Collision Risk Simulator: a Safety Assessment Tool

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Abstract: This paper discusses the air traffic simulation based on a Collision Risk Model to calculate the estimated risk for track A576 to create an actual flight conditions by using a scenario used to create the desired environmental conditions for this simulation. The main procedure in this paper is divided into three parts: determining the parameter of laplace distribution for longitudinal, lateral and vertical error distribution, determining which scenario will be used in the simulation, and calculating the Estimated Collision Risk. Lastly, it proposes future avenues for research involving Collision Risk Simulator.

Key–Words: Collision Risk Model, Target Level of Safety, Simulation, Technical Risk Estimation

1 Introduction

The International Civil Aviation Organization (ICAO) Asia / Pacific Regional Airspace Safety Monitoring Advisory Group (RASMAG) has considered the new requirements for long term height monitoring in some detail, and has agreed that the Reduced Vertical Separation Minimum (RVSM) Minimum Monitoring Requirements (MMRs) that have been adopted for global application by all ICAO Regional Monitoring Agencies (RMAs) should be the basis for implementation of the Annex 6 requirements.

As part of the RMA duties and responsibility, the Monitoring Agencies conducts periodic safety assessments, now called safety oversight, to ensure that the RVSM implementation in the Asia Region continues to be safe. This include the monitoring of non-compliant aircraft operating in the RVSM airspace. In this regard, the support of information from the States Concerned is very important.

Indonesia haves large airspace that need to implement RVSM to ensure its safety on daily flights, along with the increasing volume of traffic then the risk of accidents also increased. One way to find out the level of safety of the air space by calculating the estimated risk to know the value of estimated risk in Indonesian air space especially on route A576.

With the opening of Indonesian opportunity to empower its air space to be an economical solution for the government to determine the optimum air safety standards with the utilization of air space that exists today.

1.1 Background

In 1999 the Federal Aviation Administration (FAA) design project capstone to improve the efficiency and safety of flight [2], safety oversight of the implementation RVSM in Indonesian airspace should be done to reduce the number of accidents which continues to increase with the volume of air traffic each year. This paper discusses another approach that can be done to measure the value of the estimated risk using simulation which is expected to help predict the level of accidents, particularly in this paper on the track A576, which has a fairly high level of density applied through the application of this simulation. The selection method in this paper is proposed due to limited data generated by the radar to know the detailed flights information required in the calculating of the estimated risk (we need to find an acceptable alternative to calculate it). Therefore, we define this method as a basic model that will be used for simulation to calculate number of collision incidences per flight hour.

2 Procedures and Methodology

This section will describe the methods to be used as the basis and the stages that will be done in this study and will be described in a series of process performed by the system to generate predictions and simulation results data.

2.1 Procedures

On this paper there are a series of processes performed by the system to produce the aircraft and the collision

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prediction to calculate the estimated risk. Series of process flow diagrams can be viewed in Figure 1.

From the Figure 1, it can be seen that the processing of configuration divided into three steps as follows:

1. Phase Determination of Laplace Distribution

   There are three component parameter distribution error module in three directions which are longitudinal, lateral and vertical.

   Longitudinal component is used to determine how the optimum longitudinal separation standard applied on the track to see the value of optimal occupancy of these pathways (e.g., track A576). The value of this input will affect the speed of the aircraft during a flight from a departure airport to a destination airport.

   Lateral component is used to determine the amount of deviation that occurs when a plane experienced turbulence in the air. The value of this input will determine how wide a shift in the plane in case of turbulence or obstacles in the flight whether caused by weather conditions, wind and so forth as well as pilot error after that the plane will shift back into its correct line automatically.

   Vertical component is used to determine how much vertical height irregularities that occurred during the trip that can be caused by turbulence or pilot error. In case of irregularities as far as 100 feet or more then according to the appropriate regulation of the ICAO the incident should be recorded as a Large Height Deviation (LHD). [4]

2. Phase Determination of Simulation Scenarios

   This stage plays an important role to help create conditions where the flight tested in simulation which determined by three components shown in Figure 2.

   (a) Length of Simulation (hours)

   This input indicates how long the simulation will take place. In Figure 2 the simulation was conducted for one month with data taken in this research with a distance of five minutes, fifteen minutes and thirty minutes of flight gap.

   (b) Spawn Every (minutes)

   This input will determine the schedule flight departure to determine the level of density in the flight path which will be simulated to determine how many planes will pass through the path during the simulation progress intended to test the level of density / stress test on the track.

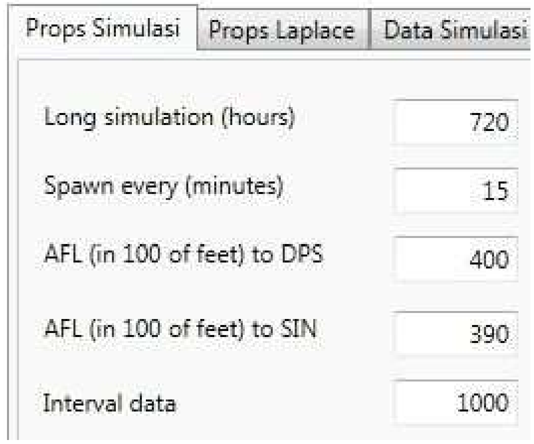

Figure 2: Simulation Scenario.

   (c) Assigned Flight Level (AFL) to DPS/SIN

   This input determines the point of Flight Levels are used in aviation regulation in accordance with the RNP type that is used. In this case the RNP type 10 with a separation standard of 1000 feet for the application of RVSM. [1] [6]

   (d) Interval Data

   This input is used to simulate the recording time for recording the data by radar with a recording interval during the simulation runs.

Parameters used in the distribution of longitudinal, lateral, and vertical should be derived from real data obtained from the radar, this calculation will yield the mean value and the scale that occurred. Given the data limitations and manually recorded data from the radar system, the input mean values and scale on LHD done by looking at history that occurred from 2009 to 2010. A Generalized Laplace probability reduces to a Double Exponential probability density when the shape parameter is given a value of 1.0. [8]

From observations LHD history, it is known that there are two major factors that occurred in Indonesia air space. The first was the figure for the highest category of E that is equal to six events recorded during the duration of 17 minutes. The second was occurred during the duration of 28 minutes caused by failure of equipment belong-

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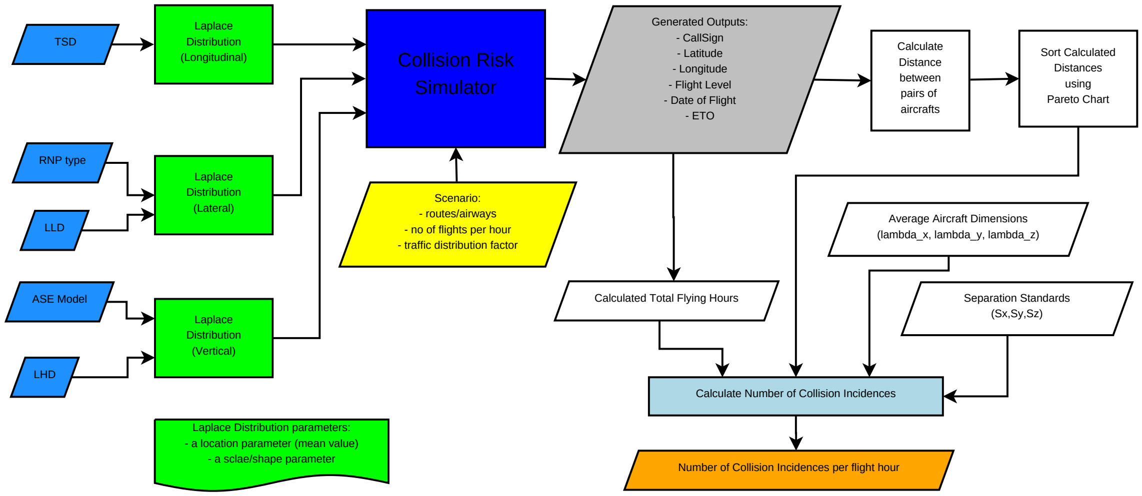

Figure 1: Flow Diagram of the Collision Risk Simulator.

ing to the category M. Therefore in this simulation, the distribution rates are shown in Table 1.

Table 1: Laplace Distribution Parameters.

Distribution	Mean	Scale
Lateral	1	2
Longitudinal	1	1
Vertical	1	3

3. Calculate the Proximate Pairs

In previous studies in determining the method of estimation of three-dimensional air space to be used in the separation plane [10], produced four forecasts to predict the behavior of vector [AB] in Figure 3 for each pair of planes which are:

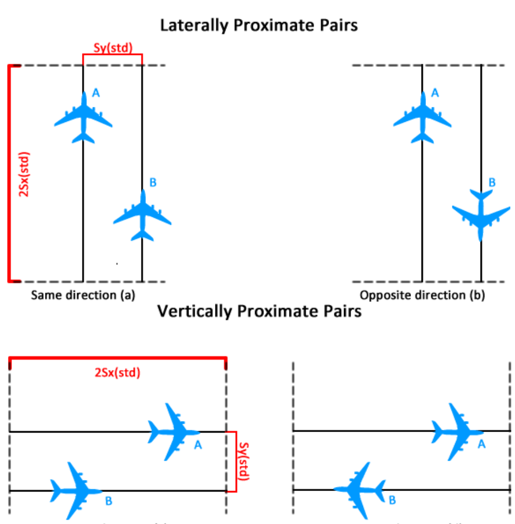

Figure 3: Proximate Pairs Visualization. [9]

Reich, PG, [11],[10],[9] reveals that to calculate the collision risk for the failure of the vertical and lateral standard can be calculated by the following formula:

$$\begin{aligned} Ty(same) = & \frac{T_y(same)}{S_x(std)}[\\ & \frac{\triangle\bar{V}}{2}P_y(std)P_z(0)+ \\ & \lambda_x P_y(std)N_z(0)+ \\ & \lambda_x N_y(std)P_z(0)] \end{aligned} \tag{1}$$

Aggregate off time spent by all pairs in the configuration on Fig 3(a) as found in [9].

$$\begin{aligned} Ty(opp) = & \frac{T_y(opp)}{S_x(std)}[\\ & \bar{V}P_y(std)P_z(0)+ \\ & \lambda_x P_y(std)N_z(0)+ \\ & \lambda_x N_y(std)P_z(0)] \end{aligned} \tag{2}$$

Aggregate off time spent by all pairs in the configuration on Fig 3(b) as found in [9].

$$\begin{aligned} Tz(same) = & \frac{T_z(same)}{S_x(std)}[\\ & \bar{V}P_y(0)P_z(std)+ \\ & \lambda_x N_y(0)P_z(std)+ \\ & \lambda_x P_y(0)N_z(std)] \end{aligned} \tag{3}$$

Aggregate off time spent by all pairs in the configuration on Fig 3(c) as found in [9].

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$$Tz(opp) = \frac{T_z(same)}{S_x(std)}[\frac{\triangle \bar{V}}{2} P_y(0)P_z(std) + \lambda_x N_y(0)P_z(std) + \lambda_x P_y(0)N_z(std)] \quad (4)$$

Aggregate off time spent by all pairs in the configuration on Fig 3(d) as found in [9].

In this application will use the formula $T_z(same)$ and $T_z(opp)$ to calculate the proximate pairs from the TSD data from the simulation results.

4. Calculate the Value of Estimated Risk with Collision Risk Model (CRM)

   The models were originally developed by P.G. Reich as found in [10], [9], [11]. The equation for the lateral collision risk is given by [5]:

$$C = P_y(S_y)P_z(0)\frac{\lambda_x}{S_x}[E_s\left[\frac{|\bar{\dot{x}}_s|}{2\lambda_x} + \frac{|\bar{\dot{y}}|}{2\lambda_y} + \frac{|\bar{\dot{z}}|}{2\lambda_z}\right] + E_o\left[\frac{|\bar{\dot{x}}_0|}{2\lambda_x} + \frac{|\bar{\dot{y}}|}{2\lambda_y} + \frac{|\bar{\dot{z}}|}{2\lambda_z}\right]] \quad (5)$$

C = the expected number of total accidents per aircraft flying hour.

$P_y(S_y)$ = lateral overlap probability, i.e. the likelihood that any two aircraft which have been assigned the correct lateral separation are in fact not separated laterally.

$P_x(0)$ = probability of longitudinal overlap, depends on the amount of traffic in the system.

$P_y(0)$ = probability that two aircraft assigned to the same track are in lateral overlap.

$P_z(0)$ = probability that two aircraft assigned to the same flight level are in vertical overlap.

$|\bar{\dot{x}}|$ = average along-track component of the relative velocity of two aircraft which collide due to loss of longitudinal separation.

$|\bar{\dot{y}}|$ = average relative cross-track speed for two aircraft assigned to the same track.

$|\bar{\dot{z}}|$ = average relative vertical speed for two aircraft assigned to the same level.

λ_x = average length of aircraft using the airspace.

λ_y = average wing-span of aircraft using the airspace.

λ_z = average vertical dimension of aircraft using the airspace.

S = separation standard in use.

E = the systems occupancy and provides a measures of the traffic density. The system occupancy (E_s and E_o where "s" represents same direction traffic and "o" represents opposite direction traffic) is estimated from flight plan data for a set of sample days throughout the year.

5. Processing Stage Output

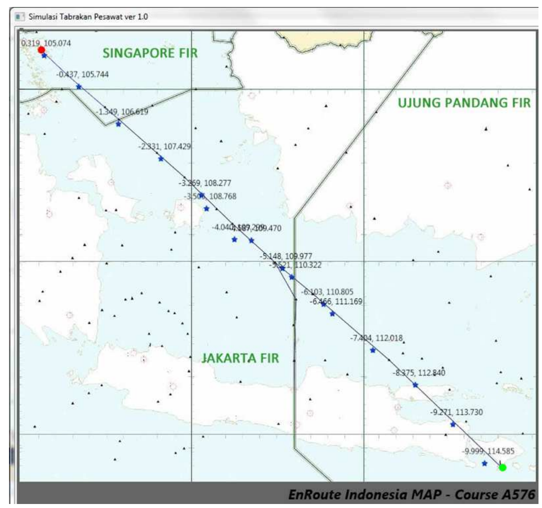

Figure 4: A Snapshot of Running Simulation.

The results of the data generated from the Collision Risk Simulation (CRS) process is directly entered into the database in accordance with the format of the tabulation of Traffic Sample Data (TSD) [7] [4] reported to the AAMA as a regional monitoring agency appointed by the ICAO for airspace in Indonesia.

This data will then be pre-processed containing data that has been screened only latitude and longitude position of the aircraft which has the closest point to the position of way points along route A576 are Aktod, Sanos, Liana, Apari, Apaga, Akula, Sabil, Axes and Snails are shown in Figure 5.

In this stage, the data have been generated from the CRS is sorted again to filter out invalid data in order to minimize calculation errors in the future. The next step performed the calculation of total hours of flying planes during the simulation progresses, by calculating the travel time from the initial point of departure until the end point of arrival during the simulation runs. With the scale comparison between simulation and real time is one minute in the simulation presented an hour in real time.

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id	callsign	aircraft_type	dof	fixes	lat	lon	eto	afl	speed
1	GA_East_0	FA99X	2011-09-11	AKTOD	0.1963217285	105.1418305102	2011-09-11 23:00:34	399.29	936
2	GA_East_0	FA99X	2011-09-11	SANOS	0.0971911505	105.2217887601	2011-09-11 23:00:35	406.83	921.906
3	GA_East_0	FA99X	2011-09-11	LIANA	0.3866270236	104.970659685	2011-09-11 23:00:28	400	936
4	GA_East_0	FA99X	2011-09-11	APARI	0.3866270236	104.970659685	2011-09-11 23:00:28	400	936

Figure 5: TSD data from the simulation results

2.2 Methodology

Methodology used in this paper is :

1. Field Study

   At this stage we collected data by conducting interviews and direct visits to ATC (Air Traffic Control) to find out how the processed data can be generated by the radar and understand the information processes running on the current system.

2. Data Analysis

   Done on some previous research papers concerning the application of RVSM to determine whether the best features to be applied in measuring the value of the estimated risk during the simulation process takes place, and to identify barriers or limitations that exist in collecting the required data.

3. System Design

   An understanding of the algorithm application stage, which includes the distribution of Laplace and methods of estimated risk calculation into a software.

4. System Implementation

   This is the last stage where the data generated from simulations that have been run by setting the desired scenario and the separation standard that will be tested.

3 Result and Discussion

Testing in this paper consists of three simulated scenarios with simulated time of five minutes, 15 minutes and 30 minutes consecutively.

At this stage the TSD data for five minutes produces 13.578 plane object with a total of 23.761,5 flying hours, the simulation time for 15 minutes produces 5.656 plane object with a total of 9.898 flying hours and for the simulation time for 30 minutes produces 2.874 object plane with a total of 5029,5 hours of flying hours.

In calculating the value of estimated collision risk by using the formula of Collision Risk Model (CRM), not all the components of the CRM can be calculated with simulated data generated due to limited data, and not all components of the formula can be derived from TSD data simulation results because it has not fully understood to be used. Therefore many of the parameter components are taken from data and assumptions generated in the AAMA reports.

Therefore, the we divide these components into two parts namely the component which is calculated by TSD data and component data extracted from the data report by AAMA. CRM components that can be calculated from the TSD data are shown in Table 3 and CRM components derived from AAMA data are shown in Table 2.

The data in Table 2 were taken from the AAMA report [3], with consideration of the value of the component that is used to calculate the value based on the previous TSD data for FIR (Flight Information Region) Jakarta and FIR Ujung Pandang and the limited data that can be collected to determine calculation of that value.

The calculated value for the FIR Jakarta estimated risk resulting from TSD data by simulations that have been run previously will be combined with that of Ujung Pandang FIR to get the value of Technical Risk Total Value which is a combination of the two FIR estimated risk value in Indonesia, namely Jakarta FIR and FIR Ujung Pandang to Jakarta FIR that value obtained from the simulation results while the Ujung Pandang FIR ADSB obtained from data which is equal to $9.01952E^{-}11$.

Table 2: CRM component from AAMA reports data

Component	Value
λ_x	0.0259
λ_y	0.0234
λ_z	0.0076
$P_z(same)$	0.0000000186
S_x	121.6
$\triangle V$	30.22
$\lvert\bar{\dot{y}}\rvert$	13
$\lvert\bar{\dot{z}}\rvert$	1.5

The following is the result of calculation of estimated risk based on data generated in the simulation

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Table 3: CRM component of TSD data

Component	Data 1 (five minutes)	Data 2 (15 minutes)	Data 3 (30 minutes)
$N_z(same)$	0.008147094	0.001997732	0.000387985
$N_z(opp)$	0.235713028	0.115597392	0.022450494
$\|V\|$	502.6 knots	497.3 knots	500.6 knots

:

Table 4: The results of the Calculation of the First Data.

a. First scenario data			
Indonesian RVSM Airspace - estimated annual flying hours = 23.761,5 hours			
Source of Risk	Risk Estimation	TLS [1]	Remarks
Technical Risk	2.44 x 10^{-10}	2.5 x 10^{-9}	Below Technical TLS
Operational Risk	3.03 x 10^{-9}	-	-
Total Risk	3.27 x 10^{-9}	5.0 x 10^{-9}	Meets Overall TLS
b. Second scenario data			
Indonesian RVSM Airspace - estimated annual flying hours = 9.898 hours			
Source of Risk	Risk Estimation	TLS	Remarks
Technical Risk	2.10 x 10^{-10}	2.5 x 10^{-9}	Below Technical TLS
Operational Risk	3.03 x 10^{-9}	-	-
Total Risk	3.24 x 10^{-9}	5.0 x 10^{-9}	Meets Overall TLS
c. Third scenario data			
Indonesian RVSM Airspace - estimated annual flying hours = 5.029,5 hours			
Source of Risk	Risk Estimation	TLS	Remarks
Technical Risk	1.84 x 10^{-10}	2.5 x 10^{-9}	Below Technical TLS
Operational Risk	3.03 x 10^{-9}	-	-
Total Risk	3.21 x 10^{-9}	5.0 x 10^{-9}	Meets Overall TLS

4 Conclusion

Several conclusions that can be drawn from this paper:

- Simulation and modifications made to the application of Aircraft Collision Simulator to see the influence of the density of traffic flow aircraft with a value of estimated risk successful. It is characterized by the value of estimated risk based on TSD data obtained from the simulation results directly proportional to the total hours of flying planes and little possibility of error simulation results of both data reception position latitude, longitude, recording flight time, speed and altitude aircraft during the simulation takes place.

- The need for the application of radar system ADSB in Jakarta FIR to facilitate the process of analysis and comparison data to see the accuracy of the results of simulation data. Determination of the Laplace distribution lateral can represent preliminary results that the system has successfully predicted the TSD data but less good for use as a comparison of real data because real data are not derived from ADSB radar.

- The determination of the value of the Laplace distribution using LHD document acceptable to represent the data while ADSB is not yet available as the main reference of determining the value of the distribution but does not fully reflect the actual conditions.

- The system is a useful tool to measure the effectiveness of aircraft separation standards on the track, especially on route A576. We have demonstrated the program ability to simulate airline traffic conditions for the entire month including as many as 829.890 flights with no problems. For larger airline traffic conditions the program needs some optimizations to work smoothly.

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