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A Modified Weighted Connectivity Ratio for Measuring a Low-cost Carrier's Connectivity at its Major Airports

An AirAsia Group Study on its Informal Hub-and-spoke Network

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Abstract

This study aims to analyze how good and efficient the low-cost carriers' connectivity is at their major airports by studying one of the largest low-cost carriers in the world, AirAsia Group. Weighted Connectivity Ratio is used in the calculation, applied with slight modifications to suit the operations of low-cost carriers at their airports. The results reveal that some airlines have very good connectivity, even when it is compared to the connectivity of several big full-service carriers in Europe. This research brings a novelty in the form of an analysis of connectivity of low-cost carriers, considering that most of the previous research only focused on the connectivity of full-service carriers that implement a hub-and-spoke strategy. This is important because low-cost carriers are currently present with a very rapid growth as an alternative flight option that is more affordable for passengers in addition to full-service carriers that have previously dominated the aviation market.

Keywords

low-cost carriers, connectivity, point-to-point, hub-and-spoke, weighted connectivity ratio

1 Introduction

Lately, low-cost carriers (LCCs) have experienced rapid growth in the aviation world, but research to measure the quality of the connectivity they have is very little. This is because the LCCs formally implement a point-to-point strategy in their network, while most of the current research calculates how good the connectivity of airlines with the hub-and-spoke network is, which is formally implemented by full-service carriers (FSCs). This topic is important since one of the most important parts of an airline in maximizing its profit and network performance is its connectivity.

The two network models used by airlines around the world are hub-and-spoke and point-to-point. Hub-and-spoke has become a popular network model since deregulation in the airline industry was enacted (Doganis, 2002). However, this model seems to be the hallmark of the FSCs, which rely on the traffic demand from airports that are hubs. As for LCCs, most of these types of airlines believe that point-to-point is a wise choice in maintaining cost-competitiveness and in competing with incumbent airlines on a schedule without having to face problems with the connecting wave system (Fageda et al., 2015; Zeigler et al., 2017).

The current research mostly discusses the connectivity performance of FSC in its hubs. Thus, it is important to conduct research on connectivity of LCCs for a wider range of study in the world of air transportation.

1.1 LCC and point-to-point network model

FSC is known as an airline's business model that implements a hub-and-spoke network. Using this network model, which makes one or several airports a hub, airlines can make many combinations of arrivals and departures with high frequency (Rietveld and Brons, 2001), which means that the possibility for a flight to have a connection with the previous or next flight is very high. However, Rietveld and Brons (2001) also explain that one of the disadvantages of this model is that passengers must have an extra stop (i.e., at the hub airport) to continue their journey to the final destination airport.

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On the other hand, LCC is run by an airline for the realization of low operating costs, a simple business model to implementing a point-to-point network. In a point-to-point network, major airports play the role of "technical bases", while in a hub-and-spoke network, they are hubs. A base is indeed designed to serve direct flights (Alderighi et al., 2007). They "only" function as a stopover for aircraft for overnight stays, especially for short-haul domestic and regional flights, not formally designed as connecting nodes. An illustration of the comparison between hub-and-spoke and point-to-point networks can be seen in Fig. 1. Hub-and-spoke network has the opposite end of connectivity to point-to-point. A hub-and-spoke network connects each point through an intermediary called a hub. Meanwhile, point-to-point directly connects a route without any service interruptions (such as pick-up and drop-off) even if the route chosen by the passenger is not a direct route.

Alderighi et al. (2007) also state that in the point-to-point network run by LCC, in theory, all points (airports) served must be connected to each other, but in reality, not all points are connected. Why? This is due to various factors, such as economic and political reasons, some city pairs that do not have sufficient volume of demand to justify that a route can generate profits, some flight slots for certain airports are difficult to obtain which can add complexity, additional logistics costs which may arise due to changes in the rotation of the aircraft. Therefore, most LCCs focus more on the growth of a route than on how the route has a connectivity impact for the previous and subsequent flights. For this reason, Fichert and Klophaus (2016) argue that for airlines, changing point-to-point services into route networks is not easy as it will increase complexity and surely will increase costs, but the advantage is that there is a possibility of additional potential revenue from connecting flights.

Therefore, this study attempts to conduct research on the connectivity quality of an LCC at its large airports, because de Wit and Zuidberg (2012) view that large airports have the potential to trigger a random connect system that provides additional access to airports' traffic volume, as in the case of one of the major LCCs in Europe, Ryanair. A survey by O'Connell and Williams (2005) stated that 17.2% of passengers had connections to other flights at London Stansted Airport, the majority of which were Ryanair flights as well. Thus, from the given research and facts, it is suspected that good connectivity between AirAsia flights is possible at major airports served by the AirAsia Group, the largest LCC in Asia, with a fleet of more than 200 aircraft.

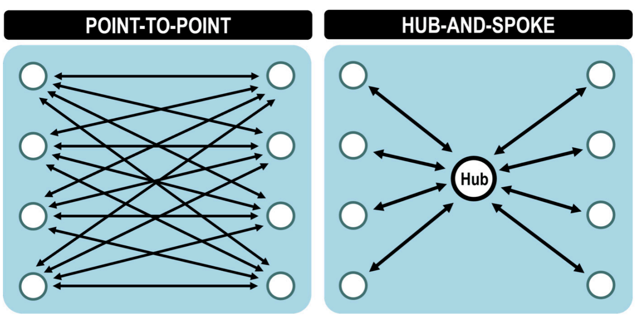

Fig. 1 Point-to-point vs. hub-and-spoke. Adapted from Rodrigue (2020)

1.2 AirAsia: A single airline brand in multiple countries

AirAsia Group is one of the largest LCC airline groups in the world, with a fleet of more than 200 aircraft, making it the largest LCC in Asia. This airline group has reached many achievements, one of which is being the best LCC in the world 14 times in a row. This cannot be separated from how the contribution of network performance is applied to each airline, most of which focus on the Southeast Asian market. These airlines are Malaysia AirAsia (AK) which has its main hub at Kuala Lumpur International Airport (KUL), Thai AirAsia (FD) with Don Mueang International Airport (DMK) as the main headquarters, Indonesia AirAsia (QZ) with Soekarno-Hatta International Airport (CGK) as the main hub and Philippines AirAsia (Z2) which has Ninoy Aquino International Airport (MNL) as its main hub. In addition, the AirAsia Group also has airlines that specifically serve long-haul flight routes, AirAsia X (D7) with KUL as the hub and Thai AirAsia X (XJ) with DMK as the hub. With the average aircraft age being 8.8 years, Table 1 shows the breakdown of the AirAsia Group hub and fleet, while Fig. 2 shows the analysed hubs.

Although some airlines have more than one hub, this research focuses on the main hubs only. Airlines with short-to-medium haul (AK, FD, QZ and Z2) have larger domestic routes than international ones. This is understandable because the four countries that have been served

Table 1 AirAsia Group: hubs and fleet (internal data)

Airlines	Main hub	Fleet
Malaysia AirAsia (AK)	KUL	97
Thai AirAsia (FD)	DMK	58
Indonesia AirAsia (QZ)	CGK	25
Philippines AirAsia (Z2)	MNL	23
AirAsia X (D7)	KUL	21
Thai AirAsia X (XJ)	DMK	10
Total Fleet		234

Fig. 2 AirAsia Group's main hubs. Source: Swartz's Great Circle Mapper

(Malaysia, Thailand, the Philippines and Indonesia) have a very large domestic market potential, especially for inter-island domestic services, which are currently the favorite and most popular mode of transportation and more efficient for passengers, compared to other modes of transportation, ships for example, which in terms of costs are not much different from the cost of LCC flight tickets (especially if there are promos), as well as in terms of travel time which takes much longer. However, although the percentage of international flights has a smaller portion than the domestics, this does not necessarily indicate that the size of international flights is small. For example, Malaysia AirAsia has many flight routes not only to Southeast Asian countries, but also to other countries, such as China, India, Bangladesh, Sri Lanka and the Maldives. Likewise with Thai AirAsia, the airline with the most destinations on Chinese routes (among all other AirAsia airlines) has a lot of destinations in international cities such as Hong Kong, Beijing, Shanghai, Chennai, Kolkata and Kochi. This indicates that the role of the hub is very important in terms of the performance of the connectivity, which in this case is emphasized on connectivity related to international flights (domestic-international, international-domestic and international-international). However, returning to the LCC business concept that applies point-to-point models, this will certainly be very interesting if it is found that the connectivity value obtained from these hubs is sufficient for the network to be referred to as an "informal hub-and-spoke network".

Switching to long-haul carriers, in this case AirAsia X and Thai AirAsia X, where these airlines only serve international routes, is certainly a very interesting thing to study because as is well known, most of the LCCs are only serving short-to-medium-haul routes using narrow body aircraft, as the world's major airlines, Ryanair and Southwest, for example. Once again, this will certainly have implications for the importance of the hubs owned in the effort to establish good connectivity, not only connectivity with fellow long-haul carriers, but also with short-medium haul carriers; as well as connectivity with other international and domestic flights. In this case, international and domestic routes will complement each other in terms of load factor, which will have an impact on increasing revenue, especially for improving the performance of routes whose load factor are still not good. For example, some flights from cities in India (e.g., Chennai, Kolkata and Kochi) on Thai AirAsia, are scheduled to arrive at DMK around 04:30 a.m. in order to connect with domestic flights in Thailand, in this case to Phuket City (HKT) with the earliest departure from DMK at around 06.00.

2 Literature review

The current research mostly discusses the connectivity performance of an FSC in its hubs. For example, the connectivity performance of All Nippon Airways in its dual-hubs, Narita Airport and Haneda Airport (Li et al., 2012); China Eastern Airlines' connectivity at its two hubs in Shanghai City, PVG and SHA (Yang and Liu, 2019); hub performance of Emirates, Etihad Airways and Qatar Airways compared to several major European airlines (O'Connell and Bueno, 2018); network performance of Turkish Airlines and Emirates (Logothetis and Miyoshi, 2018); performance of the hub-and-spoke network of several European and American airlines (Števárová and Badánik, 2018); and a comparison of the performance of the hubs in China in 2010 vs. 2015 (Huang and Wang, 2017). There is a research that discusses LCCs in relation to network connectivity, but it is limited to small airports in Europe (Zeigler et al., 2017). Some of the studies that have been described can be found in Table 2.

In this research, the focus is on the connectivity performance of LCCs at their bases, where the bases are mostly large airports, which means that FSCs also serve flights to these airports. Although formally LCCs do not implement hub-and-spoke in their network system, if it is looked at the large volume of flights carried out in their point-to-point system, it will be found that there are many possible options

Table 2 Research comparison on hub connectivity

Author	Model	Limitation	Review/Improvement
Li et al. (2012)	Hub Connectivity Indicator (HCI)	FSC only	Research on LCC
Yang and Liu (2019)	Hub Connectivity Indicator (HCI)	FSC only	Research on LCC
O'Connell and Bueno (2018)	Weighted Connectivity Ratio (WCR)	FSC only	Research on LCC
Logothetis and Miyoshi (2018)	Hub Connectivity Performance Analyser (HCPA)	FSC only	Research on LCC
Števárová and Badánik (2018)	Wave Patterns	FSC only	Research on LCC
Huang and Wang (2017)	Weighted Indirect Connectivity (WIC)	FSC only	Research on LCC
Zeigler et al. (2017)	Shortest Path Length (SPL)	LCC, but only for small airports	Research on LCC at big airports

for connecting flights for passengers (Zeigler et al., 2017), especially at large airports.

There have been many studies that explain the previous hub connectivity calculation model, even Burghouwt and Redondi (2013) conducted a study on the comparison of the previously made hub connectivity models. At least, there are 11 models that are compared. The models are classified based on at least two main dimensions, temporal coordination and routing factor.

In simple terms, temporal coordination can be said to be a time-based approach in calculating hub connectivity. To make it easier to explain, imagine that there is a passenger on a flight from airport A to airport B, but has to transit through airport X first because there are no direct flights from A to B. Temporal coordination can easily be explained as waiting or transit time at airport X, which is the time from when the passenger lands from airport A to the scheduled departure to airport B.

On the other hand, routing factor sees distance as something that must be considered in calculating hub connectivity.

Looking at the case of the passenger from airport A to B via X in the previous explanation, then the routing factor can be defined as the distance traveled on a flight from airport A to X and X to B, compared to the theoretical distance directly from airport A to B. The comparison of the two distances is one of the elements of consideration to determine whether or not the connectivity is good at a hub airport.

Of the many models proposed, this study uses the model approach studied by Danesi (2006). This calculation model presented by Danesi (2006), as explained by O'Connell and Bueno (2018), has advantages compared to other calculation methods. Briefly, O'Connell and Bueno (2018) explain that there are 2 advantages in the method proposed by Danesi (2006). First, he limits the maximum acceptable connecting time (MACT) in its index, this will certainly have an impact on the elimination of flights with connectivity that exceeds the MACT limit, so that the amount of data to be processed can be reduced. This limitation on MACT is not carried out in several methods, such as the Quickest Path Length (Malighetti et al., 2008; Paleari et al., 2010), Continuous Connectivity Index (Lee et al., 2014) and the Netscan model pioneered by Veldhuis (1997). Second, not only limiting MACT, Danesi (2006) also limits the value of the de-routing index to 1.5. This, in addition to simplifying calculations by reducing unnecessary connections due to the large number of backtracking connections, is very coherent from the passengers' point of view as most passengers will not be interested in backtracking connections that are too extreme. In addition, Danesi (2006) sharpens the accuracy in his research by introducing Intermediate Connect Time (ICT), which is a connecting time value that is between Minimum Connect Time (MCT) and Maximum Acceptable Connect Time (MACT) where the transit time of passengers is between MCT and ICT. This transit time is the most optimum or "more desirable" for passengers. The comparison between the existing methods can be observed in Table 3. It is evident in Table 3 that for the first six models, the calculation of connectivity does not consider the routing factor so that this is one of the weakness factors that causes these models not to be taken into account in the comparison in the previous explanation.

3 Research method

3.1 Weighted Connectivity Ratio model

Let T be the time period that shows the operating hour of a hub. Suppose $i = 1, 2, \ldots, n_a$ are flights arriving to the hub in period T and $j = 1, 2, \ldots, n_d$ are flights departing from that hub in period T. Then suppose $t_{a,i}$ is the arrival time of flight i and $t_{d,j}$ is the departure time of flight j, then $TT_k = t_{d,j} - t_{a,i}$, where $k = (i,j)$ is the connection time between flights i and j. Then suppose $n_{a,dom}$ is the number of domestic flights coming to the hub and $n_{d,dom}$ is the number of domestic flights

Table 3 Classification of various connectivity models. Adapted from O'Connell and Bueno (2018)

Model	Reference	Temporal coordination	Routing factor	Connection quality
Hub potential	Dennis (1999)	No	No	No
Gross vertex connectivity	Ivy (1993); Ivy et al. (1995)	No	No	No
Shortest path length	Cronrath and Arndt (2008); Malighetti et al. (2008); Shaw (1993); Shaw and Ivy (1994)	No	No	Binary
Number of connection patterns	Budde et al. (2008)	Yes	No	Binary
Bootsma connectivity	Bootsma (1997)	Yes	No	Discrete
Doganis and Dennis connectivity	Doganis and Dennis (1989); Doganis (2002); Dennis (1994a); (1994b); (2001); Lee et al. (2014)	Yes	No	Binary
Quickest path length	Malighetti et al. (2008); Paleari et al. (2010)	Yes	Yes	Binary
Weighted Number of Connections (WNX)	Burghouwt and de Wit (2005); Lipovich (2012)	Yes	Yes	Continue
Netscan Connectivity Units (CNU)	ACI Europe and SEO Economic Research (2014); Burghouwt and Veldhuis (2006); Matsumoto et al. (2008); Veldhuis (1997)	Yes	Yes	Continue
Continuous Connectivity Index (CCI)	Lee et al. (2014)	Yes	Yes	Continue
Hub Connectivity Indicator (HCI)	Li et al. (2012)	Yes	Yes	Continue
Weighted Connectivity Ratio (WCR)	Danesi (2006); Lee et al. (2014)	Yes	Yes	Discrete

departing from the hub in period T. Likewise, with $n_{a,int}$ and $n_{d,int}$ which refers to international flights.

In this study, "domestic" and "international" are used instead of "continental" and "intercontinental" because almost all AirAsia flights, which are international flights, are still in one continent. For example, all international flights for Thai AirAsia still operate within one continent, to countries such as Malaysia, Indonesia, Singapore, India, China, Japan and others. Likewise with Indonesia AirAsia which has international flights to Malaysia, Thailand, Singapore and others.

Then, MCT_k is defined as Minimum Connect Time and $MACT_k$ as Maximum Acceptable Connect Time between flights i and j. Danesi (2006) added ICT_k as Intermediate Connect Time to separate between "rapid connection", $MCT_k \leq TT_k \leq ICT_k$ and "slow connection", $ICT_k < TT_k \leq MACT_k$.

Table 4 presents the information of MCT, ICT and MACT with modifications to MCT as follows:

1. For domestic-domestic flights, 30-minute MCT is used instead of 45 minutes proposed by Danesi (2006). This is because it is assumed that, as stated by Dennis (2001), the airport (hub) has upgraded its facilities to allow a 30-minute MCT to be carried out, as was done by Brussels Airport. There is even one airport in Sweden, namely ARN (Arlanda) which has an MCT of only 25 minutes. With the modification of the MCT from 45 minutes to 30 minutes, an increase in the WCR value will occur because the connecting time of 30 to 44 minutes which was previously not calculated on the 45-minute MCT, becomes calculated on the 30-minute MCT.
2. Dennis (2001) also added that one of the successes in minimizing MCT is by minimizing passenger bussing (accommodation of passengers using buses) and aircraft towing at the apron between planes arriving and departing time at a hub, which requires a system to change a gate that can switch functions from domestic gates to international gates or vice versa. Dennis (2001) also thinks that a special terminal is needed called "satellite" or "midfield terminal" which allows access to all aircraft, where this terminal is specifically for connecting passengers. This terminal is separated from the land-side area which is a place for check-in, baggage collection and more.

Table 4 MCT, ICT and MACT. Adapted from Danesi (2006) with modifications

Connectivity type	MCT_k	ICT_k	$MACT_k$
Domestic-Domestic	30	90	120
Domestic-International (*vice versa*)	45	120	180
International-International	45	120	180

Here it is assumed that all the things that were mentioned by Dennis (2001) have been able to be fulfilled by the major airports served by the AirAsia Group. With that justification, it is presented that MCT_k for domestic-international (and vice versa) and international-international is 45 minutes (instead of 60 minutes which was presented by Danesi (2006)). For ICT_k and MACT_k, they are assumed to be the same as those presented by Danesi (2006).

Then, suppose we define a TCM (Temporal Connectivity Matrix) matrix with n_a rows and n_d columns containing elements τ_{ij}, $i = 1, 2, \ldots, n_a$, $j = 1, 2, \ldots, n_d$, then Eq. (1) applies:

$$\begin{cases} \tau_{ij} = 1 \text{ if } \mathrm{MCT}_k \le TT_k \le \mathrm{ICT}_k \\ \tau_{ij} = 0.5 \text{ if } \mathrm{ICT}_k < TT_k \le \mathrm{MACT}_k \\ \tau_{ij} = 0 \text{ if otherwise} \end{cases} . \quad (1)$$

Then, let's define an SCM (Spatial Connectivity Matrix) matrix with n_a rows and n_d columns containing elements δ_{ij}, $i = 1, 2, \ldots, n_a$, $j = 1, 2, \ldots, n_d$, then Eq. (2) applies:

$$\begin{cases} \delta_{ij} = 1 \text{ if } DR_k \le 1.2 \\ \delta_{ij} = 0.5 \text{ if } 1.2 < DR_k \le 1.5 \\ \delta_{ij} = 0 \text{ if otherwise} \end{cases} \quad (2)$$

where

$$DR_k = \frac{ID_k}{DD_k} \quad (3)$$

is the "de-routing index" ($DR_k \ge 1$), where DD_k is the great circle distance from the start point of flight i and the end point of flight j; and ID_k is the total distance of the great circle from each flight corresponding to i and j.

Then, define a WCM (Weighted Connectivity Matrix) matrix with n_a rows and n_d columns whose elements contain ω_{ij}, $i = 1, 2, \ldots, n_a$, $j = 1, 2, \ldots, n_d$, where

$$\omega_{ij} = \tau_{ij} \times \delta_{ij} . \quad (4)$$

Thus, Eq. (5) applies:

$$\begin{cases} \omega_{ij} = 1 \text{ if } \tau_{ij} = \delta_{ij} = 1 \\ \omega_{ij} = 0.5 \text{ if } \tau_{ij} + \delta_{ij} = 1.5 \\ \omega_{ij} = 0.25 \text{ if } \tau_{ij} = \delta_{ij} = 0.5 \\ \omega_{ij} = 0 \text{ if otherwise} \end{cases} . \quad (5)$$

Finally, the weighted connectivity ratio is defined as

$$\mathrm{WCR} = \frac{WN_c}{WN_r} \quad (6)$$

where

$$WN_c = \sum_{i=1}^{n_a} \sum_{j=1}^{n_d} \omega_{ij} = \sum_{i=1}^{n_a} \sum_{j=1}^{n_d} \tau_{ij} \times \delta_{ij} \quad (7)$$

is the number of weighted connections in the hub during period T, whereas

$$\begin{aligned} WN_r = \frac{\sum_{i=1}^{n_a} \sum_{j=1}^{n_d} \delta_{ij}}{n_a n_d} \Bigg[& n_{a,dom} \frac{n_{d,dom}}{T} \times \left(\mathrm{ICT}_1 - \mathrm{MCT}_1 + \frac{\mathrm{MACT}_1 - \mathrm{ICT}_1}{2} \right) \\ & + n_{a,dom} \frac{n_{d,int}}{T} \left(\mathrm{ICT}_2 - \mathrm{MCT}_2 + \frac{\mathrm{MACT}_2 - \mathrm{ICT}_2}{2} \right) \\ & + n_{a,int} \frac{n_{d,dom}}{T} \left(\mathrm{ICT}_2 - \mathrm{MCT}_2 + \frac{\mathrm{MACT}_2 - \mathrm{ICT}_2}{2} \right) \\ & + n_{a,int} \frac{n_{d,int}}{T} \left(\mathrm{ICT}_3 - \mathrm{MCT}_3 + \frac{\mathrm{MACT}_3 - \mathrm{ICT}_3}{2} \right) \Bigg] \\ = \frac{\sum_{i=1}^{n_a} \sum_{j=1}^{n_d} \delta_{ij}}{n_a n_d} \Bigg[& n_{a,dom} n_{d,dom} \left(\frac{\mathrm{MACT}_1 + \mathrm{ICT}_1 - 2\mathrm{MCT}_1}{2T} \right) \\ & + \left(n_{a,dom} n_{d,int} + n_{a,int} n_{d,dom} \right) \left(\frac{\mathrm{MACT}_2 + \mathrm{ICT}_2 - 2\mathrm{MCT}_2}{2T} \right) \\ & + n_{a,int} n_{d,int} \left(\frac{\mathrm{MACT}_3 + \mathrm{ICT}_3 - 2\mathrm{MCT}_3}{2T} \right) \Bigg] \end{aligned} \quad (8)$$

is the number of weighted connections that are predicted to occur in a random schedule of incoming and outgoing flights during period T.

Weighted Connectivity Ratio identifies whether viable weighted connectivity is not a purely random connectivity. According to Dennis (1994b), the WCR of a hub is called optimal if it is worth 2 to 3, random or even counterproductive connectivity will be worth 1 or less, while the value between 1 and 2 indicates that an airline has "integrated schedules".

3.2 Data collection

The data were taken from the internal data of the AirAsia Group which consists of six airlines, namely Malaysia AirAsia (AK), Thai AirAsia (FD), Indonesia AirAsia (QZ), Philippines AirAsia (Z2), AirAsia X (D7) and Thai AirAsia X (XJ). A date was chosen around the end of 2019 because that was a period where the airline was still operating at 100% full capacity before the Covid-19 pandemic which forced the aviation industry to reduce most of its flights. In this case, it was chosen Friday, December 13, 2019. It is hoped that later the airline will be fully operational again after the Covid-19 period ends.

There are more than 1200 non-stop and direct flights with 130 unique airports from the data collected. Of the total flights, 371 unique O-D (Origin-Destination) pairs were analyzed which resulted in more than 109,000 flight combinations with indirect connections.

Fig. 3 describes the sample data taken from one of the AirAsia Group airlines, Thai AirAsia (FD). The data collected contains at least five main pieces of information, Flt No (Flight Number), Dep (Airport of Origin), Arr (Destination Airport), STD (Time of Departure) and STA (Time of Arrival). The same data were also taken from other airlines, which is then processed in calculating the Connectivity Index which in this case is obtained by calculating the Weighted Connectivity Ratio (WCR).

4 Results and discussions

4.1 Weighted connectivity ratio of every AirAsia airline

Section 4.1 discusses the connectivity performance of each airline, which is noticeable from the value of its Weighted Connectivity Ratio.

Data are presented in Table 5 which shows the number of incoming flights, the number of weighted connections, the random weighted connections and the number of weighted connectivity ratios which are used to estimate the connectivity quality of each airlines of AirAsia Group.

From Table 5, it can be explained in more detail here that the WCR from Thai AirAsia was obtained from 152 arriving flights (n_a), with details of 90 domestic flights ($n_{a,dom}$) and 62 international flights ($n_{a,int}$), resulting in weighted connections of 915.25 (WN_c) with random weighted connections of 781.89 (WN_r).

The calculation results show that among all AirAsia Group Airlines, Thai AirAsia shows the best connectivity, with a WCR of 1.17. Although according to Dennis (1994b)

Flt No	Dep	Arr	STD	STA
FD1030	DMK	LPQ	13.55	15.20
FD1031	LPQ	DMK	15.50	17.20
FD1040	DMK	VTE	12.50	14.00
FD1041	VTE	DMK	14.30	15.40
FD120	DMK	CCU	00.05	01.10
FD121	CCU	DMK	01.40	05.40

Fig. 3 Thai AirAsia sample data

this number is still relatively low, Thai AirAsia's connectivity performance exceeds what was achieved by British Airways (BA) at Heathrow Airport in 2014, which only had a WCR of 1.13 (O'Connell and Bueno, 2018). In fact, as is well known, British Airways is an FSC airline with a hub in one of Europe's major cities, London, which applies the pure hub-and-spoke concept. This indicates that even if an LCC implements a point-to-point network, it does not necessarily imply that its connectivity quality will always be lower than what an FSC has.

Furthermore, it is observable that Malaysia AirAsia and Philippines AirAsia have almost the same WCR values, 1.02 and 1.09, respectively. Although when it is viewed in terms of fleet and network size, Malaysia AirAsia is far more superior, even among all airlines within the AirAsia Group. However, even though their WCR values are similar, there are things that look very different, that is the composition of domestic-international flights. Malaysia AirAsia has a very large composition of international flights, even bigger than its domestic ones, which are 119 out of 227 flights (52.42%), with Philippines AirAsia which only has 14 international flights out of a total of 63 flights (22.22%). This indicates that the concept of feeder flights, i.e., the existence of domestic flights that are very useful to support international flights in improving connectivity, or vice versa, at least runs better than just random on Malaysia AirAsia with more than 50% international flights; and Philippines AirAsia which only owns less than 25% of its total flights.

Indonesia AirAsia has a WCR of less than one, which is only 0.75. This implies that the airline's connectivity value is even lower than its random connectivity value, which means that, based on Dennis (1994b), CGK is a counterproductive hub for Indonesia AirAsia in terms of connectivity. An important point to take is the possibility that Indonesia AirAsia only focuses on the concept of a point-to-point network.

Moving on to the airlines operating wide-body airliners, AirAsia X and Thai AirAsia X show a very significant difference. On the one hand, AirAsia X even has the highest

Table 5 Amount of n_a, WN_c, WN_r and WCR of each airlines on Friday, 13 December 2019. Source: compiled by Pino Rachmandika

Airlines	Main hub	$n_{a,dom}$	$n_{a,int}$	n_a	WN_c	WN_r	WCR
Malaysia AirAsia (AK)	KUL	108	119	227	1698.75	1668.39	1.02
Thai AirAsia (FD)	DMK	90	62	152	915.25	781.89	1.17
Indonesia AirAsia (QZ)	CGK	30	12	42	39.25	52.18	0.75
Philippines AirAsia (Z2)	MNL	49	14	63	88.25	81.04	1.09
AirAsia X (D7)	KUL	0	33	33	36.75	26.32	1.40
Thai AirAsia X (XJ)	DMK	0	12	12	0.25	0.27	0.93

connectivity value among AirAsia Group with a WCR value of 1.40. The value even exceeds the WCR value of three major European airlines analyzed by O'Connell and Bueno (2018), namely KLM (KL), Lufthansa (LH) and British Airways (BA) of which each has a value of 1.31, 1.25 and 1.13, respectively. Graphically, it can be observed in Fig. A5 (in Appendix) that the D7 has a very good arrival and departure wave in 24 hours compared to other airlines.

The graph shows that the arrival wave from AirAsia X in the morning from 03:00 to 07:00, is very well-connected with the departure wave from 07:00 to 10:00. Meanwhile, the arrival wave at night, from 19:00 to 21:00, is captured quite well by the departure wave from 22:00 at night to 02:00 in the morning. For the hub configurations for each airlines and AirAsia as a group at all the four hubs, the graphics can be observed in Figs. A1–A10 (in Appendix).

On the other hand, Thai AirAsia X, almost the same as Indonesia AirAsia, finds that good connectivity is one thing that needs to be continuously improved because its WCR value is only 0.93. These two airlines have a WCR value of less than 1 which as previously explained, means that DMK and CGK are counterproductive hubs for Thai AirAsia X and Indonesia AirAsia, respectively.

4.2 Weighted connectivity ratio of AirAsia as a group

Section 4.1 discussed how good the connectivity of each airline at their main hub is. Then a question arises, "then how is the connectivity of AirAsia as a group?". Therefore, Section 4.2 will also discuss the WCR value for all four AirAsia hubs, namely KUL, DMK, CGK and MNL taking into account the six AirAsia airlines.

Table 6 shows the same thing as Table 5, the number of arriving flights (n_a), the number of weighted connections (WN_c), the number of random weighted connections (WN_r) and the weighted connectivity ratio (WCR). But what makes difference is, for the main KUL hub, that it does not only count connectivity from Malaysia AirAsia or AirAsia X, but also considers all AirAsia Group flights serving flights to KUL, to which in this case, 3 other airlines also have routes. More details are presented in Table 7.

For example, Thai AirAsia has the DMK-KUL route, Indonesia AirAsia operates its CGK-KUL and Philippines AirAsia serves MNL-KUL. However, there are other examples where a hub is only served by two airlines, CGK with Indonesia AirAsia and Malaysia AirAsia; and MNL with Philippines AirAsia and Malaysia AirAsia. As for DMK, we get the same thing as KUL, which is served by 5 airlines,

Table 6 Amount of n_a, WN_c, WN_r and WCR of AirAsia Group at each hub on Friday, 13 December 2019. Source: compiled by Pino Rachmandika

Main hub	$n_{a,dom}$	$n_{a,int}$	n_a	WN_c	WN_r	WCR
KUL	108	158	266	2217.75	2305.81	0.96
DMK	90	86	176	1280.50	1141.19	1.12
CGK	30	19	49	67.25	81.42	0.83
MNL	49	16	65	95.25	95.55	1.00

Table 7 AirAsia's hubs and airlines

Main hub	Serving airlines
KUL	Malaysia AirAsia AirAsia X Thai AirAsia Indonesia AirAsia Philippines Airasia
DMK	Thai AirAsia Thai AirAsia X Malaysia AirAsia Indonesia AirAsia Philippines AirAsia
CGK	Indonesia AirAsia Malaysia AirAsia
MNL	Philippines AirAsia Malaysia AirAsia

Thai AirAsia and Thai AirAsia X as local airlines, as well as Malaysia AirAsia, Indonesia AirAsia and Philippines AirAsia which serve from their respective main hubs.

One of the most surprising information from Table 6 is that how low the WCR value of KUL is, which is only 0.96 (included in the counterproductive category), given that AirAsia X itself has the best connectivity here (1.40) and Malaysia AirAsia which has a WCR value above 1. This implies information that with increasing flights in a hub, it does not guarantee that connectivity at that hub will increase. This is a homework for big airlines like AirAsia Group on how to maintain good connectivity for one of its airlines to be better (or at least consistent) if the connectivity is seen from the whole group view.

CGK has a WCR value of only 0.75 for Indonesia AirAsia itself, but an increase of 0.08 points if CGK also considers Malaysia AirAsia flights for the connectivity. This improvement can certainly be used as a benchmark for other hubs on how CGK can increase its connectivity value when viewed from the entire AirAsia Group.

Meanwhile, the remaining two hubs, DMK and MNL, experienced the same thing as KUL, a decrease in the value of WCR. However, DMK, when it is viewed from the point of view of Thai AirAsia X, experienced an increase in the WCR value from only 0.93 to 1.12.

The decline in the value of connectivity at these 3 hubs, namely KUL, DMK (especially from the point of view of Thai AirAsia) and MNL is because of the focus of each airline to develop their respective networks and connectivity is very strong, so that the addition of flights in a hub does not affect (or worsen) the WCR value.

4.3 Average connections per arriving flight and routing factors

It has been explained that the results obtained for WCR are a combination of two things, the transit time (temporal) approach and the geographical/distance (spatial) approach, so it is very interesting to conduct a more in-depth study of each approach to provide an overview of how each of these approaches contributes to the WCR value. Table 8 shows the average of total connections from each arriving flight and their quality by taking into account the ICT and MACT values as well as the routing factor limit (i.e., 1.5) which has been indicated previously. Connections with a transit time of the same as or less than 90 minutes for domestic-domestic flights and 120 minutes for domestic-international flights (vice versa) and international-international flights are categorized as rapid connections, while connections exceeding 90 minutes (for domestic-domestic) and 120 minutes (for others) are categorized as slow connections.

Table 8 Average total connections per arriving flight of each airlines

Airlines	Main hub	Average total connections per arriving flight	Average rapid connections per arriving flight		Average slow connections per arriving flight	
		C_a	No.	%	No.	%
Malaysia AirAsia (AK)	KUL	20.51	12.61	61.47%	7.90	38.53%
Thai AirAsia (FD)	DMK	14.34	8.51	59.36%	5.83	40.64%
Indonesia AirAsia (QZ)	CGK	2.76	1.81	65.52%	0.95	34.48%
Philippines AirAsia (Z2)	MNL	4.90	3.02	61.49%	1.89	38.51%
AirAsia X (D7)	KUL	3.82	2	52.38%	1.82	47.62%
Thai AirAsia X (XJ)	DMK	1.08	0.75	69.23%	0.33	30.77%

Although the average total connections from each arriving flight (C_a) is not a measure to determine whether a transit time is good or not (temporal coordination) because airlines that have more flights from their hubs tend to have large C_a values (Danesi, 2006), but it is very relevant to know how long the connections last (transit time) as it can affect the quality of the connections themselves.

Table 8 shows that although Thai AirAsia X and Indonesia AirAsia do not offer great value for the number of connections from each of their arriving flights, they can ensure that more than 65% of their connections are under 120 minutes. Philippines AirAsia is slightly below this value, at 61.49%.

Meanwhile, Malaysia AirAsia, which is the airline that offers the highest value for the number of connections from each arriving flight, with 20.51, gave an impressive result on their rapid connections, which is 61.47%. The remaining two airlines, Thai AirAsia and AirAsia X, have rapid connections below 60%, but the value of Thai AirAsia is very close to 60%, which is 59.36%.

Then, in the spatial approach as presented in Table 9, the value of the average routing factor corresponds to the value of DR_k, the calculation of which has been explained (with an example) in Section 3.1, using Eq. (3). Basically, the average routing factor is the average value of the comparison of the total distance on indirect flights with the distance of direct flights between two airports from all combinations of routes owned by an airline.

In Table 9, Philippines AirAsia is the airline with the best average routing factor, which is only 1.08, followed by Thai AirAsia and Indonesia AirAsia each with a value of 1.14 for the average routing factor. Malaysia AirAsia and AirAsia X have close scores of 1.17 and 1.19, respectively. The worst average routing factor is that of Thai AirAsia X with a value of 1.41.

Furthermore, if it is viewed from the hub side, that is AirAsia as a group, it is visible in Table 10 that CGK is a hub that offers the best rapid connections with a value of 65.87%. As for the Philippines AirAsia, it is found that

Table 9 Average routing factor of each airlines

Airlines	Main hub	Average routing factor
Malaysia AirAsia (AK)	KUL	1.17
Thai AirAsia (FD)	DMK	1.14
Indonesia AirAsia (QZ)	CGK	1.14
Philippines AirAsia (Z2)	MNL	1.08
AirAsia X (D7)	KUL	1.19
Thai AirAsia X (XJ)	DMK	1.41

60.94% of their connections are rapid connections. The next two hubs also offer fairly high rapid connections, which are still around 60% (59.88% and 58.13% respectively).

As for the average routing factor value seen from the AirAsia Group side, it is found that MNL is the best hub with a value of 1.08, followed by CGK and DMK with a value of 1.12 and 1.13, respectively. Meanwhile, KUL occupies the lowest position with an average routing factor of 1.17. More details are presented in Table 11.

5 Conclusion

There have been many studies that have focused on calculating the value of connectivity on FSC airlines that have formally implemented a hub-and-spoke network in their flight strategy. Meanwhile, LCCs are only seen as airlines that do not implement this strategy. The main objective of this research is to measure the quality of the LCCs connectivity at their main airports, although formally the LCCs do not use a hub-and-spoke network in carrying out their flight concepts and strategies. LCCs are essentially only focused on developing their network through a point-to-point strategy, which can be simply explained that they prioritize direct flights over indirect flights through connectivity at the hub. However, looking at the large volume of flights in the point-to-point system, it becomes clear that there are numerous alternatives for connecting flights for passengers (Zeigler et al., 2017), particularly for an LCC with a sizable fleet at its major airports. Thus, there is an assumption that the LCCs' connectivity value in their "informal" hubs is not bad, or even better than that of some FSCs.

Based on this research, there are four important findings:

- First, the novelty of this research is the analysis of connectivity to LCCs at major airports. As presented in Table 2, most of the previous studies only discussed connectivity of FSCs, which is already very mainstream since the nature of FSCs is the provision of transit flight services with indirect flights through their hubs, for example Emirates, Qatar Airways and Etihad which have been researched by O'Connell and Bueno (2018). In fact, Zeigler et al. (2017) have discussed connectivity for LCCs, but unfortunately only limited to small airports.
- Second, the novelty is done by performing a modification of the connectivity calculation model on the airline, in this case the Danesi's (2006) model.
- Third, based on the results of calculating the value of the Weighted Connectivity Ratio (WCR), the connectivity values of several LCC airlines are better than some FSCs' connectivity that implement a pure hub-and-spoke network.
- Fourth, as a single brand that has been operating and has bases in Southeast Asian countries (Malaysia, Thailand, Indonesia and the Philippines), AirAsia's connectivity performance as a group for certain airports is better than the connectivity performance of certain airlines.

For further in-depth research, it can be considered how Thai AirAsia and AirAsia X can produce excellent schedule coordination, even better than several major European airlines. It is also possible to investigate Indonesia AirAsia and Thai AirAsia X regarding their poor schedule coordination at CGK and DMK: "Is this because they only focus on point-to-point strategies without considering connectivity?". For the connectivity that has increased from the hub-wise view, such as CGK, it can be investigated what actually affects the increase. Meanwhile, for the connectivity that has decreased hub-wise, such as KUL, DMK and MNL, further research can be also carried out on whether Malaysia AirAsia, AirAsia X, Thai AirAsia and Philippines AirAsia only consider their respective connectivity without looking at the AirAsia as a group.

Table 10 Average connections per arriving flight of AirAsia Group at each hub

Airlines	Main hub	Average total connections per arriving flight	Average rapid connections per arriving flight		Average slow connections per arriving flight	
		C_a	No.	%	No.	%
AirAsia Group	KUL	25.86	15.49	59.88%	10.38	40.12%
	DMK	16.84	9.79	58.13%	7.05	41.87%
	CGK	3.41	2.24	65.87%	1.16	34.13%
	MNL	4.92	3.00	60.94%	1.92	39.06%

Table 11 Average routing factor of AirAsia Group at each hub

Airlines	Main hub	Average routing factor
AirAsia Group	KUL	1.17
	DMK	1.13
	CGK	1.12
	MNL	1.08

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Appendix

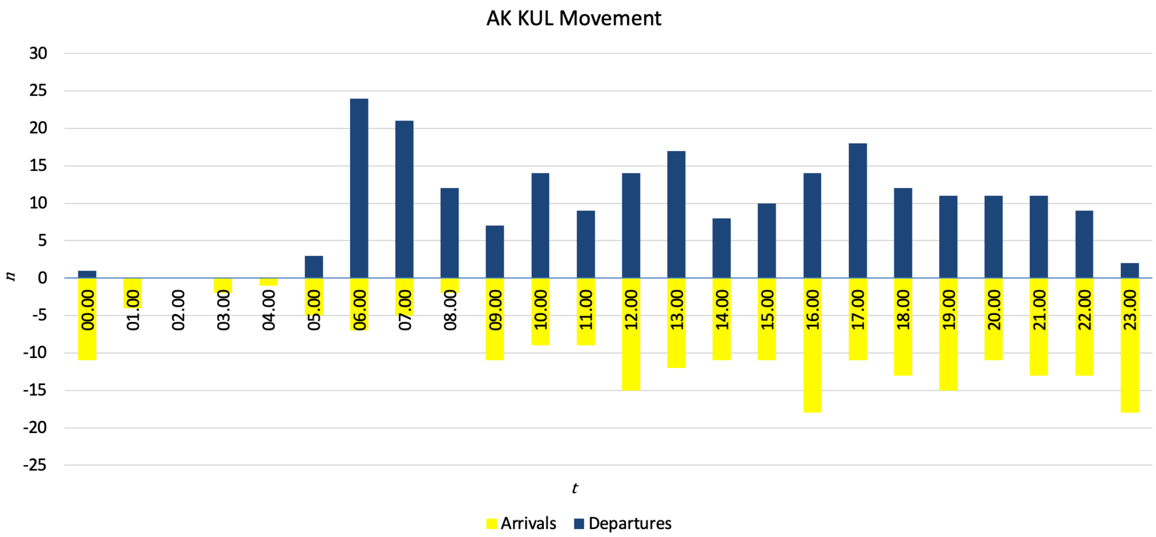

Fig. A1 Hub configurations for Malaysia AirAsia at Kuala Lumpur International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika

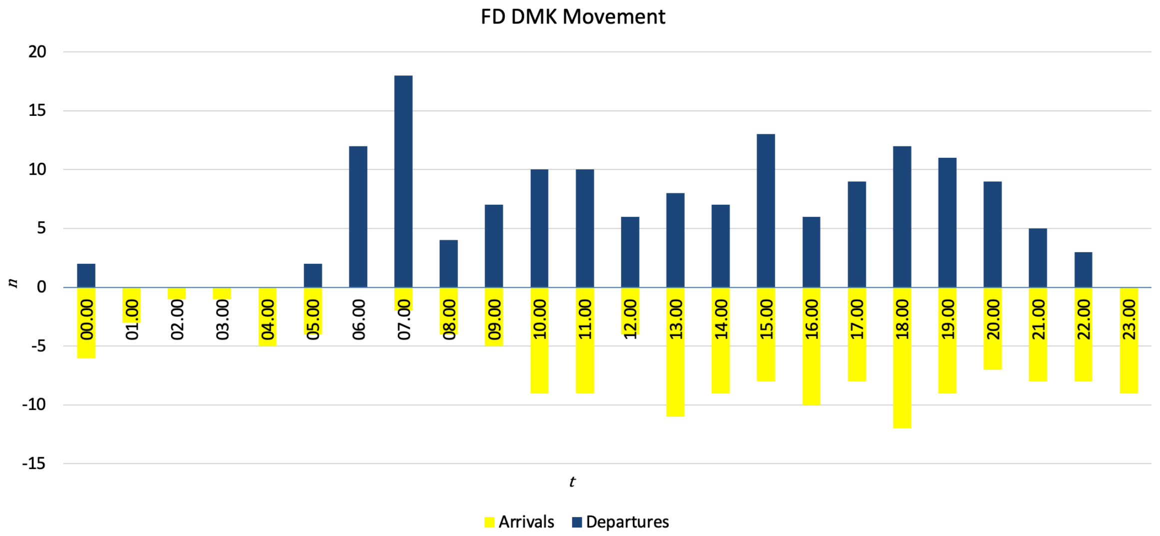

Fig. A2 Hub configurations for Thai AirAsia at Don Mueang International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika

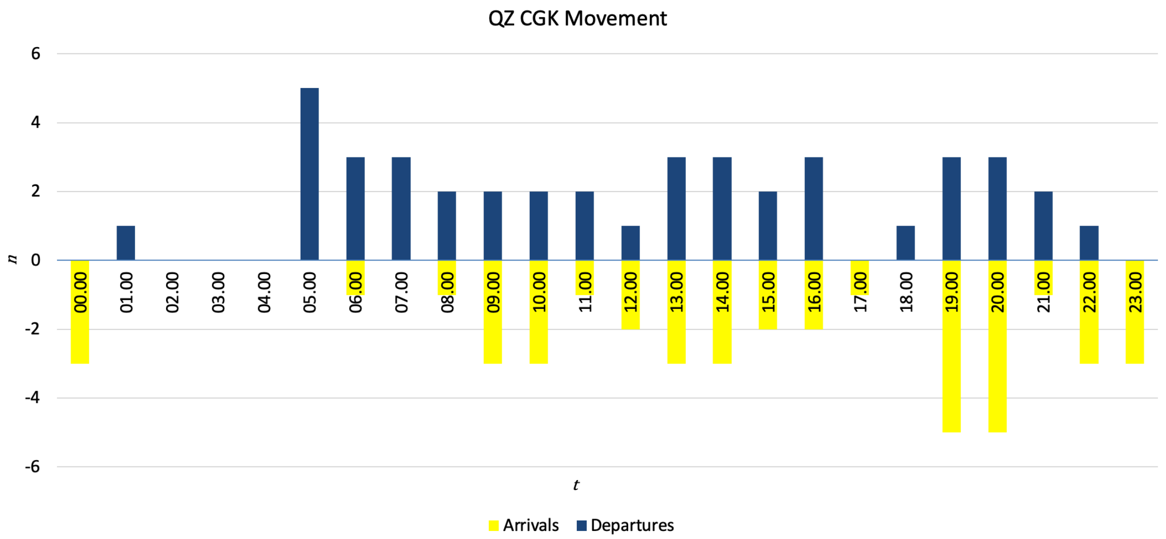

Fig. A3 Hub configurations for Indonesia AirAsia at Soekarno-Hatta International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika

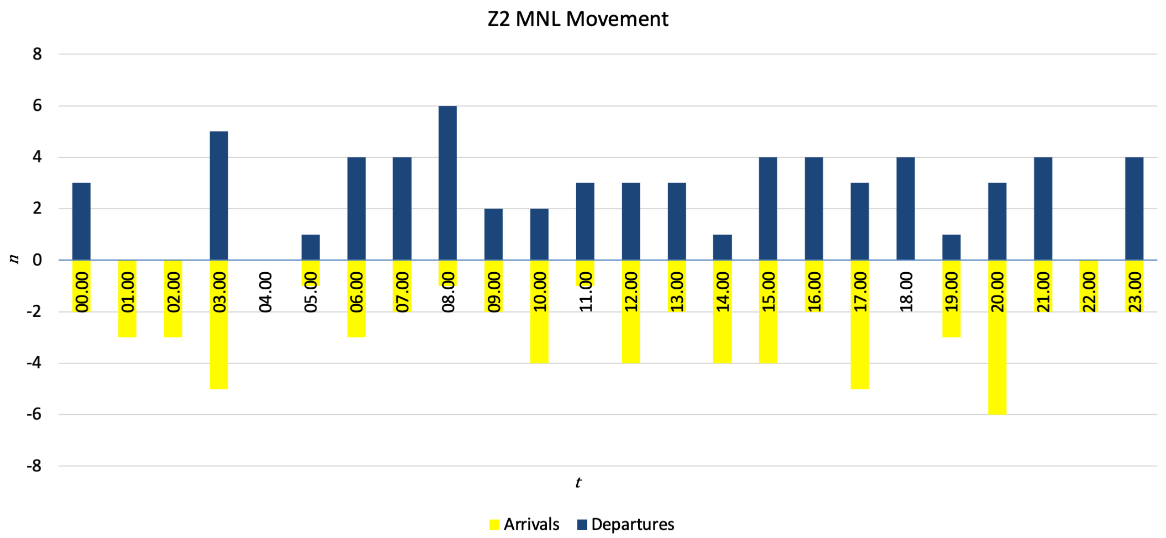

Fig. A4 Hub configurations for Philippines AirAsia at Ninoy Aquino International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika

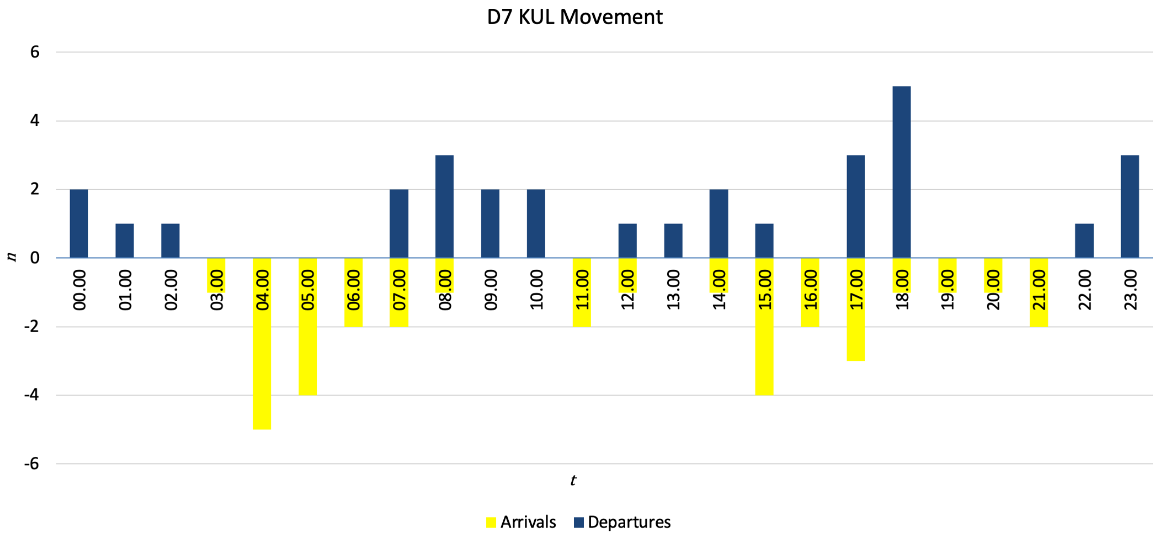

Fig. A5 Hub configurations for AirAsia X at Kuala Lumpur International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika

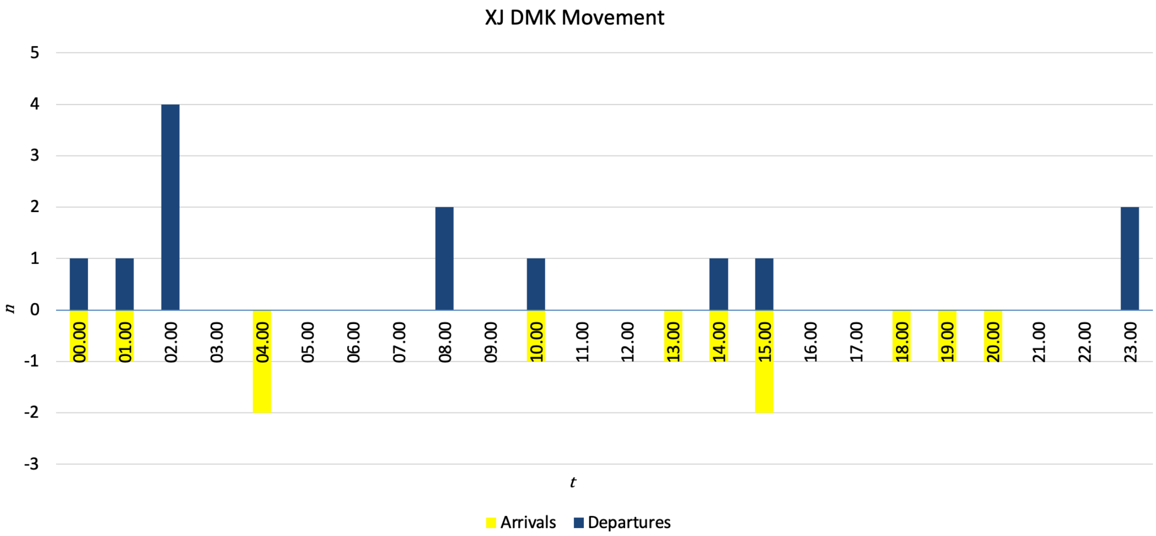

Fig. A6 Hub configurations for Thai AirAsia X at Don Mueang International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika

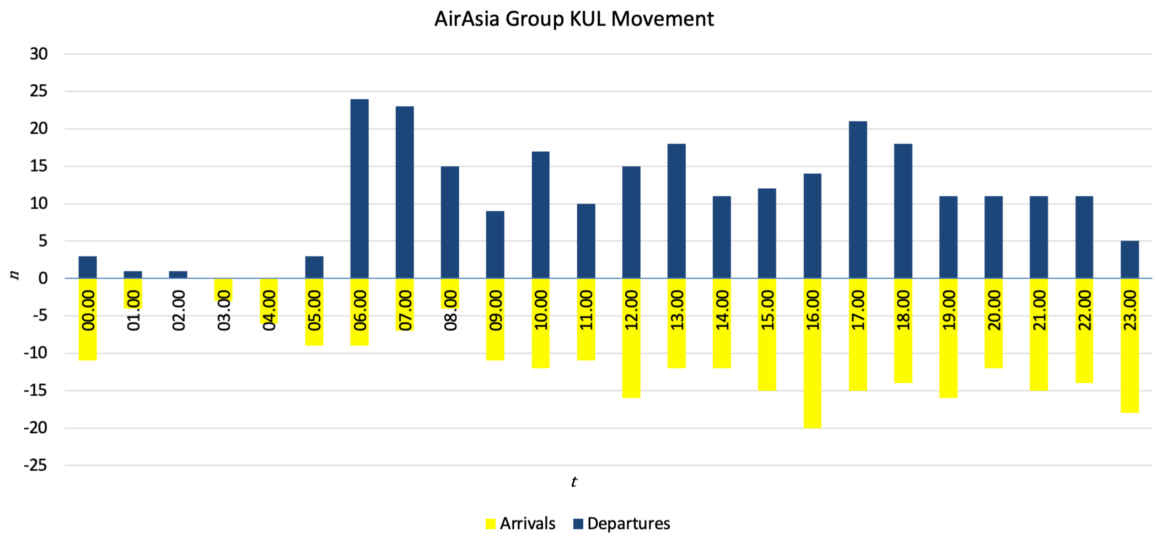

Fig. A7 Hub configurations for AirAsia Group at Kuala Lumpur International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika

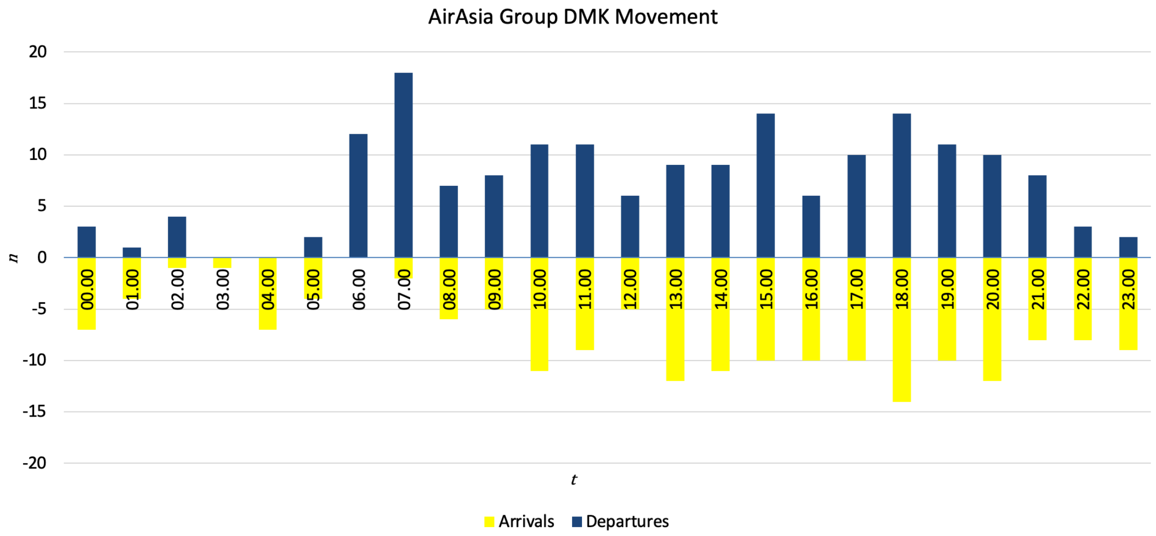

Fig. A8 Hub configurations for AirAsia Group at Don Mueang International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika

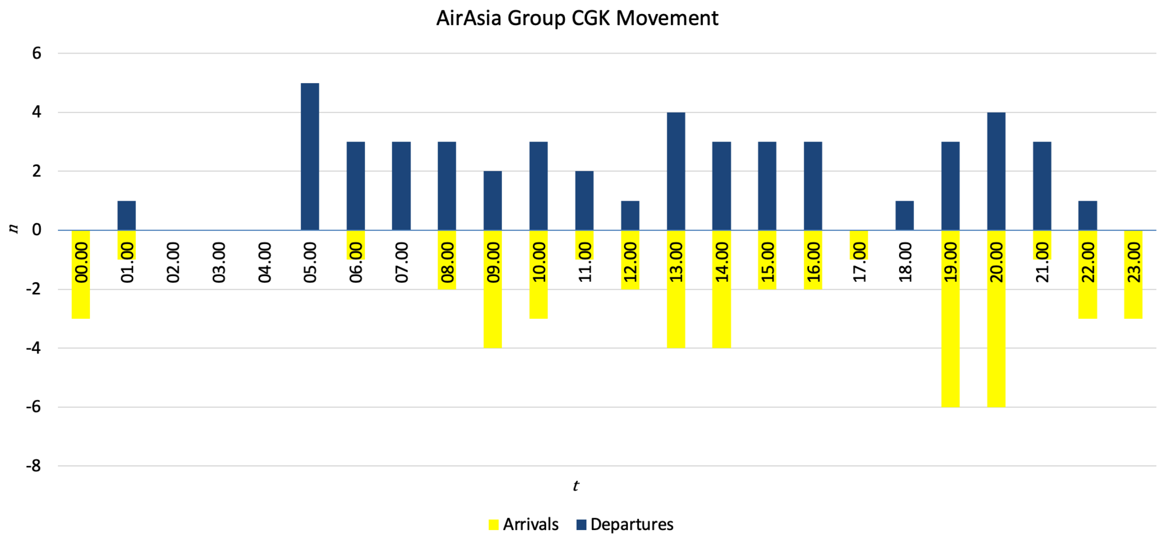

Fig. A9 Hub configurations for AirAsia Group at Soekarno-Hatta International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika

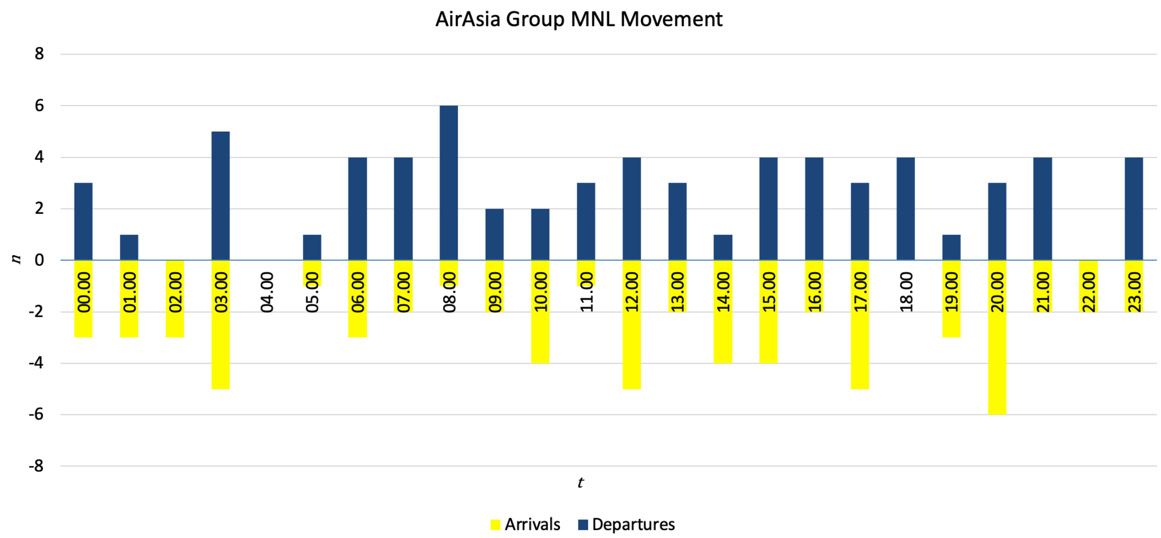

Fig. A10 Hub configurations for AirAsia Group at Ninoy Aquino International Airport on Friday, 13th December 2019. Source: compiled by Pino Rachmandika