1. Introduction

Air transport significantly contributes to the world economy development. Therefore, it is very important to sustain its further resilience, ensure effective, ecological activities and mainly ensure its safety.

In 2015, more than 3.5 billion passengers used scheduled air transport. When compared with 2014, the growth was 6.4%. The number of flights worldwide reached 34 million.

Based on the air traffic development the ICAO identified the Performance Based Navigation (PBN) as the main global priority. The ICAO concentrated as well on the PBN implementation at international airports during Continuous Descent Operations and Continuous Climb Operations. The SESAR AMAN and DMAN concepts, Free RouteAirspace and growing air traffic require delineation of new routes.

All the above facts lead to the need of research of conflicts at route intersections in order to prevent them. The mathematical model presented in the paper “A number of conflicts at route intersections - a rectangular model” enables comparing different alternatives of intersection configuration of air traffic services routes. The comparison is based on the results: average number of potential conflicts per hour at route intersections, index of conflict intensity, and intersection capacity. The results are intended to help choose the safest intersection configuration of routes.

The consequences of a particular conflicts depend on the design of item and the equipment in which it is install. Although the impairment in which the equipment is operated is sometimes an additional factor conflict consequences are primary inherent characteristic.

A conflict is an infringement of minimum separation between at least two aircraft. Air traffic controllers build a protected area in front of an aircraft; its shapes and dimensions depend on the speed of an aircraft and on the minimum separation. The protected zone in this mathematical model is the horizontal rectangular zone. If an aircraft is inside this protected zone, a conflict occurs. The model is based on these assumptions: aircraft fly in level straight line routes; only an infringement of the lateral separation is considered; deviations are excluded; aircraft at the same flight level fly at the same average speed; aircraft fly towards an intersection and change direction after the intersection. Hence, conflicts mainly occur owing to the loss of minimum separation between aircraft flying at the same flight level. The calculation of average number of potential conflicts is designed for a long time interval; hence, aircraft velocity deviations are negligible. The mathematical model in this paper is intended to compare different alternative intersection configurations of air traffic service routes. The comparison is based on the following results: an average number of potential conflicts per hour at route intersections, index of conflict intensity, and intersection capacity.

Keywords: Intersection configuration, aircraft conflicts, horizontal separation, protected zone.

2. Model

A conflict situation in a radar environment occurs when the radar separation between aircraft is less than the prescribed
The whole situation is illustrated in Fig. 1. First, we will define critical zone in front of $P$.

If aircraft $\overrightarrow{a}$ is on the left of $N$, which is a perpendicular projection of $R$ on $AP$. If we consider backward time shift of both aircraft so that $\overrightarrow{a}$ is in $P$, the protected zone front part of aircraft $\overrightarrow{a}$ is in a such point $\overrightarrow{U}$ left of $N$ that $\overrightarrow{UN} = \overrightarrow{RP}$. Therefore, aircraft $\overrightarrow{a}$ must be in $L$ left of $\overrightarrow{U}$ and $\overrightarrow{LU} = l$.

Let us find the critical zone behind point $P$. If the protected zone front part of aircraft $\overrightarrow{b}$ is in $Q$, i.e. the distance between $\overrightarrow{b}$ and $P$ is $l - |QG|$, aircraft $\overrightarrow{a}$ must be right of $Q$. Assuming the forward time shift, aircraft $\overrightarrow{b}$ will be in $P$, aircraft $\overrightarrow{a}$ must be in such $M$ that $|QM| = l - |QG|$.

In the right-angled triangle $QGP$ angle $\angle QGP = \frac{\pi}{2} + \alpha - \delta$, therefore

$$\angle QGP = \frac{\pi}{2} + \alpha - \delta.$$
INDEX OF CONFLICT INTENSITY

It describes the intersection \( I \) without the influence of traffic flows

\[
I = \frac{E}{f_2} = \frac{1}{V}(2l + \frac{w}{2}(\text{tg} \frac{\delta - \alpha}{2} + \text{tg} \frac{\delta + \beta}{2})�).
\]

CAPACITY OF INTERSECTION

The equation above can be modified to the following expression

\[
f_2 = \frac{EV}{2l + \frac{w}{2}(\text{tg} \frac{\delta - \alpha}{2} + \text{tg} \frac{\delta + \beta}{2})�}.
\]

2.3 Average number of potential conflicts per hour

If the average speed of both aircraft is \( V \), the time of flight on \( LM \) is \( LM/V \).

Let us denote:

- \( f_1 - \) average traffic flow on \( APB \),
- \( f_2 - \) average traffic flow on \( CPD \).

Hence, the average occupancy time \( T \) of aircraft from flow \( f_1 \) on segment \( LM \) is

\[
T = \frac{f_1 LM}{V} = f_1 \left( 2l + \frac{w}{2} \left( \text{tg} \frac{\delta - \alpha}{2} + \text{tg} \frac{\delta + \beta}{2} \right) \right).
\]

During the time \( T \) we can expect \( f_2 \) aircraft from the flow \( f_2 \). This value \( T_f \) is obviously an average number \( E \) of potential conflicts per hour

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