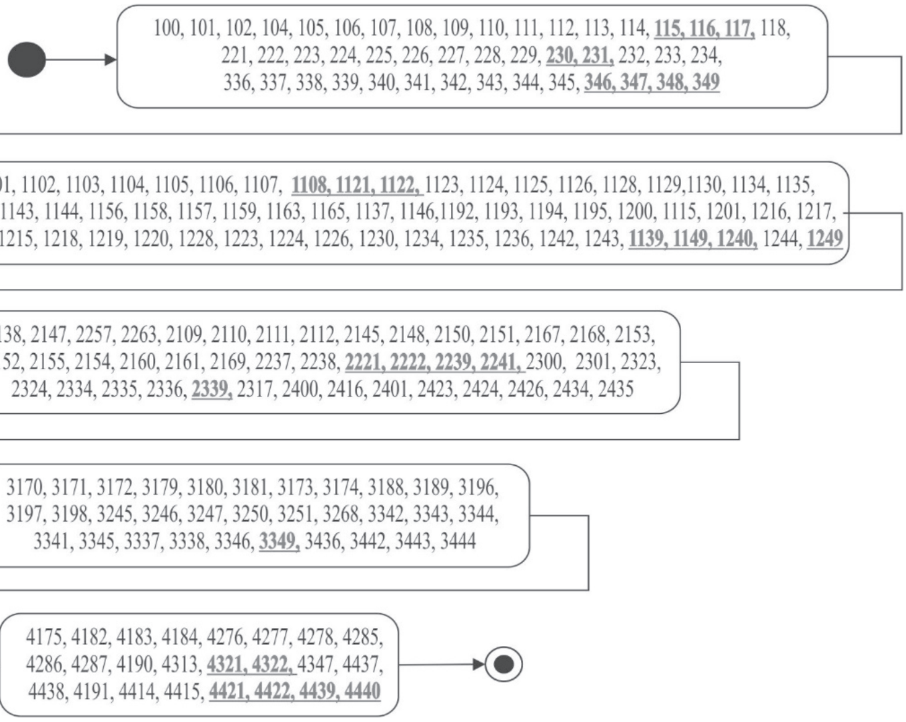

Figure 2 – Flow diagram of single-path flight training syllabus

shown in *Figure 1* transforms into the single-path flow diagram of the flight training syllabus shown in *Figure 2*.

For all flight training syllabus flow diagrams (*Figures 1–4*), exercises flown in flexible airspace structures at FL300-FL450 are bolded and underlined.

The flow diagram of a two-path flight training syllabus organised to enable parallel performance of different exercises by different students at the same time on two parallel branches is shown in *Figure 3*. The diagram shown in *Figure 3* respects the previously accomplished exercise(s) requirement(s) of the original flight training syllabus.

To enable the research of flight training syllabus structure's influence on the planning process, a segregated flight training syllabus was created. That syllabus respects all other characteristics except the previously accomplished exercise(s) requirement(s) of the original flight training syllabus. Only the initial part of flight training remains one-path structured. The flow diagram of the segregated flight training syllabus is shown in *Figure 4*.

Flexible airspace structures LDTR1, LDTR2, LDTR3 and LDTR4 at the eastern part of Zagreb FIR have been considered for this research. These structures are used for high performance aircraft pilot training. The volumes and altitudes or flight levels are specific for each flight, as prescribed in the flight training syllabus. The impact of all four LDTRs activated on civil air traffic during a one-hour period (7.8.2019, 10-11 UTC) at FL300-FL450 is shown in *Figure 5*.

Civil air traffic in the same airspace during the same period without LDTR activation is shown in *Figure 6*. There is a noticeable divergence of civil

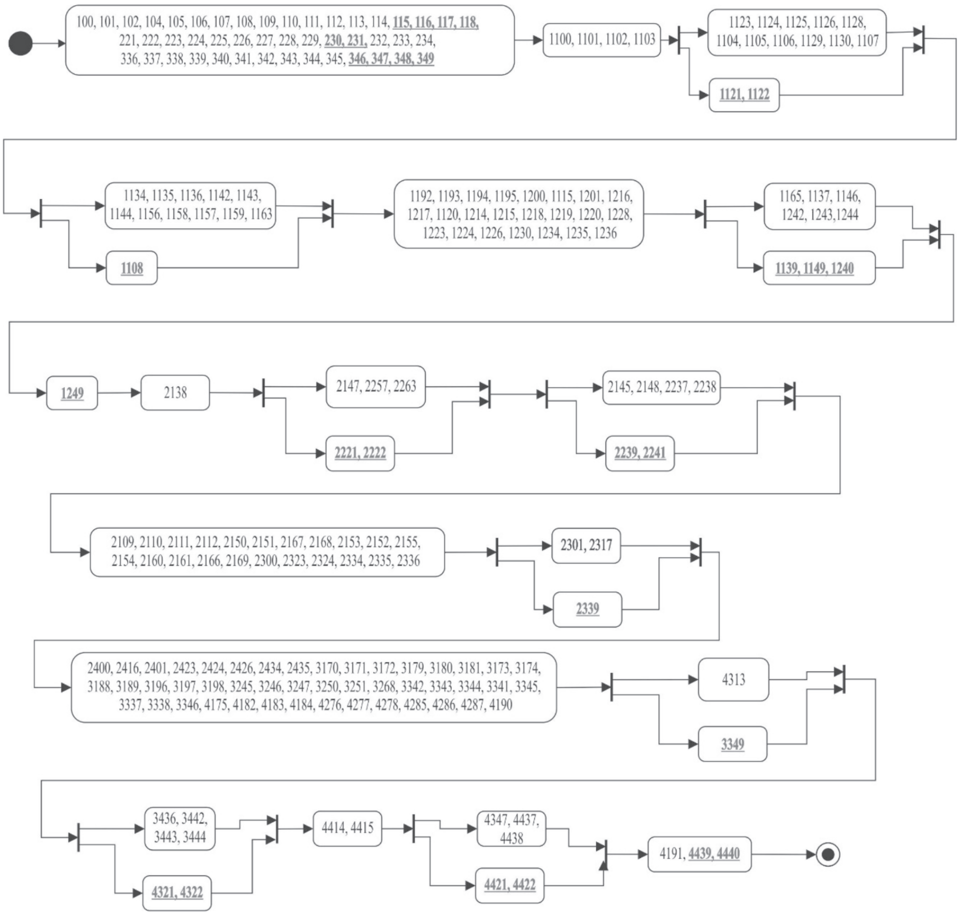

Figure 3 – Flow diagram of double-path flight training syllabus

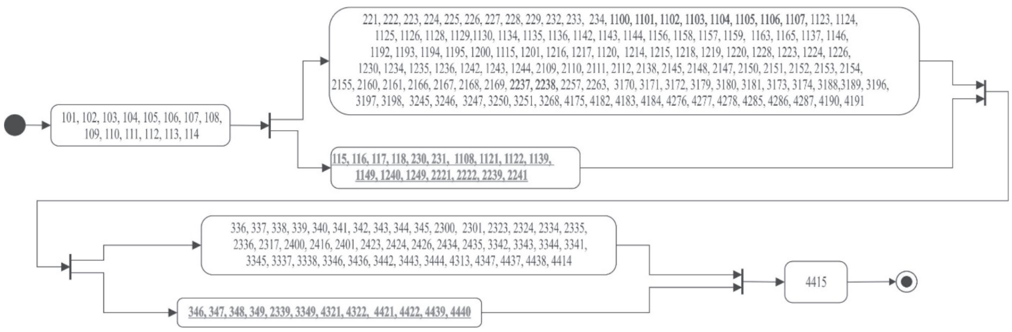

Figure 4 – Flow diagram of segregated flight training syllabus

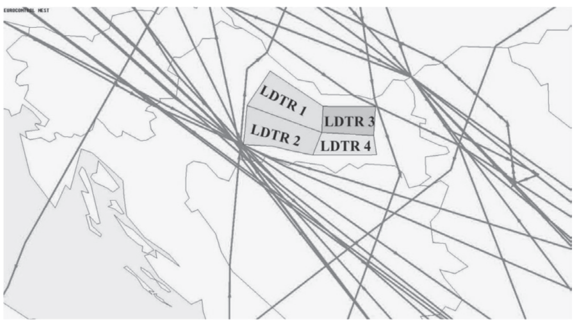

Figure 5 – Civil air traffic trajectories in case of LDTR1-4 activated at FL300-FL450

Figure 6 – Civil air traffic trajectories in case of LDTR1-4 not activated

flights not only outside these flexible airspace structures but outside Zagreb FIR as well (Zagreb FIR boundaries are collocated with Croatian borders).

Civil flights through these flexible airspace structures are distributed during the day. Military high-performance aircraft flights are performed during the day in slots. Depending on exercise flown, flight time duration and the turn-around time between two successive slots, there can be two or three slots in one day. Each slot can be shifted earlier or later for a certain period, provided the total operational flight time is not breached. The timing and the possibility of shifting the flights are shown in *Figure 7*.

Actual flight time measured from take-off to landing is defined in the syllabus for each of the exercises. To provide safe separation of civil traffic from military aircraft, the flexible airspace structures used have to be cleared some time before military aircraft entry time. Similarly, once the military aircraft use of the flexible airspace structures is over, it takes some time before normal civil traffic is established inside these structures. Additional to these times, there is safety buffer time. For this research, the periods of use of the flexible airspace structures are defined as one-hour periods in three intervals for daytime flying and three intervals for night-time flying. The periods of use of flexible airspace structures, three for day and three for night during the year selected for this research, are shown in *Table 2*. Local adjustments of flight times are excluded from this research.

For the periods of use of flexible airspace structures shown in *Table 2*, research of civil traffic demand on complete European air traffic network is performed by using the NEST program. The simulation defined the shortest routes depending on data regarding actual traffic demand for 2017, 2018 and 2019 and revealed the number of civil aircraft affected by flexible airspace structures LDTR1-4 at FL300-FL450.

Research data was used to prioritise periods of use of flexible airspace structures. The one with the lowest number of civil aircraft is defined as usable for military activation of flexible airspace structures in daytime, while for the other two daytime peri-

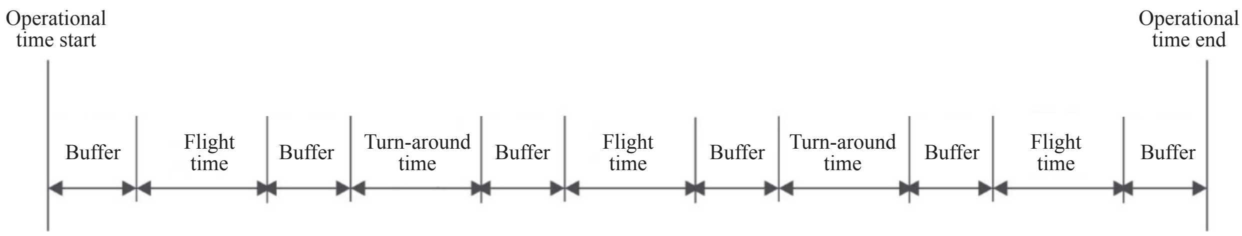

Figure 7 – Flight timing and adjustment during a daily operational time

Table 2 – Periods of use of flexible airspace structures (UTC)

	Day 1		Day 2		Day 3		Night 1		Night 2		Night 3	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Jan	08.45	09.45	10.30	11.30	12.15	13.15	16.15	17.15	18.00	19.00	19.45	20.45
Feb	08.45	09.45	10.30	11.30	12.15	13.15	16.55	17.55	18.40	19.40	20.25	21.25
Mar	08.45	09.45	10.30	11.30	12.15	13.15	17.40	18.40	19.25	20.25	21.10	22.10
Apr	07.45	08.45	09.30	10.30	11.15	12.15	18.15	19.15	20.00	21.00	21.45	22.45
May	07.45	08.45	09.30	10.30	11.15	12.15	18.55	19.55	20.40	21.40	22.25	23.25
Jun	07.45	08.45	09.30	10.30	11.15	12.15	19.05	20.05	20.50	21.50	22.35	23.35
Jul	07.45	08.45	09.30	10.30	11.15	12.15	19.05	20.05	20.50	21.50	22.35	23.35
Aug	07.45	08.45	09.30	10.30	11.15	12.15	18.40	19.40	20.25	21.25	21.10	22.10
Sep	07.45	08.45	09.30	10.30	11.15	12.15	17.40	18.40	19.25	20.25	21.10	22.10
Oct	07.45	08.45	09.30	10.30	11.15	12.15	16.40	17.40	18.25	19.25	20.10	21.10
Nov	08.45	09.45	10.30	11.30	12.15	13.15	16.00	17.00	17.45	18.45	19.30	20.30
Dec	08.45	09.45	10.30	11.30	12.15	13.15	15.35	16.35	17.20	18.20	19.05	20.05

ods flexible airspace structures were unavailable for planning. This provided for a minimised impact of military high performance aircraft use of flexible airspace structures.

To examine exclusively the impact of flight training syllabus structure on proactive planning of high-performance military aircraft pilot training operations in flexible airspace structures, the following restrictions were introduced:

- Three student pilots with one flight per day are allowed,
- Nine instructor pilots and six pilots; no restrictions regarding flights per day,
- Six single-seater and three two-seater aircraft available for three flights per day each.

The first set of simulations was performed with flexible airspace structures available without restrictions. The second set of simulations was performed with flexible airspace structures available only in the period with minimum civil traffic demand on that day. The planning was done one day in advance, as there was no reliable prediction tool for longer periods.

3. RESULTS AND DISCUSSION

The analysis of civil traffic in LDTR1, LDTR2, LDTR3 and LDTR4 during 2017, 2018 and 2019 was performed for two sets of flight levels: FL060-FL300 and FL300-FL450, in accordance with the periods of use of flexible airspace structures shown in *Table 2*. The average number of civil aircraft affected by activation of flexible airspace structures comprising LDTR1, LDTR2, LDTR3 and LDTR4 for military high performance aircraft pilot training operations varies depending on time of day and operational flight levels reserved.

The average number of civil aircraft in LDTR1, LDTR2, LDTR3 and LDTR4 for periods of use of flexible airspace structures, daytime and night-time flying for FL300-FL450 during 2017, 2018 and 2019, is shown in *Table 3*.

The average number of civil aircraft in LDTR1, LDTR2, LDTR3 and LDTR4 for periods of use of flexible airspace structures, daytime and night-time flying for FL060-FL300 during 2017, 2018 and 2019, is shown in *Table 4*. The values obtained range between 1 and 3.1. These values are comparable and equalled by the number of military aircraft using these flexible structures. Therefore, there is no indication for further research of the influence of military reservations of these structures at these flight levels.

The original flight training syllabus as well its modified two-path, single-path and segregated versions contain identical total number of exercises as well as the relative share of exercises (9%) flown at FL300-FL450 in LDTR1, LDTR2, LDTR3 and LDTR4. The average number of civil aircraft in LDTR1, LDTR2, LDTR3 and LDTR4 for FL300-FL450 during 2017, 2018 and 2019 for periods of use of flexible airspace structures during daytime is 24–34 aircraft. The average numbers of civil aircraft in these structures at the same flight levels during the same periods for night-time flying are 12–24 aircraft. These values are multiple times greater than the number of military aircraft using these flexible structures. Therefore, further examination of the results of the influence of military reservations of these structures at these flight levels was performed.

The relative share of civil traffic for daytime flying operations performed in LDTR1, LDTR2, LDTR3 and LDTR4 at FL300-FL450 is shown in *Figure 8*. Periods of use of flexible airspace structures with minimal and maximal number of civil aircraft affected are presented. The average minimal value is 25.59%, the average median value is 33.63%, and the average maximal value is 40.78% of total traffic in all three periods. Successively, due to proactive planning interval with minimal value of civil traffic, there would be a reduction of impact on civil traffic of 8.4% or 15.29%.

The relative share of civil traffic for night-time flying operations performed in LDTR1, LDTR2, LDTR3 and LDTR4 at FL300-FL450 is shown in *Figure 9*. Periods of use of flexible airspace structures with minimal and maximal number of civil aircraft affected are presented. There is the average minimal value 21.21%, average median value 33.38% and average maximal value of 45.41% of total traffic in all three period. Successively, due to proactive planning interval with minimal value of civil traffic, there would be reduction of impact on civil traffic of 12.7% or 24.2%.

Table 3 – Average civil traffic at FL300-FL450

D1	D2	D3	N1	N2	N3
24	34	33	24	19	12

Table 4 – Average civil traffic at FL060-FL300

D1	D2	D3	N1	N2	N3
3.1	1	1	2.2	2	1

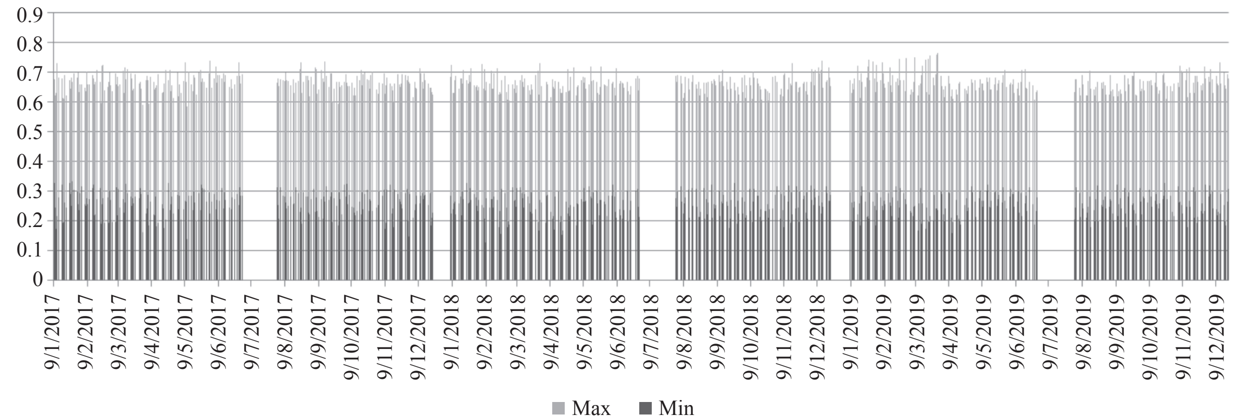

Figure 8 – Relative share of civil traffic in LDTR1-4 at FL300-FL450 for periods of use of flexible airspace structures with minimal and maximal number of flights, daytime flying, 2017, 2018 and 2019

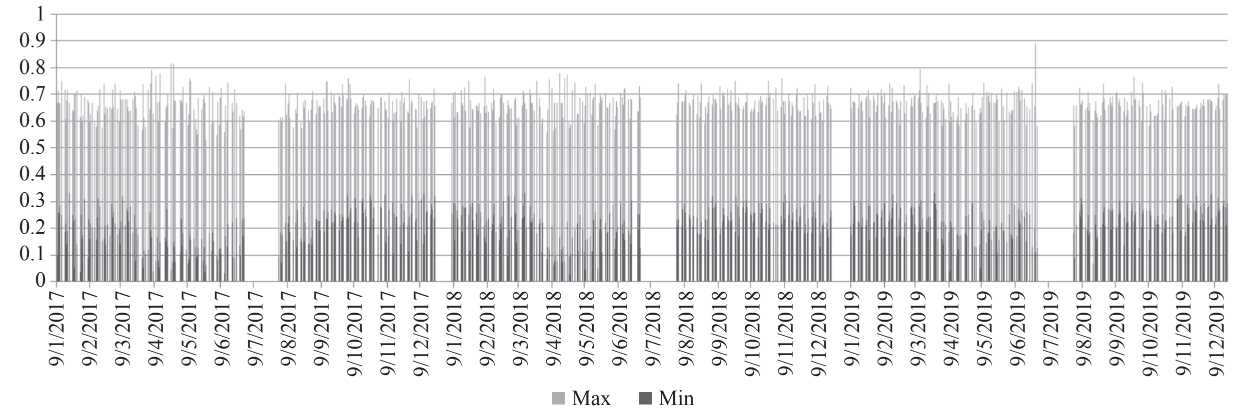

Figure 9 – Relative share of civil traffic in LDTR1-4 at FL300-FL450 for periods of use of flexible airspace structures with minimal and maximal number of flights, night-time flying, 2017, 2018 and 2019

One set of training simulations was performed under the conditions prescribed by four different versions of the flight training syllabus. The original one's number of exercises and the number of exercises flown in flexible airspace structures in LDTR1, LDTR2, LDTR3 and LDTR4 remained the same in two-path, single-path and segregated syllabuses. The path to be followed by student pilots throughout the complete training duration varies under the syllabus flow diagrams shown in *Figures 1–4*. There were no restrictions regarding flexible airspace structures use.

Another set of simulations was performed under the same conditions as the first one, adding the proactive planning restriction on flexible airspace structures. These structures are to be used only in periods with the minimal daily number of civil aircraft affected.

The duration of each simulation is shown in *Table 5*. The duration for the original, two-path, single-path and segregated syllabuses is the same – 459 days. Duration measured in days coincides with the total number of exercises in the syllabus. There is no stagnation and accumulation of delays in student pilots' progress.

Unlike the first four simulations set, there is a noticeable delay created in all four proactive simulations. All the syllabuses, the original, two-path, single-path and segregated one, created longer duration of total pilot training. Relative values show

Table 5 – Duration of complete training for original, two-path, single-path and segregated syllabus

Original, two-path, single-path and segregated syllabus	Single-path syllabus proactive planning	Original syllabus proactive planning	Two-path syllabus proactive planning	Segregated syllabus proactive planning
459 days	529 days	515 days	507 days	475 days

Table 6 – Relative increase of duration of complete training for proactive planning for original, two-path, single-path and segregated syllabus

Single-path syllabus proactive planning	Original syllabus proactive planning	Two-path syllabus proactive planning	Segregated syllabus proactive planning
15 %	12 %	11 %	4 %

an increase from 15% in the case of the single-path syllabus to 4% in the case of the segregated syllabus. The relative increase in the duration of complete training for proactive planning for original, two-path, single-path and segregated syllabuses is shown in *Table 6*.

Analysing the simulation results reveals the cause of the delays created in the proactive planning simulations. Everywhere there is a sequence of exercises that presume using flexible airspace structures at FL300-FL450, and only one student pilot can perform only one flight in one day. Others have to wait their turn and the other two intervals are unused. Further use of all three slots available per day is enabled once all the exercises that presume using flexible airspace structures are flown and exercises that follow do not presume using flexible airspace structures. The problem arises again when another sequence of exercises that presume using flexible airspace structures is reached.

Intervening in syllabus structure to create alternate paths enables parallel performance of exercises that presume the use of flexible airspace structures and exercises that do not. The two-path flow diagram created in accordance with the syllabus structure brings a reduction in total flight training duration. The segregated flow diagram created as an alteration of the syllabus structure for the research purpose enables the greatest reduction in total flight training duration.

Ideally, a syllabus that enables constant parallel performance of one exercise in flexible airspace structures at FL300-FL450 per day along with two other exercises continuously throughout the duration of flight training would create no delays in training. Notably, the research was performed on certain numbers of pilots with fixed availability of aircraft as well as flight instructors and pilots.

4. CONCLUSION

The structure of civil traffic demand in specific flexible airspace structures in Zagreb FIR proves the applicability of proactive approach to high-performance aircraft pilot training operations planning and management. There is a significant diversity in the hourly distribution of civil traffic that corroborates the possibility of noticeable reduction of the number of civil aircraft affected by high-performance aircraft pilot training operations in flexible airspace structures at congested flight levels.

The sample high-performance aircraft flight training syllabus was elaborated and adjusted to enable more agile planning, creating the graded versions of the original syllabus available for research and simulations. Simulations of proactive planning of high-performance aircraft pilot training operations produce results that indicate the direct impact of syllabus structure on pilot flight training duration, as well as the possibility to manage its restrictions.

In order to master collaborative proactive planning of high-performance aircraft pilot training operations, further research should clarify other operational tools and techniques that might reduce the prolongation of total training time. Among these, the prediction of civil traffic demand has significant importance.

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UTJECAJ PROGRAMA LETAČKE OBUKE NA PROAKTIVNO PLANIRANJE OBUČNIH OPERACIJA ZRAKOPLOVA VISOKIH PERFORMANSA U FLEKSIBILNIM STRUKTURAMA ZRAČNOGA PROSTORA

SAŽETAK

Europski zračni prostor obilježen je fragmentiranošću i iz nje proisteklim zagušenjem. Odgovor na zagušenje, fleksibilna uporaba zračnoga prostora kreirana je u cilju optimalnog ispunjenja zahtjeva svih korisnika i u njenoj samoj srži počiva civilno-vojna suradnja i uskladba uporabe zračnog prostora. Omogućavatelj takvog pristupa

- kolaborativno odlučivanje, pretpostavlja pravovremenu i cjelovitu razmjenu cjelokupnih relevantnih informacija između korisnika zračnog prostora. U cilju sudjelovanja u procesu vojni korisnici trebaju transparentno prikazati ograničenja i mogućnost prilagodbe zahtjevima ostalih korisnika zračnog prostora. Predmet istraživanja ovog rada je struktura programa letačke obuke i specifični utjecaj na proaktivno planiranje operacija obuke pilota vojnih aviona visokih performansa u fleksibilnim strukturama zračnoga prostora. Značajna raspodjela prometne potražnje civilnog zračnog prometa u fleksibilnim strukturama u FIR Zagreb čini ih primjenjivim za proaktivni pristup planiranju i upravljanju operacijama obuke pilota vojnih aviona visokih performansa. Potvrđuje se zamjetljivo smanjenje broja civilnih aviona na koje utječu operacije obuke pilota vojnih aviona visokih performansa u fleksibilnim strukturama zračnoga prostora. Simulacije proaktivnog planiranja operacija obuke pilota vojnih aviona visokih performansa otkriva indikacije utjecaja strukture programa letačke obuke na trajanje obuke kao i mogućnost upravljanja njegovim ograničenjima.

KLJUČNE RIJEČI

fleksibilna struktura zračnoga prostora; program letačke obuke; vojni avioni visokih performansa; proaktivno planiranje.

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