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Agenda Item 5: Airspace Safety Monitoring Activities/Requirements in the Asia/Pacific Region

Safety Assessment of RNAV ATS Routes Y711 and Y722 July 2012 – December 2012

(Presented by Republic of Korea)
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SUMMARY

This paper presents the safety assessment analysis for the newly implemented RNAV routes Y711 & Y722 (formerly called as Y71 & Y72) which are operated above FL140 from 16:00(UTC) on the 27th of June 2012. The estimated collision risk with TSD for the time period of July 2012 to December 2012 meets the agreed TLS value of 5.0×10^{-9} fatal accidents per flight hour.

This paper relates to –

Strategic Objectives:

- *A:* ***Safety*** *– Enhance global civil aviation safety*
- *C:* ***Environmental Protection and Sustainable Development of Air Transport*** *– Foster harmonized and economically viable development of international civil aviation that does not unduly harm the environment*

Global Plan Initiatives:

GPI-8 Collaborative airspace design and management

1. INTRODUCTION

1.1 The Republic of Korea has established the PBN implementation roadmap according to ICAO's PBN implementation plan. PBN based instrument flight procedures will be implemented to all airports and ATS routes in Incheon FIR by 2016. SID/STAR procedures around Incheon International Airport and Gimpo International Airport have been implemented recently according to Korean PBN implementation plan. This year, SID/STAR procedures around Jeju International Airport, Muan Airport, Yeosu Airport, and Ulsan Airport will be implemented.

1.2 For the implementation of PBN in the most congested route within the Incheon FIR B576, the Korea Transport Institute (KOTI), an independent institute funded by the government, has performed the preliminary analysis of ATS route B576 for safety assessment (RASMAG/16-WP10), and has performed the safety assessment of the new parallel routes to B576 (Y71 and Y72) above FL140 using a TSD of July 2012(RASMAG/17-WP19).

1.3 The collision risk of the simulated parallel routes to B576 with TSD covering January 2012 to May 2012 with 8NM lateral separation distance has been evaluated, and the collision risk of the routes Y71 and Y72 with TSD of the month of July 2012 with 8NM lateral separation distance has been also evaluated. The level risks of the both cases satisfied the TLS of no more than 5×10^{-9} fatal accidents per flight.

1.4 The names of the newly implemented parallel routes Y71 and Y72 has been changed to prevent from any confusion, and the new names of the parallel routes Y711 and Y722 has been published in AIP at 16:00(UTC) on the 12th December 2012.

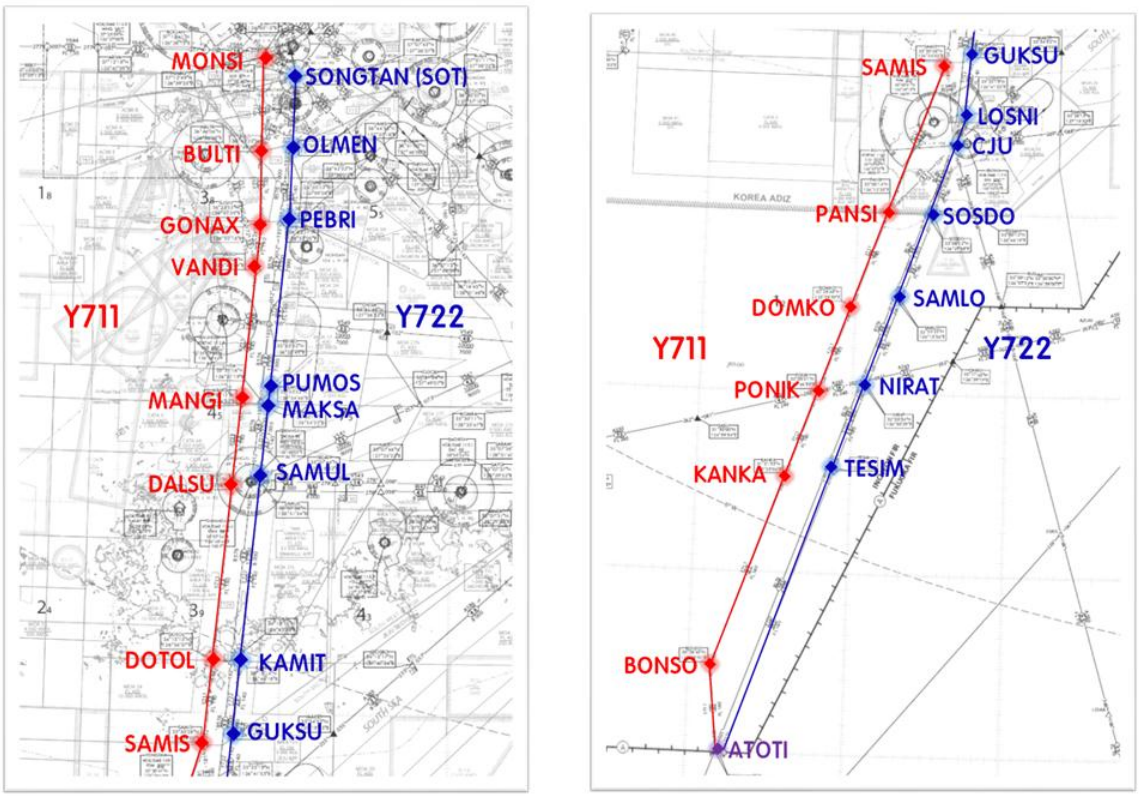
1.5 For the safety assessment of the newly implemented parallel routes Y711 and Y722, the quantitative risk analysis has been performed with the traffic sample data of the period from 1 July 2012 to 31 December 2012.

2. DISCUSSION

Airspace Description

2.1 In Incheon FIR, there are total 28 routes including 11 international routes, 8 domestic routes and 9 RNAV routes.

2.2 The newly implemented routes Y711 and Y722 were the only parallel PBN routes within the Incheon FIR, and are shown in **Figure 1**. ATS routes Y711 and Y722 are from Incheon/Gimpo Airports to South East Asia, and Jeju, for operations above FL140. However, conventional route B576 was still being utilised for operations below FL 130.



(Upper Region) **(Lower Region)**

Figure 1 Parallel ATS Routes Y711 & Y722 in Incheon FIR

2.3 ATS routes Y711 and Y722 were classified into two portions. The upper portions between MONSI and PANSI on Y711 and between SONGTAN VORTAC (SOT) and SOSDO on Y722 have been designated as RNAV2. The lower portions between PANSI and BONSO on Y711 and between SOSDO and ATOTI on Y722 have been designated as RNAV5.

2.4 Details of routes Y711 and Y722 are summarized in **Table 1**.

Regions of Routes	*MONSI~PANSI(Y711) SOT ~SOSDO(Y722)*	*PANSI~BONSO (Y711) SOSDO~ATOTI (Y722)*
Navigation Requirement	RNAV2	RNAV5
Separation Distance Between Y711 and Y722	8NM	12NM
Acceptable Equipment	DME/DME, DME/DME/IRU, GNSS	INS or IRS, GNSS

Table 1 Characteristics of Routes Y711 and Y722 within the Incheon FIR

Traffic Sample Data (TSD)

2.5 As shown in **Table 2**, traffic sample data for the six months from 1 July to 31 December 2012 were used to assess the lateral safety of parallel routes Y711 & Y722.

Items		Details
Target Data for Y711 & Y722	Period of TDS	1 July 2012~ 31 December 2012 (Total 6 Months)
	Altitude	Above FL140 (Total 80,280 Flights)
	Basic Analysis	Aircraft Types, Number of Flight, Aircraft Characteristics, Traffic Distribution (Distribution over Direction, Day, Time and Altitude)

Table 2 Traffic Sample Data of Y711 and Y722

2.6 For the safety assessment of the lateral collision risk for Y711 and Y722, the traffic sample data confirmed the following conditions.

- Aircraft operated above FL140 (Y711 & Y722) except below FL130 (B576);
- All data were RNAV approved;
- Aircraft in linear segments were separated by 8NM or more (excluded the terminal area):
  - in the segments between VANDI and SAMIS for route Y711;
  - in the segments between PEBRI and KAMIT for route Y722.

2.7 The most common aircraft types, the number of flights per type and the percentage of these types over the total flights during the given period for Y711 and Y722 had been analysed. The population was dominated by the large aircrafts such as B737, B738, A321 and A333. The percentage of these four types was about 70 % of the total number of flights.

2.8 The details of percentage of aircraft types are shown in **Table 3** and in **Figure 2**.

Y711 Route (SB)			Y722 Route (NB)		
Aircraft Type	**Count**	**% A/C**	**Aircraft Type**	**Count**	**% A/C**
B737	8295	**24.9**	**B737**	10220	**21.7**
B738	6790	**20.4**	**B738**	9396	**20.0**
A321	4299	**12.9**	**A321**	5956	**12.7**
A333	3605	**10.8**	**A333**	5832	**12.4**
A320	2328	**7.0**	**A320**	3546	**7.5**
B744	1426	**4.3**	**B744**	2576	**5.5**
B772	1040	**3.1**	**B763**	1708	**3.6**
B763	953	**2.9**	**B772**	1610	**3.4**
B773	609	**1.8**	**B773**	965	**2.1**
B739	572	**1.7**	**A306**	826	**1.8**
Others	3361	**10.1**	**Others**	4367	**9.3**
Total	**33278**	**100**	**Total**	**47002**	**100**

Table 3 Aircraft population and number of flights per type in routes Y711 & Y722

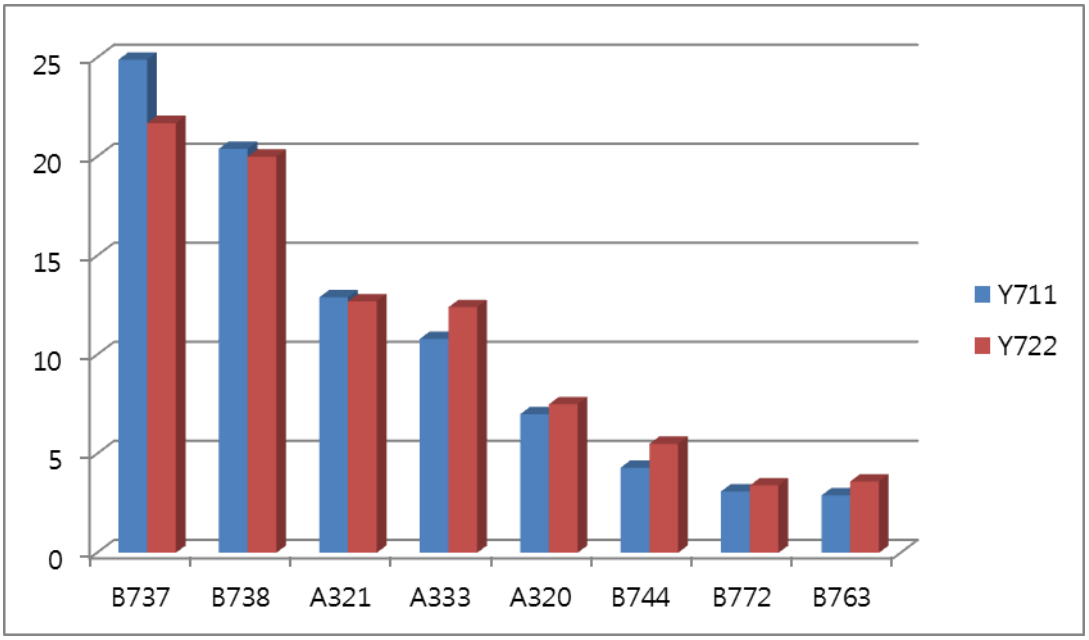


Figure 2 Percentage of aircraft type in routesY711 & Y722 (Left : Y711, Right : Y722)

2.9 The traffic distribution per flight level is shown in **Figure 3**. It shows the total air traffic distribution based on flight level in routes Y711 & Y722 in Incheon FIR. It is shown that the frequency between FL260 and FL280 is the highest in these routes.

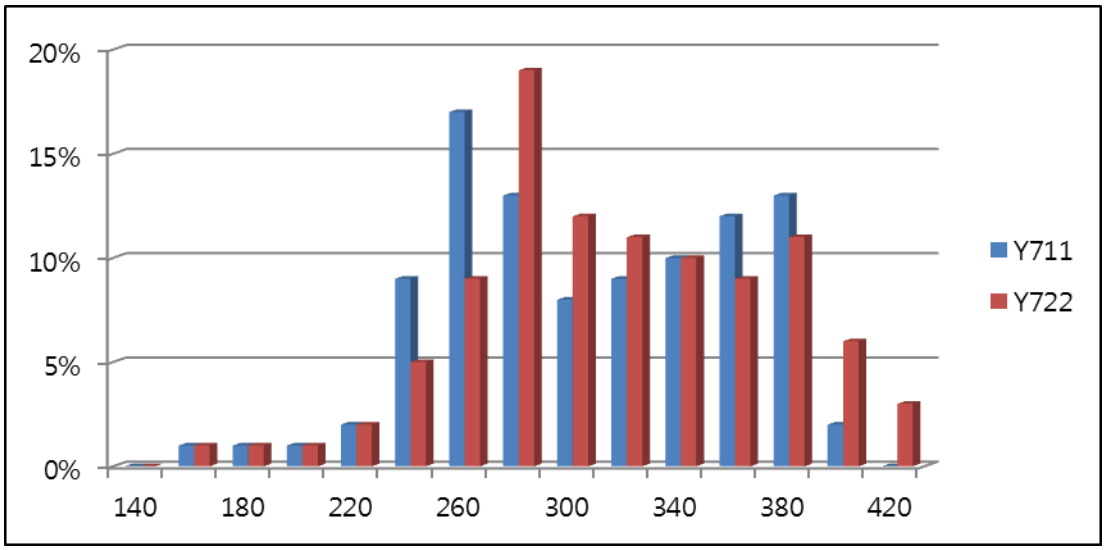


Figure 3 Distribution based on Flight Level in routes Y711 (SB) & Y722 (NB)

Lateral Collision Risk Model

2.10 The Reich lateral collision risk model was used to estimate the level of safety for lateral collision of the parallel routes Y711 & Y722. The process of the lateral collision risk model (Reich CRM) is shown in **Figure 4**.

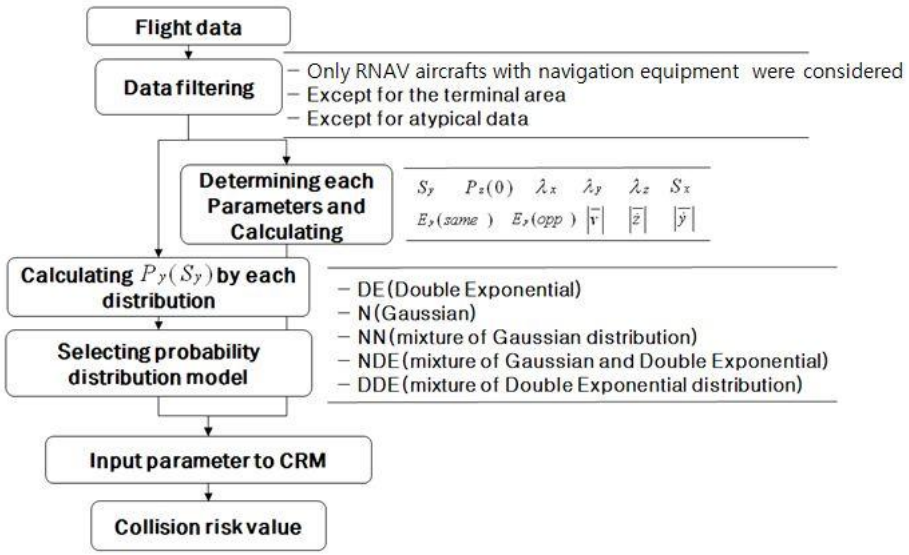


Figure 4 Process of CRM application

2.11 The model for the safety assessment of the routes Y711 & Y722 is as follows :

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

2.12 The parameters in the above 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 : Planned minimum lateral separation.
- Py(Sy) : Probability that two aircrafts assigned at the same route will be at same across-track position.
- Pz(0) : Probability that two aircrafts 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
- $|\overline{\Delta V}|$: Average relative speed of two aircraft flying on parallel routes in same direction.
- $|\overline{V}|$: Average ground speed on an aircraft.
- $|\bar{\dot{y}}|$: Average relative lateral speed of aircraft pair at loss of planned lateral separation of Sy.
- $\left|\bar{\dot{z}}\right|$: Average relative vertical speed of a co-altitude aircraft pair assigned to the same route.

2.13 The distribution of aircraft population in the TSD from Incheon FIR for the period between 1 July 2012 and 31 December 2012 is summarized in **Table 4**.

Aircraft	λ_x, length(x)		λ_y, wingspan(y)		λ_z, height(z)	
	M	NM	M	NM	M	NM
A306	54.08	0.029201	44.84	0.024212	16.62	0.008974
A320	37.58	0.020292	33.86	0.018283	12.13	0.006550
A321	44.51	0.024033	33.86	0.018283	11.81	0.006377
A332	59.00	0.031857	60.30	0.032559	17.88	0.009654
A333	63.58	0.034330	60.30	0.032559	16.84	0.009093
B737	33.6	0.018143	35.8	0.019330	12.5	0.006749
B738	39.5	0.021328	35.8	0.019330	12.5	0.006749
B739	42.1	0.022732	35.7	0.019276	12.5	0.006749
B744	70.6	0.038121	64.4	0.034795	19.4	0.010481
B763	54.9	0.029644	47.6	0.025702	15.8	0.008531
B772	63.7	0.034395	60.9	0.032883	18.5	0.009989
B773	73.9	0.039903	60.9	0.032883	18.5	0.009989

Table 4 Aircraft Dimension on the routes Y711 and Y722

2.14 The average aircraft dimension has been evaluated using the dimension of each aircraft type weighted by their proportion. The values of the length λ_x, of the wingspan λ_y, of the height λ_z of the average aircraft are shown in **Table 5**.

	Route Y711	**Route Y722**
λ_x	0.024883	0.025456
λ_y	0.022961	0.0234
λ_z	0.007526	0.007621

Table 5 Average Aircraft Dimension on the routes Y711 and Y722

2.15 For the lateral occupancy parameter Ey(opp), the data on heavy-traffic air segments DALSU-DOTOL of Y711 and SAMUL-KARMIT of Y722 have been used. The value of Ey(opp), is shown in **Table 6**.

Total number	**Proximate pair**	**Ey(opp)**
80,280	4373	**0.10894**

Table 6 Ey(opp) value

2.16 The average ground speed in the opposite direction ($|\bar{V}|$) was calculated by multiplying with the average flight speed (V) of the aircraft flying on the routes Y711 & Y722. All flight speed has been converted to NM unit, and the value is shown in **Table 7**.

Route	**Route Y711**	**Route Y722**
Object route	DALSU-DOTOL	SAMUL-KAMIT
Average Flying Speed (knots)	440.8989	439.839

Table 7 Average ground speed of an aircraft

Estimate of Lateral Collision Risk

2.17 The lateral collision risk was estimated in order to determine whether the target level of safety (TLS) is met in the parallel routes Y711 and Y722. Table 8 presents the estimate of lateral collision risk for the routes Y711 and Y722 separated by 8NM. This estimate meets the agreed TLS value of 5 x 10^{-9} fatal accidents per flight hour.

Parameters	**Route Y711 (VANDI-SAMIS)**	**Route Y722 (PEBRI-KAMIT)**	**Sources of the Estimate**	**Unit**
S_y	8	8	Current minimum lateral separation	NM
$P_y(S_y)$	1.22E-11	4.09E-12	Estimated using a mixture of Gaussian	-
$P_z(0)$	0.538	0.538	Estimated from TSD	-
λ_x	0.0249	0.0254	Estimated from TSD	NM
λ_y	0.0230	0.0234	Estimated from TSD	NM
λ_z	0.0075	0.0076	Estimated from TSD	NM

S_x	80	80	Equivalent to ±10 minutes of longitudinal separation.	NM
$E_y(opp)$	0.10893	0.10893	Estimated from TSD	-
$\bar{V}$	440.8989	439.839	Value obtained from TSD	Knot
$\lvert\bar{\dot{z}}\rvert$	1.5	1.5	Conservative value taken from EMA Handbook	Knot
$\lvert\bar{\dot{y}}\rvert$	75	75	Conservative value taken from EMA Handbook	Knot
N_{ay}	4.33E-12	1.45E-12		-

Table 8 Lateral Collision Risk Estimate for Routes Y711 and Y722

2.18 **Figure 5** presents the trends of the lateral collision risk estimates for each month from July 2012 to December 2012. It shows that the level of the collision risk for each month is steady enough and satisfied with the TLS of no more than 5 x 10^{-9} fatal accidents per flight hour.

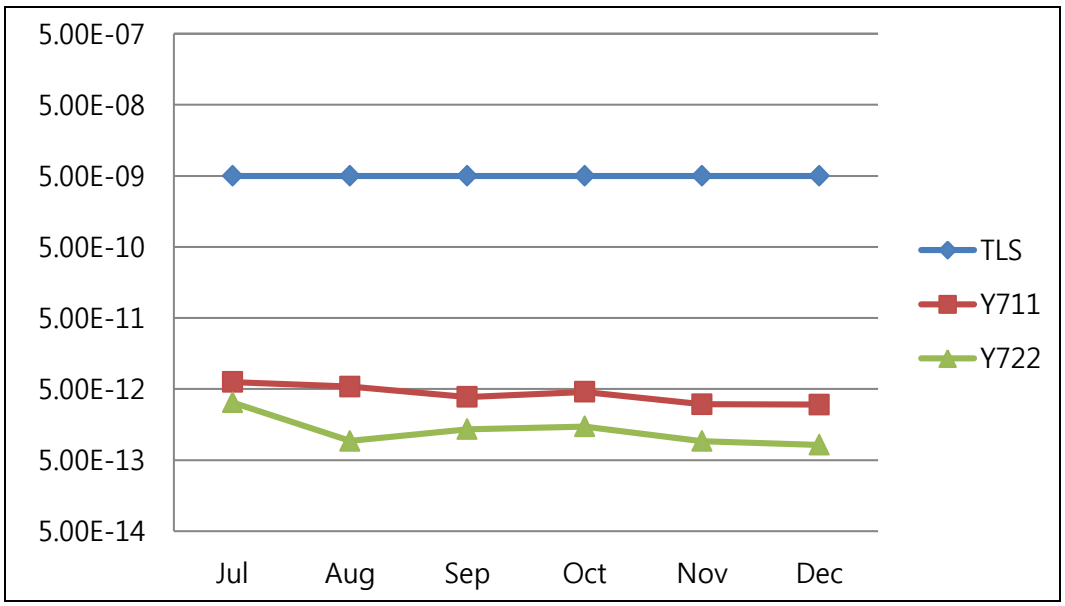


Figure 5: Trends of Lateral Collision Risk Estimates on Routes Y711 & Y722

Summary and Future Plan

2.19 In this study, the safety assessment for the newly implemented routes Y711 and Y722 with RNAV have been analysed. The estimated collision risk with TSD of the months of July-December 2012 meets the agreed TLS value of 5 x 10^{-9} fatal accidents per flight hour. It means that the operation of the parallel routes Y711 and Y722 is safe enough. However, it is necessary to monitor the situation continuously for a safe operation.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matters as appropriate.

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REFERENCES

1. 「Asia/Pacific EMA Handbook」- Version 2.0, August 2010
2. 「EUR/SAM: "Double Unidirectionality" Post-Implementation Risk Assessment」
3. 「Air Traffic Management」, Doc 4444, ATM/501, Fifteenth Edition, 2007, ICAO
4. The 15th Meeting of the Regional Airspace Safety Monitoring Advisory Group(RASMAG/15) Bangkok, Thailand, 1-5 August 2011
5. The 16th Meeting of the Regional Airspace Safety Monitoring Advisory Group(RASMAG/15) Bangkok, Thailand, 20-23February 2012
6. 「Collision Risk Model」, ENRI, Japan
7. PBN Korea Website (http://pbn.mir9.co.kr)
8. 「A Basic Study for Development of Safety Technologies in Aviation - Focusing on Development of Airspace Safety Assessment Model」, KOTI, 2011.11.
9. 「Preliminary Analysis of Airspace Characteristics in the Incheon FIR and of ATS Route B576 for Safety Assessment」, RASMAG/15−IP/02, 2011.8
10. 「Preliminary Analysis of ATS Routes B576 for Safety Assessment」, RASMAG/16−WP/10, 2012.2
11. 「Safety Assessment of RNAV ATS Routes Y71 & Y72」, RASMAG/17−WP/19, 2012.8