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Airline Network Analysis of ASEAN International Airport Region

Nattapong Jantachalobon[*], Pongtana Vanichkobchinda and Nanthi Suthikarnnarunai

School of Engineering, University of the Thai Chamber of Commerce, Bangkok, Thailand

Abstract: This research is a methodology to measure the position of hub airports in Southeast Asia. The purpose of this research was to measure the number of indirect connecting flights in ASEAN. The documents used for this research were the statistics of annual reports between 2003 and 2012 of ten airports. Four methods of analysis were used: Netscan model, Concentration ratio, Herfindahl-Hirschman index, and Comprehensive concentration index. Market share in ASEAN airports is dominated by five big companies: Suvarnabhumi International Airport (BKK) in Thailand, Changi International Airport (SIN) in Singapore, Kuala Lumpur International Airport (KUL) in Malaysia, Ninoy Aquino International Airport (MNL) in the Philippines and Sugarno Hatta International Airport (CGK) in Indonesia. The first three are of these airports are major hubs for the ASEAN region. The analysis presented in this research may be helpful for airports or airlines in identifying their network performance and position in relation to their competition.

Keywords: Airlines, airports, ASEAN, comprehensive concentration index, concentration ratio, Herfindahl-Hirschman index, netscan model.

INTRODUCTION

In 2015 the Asian Economic Community (AEC) will be established. It will be composed of ten member countries in the Asian region, and would be served by their respective airports: Singapore's Changi International Airport (SIN), Cambodia's Phnom Pehn International Airport (PNH), Brunei's Brunei international Airport (BWN), Indonesia's Sugarno Hatta International Airport (CGK), Lao PDR's Wattay International Airport (VTE), Malaysia's Kuala Lumpur International Airport (KUL), Myanmar's Rangoon International Airport (RGN), the Philippines' Ninoy Aquino International Airport (MNL), Thailand's Suvarnabhumi International Airport (BKK), and Vietnam's Tan Son Nhat International Airport (SGN) [1]. AEC helps its member countries to negotiate with their trade partners and enhance trade competition. As the AEC member countries will benefit from tax exemption, free logistics among member countries will increase. The projected increase in tourism within AEC countries will result in more competition between airlines. All airlines need to reduce their costs and gain the largest market share.

It can be seen in Fig. (**1**) that the number of international air passengers in the ASEAN region tend to increase. Subsequently, all of the airlines are creating strategic plans to manage their flight routes. Moreover, passengers in all of the destination countries will be affected economically, socially and culturally.

Fig. (**2**) illustrates that aircraft movement in each airport of the ASEAN region has a tendency to increase every year.

*Address correspondence to this author at the School of Engineering, University of the Thai Chamber of Commerce, Bangkok, Thailand; Tel: 66955175498; E-mails: nutapong.j@rsu.ac.th, avm_009@hotmail.com

There are only a few airports which have similar aircraft movements such as Suvarnabhumi International Airport, Changi Airport and Kuala Lumpur International Airport.

LITRATURE REVIEW (TABLE 1)

Hakfoort *et al*. [3] studied how the rates of aircraft movement of European airlines had changed after aviation deregulation by using concentration ratio. Lijesen [4] also studied the clumping of direct and indirect flights by using the flight data of ten routes to Europe in February 2000. The method to measure such clumps is called Herfindahl-Hirschman Index. Moreover, the market share was calculated to find out the cost of airlines. Danesi [5] studied the various forms to determine aviation centers by using flight time tables of each airline. The data of flight time tables were used to evaluate the concentration of flights by using Concentration ratio. Lohmann *et al*. [6] studied aviation and tourism center selection in Brazil by using questionnaire distribution and the Herfindahl-Hirschman Index. There are a lot of domestic airports in Brazil, so it was necessary to determine its aviation center in order to reduce operation costs of airlines and to promote the country's tourism. Scholz and Cosel [7] studied how to set a center to transport merchandise. They investigated the relation between airlines and the airports which contract themselves out to be come centers for transporting goods. If an airport needs to build a new warehouse to house the goods of an airline, it must first analyze financial and economic factors by using Gini Index, Herfindahl Index, Concentration ratio and Netscan-AirFreight model. Scholz [8] studied the network of air cargo airlines in 2007 in order to find out which airport was the most concentrated handling the cargo of six different airlines. Three study methods were used: Gini Coefficient, Herfindahl Index, and Concentration ratio.
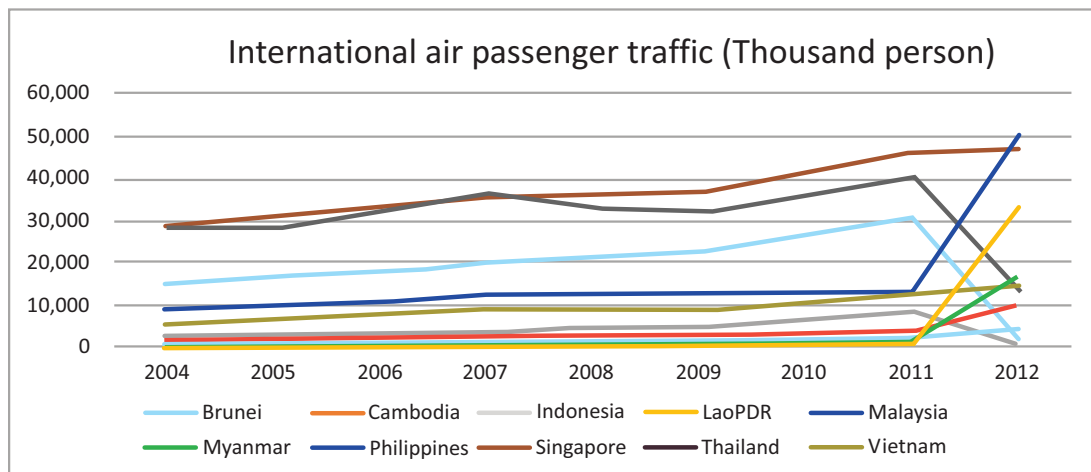
Source: Asean-Japan Transport Partnership Information Center (2012) [2].

Fig. (1). Number of International Air Passengers by Nation in the ASEAN Region between 2004-2012.
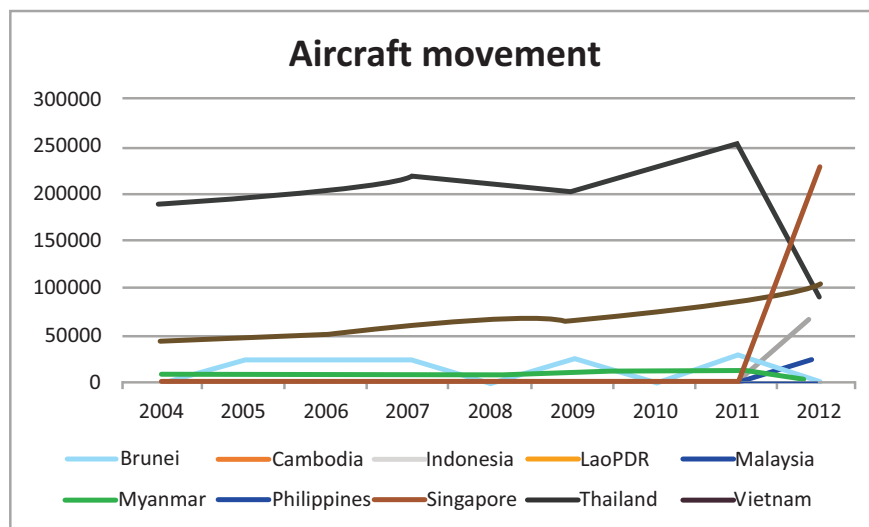
Source: ASEAN-Japan Transport Partnership Information Center (2012)

Fig. (2). Commercial Aircraft Movements in ASEAN Region between 2004-2012.

Table 1.   Comparisons of airport measurement.

Model, Authors, and Date	Theoretical Assumptions	Data Requirement
Gini Index Scholz &Cosel (2011), Scholz (2012)	Used as a measure of inequality of income or wealth	Population, Income
Concentration Ratio Hakfoort *et al*. (2003), Danesi (2006) Scholz & Cosel (2011), Scholz (2012)	Measuring the concentration of market share held by particular suppliers in a market	Percentage of total market sales accounted for by a given number of leading firms
Herfindahl-Hirschman Index Lijesen (2004), Lohmann *et al*. (2009), Scholz & Cosel (2011), Scholz (2012)	Measure of the size of firms in relation to the industry and an indicator of the amount of competition among them	The market share of each firm competing in a market and then summing the resulting numbers
Netscan Model Burghouwt & De Wit (2005), Veldhuis (1997), Kim & Park (2011)	It counts the number of connecting opportunities (direct and indirect flights), and weights these connections in terms of transfer and detour time relative to a theoretical direct flight, since the quality of direct and indirect flight connections are different	Flight schedules, minimum connection time, great-circle distance, flight time
Bootsma Model Kim & Park (2011)	It considers minimum and maximum connecting time and classify them as "excellent", "good" or "poor"	Airline schedules, flight time, minimum connection time

Dennis [9] used the data of connecting time to find airline and airport hub in Europe. Any airport with the shortest connecting time, would be a suitable hub. Dennis [10], Burghouwt and de Wit [11,12], and Veldhuis [13] studied the viability of Amsterdam-Schiphol Airport becoming a regional hub by using the data of quality and frequency of connecting flights and applied the method of NETSCAN connectivity. Moreover, Burghouwt and Veldhuis [14] used the same method to evaluate the market competition of the Western European airport model. In Asia, Burghouwt *et al.* [15] evaluated the Hub Connective Performance by using flight data from various airports in East and Southeast Asia. He used the NETSCAN model to identify the concentration of flights to pinpoint where a hub should be developed in the future. Bowen [16] studied airline hubs in Southeast Asia by using network analysis, in order to analyze which airport hosts the most connecting flights and would be most suitable as a regional gateway. Kim and Park [17] analyzed the connectivity of trans-shipments at Incheon International Airport, which is a hub. They used the data from Korean Air and Asiana Airlines and used the method of wave systems of the Bootsma model [18] and the Netscan model. Moreover, Schwieterman [19] identified airlines by using the alternative methods: airport capacity, location advantage, market size, terminal service and government policy. Park [16] evaluated airports in East Asia by determining five factors: service, demand, management, facilities and spatial qualities.

METHODOLOGY

According to Burghouwt [20], the hub-and-spoke network requires a concentration of air traffic in both space and time. Hence, the network configuration is defined as the level of spatial and temporal concentration of traffic flows in a given network. The focus here is on the spatial concentration of the airline network. To measure the level of spatial concentration of a network, different concentration measures can be used, such as the Concentration ratio, the Herfindahl-Hirschman index, Comprehensive Concentration Index, and NETSCAN Model.

There are three analytical steps. Firstly, find the market share of each airport in ASEAN member countries by using Concentration ratio, Herfindahl-Hirschman Index, and Comprehensive Concentration Index. All three methods were used to analyze the number of passenger scheduled flights departing or arriving in ASEAN airports. The input data of this first step were the annual reports of aircraft movement from official airline guides (OAG) between 2003 and 2012 of ASEAN airports. Secondly, a NETSCAN Model quantified the performance of air transport networks. The input data of this step were airline time schedules from second weeks of November, 2012. Thirdly, airline routes must be evaluated qualitatively, to find the most suitable place to build an airport hub to serve the best connecting routes.

Concentration ratio is a tool which calculates the market share of each specific airport. The results reflect intense competition within the market. The calculated results can be divided into three levels:

1. CRn of 67% or more, reflects high airport concentration with an evident monopoly.

2. CRn between 34% and 67%, reflects an airport as moderately concentrated.

3. CRn of less than 34%, reflects an airport with low concentration and that is highly competitive.

The formula for finding the concentration ratio is the following:

$$\text{CRn} = \frac{\sum_{i=1}^{n} Si}{\sum_{i=1}^{t} Si} X100$$

CRn = the ratio of major airport concentration

Si = selling revenue

t = the largest airport

n = total number of the airport in the industry

i = individual airport enterprise

Herfindahl-Hirschman index (HHI) is an index to show the quadratic sum of each airport's market share compared to the whole industry. Where Si is the share of air traffic at airport i in relation to the total air traffic. The variable n denotes the number of airports in the network. The HHI takes into account the relative size and distribution of the nodes (e.g. airports) in the network. It is size-dependent and its minimum for a fixed number of actors results in equal shares with a value of 1/t. Furthermore, the HHI is primarily sensitive to changes at the extreme ends, which is a property of the square-function giving high weights to the largest airports. The HHI is the most frequently used measure of market concentration.

The results of analysis can be divided into 4 ranges:

1. Less than 1,000 means the market has high competition but no monopoly

2. Between 1,000 and 1,800 means there is moderate competition in the market and if HHI is close to 1,800, a major market share enterprise exists.

3. More than 1,800 means there may be a monopoly in the market

4. More than 10,000 means there is only one service provider which holds a monopoly in the industry.

The formula for HHI is as follows:

$$HHI = \sum_{i=1}^{t} S_i{}^2$$

Comprehensive Concentration Index (CCI) measures concentration, but adjusts the disclose defects of HHI. Both HHI and CCI consider all enterprises in an industry but CCI emphasizes enterprises other than biggest entity. CCI gives a value between 1 and 0, and a result close to 1 indicates a monopoly is present in the market.

The formula CCI is as follows:

$$CCI = S_i + \sum_{j=2}^{t} Sj^2(1 + (1 - S_i))$$

CCI = Comprehensive Concentration Index

Si = the market share of the airport no. i:i=1,2,3,4,…, n

Sj = the market share of the airport no. j:j=1,2,3,4,…, n

Netscan Model is a method to measure the speed of connections. The results from calculation are the quality index and connectivity units. The result appears between 0 and 1. If the value is close to 1, that particular aviation route or airport has the best connection time.

The mathematical model is derived from applications to passenger transport [20]:

NST = (40+0.068*gcd km)/60   (1)

MXT = (3-0.075*NST)*NST   (2)

PTT = FLT+(3-0.075*NST)*TRT   (3)

QLX = 1-((PTT-NST)/(MXT-NST))   (4)

CNU = QLX*NOP   (5)

NST: non-stop travel time in hours

gcd km: great-circle distance in kilometers

MXT: maximum perceived travel time in hours

PTT: perceived travel time in hours

FLT: flying time in hours

TRT: transfer time in hours

QLX: quality index of a connection

CNU: number of connectivity units

NOP: number of operations

ANALYSIS AND RESULTS

In order to quantify the market share of ASEAN airports within the air transportation system we made use of the four above-mentioned measurements (CRn, HHI, CCI, and CNU). Table **2** presents the results of the application of three methods to analyze the number of international flight in ASEAN airports. According to the results, ASEAN is dominated by five big airports: Suvarnabhumi International Airport, CR1 (BKK) in Thailand, Changi International Airport, CR2 (SIN) in Singapore, Kuala Lumpur International Airport, CR3 (KUL) in Malaysia, Ninoy Aquino International Airport, CR4 (MNL) in the Philippines, and Sugarno Hatta International Airport, CR5 (CGK) in Indonesia. The combined CR for these 5 airports exceeds 67 percent. The highest concentration ratio (CR1) was Suvarnabhumi International Airport. This illustrates that airline networks in ASEAN have concentrated.

The HHI illustrates that there is moderate competition in each airport. Moreover, CCI shows that the market is highly competitive and not monopolized. It should be noted that ASEAN international airports are not different from each other, in the number of airline flights they service. There is no clear leader among ASEAN airports. Every ASEAN airport could be a hub. We selected the three most concentrated airports (CR1, CR2, and CR3) to analyze the next step.

For our final step, we used the NETSCAN model to identify ASEAN hubs. The routes with the greatest volume of transfer passengers were selected, and the NETSCAN model estimated the quality of indirect connections (Tables **3-5**).

The first criterion was to use the three airports with the highest market share. The second criterion was that flights must use each airport as an origin and destination. In other words, each airport was connection point between 2 flights.

Table **3** shows all flights that use Changi International Airport (SIN) as a hub. The highest quality route was MNL-SIN-CGK with a quality index of 0.70. This reflects an indirect route of high quality, as an index score of 1 equals a direct flight. The same route had a CNU of 4.91. The lowest quality routes were CGK-SIN-BWN and CGK-SIN-MNL, with index scores of 0.30 and 0.34, respectively (Table **3**).

Table **4** provides information regarding the connectivity of Suvarnabhumi International Airport. Again the NETSCAN model was used to analyze the schedule of airline routes, and transfers within the airport. The best quality route was VTE-BKK-SIN, with a quality index of 0.57 and CNU of 7.95. The worst route was PNH-BKK-SIN with a quality index of 0.20 (Table **4**).

Table **5** displays routes, when airlines transfer passengers through Kuala Lumpur International Airport (KUL). The

Table 2.   Concentration Ratio, Herfindahl-Hirschman Index, and Comprehensive Concentration Index between 2003-2012.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average
CR 1	24.52	23.72	23.64	23.64	21.53	19.15	18.31	17.46	17.55	24.83	21.42
CR 2	41.66	42.75	42.99	42.24	39.72	37.23	35.64	34.76	34.98	40.97	39.29
CR 3	57.17	58.65	58.78	57.48	55.67	53.7	51.99	50.89	55.27	55.84	55.84
CR 4	70.08	70.02	70.11	68.56	67.79	64.89	64.27	62.87	63.33	65.93	66.78
CR 5	79.78	70.02	79.24	78.07	77	73.88	73.27	71.86	72.77	74.4	75.03
HHI	1516.67	1529.97	1534.35	1490.57	1408.8	1338.7	1307.64	1282.26	1287.36	1424.03	1412.03
CCI	0.42	0.42	0.42	0.41	0.39	0.37	0.36	0.36	0.36	0.4	0.39

Table 3.   Hub connectivity *via* Changi International Airport (SIN).

Route	Airline	Schedule	Flight Time	Km	Transfer Time	Route	Airline	Schedule	Flight Time	Km	Freq	Total Flight Time	Total km	Quatity	CNU
KUL-SIN	MI	14:30-15:25	0:55	379	0:55	SIN-PHN	SQ	16:20-17:15	1:55	1167	28	2:50	1546	0.63	17.62
KUL-SIN	MI	10:25-11:20	0:55	379	1:05	SIN-MNL	SQ	12:25-16:00	3:35	2382	4	4:30	2761	0.48	1.94
KUL-SIN	MI	12:00-12:55	0:55	379	1:55	SIN-MNL	PR	14:50-16:25	1:35	2382	6	2:30	2761	0.58	3.50
KUL-SIN	SQ	12:00-12:55	0:55	379	1:25	SIN-MNL	SQ	14:20-17:55	3:35	2382	14	4:30	2761	0.40	5.62
KUL-SIN	SQ	19:30-20:25	0:55	379	1:00	SIN-MNL	PR	21:25-1:05	3:40	2382	12	4:35	2761	0.50	5.97
CGK-SIN	SQ	14:15-16:50	1:35	875	0:50	SIN-SGN	SQ	17:40-18:45	2:05	1085	7	3:40	1960	0.63	4.41
CGK-SIN	SQ	5:50-8:25	1:35	875	1:10	SIN-MNL	SQ	9:35-13:10	3:35	2382	2	5:10	3257	0.49	0.99
CGK-SIN	GA	6:25-9:05	1:40	875	1:20	SIN-MNL	PR	10:25-14:05	3:40	2382	7	5:20	3257	0.44	3.11
CGK-SIN	GA	7:55-10:35	1:40	875	1:50	SIN-MNL	SQ	12:25-16:00	3:35	2382	7	5:15	3257	0.34	2.39
CGK-SIN	SQ	8:25-11:00	1:35	875	1:25	SIN-MNL	Bl	12:25-16:00	3:35	2382	7	5:10	3257	0.44	3.08
CGK-SIN	GA	7:55-10:35	1:40	875	1:30	SIN-BWN	BI	12:05-14:15	2:10	1334	3	3:50	2209	0.30	0.89
CGK-SIN	SQ	8:25-11:00	1:35	875	1:05	SIN-BWN	BI	12:05-14:15	2:10	1334	3	3:45	2209	0.43	1.29
CGK-SIN	SQ	9:20-11:55	1:35	875	0:55	SIN-KUL	SQ	12:50-13:45	0:55	379	14	2:30	1254	0.54	7.54
MNL-SIN	SQ	8:10-11:45	3:35	2382	0:50	SIN-CGK	SQ	12:35-13:20	1:45	875	7	5:20	3257	0.70	4.91
MNL-SIN	PR	10:15-13:50	3:35	2382	1:30	SIN-CGK	SQ	15:20-16:05	1:45	875	6	5:20	3257	0.41	2.45
MNL-SIN	SQ	8:10-11:45	3:35	2382	1:05	SIN-KUL	MI	12:50-13:45	0:55	379	14	4:30	2761	0.48	6.79
MNL-SIN	SQ	14:15-17:50	3:35	2382	0:55	SIN-KUL	SQ	18:45-19:40	0:55	379	3	4:30	2761	0.69	2.08
BKK-SIN	SQ	15:40-19:10	2:30	1416	0:50	SIN-KUL	SQ	20:00-20:55	0:55	379	8	3:25	1795	0.60	4.79

Table 4.   Hub connectivity *via* Suvarnabhumi International Airport (BKK).

Route	Airline	Schedule	Flight Time	Km	Transfer Time	Route	Airline	Schedule	Flight Time	Km	Freq	Total Flight Time	Total km	Quatity	CNU
SIN-BKK	TG	15:55-17:15	2:20	1416	1:10	BKK-PNH	TG	18:25-19:40	1:15	538	1	3:35	1954	0.31	0.31
PNH-BKK	PG	6:40-8:15	1:35	538	0:50	BKK-RGN	PG	9:05-9:55	1:20	590	7	2:55	1128	0.44	3.06
PNH-BKK	PG	10:05-11:15	1:10	538	1:30	BKK-SIN	CX	12:45-16:10	2:25	1416	16	3:35	1954	0.20	3.27
VTE-BKK	PG	10:10-11:25	1:15	560	1:20	BKK-SIN	CX	12:45-16:10	2:25	1416	14	3:40	1976	0.26	3.64
VTE-BKK	TG	13:50-14:55	1:05	560	1:40	BKK-SIN	TG	16:35-17:55	0:20	1416	14	1:25	1976	0.57	7.95
CGK-BKK	TG	13:05-16:35	3:30	2287	1:50	BKK-PNH	TG	18:25-19:40	1:15	538	2	4:45	2825	0.30	0.60
CGK-BKK	TG	13:05-16:35	3:30	2287	1:20	BKK-RGN	TG	17:55-18:40	1:15	590	7	4:45	2877	0.44	3.06
MNL-BKK	TG	13:10-15:25	3:15	2193	1:40	BKK-RGN	PG	17:05-17:55	1:20	590	7	4:35	2783	0.34	2.37
RGN-BKK	PG	10:45-12:40	1:25	590	1:10	BKK-SIN	TG	13:50-17:10	2:20	1416	4	3:45	2006	0.32	1.27
RGN-BKK	TG	19:40-21:35	1:25	590	1:55	BKK-MNL	PR	23:30-3:50	3:20	2193	4	4:45	2783	0.26	1.05

NETSCAN model was used to estimate the quality of indirect connections for this hub. The routes with the highest transfer/transit volume were selected. The highest quality route was RGN-KUL-CGK with a quality index of 0.52 and CNU of 3.65. A close second was the CGK-KUL-RGN route with a quality index of 0.50 and CNU of 3.50. The worst route was RGN-KUL-SIN route with a quality index of 0.11 and CNU of 0.44 (Table **5**).

Table 5.   Hub connectivity *via* Kuala Lumpur International Airport (KUL).

Route	Airline	Schedule	Flight Time	Km	Transfer Time	Route	Airline	Schedule	Flight Time	Km	Freq	Total Flight Time	Total km	Quatity	CNU
CGK-KUL	MH	18:25-21:25	2:00	1243	1:25	KUL-SIN	MI	22:50-23:45	0:55	379	21	2:55	1622	0.22	4.53
CGK-KUL	MH	5:05-8:00	1:55	1243	1:25	KUL-PNH	MH	9:25-10:15	1:50	942	7	3:45	2185	0.32	2.25
CGK-KUL	MH	9:55-12:55	2:00	1243	1:45	KUL-PNH	MH	14:40-15:30	1:50	942	7	3:50	2185	0.21	1.49
CGK-KUL	MH	5:05-8:00	1:55	1243	1:05	KUL-SGN	MH	9:05-10:00	1:55	924	7	3:50	2167	0.40	2.83
CGK-KUL	MH	9:55-12:55	2:00	1243	1:05	KUL-RGN	8M	14:00-15:00	2:30	1568	7	4:30	2811	0.50	3.50
CGK-KUL	MH	15:45-18:45	2:00	1243	1:10	KUL-BWN	MH	19:55-22:15	2:20	1504	12	4:20	2747	0.47	5.70
CGK-KUL	MH	5:05-8:00	1:55	1243	1:10	KUL-BKK	TG	9:10-10:15	2:05	1081	21	4:00	2324	0.36	7.47
CGK-KUL	GA	17:05-20:10	2:05	1243	1:00	KUL-BKK	LH	21:10-22:15	2:05	1081	4	4:10	2324	0.39	1.54
MNL-KUL	MH	6:50-10:35	3:45	2409	1:25	KUL-SIN	SQ	12:00-12:55	0:55	379	42	4:40	2788	0.40	16.59
MNL-KUL	MH	6:50-10:35	3:45	2409	1:15	KUL-SIN	MI	11:50-12:45	0:55	379	38	4:40	2788	0.44	16.59
RGN-KUL	MH	12:15-16:30	2:45	1568	1:45	KUL-SIN	MI	18:15-19:10	0:55	379	4	3:40	1947	0.11	0.44
RGN-KUL	8M	8:55-12:55	2:30	1568	1:00	KUL-CGK	MH	13:55-14:55	2:00	1243	7	4:30	2811	0.52	3.65
BWN-KUL	MH	17:00-19:15	2:15	1504	1:15	KUL-SIN	SQ	20:30-21:25	0:55	379	21	3:10	1883	0.30	6.31
BWN-KUL	BI	9:10-11:35	2:25	1504	1:15	KUL-CGK	GA	12:50-13:55	2:05	1243	2	4:30	2747	0.44	0.88
BWN-KUL	BI	9:10-11:35	2:25	1504	1:30	KUL-BKK	MH	13:05-14:10	2:05	1081	4	4:30	2585	0.32	1.27

To sum up, the hubs that connected passengers the best were Changi International Airport, Suvarnabhumi International Airport, and Kuala Lumpur International Airport, respectively. Moreover, the quality index depended on the configuration of flight schedules. However, in relation to the NETSCAN results, regional routes and the volume of transit/transfer passengers did not seem to be related to quality index.

SUMMARY AND RECOMMENDATIONS

The objective of this research is to measure the ability of airports in the ASEAN region to become regional hubs. The study focused only on indirect flights which use the main airports of ten ASEAN countries, and found that Changi International Airport to be the most suitable because it has the most connecting flights. Moreover, it is noted that the best connecting hubs, have the shortest connecting time and cohere with the flight times. The results from this analysis were for each airport to improve their ground services and to improve their basic infrastructures in order to develop their potential for serving all airlines. Selecting a connecting hub should not only consider the flights involved, but also other criteria. This study may be helpful for ASEAN international airports in identifying their market position as a hub. Another application would be to evaluate effectiveness of rescheduling to improve connectivity. Further research is suggested to study with a more comprehensive view on airline hubs regarding location, economic, operational, and functional criteria.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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