[EN-A-029]Preliminary analysis on safety assessment for off-set routes

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Abstract: In Incheon FIR, there are total 48 routes including 30 area navigation routes and 18 conventional routes. All en-routes are operated by single route except Y711 & Y722 (Gimpo-Jeju-Fukuoka FIR) and Y644 & Y697 (Incheon-Shanghai FIR). With the dramatic air traffic demand of more than 80 % increase in recent 10 years, the off-set routes have been introduced in order to increase the capacity of air traffic in peak hours. However, the operation for the 6NM lateral separation of off-set routes is the big safety issue. Therefore, the safety analysis has been preliminarily performed using by Reich model and radar trajectory data of off-set routes in the paper.

Keywords: Off-set routes, Safety Assessment, Lateral Separation, Reich model, Radar Trajectory Data

1. INTRODUCTION

The air traffic in the Republic of Korea has been increased annually by 5.6 % for the last decade. Especially, it has been increased recently, annually by 7.6% which is more than the average increase rate of global air traffic during the last 5 years (from 2012 to 2016). The Korean Ministry of Land, Infrastructure and Transport (MOLIT) had introduced PBN (Performance Based Navigation) procedures in its airspace from 2010 to cope the increasing air traffic. Thereby, it gave the solution for the congested air routes with the parallel air routes. In Incheon FIR, there are now two parallel air routes segments; the segment between Gimpo and Jeju (Y711 & Y722 air routes) and the segment between China and Gimpo (Y644 & Y697 air routes). The studies on the evaluation on the lateral collision risk have been performed for the design, implementation, and operation of those parallel air routes with separation of 8NM and 10NM from 2011 to 2014 [1][2][3][4][5]. The results were confirmed as that was safe enough under the total level of safety (TLS) recommended by ICAO standard [8].

Recently, the air traffic of the route between Busan-Jeju (A586 air route) has been increased more rapidly. Thereby, 3NM off-set operation has been introduced at the peak times. In addition, there is a plan to redesign Y579 (A586) air route to operate as the parallel air routes in the future. Especially, A586 air route is neighboring with the restrict areas and the prohibited areas. Therefore, the safety issue is important for introducing the parallel routes in Y579 (A586) air route. The preliminary study on the evaluation of lateral collision risk for 3NM off-set operation is necessary to make sure on the safety of the operation. In this paper, therefore, the study on the lateral collision risk with the off-set operation data in A586 air routes will be described to investigate the possibility of introducing parallel air routes.

2. Evaluation of Lateral Collision Risk

2.1 Airspace Description

There are total 48 routes including 18 ATS routes and 30 RNAV routes in Korean airspace. The route of Y579 between Jeju and Busan is one of the RNAV routes. The air traffic on the route has been increased annually at the rate 8.5% which is more than the average rate in Korean airspace. The total distance between Jeju VOR(CJU) and Busan VOR(PSN) is 157.4 NM. There are 4 FIXs including TOPAX, GOSBO, MAKET, ATENA as shown in Figure 1.

Figure 1 Details of Y579 (A586) Air Route between Jeju and Busan

source : www.skyvector.com

2.2 Lateral Collision Risk Modelling

The Reich collision risk model was used to estimate the level of safety for lateral collision risk of the 3NM off-set air route Y579 (A586). The evaluation process of the lateral collision risk model is shown in Figure 2. The sample of flight data have been collected from radar trajectory data set. For the evaluation of collision risk, the sample data have been filtered from raw data which included neighboring and crossing flight data.

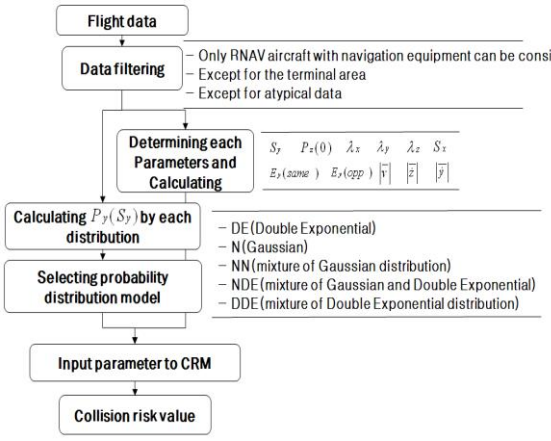

Figure 2 Procedure of Collision Risk Analysis

The model for quantitative risk evaluation used in European safety assessment has been used for the safety study of the 3NM off-set air route Y579 (A586). The equation for the collision risk model is as follows;

$$N_{ay} = P_y(S_y) \cdot P_z(0) \cdot \frac{\lambda_x}{S_x} \cdot \left\{ E_{y(same)} \cdot \left[\frac{|\Delta \bar{v}|}{2\lambda_x} + \frac{|\dot{\bar{y}}|}{2\lambda_y} + \frac{|\dot{\bar{z}}|}{2\lambda_z} \right] + E_{y(opp)} \cdot \left[\frac{2|\bar{v}|}{2\lambda_x} + \frac{|\dot{\bar{y}}|}{2\lambda_y} + \frac{|\dot{\bar{z}}|}{2 \cdot \lambda_z} \right] \right\}$$

The parameters in the equation are defined as follows;

- Nay : Expected number of accidents (two for every collision) per flight hour due to the loss of lateral separation between co-altitude aircraft flying on tracks with planned Sy NM lateral separation.
- Sy : Minimum planned lateral separation.
- Py(Sy) : Probability that two aircraft assigned at the same route will be at same across-track position.
- Pz(0) : Probability that two aircraft assigned to same flight level are at same geometric height.
- Ey(same) : Same direction lateral occupancy at same assigned flight level.
- Ey(opp) : Opposite direction lateral occupancy at same assigned flight level.
- Sx : Length of half the interval in NM used to count proximate aircraft at adjacent routes.
- λx : Average length of an aircraft
- λy : Average wingspan of an aircraft
- λz : Average height of an aircraft
- $|\Delta \bar{V}|$: Average relative speed of two aircraft flying on parallel routes in same direction.
- $|\bar{V}|$: Average ground speed on an aircraft.
- $|\dot{\bar{y}}|$: Average relative lateral speed of aircraft pair at loss of planned lateral separation of Sy.
- $|\dot{\bar{z}}|$: Average relative vertical speed of a co-altitude aircraft pair assigned to the same route.

2.3 Filtering of Raw Data

As shown in Table 1, the sample data for one month of Aug 2015 operated in the air route Y579 were used to evaluate the lateral collision risk on the 3NM off-set air route.

Table 1 Summary on Sample Data of Y579

Item	Details
Period of Sample Data	From 1 Aug 2015 to 31 Aug 2015 (1 month)
Altitude	Above FL140 (3,612 flights total)
Contents on Data	Aircraft types, Number of flight, Aircraft characteristics, traffic distribution (distribution over direction, day, time and altitude)

The raw data have been filtered to evaluate the collision risk for more accurate result. In the filtered data,

there is no information less than the flight level FL140. And the data related to the VFR and training aircrafts have been removed as well. The flight data near terminal areas have been filtered for considering the only linear segments in the air route Y579. Thereby, the flight data of aircrafts in the segments between MAKET and TOPAX have been used for the lateral collision risk analysis.

Figure 3 shows the distribution profile of raw data of Air Route Y579 between Jeju and Busan. The filtered data for east bound is shown in Figure 4, and for west bound in Figure 5.

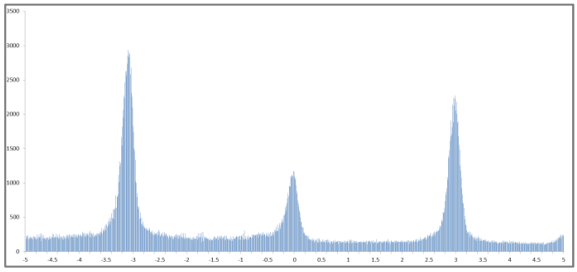

Figure 3 Raw Data of Air Route Y579 Between Jeju and Busan

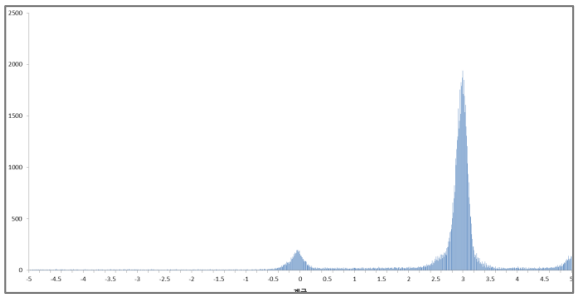

Figure 4 Filtered Data for East Bound

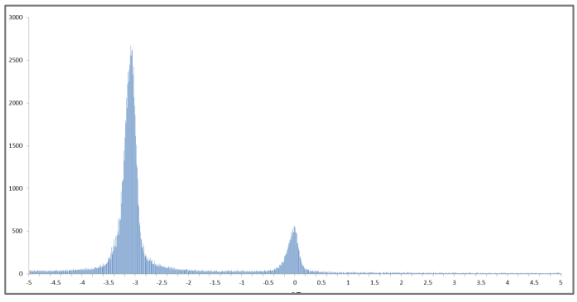

Figure 5 Filtered Data for West Bound

It is shown that the distance of the off-set operation for east and west bound is around 3NM in Figure 4 and Figure 5. The evaluation on the lateral collision risk of the off-set operation has been performed by using the above filtered data.

2.4 Evaluation of Average Aircraft Size

The average aircraft size has been evaluated based on the information on aircraft size given by Eurocontrol [9]. The weight rate of the aircraft type has been evaluated by considering the frequency of operation for each type in the filtered data. The result for the average aircraft size during the off-set operation is shown in Table 2.

Table 2 Weighted Aircraft Dimensions on Y579 Route

Parameter	Average size		Unit
	East Bound	West Bound	
λx	0.021802	0.021725	NM
λy	0.019800	0.019655	NM
λz	0.006799	0.006749	NM

2.5 Estimation of Lateral Occupancy Parameter

To calculate the lateral occupancy parameter, Ey(opp), conservatively, the data on heavy-traffic segment TOPAX-MAKET of Y579 have been used.

Table 3 Ey(opp) Value

Total number	Proximate pair	Ey(opp)
3612	404	0.112

2.6 Estimating the Average Ground Speed of an Aircraft

The average relative velocity in the opposite direction ($|\overline{V}|$) was calculated by using the average flight speed (V) of the aircraft flying in the air route Y579. All flight speeds of operation data have been converted to NM unit

Table 4 Average flying speed

Route	East Bound	West Bound
Object route	TOPAX-MAKET	
Average Flying Speed (knots)	425	427

2.7 Evaluation of Probability Function

The probability function, Py(Sy), has been determined by using the deviation distance from the center of trajectory distribution data of the aircrafts. Figure 7 and Figure 8 show the typical distributions of probability function of the trajectory data for the east bound and west bound. There are 5 probability function models (N, DE, NN, NDE, DDE) [13]. As shown in Figure 7 and Figure 8, the best fitting curve is the NN model. Thereby, the

evaluation of the lateral collision risk has been performed by using the NN model.

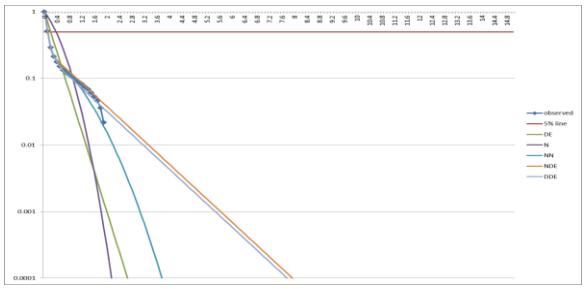

Figure 6 Distribution of Probability Function for East Bound

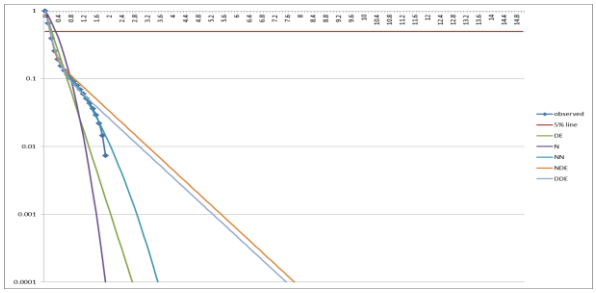

Figure 7 Distribution of Probability Function for West Bound

2.8 Other parameters

The parameter of the average ground speed was 75 knots which have used in Asia/Pacific EMA handbook (ver. 2.0) and this is conservative value. And the average relative vertical speed $\left|\bar{\dot{z}}\right|$ was used the value (1.5 knots) which have commonly used in ARINC, EMA handbook [8,9].

2.9 Results of Lateral Collision Risk Analysis

The evaluation results of the lateral collision risk analysis for Y579 with 3NM off-set separation are shown in Table 7. These results of lateral collision risk, Nay, meet the agreed TLS value of 5.0 x 10-9 fatal accidents per flight hour. Therefore, the off-set operation of Y579 may be considered as safe enough. However, if the off-set operation condition will be changed, the safety measures should be taken and the continuous monitoring may be required as well.

Table 5 Evaluation Results of Lateral Collision Risk for Y579

Parameter	East Bound	West Bound	Unit
S_y	6	6	NM
$P_y(S_y)$	4.99E-10	7.76E-11	unit
$P_z(0)$	0.538	0.538	-
λ_x	0.0218	0.0217	NM
λ_y	0.0198	0.0197	NM
λ_z	0.0068	0.0067	NM
S_x	80	80	NM
$E_y(opp)$	0.112	0.112	-
$\bar{V}$	425	427	Knot
$\left\|\bar{\dot{z}}\right\|$	1.5	1.5	Knot
$\left\|\bar{\dot{y}}\right\|$	75	75	Knot
N_{ay}	1.76x10^-10	2.76x10^-11	-

3. Conclusion

In this study, the lateral collision risk for the 3NM off-set routes Y579 (A586) has been analyzed. The evaluation result of collision risk with the traffic sample data of the month of August 2015 meets the agreed TLS value of 5.0 x 10^-9 fatal accidents per flight hour. It means that the off-set operation of the route Y579 (A586) is safe enough. However, it is necessary to be monitored continuously for the safe operation.

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