Chapter

Determination of the International Hub Airport to Support the Flight Network Efficiency of ASEAN Region Countries (Case Study of the Indonesian Airport System)

Eny Yuliawati

Abstract

Indonesia has 266 airports spread throughout the Indonesia archipelago. With the growth rate of air passengers increasing year by year, Indonesia needs to increase its role in managing the international network in Southeast Asia. Especially with the implementation of the Open Sky policy, Indonesia must take advantage of the potential opportunities. This chapter attempts to examine parameters at hub airports for international flights with the Association of Southeast Asian Nations (ASEAN), which has network efficiency performance. There are eight airports actively showing behaviour as "hubs", and considering the potential geographic and movement potential in ASEAN, the most efficient is the three hubs and 32 spokes configuration. Thus, the three hub airports that can be optimised to support the efficiency of international flight routes in ASEAN are Kualanamu Airport-Medan, Soekarno Hatta Airport-Jakarta and Juanda Airport-Surabaya.

Keywords: hub and spoke airport, flight network efficiency, international flight route, ASEAN region, open sky policy

1. Introduction

The Association of Southeast Asian Nations (ASEAN) Open Sky is an important component in ASEAN economic integration. It is based on the idea that the transport network, especially air transport, is very important in facilitating changes and reducing trade barriers. The important role of the air transportation sector becomes a decisive factor considering that the field of tourism is a major stimulus for economic growth for some countries in ASEAN. The Open Sky policy is a waiver of the rules for the international aviation market to minimise government intervention on provisions applicable to scheduled airline and charter markets, both passenger and cargo flights, where their implementation is based on bilateral and multilateral agreements. An important element in Open Sky is free-market competition where there are no longer any restrictions on the rights of international flight routes (the number of flights, capacity, frequency and type of aircraft), while prices are determined by market power as well as providing equal and fair opportunity to all airlines to compete. For that reason, Open Sky in the ASEAN region will encourage the airline industry to become more competitive in providing places for all flights from ASEAN to compete in intra-ASEAN region routes as well as providing additional flight flexibility for route (network) expansion. Furthermore, the presence of Open Sky in the ASEAN region is expected to encourage airlines to be more efficient, which in turn allows airlines to reduce unnecessary aviation operational costs so that low-cost carrier flight models will become better developed in competitive conditions.

There are two levels of measurement that can be used to determine flight efficiency, namely network and infrastructure capacity measurement. Network measurement can be done on the basis of a network structure. At this level, minimisation of the "cost" that is caused is related to the variables of travel time, distance, connectivity, etc. Meanwhile at the infrastructure capacity level, measurements are made based on airport infrastructure capabilities in serving demand such as runway, apron, terminal and other capacities, for example, in minimising the "cost" based on "connectivity" in calculating connectivity on transportation networks using algorithmic engineering so that it can find the fastest route between two points "s" and "t" [1]. Reducing the costs of travel and increasing their connectivity are major advantages of the hub and spoke network system [2]. Connectivity is increased within the hub by concentrating landings and takeoffs at the hub (hub waves) [3]. Furthermore, related to the network pattern in flight, there are "hub" and "spoke" flight network patterns where all flights head to one large central location and passengers can transfer to other flights to reach their final destination. The pattern of hub and spoke development has been used by commuter groups in the United States since the early 1980s. This pattern has been able to expand and organise the route network and could prioritise the interest of consumers or air passengers. The arrival of airplanes in the "hub" and "spoke" flight network pattern is well coordinated, and to make it easier for passengers or goods that are to be transferred to another flight, this pattern is repeated several times a day [4]. The hub airports serve as a consolidation of passengers and cargo that can move to other airports categorised as spoke airports and provide a connecting flight to various subsequent destinations. The selection of hub airports is based on strategic geographic factors and demand. For this reason a method of planning and route optimisation is used so that the system can be planned accurately.

Airports are categorised as hubs and spokes based on freight ratio, which is the ratio between the weight of goods and the number of boarding passengers served at the airport. In addition to establishing airports as hubs it is also based on consideration of passenger traffic density, airport geographic location, airport area, supporting transportation mode facilities, short and long distance flight traffic flows, the number of "banks" (grouping on a daily frequency of arrival/departure in several terms) and "bank" operating period [5]. The number of banks and the period of bank operations are determined by passenger air traffic, including demand derived from spoke passenger routes, arrival timings and departure of long-haul destinations and the choice of passenger based on flight scheduling.

Furthermore, with the implementation of the ASEAN Open Sky policy, there are a number of problems, such as:

1. There may be a change in determining the location of the airport as a hub airport (transshipment airport).

2. What is the ASEAN Open Sky can be promote the aviation industry competition and supporting the airline industry to doing competition inter ASEAN region better.

Although the largest increase in air transport movements in Indonesia is domestic flights, the implementation of the Open Sky policy will encourage international flights to grow significantly, therefore it is necessary to study the establishment of international aviation hub airports (transshipment) to improve the efficiency of flight routes to the ASEAN region.

2. Open sky policy in ASEAN

The definition of Open Sky refers to the situation of broad liberalisation in the ASEAN region and concentrates on international relations of ASEAN member countries, which will provide additional flight flexibility for route development. ASEAN Open Sky is a set target in the "Road Map for ASEAN Integration: Competitive Air Service Policy" prepared by the ASEAN Air Transport Working Group [6].

Each country has different policies. There are some countries that are very liberal but place limitations on international flights. There are also some countries that choose to gradually take steps towards liberalisation, and there are also countries that are ready to support liberalisation on a subregional basis. ASEAN members have diverse characteristics with respect to air transportation based on the levels of growth and development [7–11]. Regarding the implementation of the Open Sky policy, there are different types of agreement, such as bilateral agreement or multilateral agreement, that are used for supporting various policies in the ASEAN Region. The following are three subregions in the Open Sky policy in the ASEAN region [12]:

1. The first subregion is Cambodia-Laos-Myanmar-Vietnam plus Thailand and Brunei Darussalam

2. The second subregion is Vietnam-Indonesia-Philippines plus Brunei Darussalam; these countries have the same progress in aviation industry development.

3. The third subregion is Singapore-Malaysia-Thailand plus Brunei Darussalam; this subregion is used in countries that already have regular flights such as Singapore, Malaysia and Thailand with the possibility of Brunei Darussalam joining them.

3. Network planning and flight path

The counting of connections on the transport network performed by the application of algorithmic engineering. A problem can be solved by using transportation network modelling in a graph that describes the travel time on the trip in question. The algorithm can solve the problem by finding the fastest route between two points "s" and "t". The challenge is to determine the appropriate transport model to use in the graph. While road networks can be modelled simply (intersections as nodes, roads as links), realistic modelling on public transportation networks is far more complicated. [1].

Figure 1 describes the time-dependent model that determines a flight path; the flight of "F" is divided by a number of "R" routes. In this case, two F1, F2 and F flights are considered equivalent if they share the same airport sequence (airport (A1, ..., Ak)). The curve is built using every airport point and route through a particular airport, following the illustration of a simple example of the time-dependent model. The flight schedule for all routes has a length of 1, because almost all flights do not make a temporary stop. The flight schedule is assumed to be a direct flight for each pair of airports (Ai, Aj) with i < j; the result is that all routes have a length of 1.

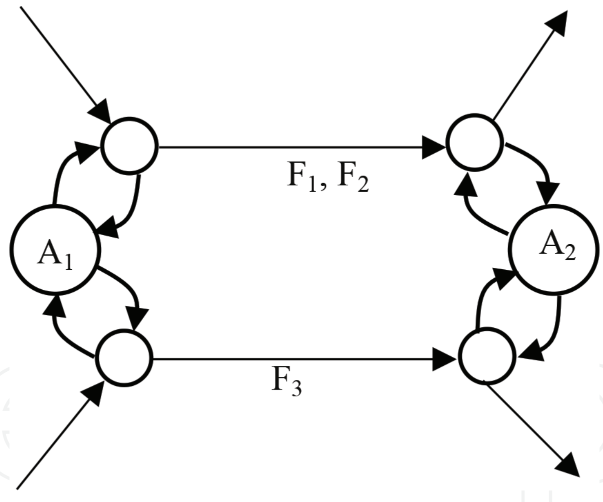

Figure 1.
Time-dependent model of the determination of a flight path.

4. Airport planning for hub and spoke pattern

The hub and spoke flight network pattern arises when all flights are heading to a large central location, passengers change flights to reach their final destination and this pattern is repeated several times a day. This pattern consists of several hub airports that function as centres of economic activity and flight activities in a region surrounded by small towns that will be in direct contact with them (**Figure 2**).

The hub and spoke pattern is not new to the aviation world. It was first introduced and developed by commuter groups in the United States in the early 1980s. This hub and spoke system has been able to develop and organise routes, as well as promote public and consumer interest which done by the trunks community (the later known as the US Majors) and then followed by the locals group (the later known as US Nationals). Progress was triggered by implementation of Airline Deregulation Acts in 1978.

Thus, in this model the flight route consists of a central point (hub) that serves multiple ends (spokes). The hub serves as a consolidation of passengers and cargos that are transferred to the various spokes and provide the connecting flights for the next destination, both domestic flights and international flights. Airline operators organise interhub flights several times a day, usually using large capacity aircraft that can carry passengers from areas (districts) around the hub airport.

Airline operators also organise fleets for the spoke airport using smaller aircraft, providing higher flight frequencies and supporting hub airports by connecting to the large number of spoke airports as well as building partnerships with regional airline operators or establishing branches to build networks to remote areas [13]. **Table 1** shows this pattern based on airlines offering the best connections per arriving flight.

The selection of hub is based on the location and the large market demand for pairing of origin–destination trips by supporting an airline operation. For this

Figure 2.
Hub and spoke for a flight network pattern. A:Hour glass hub & spoke. B: Hinterland hub & spoke.

Airline	Hub	Average total connections per arriving flight	Average rapid connections per arriving flight (%)	Average slow connections per arriving flight (%)
Etihad airways	AUH	19	66	34
Qatar airways	DOH	13	61	39
Air France	CDG	37	59	41
Lufthansa	FRA	55	55	45
KLM	AMS	45	52	48
Emirates	DXB	21	50	51
British airways	LHR	39	47	53

Source: [14].

Table 1.
Average number of connections per arriving flight at the hub of selected airlines.

purpose, the method of planning and optimising for detailed route determination is used to obtain an accurate basis for transportation system planning.

5. Hub airport identification

To identify the determination of hub airports the Herfindahl–Hirschman Index method can be used. HHI is a distribution and market size measure equal to the sum of squares of participation of a corporation "i" ($\text{HHI} = \Sigma\pi^2$). HHI is widely implemented in transportation to analyse the relationship between ticket prices and market concentration and is also recommended by some organisations, including the US Department of Justice and the US Federal Trade Commission [15]. HHI is attractive because it correlates directly with the number of effective market participants. HHI can be considered to be in contrast withthe number of companies that have the same size, so if the HHI in a market has value 0.1, then this market will be as competitive as the 10 companies with the same large size. Symmetrically, the opposite of HHI can be regarded as the number of airports (ne) in the market, which are airports with a significant market share in the system.

The values of HHI should be in the range of "0" to "1"; however, in the case of airports only in the range of 0 to 0.5, every time an aircraft takes off means one is landing at another airport. Therefore, any airport cannot have more than 50% of the movement of aircraft in an aviation network. The maximum concentration of air transport systems with "n" airports occurs when there is only one hub airport with 50% of the market share and the remainder is distributed equally on the spoke airports.

Figure 3 illustrates the dashed blue line at four departure banks, which begins with a low frequency and climbs to a high frequency; the banks begin with a high density until the levels decline, as follows:

1. Bank 1 at 6.30 am to 11.30 am, the peak hours at 8.30 am to 10.00 pm.

2. Bank 2 at 11.30 am to 14.30 pm, the peak hours at 11.30 am to 13.00 pm.

3. Bank 3 at 14.30 am to 19.00 pm, the peak hours at 15.30 pm to 18.00 pm.

4. Bank 4 at 19.00 pm to 23.30 pm, the peak hours at 20.30 pm to 22.00 pm.

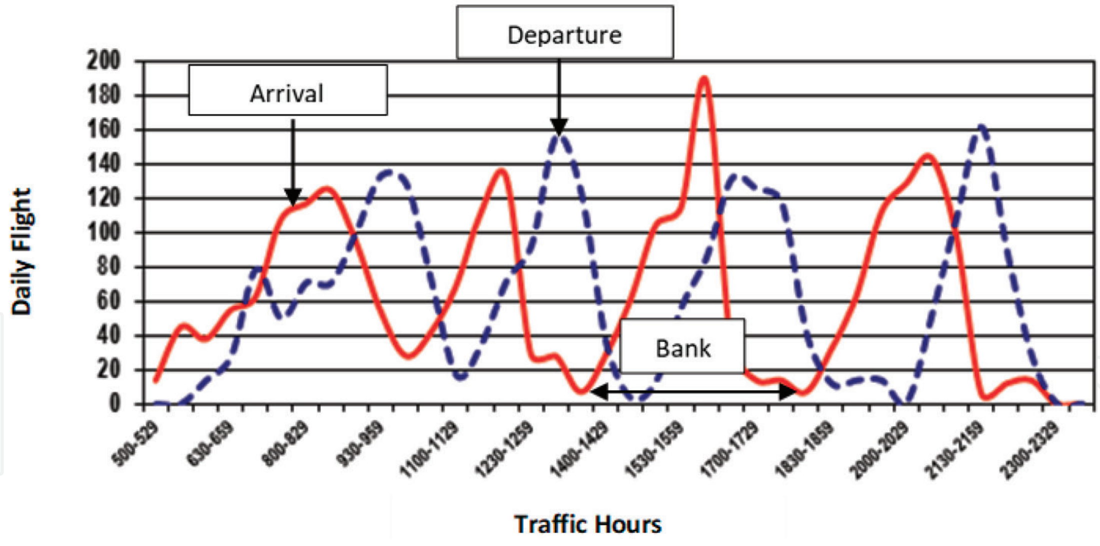

Figure 3.
Grouping of arrival and departure movements for a conventional hub.

The air transport network in Indonesia using the hub and spoke airport system can be assessed using an analysis of the relationship between airports as nodes and attributes, for example the number of routes served at the airport, the number of boarding passengers at the airport and the weight of cargo carried through the airport. If the relationship between nodes and attributes forms a normal distribution curve, then the network pattern system is the hub and spoke pattern system.

There are three main points that are the reference for air transport business corporates and hub airport managers to attract as many passengers as possible:

1. To arrange the wave of arrivals and departures on "banks" from the beginning (morning period) to the end (night period) during the day (during the operational hours), so that the waiting time for passengers was not too long.

2. To set up the flight arrival path of the spoke airport in the long-haul (domestic/international) flight departure path, and vice versa, to make it comfortable for passengers due to GMT time difference.

3. To serve the suburbs and specific markets that cannot be served by a point-to-point system.

6. Analysis of hub airport efficiency for international air traffic in the ASEAN region

6.1 Eigen vector centrality method

Eigenvector centrality (EVC) analysis is performed by assessing the level of importance of an airport in relation to another airport based on airport connectivity in the network system [1]. As a simple illustration, airport A is more important in a network structure if it is connected to airport B (the primary hub airport category) than if it is connected to airport C (the secondary hub airport category). For example, Radin Inten II Airport-Lampung Province will be rated more important if it is provided with the flight route to Soekarno-Hatta International Airport-Jakarta Province (the big hub airport category) compared to the flight route to Sultan Thaha Airport-Jambi Province (the medium hub airport category).

To obtain this level of importance requires the simultaneous assessment of all the airports under observation. Therefore, assessment is done by using a matrix operation, in this case the Origin Destination Matrix, to facilitate an understanding of the form of graphical visualisation as presented in **Figure 4**.

Statistical analysis shows that the distribution pattern of EVC value (Ev) follows the power law pattern when the value of the square coefficient is 2233. It is proven that the structure of aviation networks in Indonesia forms a hub and spoke system. However, if the distribution is formed following the normal distribution pattern, it shows that the structure of the flight network in Indonesia forms a point-to-point system.

It is shown in **Figure 4** that Juanda International Airport in Surabaya, Soekarno-Hatta International Airport in Jakarta, and Sultan Hasanuddin International Airport in Makassar are the airports with the highest connectivity level in Indonesia. This means that these three airports play the most important role (main hub airports) for the whole structure of aviation networks in Indonesia. Based on government regulations concerning the airport system in Indonesia as stated in Government Regulation No. 69 of 2013, the three airports are included in the primary hub airport category, a level below I Gusti Ngurah Rai International Airport in Denpasar, which is included in the category of secondary hub airport [16]. However, the level of tertiary hub airport has two other airports, namely Kualanamu International Airport in Medan and SAMS International Airport in Balikpapan. In addition to these six airports, the other airports serve as spoke airports.

6.2 Herfindahl: Hirschman index method

HHI is a distribution and market size measure equal to the sum of squares of participation of a corporation "i" ($HHI = \sum Pi^2$). HHI is widely implemented in transportation to analyse the relationship between ticket prices and market concentration and correlates directly with the number of the effective market participants.

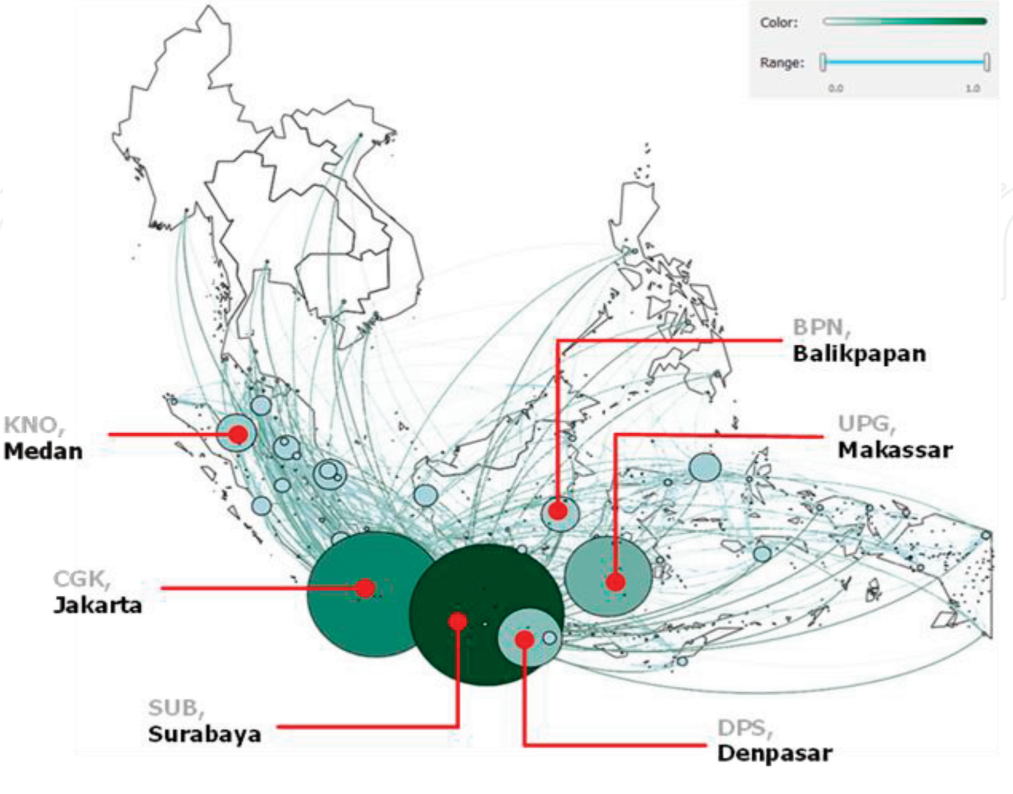

Figure 4.
Airport system based on eigenvector centrality.

No.	Airport	Number of international air passengers**	π	π^2
1	Sultan Iskandar Muda	74,380	0.00309	0.00001
2	**Kuala Namu***	2,153,244	0.08946	0.00800
3	Minangkabau	89,455	0.00372	0.00001
4	Sultan Syarif Kasim II	447,858	0.01861	0.00035
5	Hang Nadim	31,634	0.00131	0.00000
6	S.M. Badaruddin II	121,987	0.00507	0.00003
7	Husein Sastranegara	295,849	0.01229	0.00015
8	**Soekarno-Hatta***	11,849,161	0.49229	0.24235
9	Halim Perdana Kusuma	14,562	0.00060	0.00000
10	Ahmad Yani	116.426	0.00484	0.00002
11	Adi Sumarmo	124,016	0.00515	0.00003
12	Adi Sutjipto	294,701	0.01224	0.00015
13	**Juanda***	1,822,372	0.07571	0.00573
14	**Ngurah Rai***	6,140,721	0.25512	0.06509
15	Lombok	143,872	0.00598	0.00004
16	Supadio	23,101	0.00096	0.00000
17	**SAMS***	98,808	0.00411	0.00002
18	Juwata	22,008	0.00091	0.00000
19	Sam Ratulangi	46,530	0.00193	0.00000
20	**Sultan Hasanuddin***	150,445	0.00625	0.00004
21	Syamsudin Noor	8362	0.00035	0.00000
	$\sum$Xi	24,069,492		
	HHI	0.322		
	ne	4		
	n	29		
	$n^2 – ne.n$	725		
	$(n^2 – n^2.n)^{0.5}$	26.92582		
	$n – (n^2 – ne.n)^{0.5}$	2.07418		
	$0.5(n – (n^2 – ne.n))^{0.5}$	1.03709		
	Number of hub	2		

*Note: *Year of 2014. **Sample of airports.*

Table 2.
HHI method to determine hub airport on supporting open sky ASEAN.

The method of HHI becomes attractive because it correlates directly with the number of effective market airports, for example if the HHI in a market has a value 0.1, then this market will be as competitive as the 10 companies with the same large size. The values of HHI should be in the range of “0” to “1”; however, in the case of airports only in the range 0 to 0.5, every time an aircraft takes off one is landing at another airport.

In the HHI method, the input parameter used as the basis for determining a hub airport is the production of air transport movement (passenger, cargo). In this research, as many as 21 airports that provide international flights are analysed. The flights that are calculated are the number of international flight passengers. **Table 2** analyses the calculation of the HHI method.

In **Table 2**, the calculation result shows that the distribution of international air passenger production has an HHI value of 0.322%, meaning this value gives an indication that the distribution of international air passenger production has a high concentration on a certain airport. The data in the table shows that the airport with the biggest international air passenger production is Soekarno-Hatta Airport-Jakarta, with 11,849,161 passengers or 49.23% of international flight total movement. Further, the number of effective airports is four, as follows:

1. Soekarno-Hatta Airport-Jakarta;

2. Ngurah Rai Airport-Bali;

3. Kuala Namu Airport-Medan; and

4. Juanda Airport-Surabaya.

The four effective airports are designated as ASEAN hub airports. Sultan Hasanuddin Airport-Makassar, although established as an ASEAN hub airport, is not an effective airport, this is because domestic air passenger production is less than Soekarno-Hatta Airport-Jakarta, Ngurah Rai Airport-Bali, Kuala Namu Airport-Medan and Juanda Airport-Surabaya. However, the position of Sultan Hasanuddin, which is geographically located in the middle of Indonesia, gives it good geographical potential to be developed as an ASEAN hub in the future.

6.3 Flight path efficiency

Furthermore, calculation of the efficiency route combines several configurations, as follows:

1. Flight route efficiency with a configuration of 7 hub airports +28 spoke airports; analysis of transportation efficiency value for an aviation network system with a configuration of 7 hub airports +28 spoke airports gives a value equal to 72.09%. This value is still too far from the efficient range (49–52%).

2. Flight route efficiency with a configuration of 6 hub airports +29 spoke airports; analysis of transportation efficiency value for an aviation network system with a configuration of 6 hub airports +29 spoke airports gives a value equal to 71.81%. This value is still too far from the efficient range (49–52%).

3. Flight route efficiency with a configuration of 5 hub airports +30 spoke airports; analysis of transportation efficiency value for an aviation network system with a configuration of 5 hub airports +30 spoke airports gives a value equal to 71.15%. This value is still too far from the efficient range (49–52%). The value of transportation efficiency does not vary much with transportation efficiency in the 6 hub +29 spoke configuration. The problem with this configuration caused the hub airport that is not taken into account (SAMS Airport-Balikpapan) has the flight movement not too large production movement in the system.

4. Flight route efficiency with a configuration of 4 hub airports +31 spoke airports; analysis of transportation efficiency value on an aviation network system with a configuration of 4 hub airports +31 spoke airports gives a value

equal to 66.48%. This value is still quite far from the efficient range (49–52%); however, it is better than the previous configuration.

5. Flight route efficiency with a configuration of 3 hub airports +32 spoke airports; analysis of transportation efficiency value on an aviation network system with a configuration of 3 hub airports +32 spoke airports gives a value equal to 63.21%; this is better than the previous configuration.

These results provide an understanding of the value of flight efficiency in terms of flight network modelling but is still quite far from the optimum efficiency range, i.e. 49–52%, and shows that the flight network system with various hub and spoke models needs to be improved.

7. Conclusions

The main conclusion from the research is that the simulation of flight networks is still above the optimum efficiency range, i.e. 49–59%, meaning that the result of the configuration alternatives is dynamic depending on increasing performance. Performance could be improved if there were a high concentration value of emergence of international flight networks heading to the airport. The overall conclusion is as follows:

- Regarding the existing air transport, the production of air transport in Indonesia is distributed between 35 major airports in 34 provinces. Air passenger movements are divided by the number of active domestic flight routes.

- The hub and spoke model of the existing airport system, based on the pattern of existing air transport movement, shows that the number of active hub airports is eight:

1. Kuala Namu Airport-Medan;
2. Hang Nadim Airport-Batam;
3. Soekarno-Hatta Airport-Jakarta;
4. Adi Sucipto Airport-Yogyakarta;
5. Juanda Airport-Surabaya;
6. Ngurah Rai Airport-Bali;
7. Sultan Hasanuddin Airport-Makassar; and.
8. SAMS Airport-Balikpapan.

These eight airports are considered as the existing hub and have a number of connecting flights.

- There is an alternative to the hub and spoke model that supports ASEAN open sky. With reference to government regulation number 69 of 2013 the number of international hubs that support ASEAN open sky is five

1. Kuala Namu Airport-Medan;

2. Soekarno-Hatta-Jakarta;

3. Juanda Airport-Surabaya;

4. Ngurah Rai-Bali; and

5. Sultan Hasanuddin-Makassar.

In addition to the regulation, hub and spoke patterns also consider the production of trips by trip route. Based on the production of the trip there are three airports with considerable production and a large number of flight routes:

1. Kuala Namu Airport-Medan;

2. Soekarno-Hatta Airport-Jakarta; and.

3. Juanda Airport-Surabaya.

The hub and spoke airport model system that supports ASEAN Open Sky was developed with various configurations, as follows:

a. 7 hub and 28 spoke configuration models (considering the Indonesian Economic Infrastructure Development Acceleration Program);

b. 6 hub and 29 spoke configuration models;

c. 5 hub and 30 spoke configuration models (considering Government Regulation number 69 of 2013);

d. 4 hub and 31 spoke configuration models;

e. 3 hub and 32 spoke configuration models (considering airport production).

- Efficiency of flight routes:

a. The flight efficiency of various hub and spoke configuration models is as follows:

   i. Efficient transport value 7H + 28S = 72.09%;

   ii. Efficient transport value 6H + 29S = 71.81%;

   iii. Efficient transport value 5H + 30S = 71.15%;

   iv. Efficient transport value 4H + 31S = 66.48%;

   v. Efficient transport value 3H + 32S = 63.21%;

b. The alternative to the hub and spoke models suggests that the 3 hub configuration (Kuala Namu Airport-Medan, Soekarno-Hatta Airport-Jakarta and Juanda Airport-Surabaya) is the best configuration, although it does not reach the efficiency range of 49–52%.

c. In general, the various configurations of the number of hubs for supporting the Open Sky policy are still quite far from the flight efficiency value and need to be improved.

Acknowledgements

The author is grateful to the Centre of Research and Development for Air Transportation of the Ministry of Transportation Indonesia for encouragement in writing this chapter and the academic editor who gave valuable comments on aspects of book production.

Author details

Eny Yuliawati
The Centre of Research and Development for Air Transportation, Ministry of Transportation, Indonesia

*Address all correspondence to: enjulia_2005@yahoo.co.id

References

[1] Barabasi AL. Linked: The New Science of Network. Cambridge, Massachussets: Perseus Publishing; 2002

[2] Pels E. A note on airline alliances. Journal of Air Transport Management. 2001;**7**(1):3-7

[3] Alderihi M, Cento A, Nijkamp P, Rietveld P. Network competition—The coexistence of hub and spoke and point to point systems. Journal of Air Transport Management. 2005;**1**(5):328-334

[4] Dennis NP. Airline hub operation in Europe. Journal of Transport Geography. 1994;**2**(4):219-233

[5] Haryanto IW. Studi Kasus Perencanaan Sistem dan Teknik Transportasi Udara di Indonesia. Case Study of System and Engineering Planning on Indonesia Air Transportation. Yogyakarta-Indonesia: Gadjah Mada University Press; 2015

[6] ERIA Study Team. Assessment of the Implementation of ASEAN Transport Cooperation in ASEAN Strategic Transport Plan 2011-2015. Jakarta: ASEAN Secretariat and ERIA. pp. 4-1-4-74

[7] Bowen J. The Asia Pacific airline industry: Prospects for multilateral liberalization. In: Findlay C, Chia Lin S, Singh K, editors. Asia Pacific Air Transport: Challenges and Policy Reforms. Singapore: Institute of South East Asian Studies; 1997

[8] Findlay C, Forsyth P. Air transport in the Asian Pacific region. Asia Pacific Economic Literature. 1992;**6**:1-10

[9] Air Transport Policy. Workshop on Air Transport Policy. Bangkok: ICAO Printed; 2001

[10] Li M. Air transport in ASEAN: Recent developments and implications. Journal of Air Transport Management. 1998;**4**:135-144

[11] Oum TH, Yu C. Shaping Air Transport in Asia Pacific. Aldershot: Ashgate; 2000

[12] Implementation Blueprint. Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA). Philippines: ADB printed; 2012

[13] Graham B. Geography and Air Transport. Chichester, England: Wiley; 1995

[14] O'Connell JF, Bueno OE. A study into the hub performance of emirates, Etihad airways and Qatar airways and their competitive position against the major European hubbing airlines. Journal of Air Transport Management. 2018;**69**:257-268

[15] Herfindahl–Hirschman Index, The United Stated Department of Justice. Retrieved from http://www.justice.gov/atr/herfindahl-hirschman-index

[16] Tatanan Kebandarudaraan Nasional. Peraturan Menteri Perhubungan Nomor PM 69 Tahun 2013. Kementerian Perhubungan Indonesia; 2013