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Modeling and Simulating Direct Route Environment in Singapore Airspace to Examine Conflicts, Aircraft Performance Output and Workload

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ABSTRACT

As air traffic is rapidly growing in the ASEAN region, it is essential to undertake proper planning and measures to modernize or improve current ATM operations in order to accommodate future traffic. One operational concept that may be of interest to the ASEAN region is the Direct Route Environment within ASEAN airspace to facilitate shorter flight routes for increased capacity, efficiency and safety. In this study, a Direct Route Environment was modelled within Singapore's Flight Information Region which is within the ASEAN airspace. The direct route operations were modeled and simulated by assigning optimum flight profile under normal wind and weather conditions. The conflict patterns and aircraft performance output were then compared between current and direct route operations, with the latter showing considerable economic, safety and environmental benefits over the former.

I. Introduction

Air traffic in ASEAN is projected to increase by 6.5% annually from 2013 to 2033[1]. At this rate of growth, air traffic within ASEAN will triple to more than 20,000 flights a day by the year 2033. As noted by the ASEAN aviation community, if no improvements are made to the current ATM system in ASEAN to support the expansion in air traffic, economic gains will be curtailed as aviation infrastructure and facilities are already stretched to the limit in many parts of the region. Inaction on the part of States and air navigation service providers (ANSP) could cost ASEAN as much as 9 million jobs and US$ 105.7 billion annually. Thus, it is time that the region quickly looks into concepts and systems that may improve the current ATM operations in the region.

The region envisions a seamless sky operation where one of the focus areas is to transition from airspace to 4D trajectory management. Such transition describes an environment where air and ground stakeholders focus on the aircraft's trajectory and its management according to the airspace user's preferred optimum performance, considering wind, destination, and traffic. FIRs should not necessarily be based strictly on the boundaries of sovereign territories. This aims to reduce existing airspace and route structures and move towards a user-preferred environment keeping in view of the changing needs of the users.

As a first step towards such a transition, the ASEAN region could look into implementing Direct Route Operations(DRO) within the upper airspace of its Flight Information Regions (FIRs), which have the necessary systems and technology. With this consideration, a direct route environment was modelled and simulated in the upper airspace of Singapore's FIR, which is one of the FIRs with up-to-date systems and technology in the region. The direct routes were created by assessing the different aircraft types captured in the traffic data for Singapore and by assigning optimum flight profile under normal wind and weather conditions based on Base of Aircraft Performance Data (BADA). The modeling and simulation was undertaken using EUROCONTROL's SAAM tool and the results indicate that there is a potential for implementing direct route operations within Singapore airspace, given its technological capabilities and that there are lesser conflicts, lesser emissions and better fuel efficiency in a direct route environment in comparison with current environment with existing ATS route structures.

II. Preparing 3D Airspace Model for DRO

Using data from SkyVector and Singapore AIP, the current structure of Singapore Airspace was modelled to establish the baseline as shown in Figure 1 below. The boundaries were slightly extended to capture waypoints slightly outside the airspace boundary. This is to facilitate better assignment of 4D flight profile when simulating direct routes. As the aim of transitioning from airspace to 4D trajectory management is to minimize thenumber of FIRs particularly along traffic flows, in this study, no sectors were modelled within Singapore airspace. This is to promote seamless operations which are not impeded by structural boundaries. As the transition is particularly expected to be done in the upper airspace, the 3D airspace was modelled with a vertical limit of FL 195 and above.

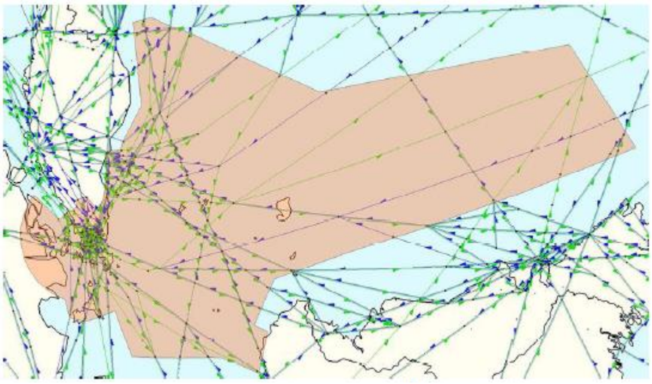

Figure 1. Current Airspace Model in 2D View.

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III. Simulating Current and Direct Routes

Assumptions and Technical Specifications

The following assumptions and specifications were followed, during the simulation process:

1. Optimum flight level was assigned to each aircraft based on BADA 3.4 and CFMU Aircraft Performance Data with the assumption of normal wind and weather conditions
2. Minimum Cruising Distance was kept at 50 NM. If the optimum profile did not meet this condition then the cruise flight level was automatically lowered.
3. Separation Minima criteria were assigned to follow the general Reduced Vertical Separation Minima (RVSM) of 1,000 feet to allow aircraft to operate closer to the optimum Flight Level.
4. No intermediate waypoints were simulated, except for last declared Standard Instrument Departure Routes (SIDs) and first declared Standard Terminal Arrival Routes (STARs)to the ATC-cleared FIX for arriving and departing aircraft within the Direct Route Airspace (DRA).
5. The randomization level of flight level allocation was set to be wide as shown in Table 1 below, to avoid having all equivalent flights (same City Pair, same aircraft) on the same level.This is done to improve the degree of realism.

Type	Same FL	1 FL Up	1 FL Down	2 FL Up	2 FL Down	3 FL Up	3 FL Down
Narrow	90%	5%	5%				
Medium	72%	10%	10%	4%	4%		
Wide	50%	15%	15%	8%	8%	2%	2%

Simulating Current Traffic Flow

Historical traffic data for Singapore airspace over 24 hours was used to establish the baseline for traffic flow. The data was obtained from Flightglobal INNOVATA and consists of scheduled flights. Using this, flight rules considering turn angle restrictions and extension validity were generated to simulate traffic flows along existing ATS route structure in Singapore airspace to represent current operations as much as possible. A total of 1606 4-Dimensional trajectories were then generated.

Simulating Direct Traffic Flow

Using the current traffic flow 4-D profile, a direct route alternative was generated for each trajectory by adding time and flight level elements, containing auto-generated segments between entry and exit points on our defined airspace boundary. For convenience, this defined airspace, which is FL 195 and above, shall be referred to as Direct Route Airspace (DRA) throughout this paper.

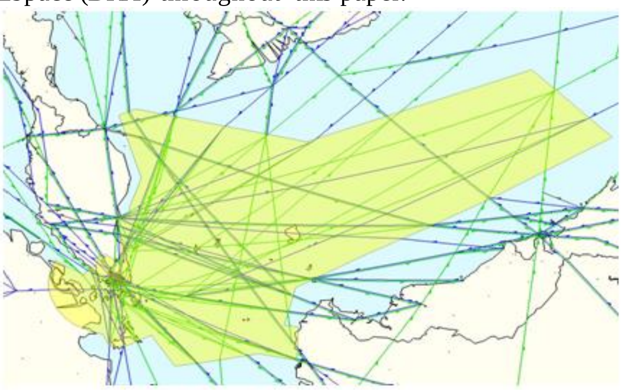

Figure 2. Direct Route Network With Parity.

Based on the direct trajectories generated, a direct route network was created, to serve as reference for ATC operations to allow aircraft to follow these direct routes. The generated direct route network can be seen in Figure 2, with green routes structures indicating odd Flight Levels and blue route structures indicating even Flight Levels.

IV. Examining Conflict Patterns

A vertical separation minima of 1000 feet and horizontal separation minima of 5 NM were set to identify the number of conflicts and their distribution in current and direct route environment.

Conflict Distribution

From figures 3 and 4, it can be seen that there is better conflict distribution in the direct route airspace, with reduced 'hotspots'.

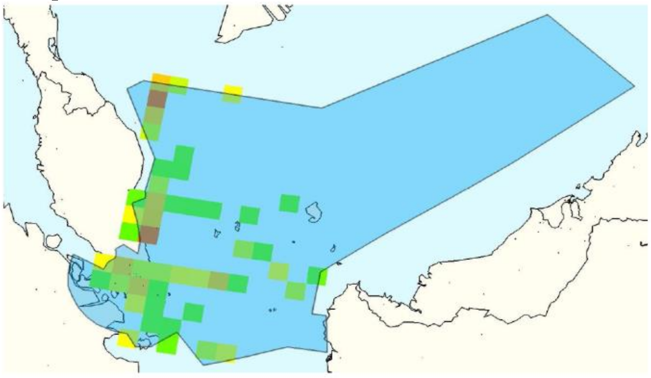

Figure 3. Conflict Distribution in Current Airspace.

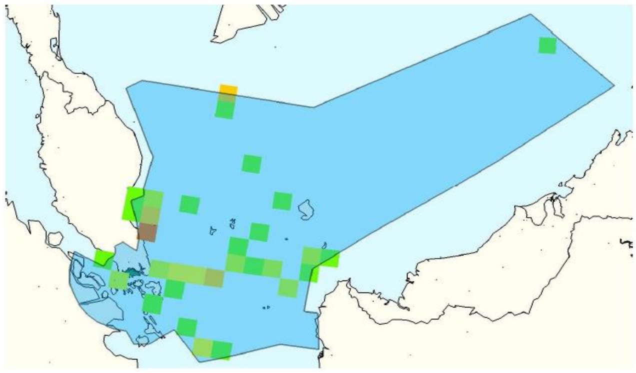

Figure 4. Conflict Distribution in Direct Route Airspace.

Results on Conflict Occurrence

The number of conflicts in the DRA was about 45% lesser in comparison with current airspace. The results are tabulated in Table I below.

Table I. Comaprison of Conflict Occurence in Current vs Direct Route Airspace.

Simulation Environment	Number of Conflicts
Current Airspace	148
Direct Route Airspace	81

V. Examining Aircraft Performance Output

Model for Estimating Aircraft NO_X and CO_2 Emissions

The approach used for estimating fuel consumption and $NO_X$and CO_2 emissions by the model we have adopted is summarized in Table II below [2].

TABLE II. Approach for estimating Fuel Consumption and Gas Emissions [2].

	Fuel Burn	NO_X	CO_2
Above 3000 ft Non-Landing Take-Off phases	BADA Data	Boeing Method 2	Proportional to Fuel Burn

Fuel consumption is estimated based on the aircraft-engine characteristics provided in the Base of Aircraft Data (BADA) for different aircraft [2]. The formula for estimating total gas emissions based on EUROCONTROL's Advanced Emission Model, which is an improvisation to the original Boeing Method 2 model, is provided as [3]:

$$\text{Total (HC, CO, NOx)} = N \times \Sigma_i (\text{EIHC, EICO, EINOX})_i \times Wf_i \times t_i \times 10^{-3} \quad (1)$$

Where,
N = Number of Engines;
EIHC= Emission Index of HC;
EICO= Emission Index of CO;
$EINO_X$ = Emission Index of NOx;
Wf = Fuel Flow;
t= Time [3]

Thus, the model for calculating total NO_X emissions could be simplified from equation (1) as [3]:

$$\text{Total (NOx)} = N \times \Sigma_i(\text{EINOx}) \times Wf_i \times t_i \times 10^{-3} \quad (2)$$

The emission index for CO_2 is 3,149 kg/kg fuel. This emission index will be constant for all flight phases, as CO_2 is proportional to fuel burn [4].

Results on Aircraft Performance Output

Table III shows that with direct route implementation there could be huge savings in fuel burn and significantly lesser aircraft emissions.

Table III. Comaprison of Aircraft Performance Output in Current vs Direct Route Airspace.

Length (NM)	Time (Hours)	Fuel (t)	CO_2 (kg)	NO_X (kg)
4,483	10	31.4	99,232	433

VI. Examining Macroscopic Controller Workload

Macroscopic Model for Estimating Workload

The macroscopic workload model adopted for the experiment is determined by an analytical formula that comprises of three main components. These three components are the aircraft entry rate, conflicting tasks and de-conflicting tasks [5], [6] & [7].

$$Wkl = C*p1+SHER*p2+Avg*p3 \quad (3)$$

Where,
- C denotes number of conflicts
- SHER is Sliding Hourly Entry Rate
- Avg is the average time in the sector in minutes
- p1, p2 and p3 are constants.

SHER is the Sliding Hourly entry rate,providingthe number of flights entering a sector every hour.

The entry time centering value was set as 0, so that aircraft will be started to be counted only at its entry time.

Results on Contoller Workload

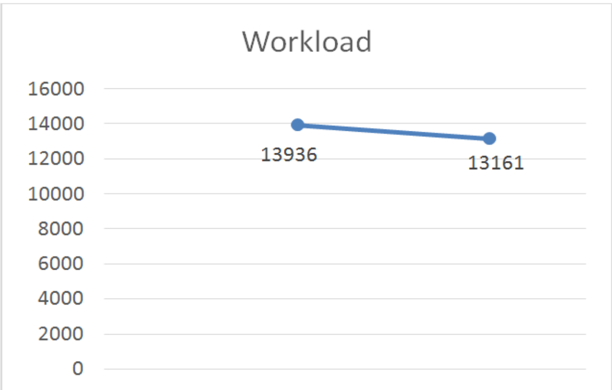

Figure 5. Controller Workload Current Vs Direct Route Airspace.

Figure 5 above shows that in the direct route environment, there was a reduction in the controller workload. This should be due to the reason that the simulations indicated lesser conflicts and lesser time spent in the sector.

VII. Conclusion

This paper presented a case study conducted for Singapore Airspace, to quantify the potential benefits of implementing direct route operations within its airspace. The results suggested that in a single day, about 31 tonnes of fuel could be saved, which translates to 16,049 USD. There was also a reduction of nearly 99,000 kg of CO_2 emissions and 400 kgof total NO_X emissions in a day. A macroscopic estimation of controller workload also indicated reduction in the direct route airspace. This could be due to the reason that the total number of conflicts reduced by 45% in the direct route airspace.

Given the necessary equipment and technology management, direct route operations can help to improve the traffic operations in many of the airspace facing demand-capacity imbalance in the ASEAN region. Regional collaboration is essential for the implementation of seamless direct route operations over the entire ASEAN airspace, regardless of Flight Information Region boundaries.

Acknowledgment

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References

[1] Airbus S.A.S. "Airbus Global Market Forecast 2015-2034." 2015,[Online]. Available: http://www.airbus.com /company/market/forecast/

[2] Jelinek, F., Carlier, S., & Smith. J. *"The Advanced Emission Model (AEM3) -Validation Report."* 2004, [Online]. Available: http://www.eurocontrol.int/sites/default /files/library/016a_AEM_Validation.pdf

[3] Jelinek, F., Carlier, S., Smith, J., & Quesne, A. *"The EUR RVSM implementation Project-Environmental Benefit Analysis."* EUROCONTROL Experimental Centre, 2002, [Online]. Available: http://www.eurocontrol.int/sites/default /files/library/023_RVSM_Implementation_Project.pdf

[4] Celikel, A., & Jelinek, F. *"Forecasting Civil Aviation Fuel Burn and Emissions in Europe."* EUROCONTROL Experimental Centre, 2011. [Online]. Available: http:// publish.eurocontrol.int/eec/gallery/content/public/document/eec/report/2001/015_Forecasting_Fuel_Burn_and_Emissions_in_Europe.pdf

[5] Eurocontrol. *"Comparison of Different Workload and Capacity Measurement Methods Used in CEATS Simulations, Comparison of SAAM 3; FTS 3, SSRTS3 and CEATS 2007 UAC Capacity."* EUROCONTROL CEATS Research, Development and Simulation Centre, Budapest, Hungary, 2007.

[6] Trandac, H., Baptiste, P., & Duong, V. *"Optimized Sectorization of Airspace with Constraints."* Heudiasyc Laboratory, UMR CNRS 6599, University of Technology of Compiègne, Centre de Recherches de Royallieu, BP 20529, F-60205 Compiègne cedex, France; EUROCONTROL Experimental Centre, Centre de Bois des Bordes, BP15, F-91222 Bretigny sur Orge cedex, France, 2003.

[7] Vergne, F. *"Model Simulation of Czech Republic Airspace, EEC Note No. 5/99, Project SIM-F-E1 (F24)."* ATM Operational & Simulation Expertise, EUROCONTROL Experimental Centre, Bretigny-sur-Orge CEDEX, France, 1999.