GROSTLOG 2019
Global Research on Sustainable Transport & Logistics

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

An Evaluation of Airspace Congestion: A Case of Peninsular Malaysia

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Abstract. Airspace may look like a vast and limitless area. However, without proper airspace management, the airspace can be congested and saturated, and future air traffic movements will be affected. This paper seeks to understand the airspace congestion level in Peninsular Malaysia. There is no known research published to evaluate the airspace congestion and the structure of Kuala Lumpur Flight Information Region (KLFIR). In this paper, the structure of Malaysian airspace by looking into the categorisation of the airspace and aircraft separation standards, the flight movements and the effects of airspace congestion are being investigated. Data are collected through observation at the Air Traffic Control Centre of KLFIR and unstructured interviews with the Air Traffic Controllers. Based on the sectoral analysis of the data, it is found that Sector 2 of KLFIR is the busiest sector and recommends for the restructuring of the flight information region of Peninsular Malaysia for efficient air traffic management and to cater for future air traffic growth.

Keywords: airspace, kuala lumpur flight information region, air traffic control centre

1. Introduction

Airspace is an area at the atmosphere that is controlled by a country above its territory, including water territorial [1]. International Civil Aviation Organisation (ICAO) has categorized the airspace into two basic categories namely, controlled airspace and uncontrolled airspace. The distinct difference between these two airspaces is in the type of air traffic services provided. In controlled airspace, the air traffic services provided are Alerting Services, Air Traffic Control Services, and Flight Information Services. While in uncontrolled airspace, the Air Traffic Control services are not provided but Flight Information Services and Alerting Services are still being provided.

Airspace congestion is a situation relates to the inability of current airspace to conduct a smooth flow of traffic management due to increasing demands. Airspace congestion occurs when flights are close to each other as the four-dimensional airspace reaches its capacity limits [2]. In most cases, the airspace will be congested at certain areas with high flight density. Countries around the world are finding ways to solve the congestion issue as it could bring many negative effects to the safety and operation of flights.

There is no specific way to prove the airspace congestion apart from observing the traffic growth of aircraft movements. However, another alternative to evaluate airspace congestion is by analysing the number of aircraft landings and taking offs at the main airport per hour. As an example, in Kuala Lumpur International Airport (KLIA) the maximum capacity in handling the flights taking off and landing is 84 aircraft per hour. If the number exceeds, hence it is considered that the airspace is congested.

This research seeks to understand the airspace congestion in Peninsular Malaysia, firstly by examining the structure of Malaysian airspace, and then look into the air space categorisation, aircraft separation standards, analysing the flight movements and evaluate the airspace congestion level.

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2. Structure of Malaysian Airspace

The global airspace is a vast area where diverse airspace users are present; military, leisure, commercial, cargo and many more. The airspace around this world is divided according to Flight Information Regions (FIR). Flight Information Region is assigned airspace of defined dimensions within which Air Traffic Service is provided.

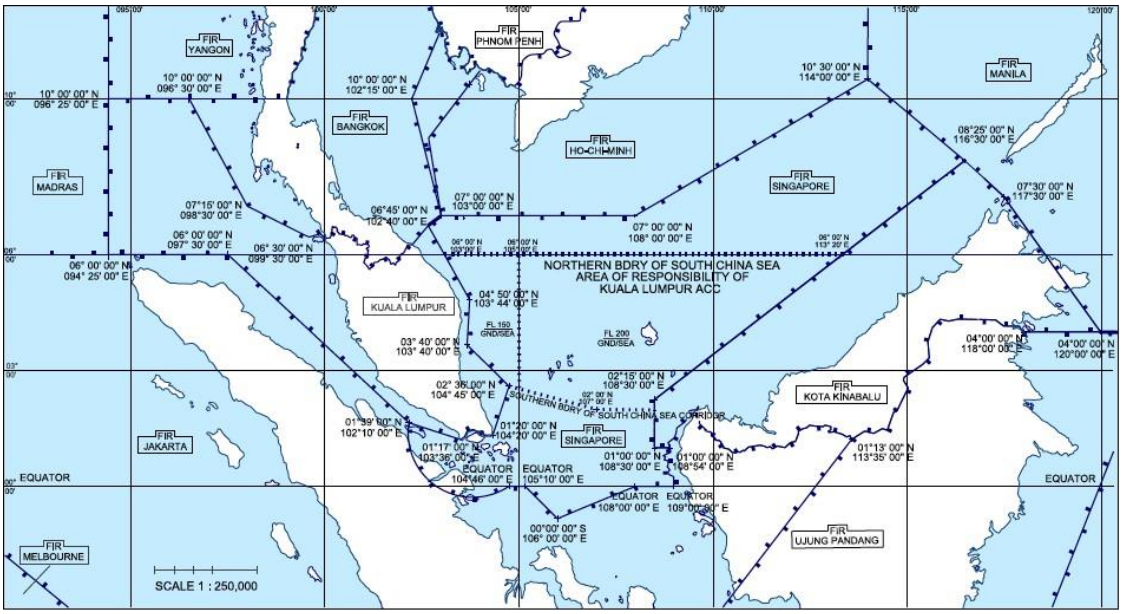

Figure 1: Malaysian Flight Information Regions
(Source: Civil Aviation Authority Malaysia)

Figure 1 illustrates the Flight Information Region (FIR) in Malaysia. The Malaysian airspace is being divided into two FIRs which are Kuala Lumpur Flight Information Region (KUL FIR) and Kota Kinabalu Flight Information Region (BKI FIR). To avoid conflicts and better monitoring of flights the airspace is divided into sectors that are being controlled by the human controller [3]. Within an FIR, the airspace is further divided into areas of all different shapes, sizes and type of airspace that is called sectors. For efficient control of air traffic movements, Civil Aviation Authority Malaysia (previously known as Department of Civil Aviation) has sectorized KUL FIR into a total of 7 sectors and for Kota Kinabalu FIR, it is being divided into 5 sectors controlling the air traffic movements in the Borneo area.

The Kuala Lumpur Flight Information Region (KUL FIR) has been assigned to Peninsular Malaysia. It is home to 12 airports comprised of international and domestic airports. Apart from having to handle 12 airports, one of the routes, KUL-SIN under this FIR has also been recognized as No.1 World's Busiest Route based on the report made by OAG Aviation Worldwide (2018) [4]. Kuala Lumpur Flight Information Region (KUL FIR) is sectorised as follows (Figure 2):

- Sector 1
  The Area of responsibility for Sector 1 consists of controlled airspace and outside controlled airspace above FL 145 until FL 325. Sector 1 covers the area of routes heading to Thailand And Cambodia

- Sector 2
  The Area of responsibility for Sector 2 consists of controlled airspace and outside controlled airspace above FL 145. The airspace of Sector 2 covers the southward area

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Advances in Transportation and Logistics Research
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of peninsular. The flights that use these routes are mainly heading towards Singapore, Jakarta, and Australia

- Sector 3
  The Area of responsibility for Sector 3 consists of controlled airspace and outside controlled airspace above FL 145. Sector 3 covers the area of routes heading towards West Malaysia and Brunei. Sector 3 is also responsible for the provision of FIS and Alerting Service in the South China Sea Corridor.

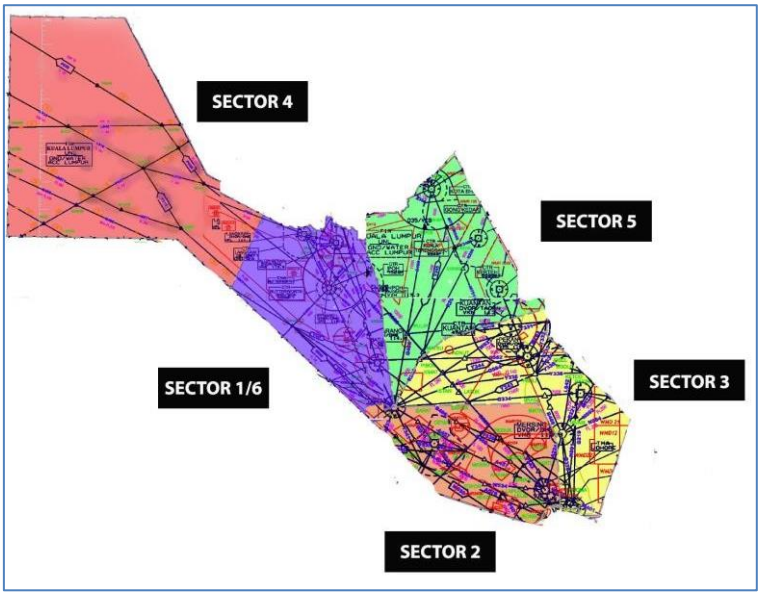

Figure 2: Sectors in KUL FIR
(Source: Civil Aviation Authority Malaysia)[6]

- Sector 4
  The Area of responsibility for Sector 4 consists of controlled airspace and outside controlled airspace above FL 145. The area covers the westward airspace until the FIR Boundary to Tasek. The airspace is highly concentrated for flights flying to Europe, UAE and India.
- Sector 5
  The Area of responsibility for Sector 5 consists of controlled airspace and outside controlled airspace above FL 145. Sector 5 covers the airspace of eastwards of Peninsular Malaysia. Flights that travel to Sector 5 are usually bound to Korea, Japan, Taiwan or China.
- Sector 6
  The area of responsibility in Sector 6 shares the same Area Of Responsibility (AOR) with Sector 1 except that it covers the upper level from FL 325 until FL 460.

3. Categories of Airspace

International Civil Aviation Organisation (ICAO) has categorized the airspace into two basic categories namely, controlled airspace and uncontrolled airspace. The distinct difference between these two airspaces is in the type of air traffic services provided. In controlled airspace, the air traffic services provided are Alerting Services, Air Traffic Control Services, and Flight Information Services. While in uncontrolled airspace, the Air Traffic Control services are not provided but Flight Information Services and Alerting Services are still being provided.

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Under each FIR of state, it contains both controlled and uncontrolled airspace. For each category of airspace, it can be further narrowed down into a few classes. In Malaysia, the airspace classifications for controlled airspace are Class A, Class B, and Class C. As for the uncontrolled airspace, only Class G is available in Malaysia. Further details characteristic of the classes of the airspace as according to the AIP are as follows:

Table 1: Airspace Classes (*Source: ICAO*)[6]

Airspace Class	Definition
Class A	Only Instrument Flight Rules (IFR) Flights are permitted to fly. All flights in operation are subjected to air traffic control and are being separated from each other.
Class B	Instrument Flight Rules (IFR) Flights and Visual Flight Rules (VFR) Flights are permitted to fly. All operating flights are subjected to air traffic control service and are separated from each other.
Class C	Both IFR and VFR Flights are permitted to fly and subjected to an air traffic control service. IFR Flights are separated from other IFR Flights and VFR Flights. VFR Flights are separated from IFR Flights and receive traffic information in regards to other VFR Flights
Class G	Both IFR and VFR flights are permitted to fly and will receive flight information services upon request.

4. Aircraft Separation Standards

Generally, airspace is also being divided vertically and horizontally as depicted in Figure 3 and 4. The vertical Separation can be measured in height, altitude, or flight level. For aircraft flying above FL 290, the vertical separation is 2000 feet while for aircraft flight below FL 290 the separation would be 1000 feet vertically [5]. However, for areas where Reduced Vertical Separation Minima is applied, the separation between aircraft would be 1000 feet for aircraft flying between FL290 until FL 410.

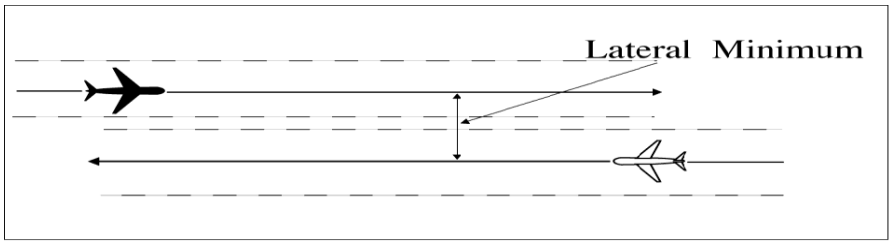

Figure 3: Lateral Separation on different routes
(Source: Civil Aviation Authority Malaysia)[6]

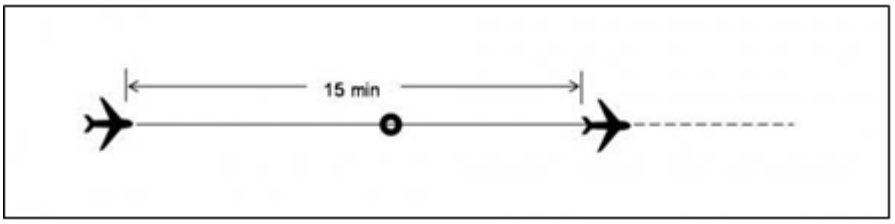

Figure 4: Longitudinal separation expressed in time
(Source: Civil Aviation Authority of Malaysia)[6]

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As for horizontal separation, according to ICAO (2001) [7], Annex 11 aircraft can be separated through longitudinal separation and lateral separation. For longitudinal separation, it can be done by maintaining an interval expressed in time or distance between aircraft operating along the same, converging or reciprocal tracks. To separate as according to longitudinal separation the Air Traffic Controllers (ATC) must take into account the size and wake turbulence of the aircraft. As for lateral separation, it is separation by maintaining aircraft on different routes or in different geographical areas [7].

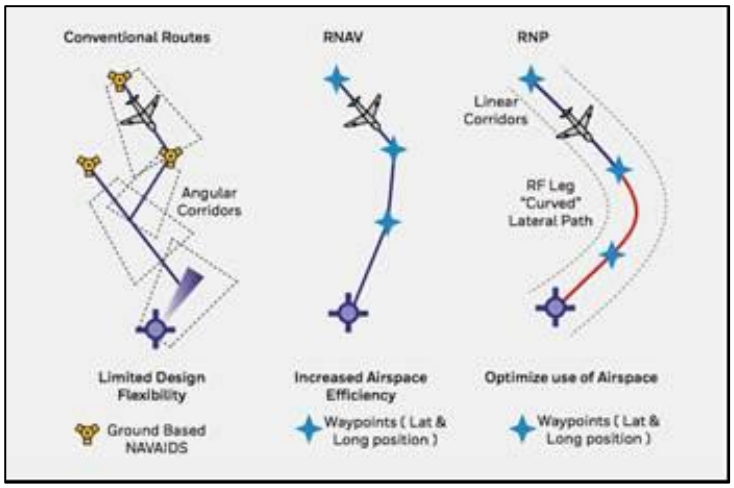

Figure 5: Performance-Based Navigation Systems
(Source: Civil Aviation Authority Malaysia)[6]

Another two types of separation that are being used by ATC are through Area Navigation System (RNAV) and Required Navigation Performance (RNP) equipment (Figure 5). The RNAV works by enabling aircraft to fly on any desired flight path made up of waypoints in accordance with the flight plan rather than constrained to an airway. RNP, on the other hand, provides onboard navigation capability that allows crews to fly aircraft along a precise flight path with exceptional accuracy and ability to determine the aircraft position accurately. The main difference between RNP and RNAV is that RNP navigation specifications for monitoring and alerting will be activated when the system does not perform the way it should be. With these two performance-based navigation system, more aircraft can fly simultaneously at the same level in safe separation standards, saving fuel and also time.

5. Air Traffic Flow Management (ATFM)

Apart from the normal separation standards, another system that is being used for efficient coordination of air traffic across FIR is Air Traffic Flow Management System [8]. In Malaysian Airspace, the ATFM is being used for planning the traffic flow to achieve optimum use of available airspace and runway capacity at the airport [9]. An example of the use of ATFM system can be seen from the sequencing order of the arrival aircraft at KLIA (KUL) and Subang (SZB) airports. Generally, the flow control sequencing action will include speed control, radar vectoring and holding of aircraft.

6. Data Analysis and Discussion

In order to understand the airspace congestion level in Kuala Lumpur Flight Information Region (KUL FIR), the data of overall aircraft movements were collected and sorted based on sectors and analysed.

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6.1 Aircraft Yearly Movements Trend in KUL FIR

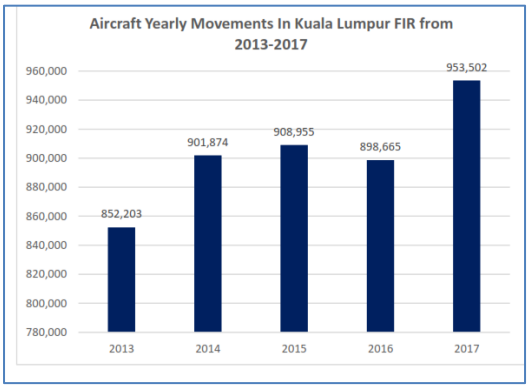

Figure 6: Aircraft Yearly Movements in KUL FIR from 2013-2017

As shown in Figure 6, it is observed that the number of aircraft movements has grown over the years with the addition of fleet and destinations by the Air Carriers inside the country itself. According to the financial report of Air Asia, in 2017 [10] the low-cost carrier had a total fleet of 116 as opposed to only 77 in 2016. With the increase in the number of aircraft in the fleet, it has resulted in a higher number of aircraft movements. In addition to this, based on Economic Report 2018 [11] published by the Ministry of Finance Malaysia, the air transport segment has expanded largely in international passenger movements due to competitive fares offered by airlines.

The number of aircraft movements in 2017 had also risen drastically due to route activities. Kuala Lumpur FIR is home to the world's busiest air route KUL-SIN [4]. This route alone contributed 30,537 aircraft movements and operated by 7 air carriers that include Air Asia, Malaysia Airlines, Singapore Airlines, Scoot, Silk Air, Jetstar, and Malindo Airways. These high flight frequencies had contributed to the increase in a number of aircraft movements for 2017.

The increase in demand for air cargo has also contributed to an increase in air traffic movements in Malaysia. Air cargo has rebounded to 8.4% which previously was -14.7% in 2016 due to stronger trade activities inside Malaysia [10]. These had led to the increased aircraft density in the Kuala Lumpur Flight Information Region.

6.2 Aircraft Overfly Movement Trend in KUL FIR

The aircraft overfly pattern is important to be observed because it represents the movement of upper airspace inside the FIR. The trend of overflying pattern is presented below:

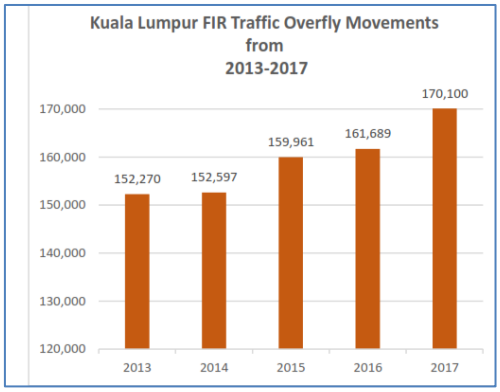

Figure 7: KUL FIR Traffic Overfly Movements from 2013-2017

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As can be seen from the graph presented in Figure 7, the overfly movements has been increasing every year from 152,270 aircraft movements in 2013 to 170,100 aircraft movements in 2017. These increasing aircraft overfly trend also suggests increasing aircraft density in KUL FIR. It shows that there is a strong possibility of an increase in aircraft movements in the coming years. This is supported by IATA report *Southeast Asia Economic Outlook* [12] whereby it stated that air travel demand forecasts robust for Asia with an approximate increase of 360 million passengers in 2026. Increase in movements of upper airspace will result in congestion as aircraft prefer to fly at higher altitudes for faster movement due to less drag and to reduce fuel usage as at higher altitudes, less carbon dioxide is present to burn fuel.

6.3 Aircraft Monthly Movements

From the annual aircraft movements above, it is important to examine the breakdown of the aircraft movements on a monthly basis to understand the monthly trend. The monthly movements are tabulated in Table 2. Table 2 shows data on Aircraft Monthly Movements at Kuala Lumpur FIR from 2013 until 2017. From the table above, it can be seen that the pattern of the highest aircraft movements in a month alternates between March and December every year. This is due to during the odd years (2013, 2015 and 2017) the movements were highest in March as Langkawi International Maritime and Aerospace Exhibition (LIMA) was held.

Table 2: Aircraft Monthly Movements at KUL FIR from 2013 until 2017 (Source: Civil Aviation Authority Malaysia)

MONTH	YEAR				
	2013	2014	2015	2016	2017
Jan	69,913	75,791	79199	75,045	77,086
Feb	60,089	68,501	70716	69,837	74,006
Mar	76,434	78,249	81843	76,419	83,597
Apr	71,061	76,798	76723	73,221	79,332
May	74,422	74,953	79114	76,236	79,569
Jun	67,498	75,937	78533	72,487	77,016
Jul	71,126	70,457	77421	77,093	81,414
Aug	68,264	73,805	76030	76,614	81,471
Sep	70,826	72,927	69113	71,912	77,400
Oct	75,282	76,508	69608	75,946	81,963
Nov	71,345	76,296	74345	75,854	77,808
Dec	75,943	81,652	76310	78,001	82,840
TOTAL	852,203	901,874	908,955	898,665	953,502

Apart from that, the movements were the highest due to Term 1 of school holidays in Malaysia. As for the even years (2014 and 2016), the movements were highest during December. According to IATA, traditionally December is the peak travel month in many countries. This is due to Christmas and also to celebrate the New Year. Apart from that December also recorded the highest reading because of the long school holidays in Malaysia that corresponds to winter break for Europe and the Americas.

6.4 Aircraft Daily Movements By Sectors

The data for aircraft movements were also collected on a daily basis based on sampling to further understand the trend for the days of the week. The daily movements are tabulated in Table 3.

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Table 3: Aircraft Daily Movements Based On Sectors of KUL FIR
(Source: Civil Aviation Authority Malaysia)

Day	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6
Wednesday	604	663	526	257	509	393
Thursday	634	663	546	238	525	434
Friday	675	741	537	313	532	469
Saturday	609	643	518	296	513	469
Sunday	646	662	556	281	506	484
Monday	579	642	551	270	507	415
Tuesday	565	565	532	252	498	434
Total	4312	4579	3766	1907	3590	3098

The daily movements are depicted in Figure 8, to see the trend of the movements on a daily basis.

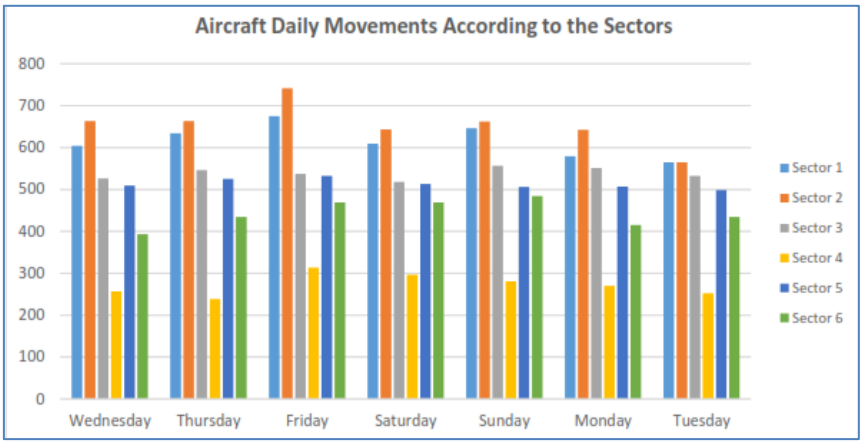

Figure 8: Sectoral Aircraft Movements

It can be seen in Table 3 and Figure 8 the Aircraft Daily Movements based on sectors for KUL FIR. The bar graph is illustrated to identify the sectoral highest movements in a week while the table depicts the number of movements. From the graph, it can be seen that Sector 2 has the highest aircraft movements compared to other sectors. The total aircraft movements for the week in Sector 2 alone was 4579.

Figure 8 shows that Sector 2 is the highest aircraft movements sector almost every day (Wednesday, Thursday, Friday, Saturday and Monday). This is due to the area of responsibility for Sector 2 is assigned to the south of Peninsular Malaysia. Most of the aircraft that fly in this area are from Singapore, Sydney, and Jakarta. The strategic location of this sector that is near to capital cities of busy countries definitely contributes to the high movements of aircraft in this sector.

The lowest number of aircraft movements is held by sector 4, with a consistent number of movements in the range of 250 to 315 aircraft in a week. Sector 4 is assigned to the northwest of Peninsular Malaysia and most flights that fly through the sector are long-haul flights to countries like Europe, India and the United Arab Emirates. Because of the frequency of long-haul flights are less if compared to short haul, hence the traffic movements in this sector are the lowest compared to other sectors.

Another significant trend of aircraft movement can also be seen in Sector 1. The movements of aircraft are relatively close in numbers to Sector 2 with only a difference of 267 aircraft movements.

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Sector 1 had also recorded the same number of aircraft movements on Tuesday (565) with Sector 2. The area of responsibility of Sector 1 is North of Peninsular Malaysia, the traffic for this sector are heavily from domestic airports (Penang and Langkawi) and foreign airports (Thailand and Cambodia). The high number of aircraft movements is contributed by the high frequencies of short-haul flights from Kuala Lumpur towards destination at the North of Peninsular area.

From here we can deduce that Sector 2 is the busiest sector inside Kuala Lumpur FIR with average 654 aircraft movements daily, the second busiest sector is Sector 1 with an average of 616 aircraft movements daily and Sector 4 is the least busy sector inside Kuala Lumpur FIR with 272 aircraft movements daily.

6.5 Aircraft Hourly Movements By Sectors

It is imperative to examine the flight movements on an hourly basis in a 24-hour window for the sectors in the KUL Flight Information Region to understand the airspace congestion. This was done by sampling method of the data made available by Civil Aviation Authority Malaysia.

6.5.1 Aircraft Hourly Movements In Sector 1

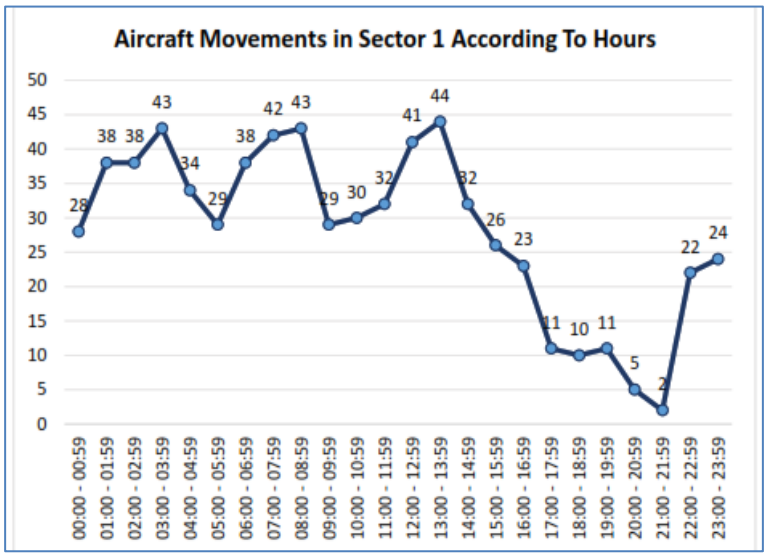

Figure 9: Hourly Aircraft Movements in Sector 1

Figure 9 illustrates the aircraft movements in Sector 1 on an hourly basis in the 24-hour window. In general, we can see that the pattern for Sector 1 fluctuates over the time whereby it has 3 peaks and a few troughs. From the graph we can see that the peak hour for sector 1 is at UTC 13:00 until 13:59

(21:00-21:59 LT) with a total of 44 aircraft within that 60 minutes time frame. The second busiest hours for Sector 1 are at UTC 03:00-03:59 (11:00—11:59 LT) and 08:00-08:59 (16:00-16:59 LT) with 43 aircraft movements. On the other hand, the off-peak for Sector 1 is during UTC 21:00-21:59 (05:00-05:59 LT) with only 2 aircraft movements.

It can be deduced that in Sector 1 the movements can be divided into three prominent times, which is during the morning, mid-day and evening. The Sector experiences morning rush during UTC 03:00-03:59, mid-day rush at UTC 08:00-08:59 and evening rush UTC 13:00-13:59. The Peak Hour movement is contributed by the high number of aircraft flying from KLIA to the northern part of Peninsular Malaysia (Kedah, Penang, Langkawi) and also aircraft from other destinations passing through Sector 1 to climb into Sector 6. These aircraft usually

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are heading to other cities like Bangkok and westward. As for UTC 21:00-21:59 the aircraft movements are the lowest because most of the airport in the Sector 1 area is not in a 24-hour operation.

6.5.2 Aircraft Hourly Movements In Sector 2

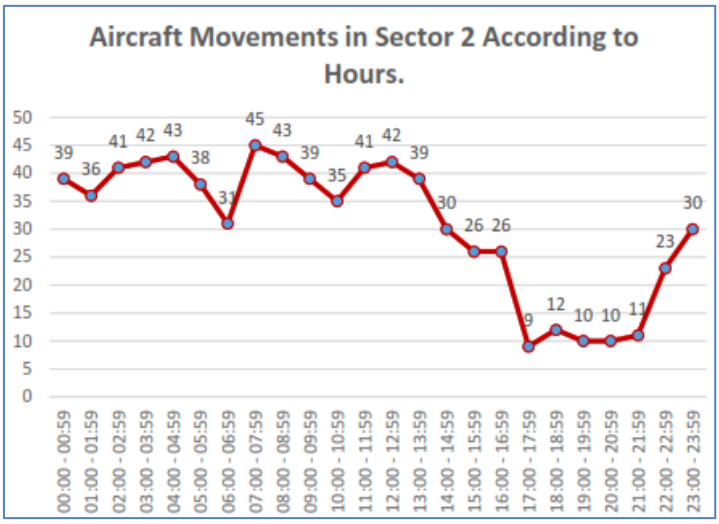

Figure 10: Hourly Aircraft Movements in Sector 2

Figure 10 illustrates the aircraft movements in Sector 2 on an hourly basis in a 24-hour window. Overall the graph pattern for aircraft movements in Sector2 increases and decreases throughout the whole day. The peak hour for Sector 2 is during 07:00-07:59 (15:00-15:59 LT) whereby there were a total of 45 aircraft movements within that 60 minutes period of time. In general, the movements of aircraft from 00:00 until 13:59 are relatively consistent in the range of 30 aircraft.

This is because of the twin city connection between KUL and SIN whereby there is a total of more than 50 flights operated daily. The number of aircraft in Sector 2 is also relatively high due to the strategic location of it, near to big cities like Singapore and Jakarta whereby there are many flightsarriving and departing at the same time. Apart from that, this sector 2 also caters for flights flying to the Australian Continent and connecting flights from Europe to the Southern Continent of the Asia Pacific. However, the number of aircraft starts to decrease after 14:00-14:59 until it reaches the off-peak at UTC 17:00-17:59 with only 9 aircraft movements. The reason for the reduction in the number of aircraft movements at those hours is due to the domestic flights and airports do not operate 24 hours.

6.5.3 Aircraft Hourly Movements In Sector 3

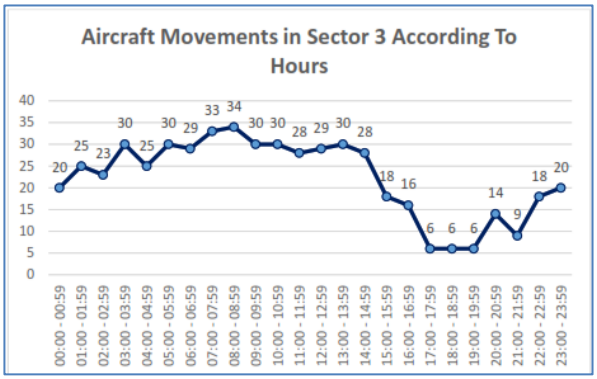

Figure 11: Hourly Aircraft Movements in Sector 3

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Figure 11 illustrates the hourly aircraft movements in Sector 3 in a 24-hour window. In general, the graph depicts the number of aircraft movements in Sector 3 fluctuates steadily from UTC 23:00 until UTC 14:59 in the range of 20 to 34 aircraft movements. This Sector caters for regional traffic that is from KUL to KCH and BKI. Most air carriers carry passengers vastly to cities within Sarawak and Sabah like Sibu, Sandakan, Lahad Datu, and even Brunei.

The peak hour for Sector 3 can be seen during UTC 08:00-08:59 (16:00-16:59 LT) with a total of 34 aircraft movements. This is due to most aircraft that depart early morning came back to the hub (KUL). On the other hand, the off-peak is during UTC 17:00-19:59 (01:00-03:59 LT) with only 6 aircraft movements at every hour.

6.5.4 Aircraft Hourly Movements In Sector 4

Figure 12 depicts the hourly aircraft movements in Sector 4 in the 24-hour window. The graph pattern shows 4 peaks and few troughs throughout the 24-hour span. The peak hour of operation in Sector 4 can be seen at UTC 21:00-21:59 (05:00-05:59 LT) whereby there were a total of 21 aircraft movements inside the Sector. Overall the aircraft movements in Sector 4 can be divided into three notable times which are during the early evening (UTC 08:00-08:59), late evening (13:00-13:59) and early morning of local time (UTC 21:00-21:59). Apart from that, the off-peak for Sector 4 can be seen during UTC 10:00-10:59 (18:00-18:59 LT).

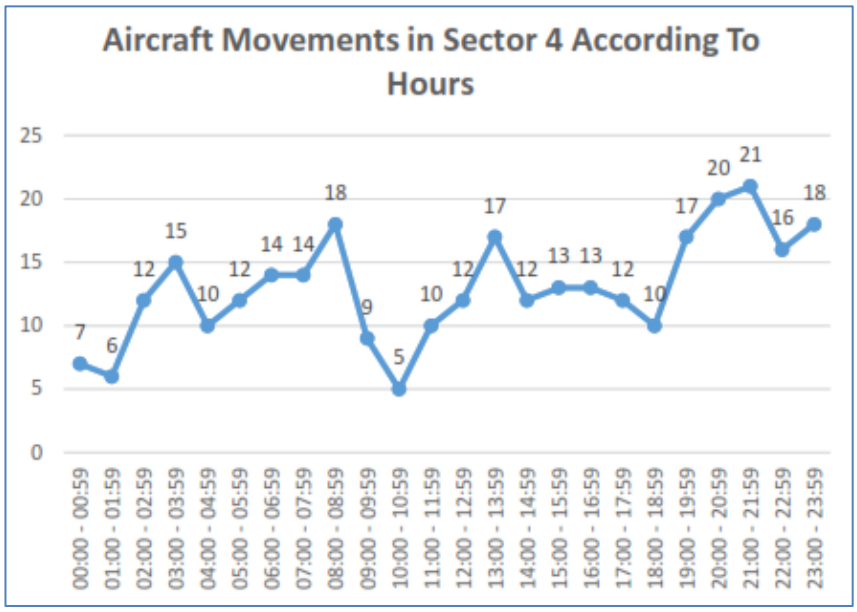

Figure 12: Hourly Aircraft Movements in Sector 4

This pattern is a result of the flight time allocation for aircraft departing to Europe, UAE, and India. Due to the time zone, most airlines prefer to fly their aircraft to these destinations either during the early evening or late evening as they want to arrive early morning at their destinations. Apart from that, the aircraft movements are also the highest during the early morning because of the return flights arrived back to Kuala Lumpur International Airport from Europe, going back to KUL and SIN.

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6.5.5 Aircraft Hourly Movements In Sector 5

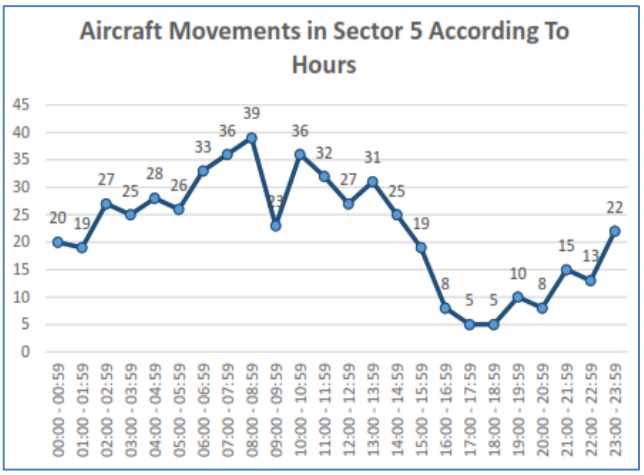

Figure 13: Hourly Aircraft Movements in Sector 5

Figure 13 shows a graph of hourly aircraft movements in Sector 5 for a 24-hour window. From the graph, it can be seen that the peak hour for the Sector 5 is at UTC 08:00-08:59 (16:00-16:59 LT) with a total of 39 aircraft movements. This is due to the fact that during this time most aircraft came back to the hub from their morning departures, especially international flights. Sector 5 governs the aircraft movements to and from the east side of Peninsular (Kelantan and Terengganu) and also international flights heading to or from South Korea, Japan, Taiwan, and China.

Apart from that, due to the airways M751 and B469, there is also a high number of aircraft movements as international flights depart and arrive in SIN will need to pass through sector 5. Overall the number of aircraft increases and decreases throughout the day and the lowest number of aircraft movements (off-peak) is during UTC 17:00-18:59 (01:00-02:59) with only 5 aircraft movements for each hour.

6.5.6 Aircraft Hourly Movements In Sector 6

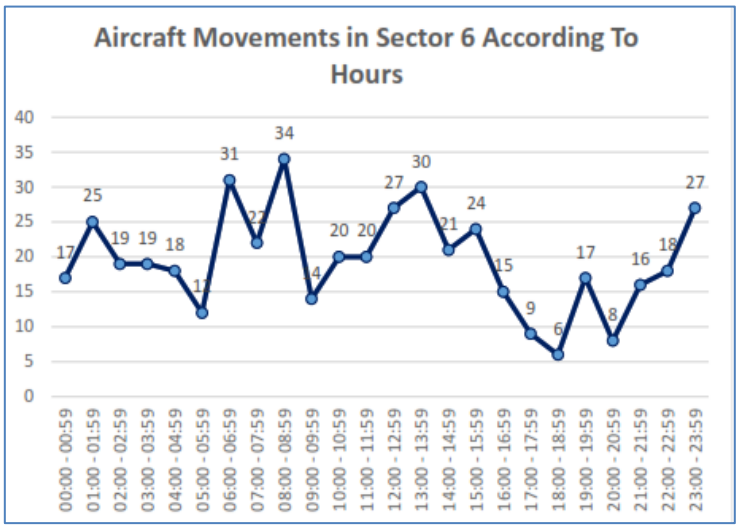

Figure 14: Hourly Aircraft Movements in Sector 6

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From Figure 14 above, it illustrates the hourly aircraft movements in Sector 6 in a 24-hour window. Generally, the data recorded shows an irregular pattern of aircraft movements in Sector 6. This is due to the location of Sector 6 between Sector 4 and Sector 2. The peak hour for Sector 6 is at UTC 08:00-08:59 (16:00-16:59 LT) with a total number of 34 aircraft movements. This is contributed by the aircraft arrivals and departures from domestic flights.

The number of aircraft movement is also highest at this hour as it is in accordance to peak hour of Sector 1, whereby most aircraft from Sector 1 is being transferred to Sector 6 as it governs the upper level of airspace. On the other hand, the off-peak for Sector 6 is during UTC 18:00-18:59 (02:00-02:59 LT) with only 6 aircraft movements. This is because at 24:00 LT Sector 6 is closed as it combined with Sector 1.

6.6 Aircraft Movements in KUL FIR Approach

It is also imperative to examine the aircraft movements in KUL FIR Approach as this is the most critical section at the Kuala Lumpur Flight Information Region due to the functions of this section is handling the aircraft arrivals and departures from the busiest airport within the KUL FIR, that is Kuala Lumpur International Airport and also other airports within KUL FIR. This section has significant effects on air traffic congestion in KUL FIR.

6.6.1 Daily Aircraft Movements in KUL FIR Approach

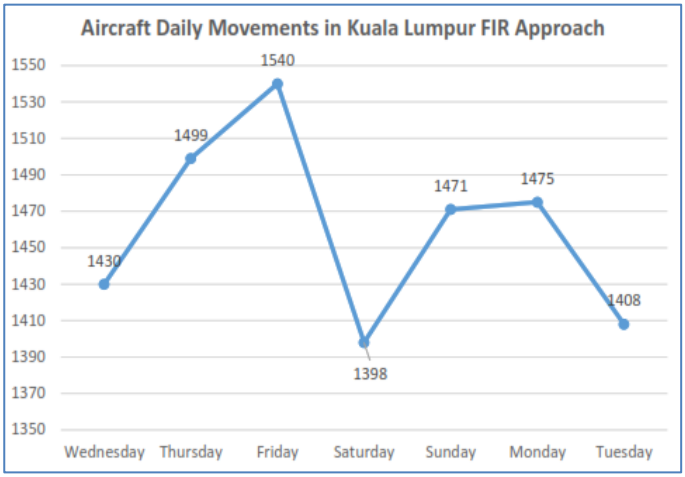

Figure 15: Aircraft Daily Movements in KUL FIR Approach

Figure 15 above the aircraft daily movements at Kuala Lumpur FIR Approach. The terminal control is a zone at Terminal Control Area or known as TMA of the airport. It is important to observe the movements of aircraft at approach as it could affect the safety of aircraft, landing sequencing, and departure sequencing. Referring to the graph above, the highest number of aircraft movement was recorded on Friday (1540) while the lowest number of movements falls on Tuesday (1408). In general, the pattern of aircraft movements at the approach directly correlates with aircraft operating in Kuala Lumpur TMA.

6.6.2 Hourly Aircraft Movements in KUL FIR Approach

Figure 16 illustrates the hourly aircraft movements at Kuala Lumpur FIR Approach in the 24-hour window. As can be seen from the graph, the highest number of aircraft movement at the approach is during UTC 06:00-06:59 with a total of 91 movements. Coming in as second highest is during 01:00-01:59 with 90 aircraft movements. It can be deduced that the peak hour of Approach Sector in a day is at UTC 01:00-01:59 which equivalent to 09:00-09:59 LT and 06:00-06:59 which equivalent to 14:00-14:59 LT. On the other hand, the off-peak hour for the Approach sectors is during 16:00-16:59 which is00:00-00:59 LT with only 12 aircrafts movements.

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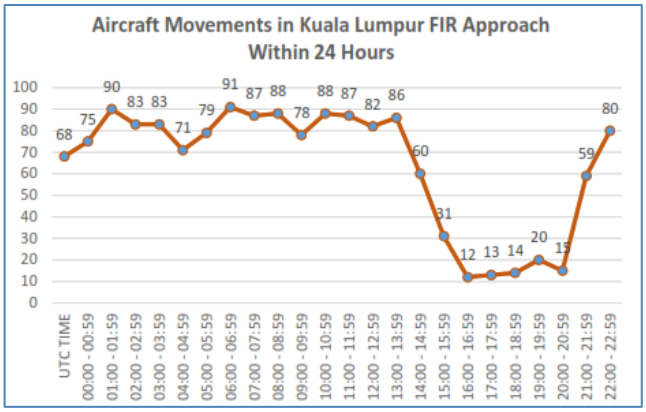

Figure 16: Aircraft Movements in KUL FIR Approach within 24 Hours

6.7 Aircraft Saturation Level

To analyze the level of saturation of aircraft movements in each sector, the researcher has plotted a bar graph displaying data recorded on aircraft movements in each sector for one week. From Figure 17 above it can be seen that Sector 2 holds the highest movements of aircraft compared to other Sectors. In a week alone, Sector 2 controls a total of 4,579 aircraft movements.

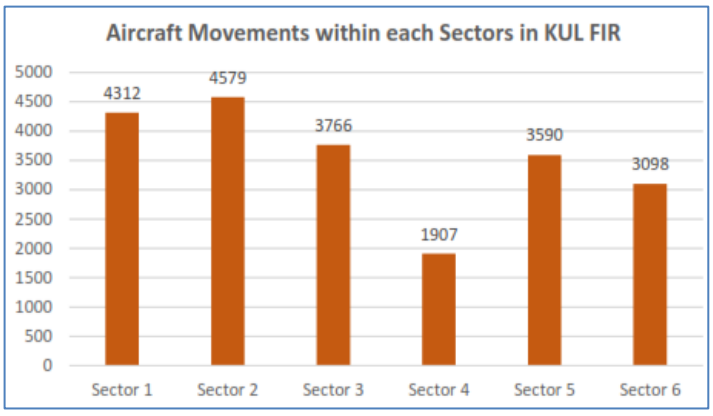

Figure 17: Aircraft Movements within each sector in KUL FIR

The daily average of the movements of aircraft in Sector 2 is 654. The second busiest sector is Sector 1 with a total of 4,312 aircraft movements. Sector 3 is the 3rd busiest sector with 3,766 aircraft movements. To further analyze the airspace structure within stipulated Area Of Responsibility (AOR), we made a comparison of aircraft movements in single level airspace structure (Sectors 2, 3, 4 and 5) against with multilevel sector airspace structure (Sector 1 and 6).

From the table above, it can be seen that in single level airspace structure, the number of air traffic movements in Sector 2 has reached 61.80% of the multilevel airspace structure. As for Sector 3, the air traffic movements are already at 50.70% in comparison to total movements of aircraft inside Sector 1 and 6. Without improvement to the airspace structure, it will limit the airspace capacity and unable to accommodate future traffic growth.

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Table 4: Comparison of aircraft movements in single sector airspace against multilevel sector airspace.

Sector	Aircraft Movements Over Total Movements in Sector 1 & Sector 6 (%)
2	61.80%
3	50.70%
4	25.70%
5	48.40%

6.8 Air Traffic Controllers (ATC) Workload

Air Traffic Controller (ATC) is a vital component in managing the airspace, as they provide information and separation distance of aircraft operations [13]. To understand the working environment of ATC it is important to know the working hours of ATC in the Area Control Centre. According to Civil Aviation Authority Malaysia, ATC operates round the clock including weekends and public holidays. In general, the controllers work according to shift whereby each shift comprises two working days and one resting day and one off-day.

Table 4: Shift Cycle of ATCs at KLATCC

Breakdown of cycle	Operation Hours
Afternoon	13:00 – 19:00
Morning	07:00 – 13:00
Evening	19:00 – 07:00

(Source: Civil Aviation Authority Malaysia)

The table above illustrates the breakdown of the shift cycle. At Kuala Lumpur Air Traffic Control Centre (KLATCC), the shift is divided into 4 viz. Shift A, Shift B, Shift C and Shift D. The shift usually starts during the afternoon from 13:00-19:00 on the first day and as for the next day Morning (07:00-13:00) and Evening (19:00-7:00). For each shift, there are 3 numbers of controllers in each sector. There is no direct formula on the number of aircrafts ATC can handle in a certain period of time. Apart from that, there is also no specific definition when it comes to ATC workload. This is because each ATC have different capabilities and skill levels in handling the number of aircraft at one time and there are also other factors that could influence the workload limitation.

In this study, we briefly analyse the workload by looking at the number of aircrafts the ATC handles in a day. To analyse the number of aircraft movements that ATC in KLATCC handled in an hour, data from hourly aircraft movements in Sector 2 (Friday) was chosen as it constitutes the highest number of movements throughout the week and the number of ATC in Sector 2 in one shift. The equation below that give the aircraft-to-controller ratio is used to reflect the workload of the air traffic controllers handling the aircraft movements in KUL FIR:

Y: Number of Aircraft each ATC controls in a day

$$Y = \frac{\text{Number of Aircraft Movements in Sector 2 during peak hour}}{\text{Number of ATC at Sector 2 in one shift}}$$

The number of aircraft movements in Sector 2 on Monday is 45, while the number of ATC at Sector in a day is 3. Based on this, it is found that during peak hour in the busiest sector, the number of aircrafts each ATC handles daily is15. From here, we can deduce that each of the aircraft has approximately 4 minutes in contact with ATC. Whereby during normal hours, each aircraft will have around 6 minutes in contact with ATC. With the reduction of 2 minutes and a

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Advances in Transportation and Logistics Research
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higher number of aircraft, this can potentially contribute to human errors as ATC has less time to concentrate and communicate with each aircraft.

7. Conclusion

This study has looked into five factors to establish the airspace congestion in Peninsular Malaysia, that is, the structure of Malaysian airspace, airspace categorisation, aircraft separation standards, flight movements, and Air Traffic Controllers workload. No single factor can be attributed solely to airspace congestion in Kuala Lumpur Flight Information Region (KUL FIR). It is the combination of factors that contribute to the airspace congestion and managing these factors in the best possible manner with the guidance of ICAO prescribed standards will achieve safe and efficient airspace management.

From the analysis of the data made available by Civil Aviation Authority Malaysia (CAAM) and the factors observed, it suggests that with a drastic increase of aircraft movements in recent years inKuala Lumpur Flight Information Region, the Malaysian airspace is reaching its saturation point. With the current aircraft separation standards used by Civil Aviation Authority Malaysia and existing technology employed to control the aircraft movements in Malaysian airspace, there is a dire need to restructure the Malaysian airspace in Peninsular Malaysia (Kuala Lumpur Flight Information Region).

Evidence has shown that the single level Sector 2 of Kuala Lumpur Flight Information Region (airspace over Peninsular Malaysia) has surpassed 60% of aircraft movements of multi-level Sector 1 and Sector 6, whereas Sector 3 has surpassed 50% level multi-level aircraft movements. With the increasing trend of the annual number of aircraft movements over Kuala Lumpur Flight Information Region, it is suggested that the authorities consider the possibility of restructuring the single level Sector 2 and Sector 3 into multi-level sectors to cater for the southwards-bound aircraft. This will also ensure the preparedness of Civil Aviation Authority Malaysia in view of the intention of the Malaysian Government to take back the control of Malaysian airspace that has been assigned to Singapore by ICAO in the south-eastern part of Peninsular Malaysia.

The other factor that is in dire need of upgrading to ease the airspace congestion is the air navigation equipment and its technology used by the Air Traffic Controllers to control the Malaysian airspace. This is the aspect of further research in airspace management in Malaysia.

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