International Journal of Engineering & Technology, 7 (4.25) (2018) 1-4

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Preliminary Study on Air Traffic Density of Peninsular Malaysia using Visual Flight Path Trajectories from Automatic Dependent Surveillance-Broadcast (ADS-B) Data

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Abstract

Automatic Dependent Surveillance-Broadcast is an alternate method of providing aircraft position data, which aircraft continually transmit their identity and navigational information. Such signals are received by ground station and relayed to Air Traffic Services and used to supplement radar data. The information can also be received by other aircraft and the nearby traffic. In this study, the ADS-B data was collected from a known website in order to investigate the movements of aircraft flying over Peninsular Malaysia's airspace by plotting the trajectories of flight path based on its flight ID, latitude, longitude, and altitude information. From flight trajectories and flight path of all collected data, the density and flow of air traffic from the ADS-B system for Peninsular Malaysia can be visualized.

***Keywords**: Automatic Dependents Surveillance-Broadcasts (ADS-B); Air Traffic Density; Traffic Management; Secondary Surveillance Radar (SSR); Visual Flight Path Trajectories*

1. Introduction

Traffic density is an approach to studying the traffic flow and predicts its behavior in future time horizons. The definition of traffic density is relative to the traffics existence domain in the space or area as a time-varying high-level view of travel. Air traffic density is introduced as an effective tool for identifying the safety and the efficiency of air traffic [1]. Furthermore, air traffic density refers to the degree of congestion and offers a time-varying high-level view of traffic in a sector of airspace. Due to the rapid increases in air traffic, this study is interested in the flow of multiple aircraft traveling within a given time horizon in a region of Peninsular Malaysia airspace. Another type of traffics density is related to vessels or ships traffic density on waterways or sea [8].

Malaysia airspace is divided into two Flight Information Regions (FIR); Kuala Lumpur FIR and Kota Kinabalu FIR and under the administration of Department of Civil Aviation, Malaysia [2]. Peninsular Malaysia falls under Kuala Lumpur FIR covering the area of Malaysia northern border with Thailand, southern border with Singapore, western border with Indonesia and India.

Peninsular Malaysia airspace is one of the busiest air traffic routes in Asia. Although the destination and origin were not from Kuala Lumpur International Airport (WMKK/KUL), all traffic that entering this airspace has contributed to density and congestion in the Peninsular Malaysia airspace

In this study, using the collected ADS-B data, each aircraft that entering peninsular region was tracked and its path or trajectories was plotted. From the plotted trajectories, we will know any point or place that is considered as congested or heavy traffics by looking into the dense of the plotted trajectories. This study will also look into the traffics by the altitudes or aircraft flight level (FL) to identify at which level the traffic are congested most.

Fig. 1: South East Asia Flight Information Region (FIR) and Kuala Lumpur FIR [2]

2. Background

2.1. Primary Surveillance Radar and Secondary Surveillance Radar

Procedural air traffic control, primary radar surveillance and secondary radar surveillance have been used by the surveillance system of national airspace on the present moment. Procedural air traffic control is a dependent surveillance technique, which requires pilots to report their positions using voice channels (e.g., HF and VHF), a technique that is slow, cumbersome and prone to human error [7].

Air Traffic Services (ATS), including Air Traffic Control and other entities, carried such a big responsibility to manage the air traffic in such a way as to prevent the collisions between aircraft. This is termed the provision of 'separation' [12]. ATS relies on the information of aircraft position in a given parcel of airspace in order to provide this service. Historically, ATS has relied on radar surveillance to provide this position information [3].

2.2. Automatic Dependent Surveillance-Broadcasting (ADS-B)

Automatic Dependent Surveillance-Broadcasting (ADS-B) categorized as Secondary Surveillance Radar (SSR) and is a surveillance technology which allows aircraft to broadcast identification, state, and position information to neighboring aircraft and nearly ground system [10]. ADS-B enhances air traffic control situation awareness, collision avoidance, surface runway incursion avoidance and air traffic control in non-radar environments. Currently, ADSB is being implemented in Europe and other areas worldwide (Asia, Australia, Canada, USA).
ADS-B systems provide air traffic information for surveillance purposes [11] using the 1090 MHz mode S signals [4]. The airborne transponders with ADS-B capabilities transmit periodically several information about the flight status including identity, 3D position (latitude, longitude, and height), and also velocity vector [9] as illustrated in Figure 2.

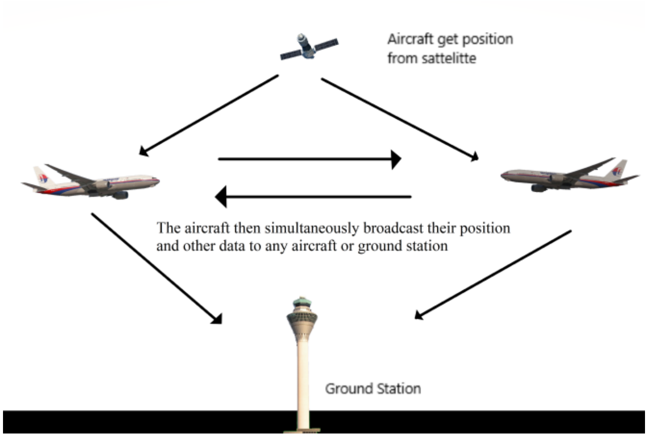

Fig. 2: ADS-B basic concept

Increased accuracy of an ADS-B will allow tighter aircraft separation standards, higher probability of clearance requests and enhanced visual approaches, all of which will contribute to greater aircraft throughput [7]. Moreover, more direct routings and optimized departures and approaches can be accomplished with ADS-B. These will contribute to the increase in capacity as well as save time and fuel. Finally, the ADS-B infrastructure relies on simple radio stations that are significantly cheaper to install and maintain than the mechanical infrastructure associated with traditional ground-based radar [6].

3. Methodology

As a preliminary study, this study only collects data using freely available data for Peninsular Malaysia from the internet. Most of the data are provided by the anonymous user that share their data collected by the own receiver. The information obtained is used to plot the flight paths trajectories of all of the flights flying over Peninsular Malaysia airspace that equipped with the ADS-B transponder. As a preliminary study and due to the size of the data collected, this study only collected data for 7 days to represent the day in a week. A computer application or program was developed to enable data being collected by running during this period on a dedicated workstation or PC. All data that was collected was saved into a database and therefore the analysis was done by extracting and analyzing all collected data from the database. We grouped the traffics into 4 flight level;

a) Flight level of 0 to 10,000 feet
b) Flight level of 10,000 to 20,000 feet
c) Flight level of 20,000 to 30,000 feet
d) Flight level of 30,000 feet and above

The collected data covered flight movement for almost all airspace of Peninsular Malaysia. Due to the high volume of data and numbers parameters received, this study only focused on the particular time frame which are from 7th April 2015 to 13th April 2015 for 24 hours in order to do the trajectories of air traffic density based on the latitude, longitude and also altitude.

4. Results

4.1. Data Analysis

The dataset contains information about all the flights over the Peninsular Malaysian Airspace in a week such as a latitude, longitude, and altitude of different aircraft. Each aircraft is identified by their unique ICAO number. It includes all flight path information from flights that took place over an area of altitude between 0 and 50,000 feet and group into 4 group of flight level

4.2. Trajectories of Air Traffic Density

The data that was collected comprised of uniquely identified flight paths, each containing latitude and longitude information for the duration of flight within the area of interest. The path of the flights is colored differently to indicate the overlapping segment.
The aircraft surveillance data was also analyzed to determine the altitude distribution. The results in Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7 show the altitude distribution of aircraft. Since ADS-B transponder are only mandatory General Aviation (GA) aircraft which are mostly passenger aircraft, no data and trajectories was recorded for small aircraft.

4.2.1. Trajectories of 0 to 10,000 feet

Figure 3 shows the trajectories of altitude distribution for flights path between 0 to 10,000 feet. This distribution indicates that most are the low-level flights and are concentrated within the region of Kuala Lumpur International Airport (KLIA/KUL) and Subang Sultan Abdul Aziz Shah (SAAS/SBZ) airports. Based on the analysis, most of the flights are either take off from or landing to KLIA and Subang airports. Furthermore, this trajectory also shows the flights have undergone the transition of altitude from the take-off to cruising altitude or from the cruising altitude to landing. In addition, most of the ADS-B data was contributed by volunteers with their receiver is located very near to airport especially KUL and SBZ. Therefore, very least data or almost no data received for other airport like Penang Airport and Johor Bahru Airport.

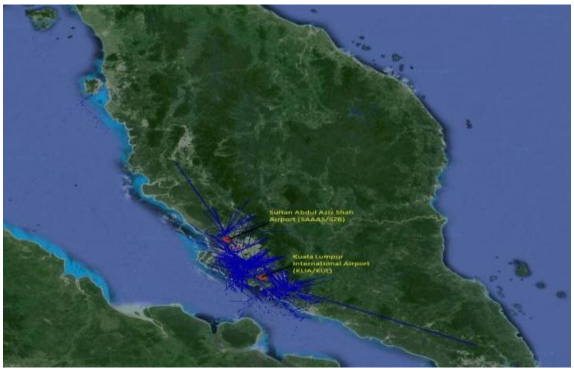

Fig. 3: The flight's path at 0 to 10, 000 feet

4.2.2. Trajectories of 10,000 to 20,000 feet

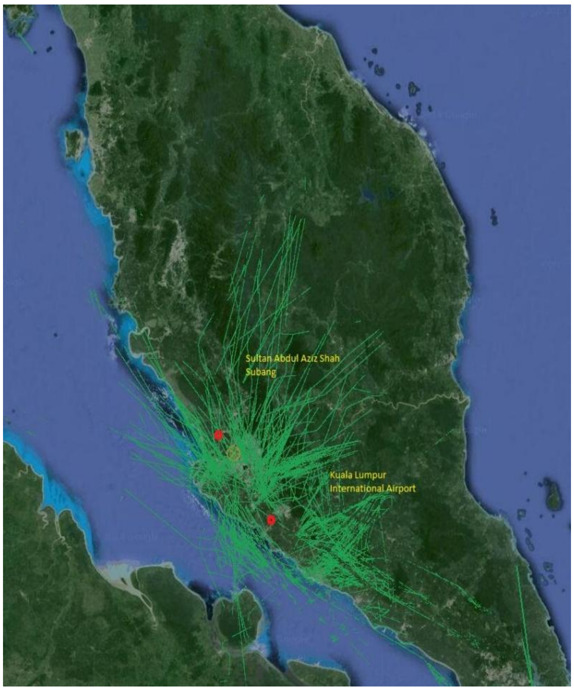

Fig. 4: The flight's path at 10,000 to 20,000 feet

Figure 4 shows the trajectories of altitude distribution of flights path at 10,000 to 20,000 feet. The distributions are also mostly dense at KLIA and Subang airports. The Higher density of the flights concentrated at both of the airport's regions can be seen to involve the transition of altitude from the take-off to cruising on a higher level and from cruising altitude to landing. Moreover, this altitude distribution also shows the holding position or circling point of the aircraft before landing. The holding position or circling point referring to the condition of which the aircraft are waiting to enter the queue for landing during the peak hour or the busy arrival time.

4.2.3. Trajectories of 20,000 to 30,000 feet

Figure 5 shows the trajectories of measured altitude distribution of flights path at 20,000-30,000 feet. The distribution indicates the cruising altitude for low-level aircraft, especially the domestic short haul flights. Besides, the flight's range can be observed from the distribution of altitude. Dense flight's path is observed to the east for Kuala Lumpur to Kuantan, north-east of Kuala Lumpur to Kota Bharu or Kuala Terengganu and south or southeast for Kuala Lumpur to Johor Baharu and Singapore. This trajectory also shows a transition altitude for higher level traffic. There are no traffics observed within KLIA region.

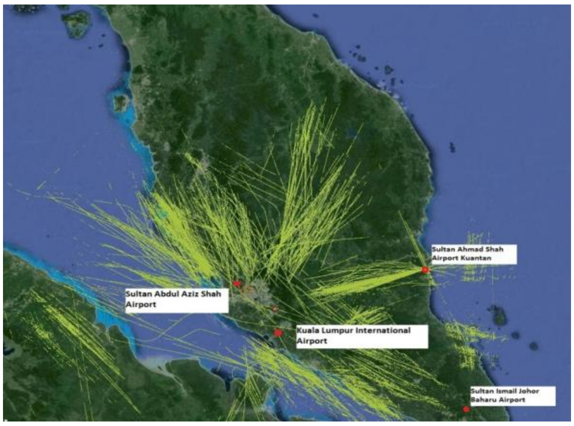

Fig. 5: The flight's path at 20,000 to 30,000 feet

4.2.4. Trajectories of 30,000 feet and above

Figure 6 shows the trajectories of flights path at 30,000 feet and above. Above 30,000 feet, the flight's path is seen to be mostly long-range or long-haul international flights. From the figure, the traffics are dense within west coast or Peninsular Malaysia covering KLIA and Subang airport. Most of these flights are international en route flight. Meanwhile, the traffics are considered to be less dense in the area of East Coast of Peninsular Malaysia and also from or to Singapore.

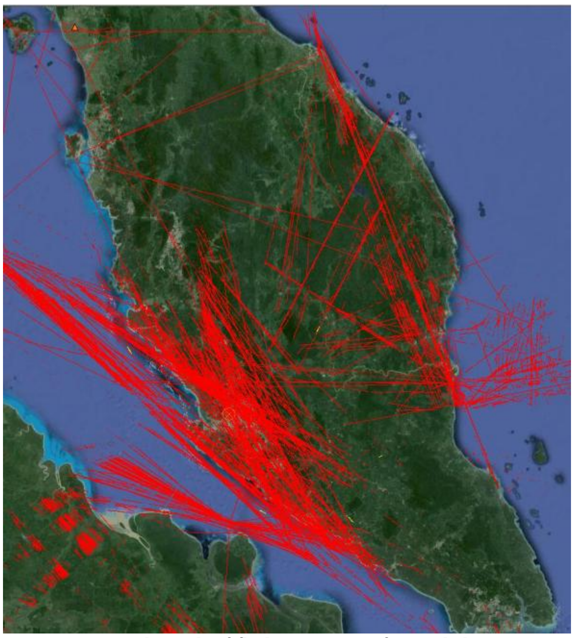

Fig. 6: The path of flights at 30,000 feet and above

Figure 6 shows the combination of all trajectories for altitude distribution of ranges between 0 feet to 10,000 feet, 10,000 feet to 20,000 feet, 20,000 feet to 30,000 feet and also 30,000 feet above. All feet are overlaid into a single image and hence indicates a unique distribution of the flight's path based on their respective altitude. The path of the flights is colored differently to indicate the overlapping segment of the entire flight's path. From this figure, we can see that aircraft traffic route is using almost all airspace of Peninsular Malaysia. The most congested airspace are around Kuala Lumpur International Airport

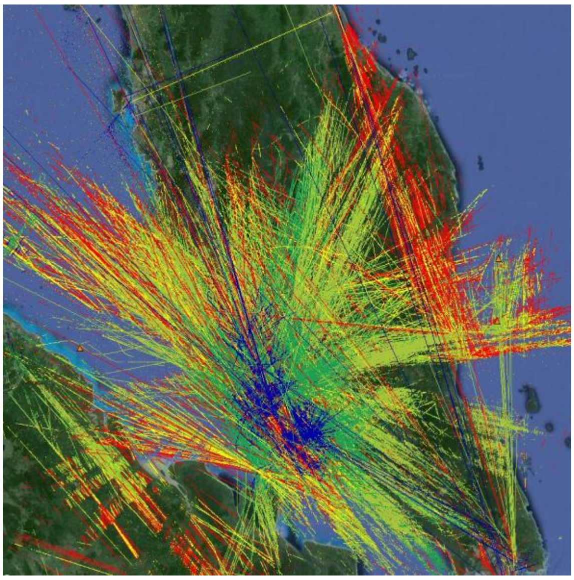

Fig. 7: The combination of recorded altitude distribution flight path

4.3. Total Number of Flights

4.3.1. Daily Flights

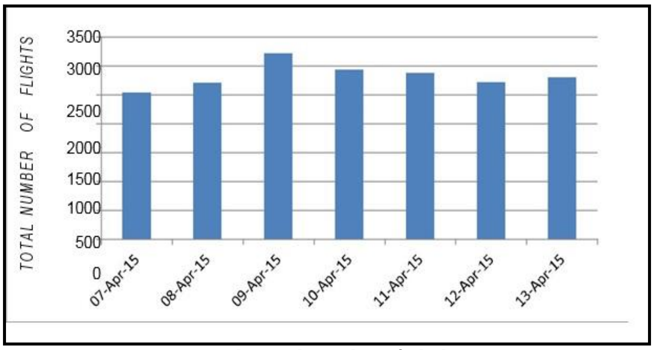

Fig. 8: Daily Total Number of Flights

From the figure 8 above, after a week the data was collected, it shows that 9th April 2015 was the highest value of the total number of flight. Then, follow by 10th April 2015 and 11th April 2015. Meanwhile, 07th April 2015 has the lowest value of a total number of flights compared to 8th April 2015, 12th April 2015 and 13th April 2015. The average of the total number of flight for a week is in a range of 2000 to 3000 per day.

4.3.2. Hourly Flights

From figure 9, the flows of air traffic movement for 9th April 2015 by the total number of flights are observed to be dramatic dropped between 12 am until 5 am, averaging about 20 to 70 flights reported from the data collection. The numbers of flights are starting to increase at 6 am until 10 am. Then, the numbers of aircraft are observed to start decreasing slowly after 10 am before increasing again at 1 pm. The increasing rates for the number of flights are continuously observed until 5 pm, averaging about 100 to 250 flights reported from the data collection. But, after 6 pm the total number of flight observed to be dramatic dropped again until 11 pm. The peak hour of air traffic on this day can be clearly observed at 5 pm.

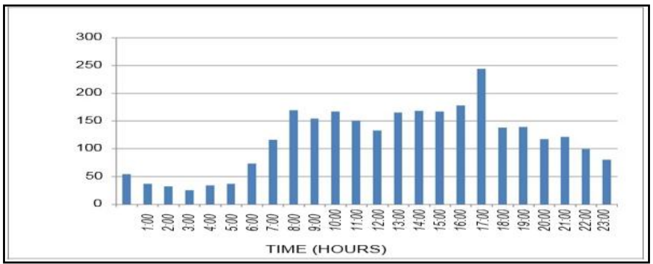

Fig. 9: Hourly total number of flights for 9th April 2015

5. Conclusion

ADS-B is a system in which latitude-longitude information is broadcasted regularly by aircraft so that receivers on the ground and in other aircraft can determine the presence and accurate locations of the transmitting aircraft [13]. ADS-B transmission also broadcasts the information of altitude, velocity, flight identity and a number of items considered as optional information.

5.1. The Trajectories of Air Traffic Density by Latitude and Longitude

The trajectories-plot of latitude-longitudinal in Figure 6 indicates a very dense air traffic density in the region of KLIA and Subang airport. Most of the flight path can be observed either to be the take-off from or the landing to the KLIA and Subang airport. There are also a few flight path can be seen either flying to or coming from Singapore airspace and also Jakarta airspace.

5.2. The Trajectories of Air Traffic Density by Altitude

The recorded altitude-distribution specifies that altitude between 0 and 10,000 feet is the most common altitude, where most of the aircraft are flying. Higher altitude aircraft are approximately uniformly distributed between 10,000 feet and 40,000 feet. Above 30,000 feet, the flight path is considered to be mostly long range haul or international flights.

5.3. Recommendation

Due to the size of the data and a lot of parameters of the ADS-B data that were collected, the computer software that was used was unable to process all of the data collected. Therefore, software with the better capability to analyze the high volume of data and also a computer with higher computing power and higher volume capacity are strongly recommended for further investigations and for a longer time frame. 3D and 4D trajectories, and also simulations are also possible if enough data are collected. Prediction of air pollution due to aircraft exhausts emission and also prediction of turbulence from ADS-B data are also possible. Collaborations with government department and agencies such as Department of Civil Aviation (DCA) of Malaysia and also Ministry of Transport (MOT) will also help the investigation on air traffic density of Malaysia to be much more relevant.

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