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Airport transfer dependency on neighbour hubs – the case of Taoyuan Airport's aviation network

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Abstract

The airports' passengers may be dependent on their neighboring hubs for the additional destination if the hub launches more routes, frequencies and provide the more convenient schedule. However, the dependency situation research hasn't been discussed recently years but it's an important and worthy topic in aviation industries. Therefore, the case of Taiwan's Taoyuan Airport's transfer dependency on its neighboring hubs for destinations in North America, Europe, the Middle East, Africa and Oceania is considered in this paper. Two composite indexes referred to as the Airport Transfer Dependency Index (ATDI) and Airport Transfer Dependency Degree (ATDD) based on the Gini coefficient and Hub Connectivity Performance Index (HCPI) are proposed in order to measure the transfer dependency. The results reveal that Taoyuan Airport has significant transfer dependence on Tokyo's Narita Airport for North American routes and on Hong Kong Airport for the other long-haul routes. The analysis could help airport authorities to understand the weakness in their aviation network and then reduce their dependence on neighboring hubs in order to avoid some risk.

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Keywords: connectivity, hub, transfer dependency, Gini coefficient

1. Introduction

After deregulation of the domestic routes in the United Stated in 1978, the global aviation industries enter the new era called liberalization, namely, a low-limit, highly-free industrial environment. It means that airlines set the operating policies such as launch new routes, destination, frequencies, and air fare become more freely and easily.

Aviation liberalization encourages the expansion of operating scale and promote the growth of demand. It also provides airports the increased opportunities to grow their services such as attract the new routes, more passengers arriving. However, it also makes airports exposed a great risk. Because airlines are free to adjust their routes or schedules, the airport is facing the risks that airlines may reduce frequencies or withdraw routes. This situation will affect the airports' revenue and survival in the future, especially true for airports that depend on a few airlines or routes. (Halpern and Graham, 2013; Koo et al., 2016).

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In addition, hub-and-spoke (HS) networks have become an essential feature of many airline network operations around the world after the deregulation (Gillen and Morrison, 2005). When a hub airport launches more routes and increases flight frequencies, its neighbouring airports might be affected by depending on them for transfers to additional destinations.

According to the Merriam-Webster dictionary, the word "dependent" is defined as relying on another for support, and "dependency" is defined as the quality or state of being dependent. Therefore, airports' dependency can be explained as the quality of airport rely on the other airports, airlines and routes. In the airport industry, traffic is dependent on the airlines, cities, countries, seasons and so on. An airport's dependency on other airports needs to take the number of routes, frequency, and quality of flights offered by these airports into account. When an airport introduces high frequencies of flights on certain routes, passengers might be attracted to fly from other airports to transfer, and this will therefore have an impact on other airports in the region.

In the past study, there were few research which focuses on the issue of airports' dependency. However, this issue is very import for the airport. In order to strength the competitiveness for sustainable operation, airport should avoid the high dependency on fewer airports, routes, and airlines, and then continue to diversify their aviation network (Koo et al., 2016).

Above of all, this study attempts to analyse the airport, depending on other hubs for transfer. We establish a method to measure the airport's dependence on its airport, and examine whether the airport is exposed to the risk of excessive dependence. This study takes Taiwan's Taoyuan airport as the example to analyse the TPE's dependency on neighbouring airports including Narita International Airport (NRT), Incheon International Airport (ICN), Beijing capital International Airport (PEK), Shanghai Pudong International Airport (PVG), Guangzhou Baiyun International Airport (CAN), Hong Kong International Airport (HKG), Suvarnabhumi International Airport (BKK), Kuala Lumpur International Airport (KUL) and Singapore Changi Airport (SIN). These nine hubs are the major hubs in the Asia-Pacific. Therefore, we select the nine hubs as the analysis examples. The routes and frequency of flights offered by these airports to North America, Europe, the Middle East, Africa and Oceania are incorporated into the analysis (see Figures 1 for the details).

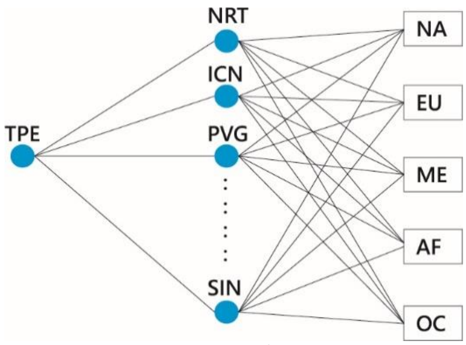

Figure 1 Scope of this research

2. Literature Review

Recent years, the most research related to the airport network has focused on "connectivity". Many researchers have proposed some methodology to measure the airport connectivity. For example, Shaw (1993) proposed "Shortest path length" to examine the hub structures of six major US airlines: American (AAL), Delta (DAL), USAir (USA), United (UAL), Northwest (NWA) and Continental (CAL). The results indicate some important realities that are not captured in the current hub location models; Veldhuis (1997) proposed the "Netscan Connectivity Units" to analyze the connectivity of Amsterdam airport (AMS); Burghouwt & de Wit (2005) proposed "Weighted Number of Connections" to investigates these post-deregulation temporal concentrations in European aviation networks; Malighetti et al. (2008) proposed "Quickest Path Length" to investigate the connectivity of the European air transportation network. A time-dependent minimum path approach is employed to calculate the minimum travel time between each pair of airports in the network, inclusive of flight times and waiting times. Li, Miyoshi, and Pagliari

(2012) proposed “Hub connectivity performance index” to measure both the quantity and quality of connections offered by an airline network that is configured around two hub airports that share the same catchment area. The paper analyses All Nippon Airways network centred on Tokyo’s Haneda and Narita airports.

Connectivity is defined as the degree of the airport connect to others. Research could refer the connectivity to analyse the market competiveness of airports in the network. According to Burghouwt and Redondi (2013), there are three parts to measuring connectivity, which include Direct Connectivity, Indirect Connectivity and Hub Connectivity. These values, however, are unable to value the dependency of one airport on the others.

According to the definition of dependency, the dependency is related to the “diversity” or “concentration” of the relying objects. Therefore, it is necessary to analyse the “diversity” or “concentration” of connectivity instead of its “quantity” if researcher want to analyse the dependency of airport’s connectivity. There is little research which has deeply discussed the dependency of airports. Koo et al. (2016) is the only one research related to this issue. This research use the concept of Gini coefficient to establish the airport dependency index (ADI) which measure whether the airport rely on the airports, routes, flights and airlines. The ADI also provide some advice on whether airport should diversify their services by expanding their network in order to avoid the survival risk in the future. This research use the Capstats database, 735 airports were identified as active for at least one year throughout the ten-year period under consideration, 2005–2014 (inclusive) in this research. The total number of active airports in 2014 (baseline year) was 607. These were subsequently classified into five airport groups according to the 2014 world traffic capacity offered by their hosted airlines in Available Seat Kilometres (ASKs).

In addition, Koo et al. (2016) only focus on the direct routes. There are few studies analyze the airports dependent on the other hubs for transfer. However, it is the common situation that passengers should depend on the neighbour hubs for transfer. Therefore, this study will focus on the transfer dependency for airport to other hubs by establishing the new dependency index.

3. Methodology

3.1 Gini coefficient

Gini coefficient is a useful tool for economic and transport geographers due to its ability to capture spatial dispersion (Koo et al., 2016; Reynolds-Feighan, 2001, 2007). Therefore, it is incorporated into several air transportation studies when measuring spatial or market concentration in airline networks (Martin and Voltes-Dorta, 2009).

The Gini coefficient measures the inequality of a distribution and was developed by the Italian statistician Corrado Gini in 1912. The calculation of the Gini coefficient can be defined as shown in equation 1. Its numerator is the area between the Lorenz curve of the distribution and the uniform distribution line. Its denominator is the area under the uniform distribution line (see Figures 2a and 2b for the details). The Gini index is the Gini coefficient multiplied by 100.

$$G = \frac{A}{A+B} \tag{1}$$

where

- A and B is the area in Figure 4.
- G is the Gini coefficient

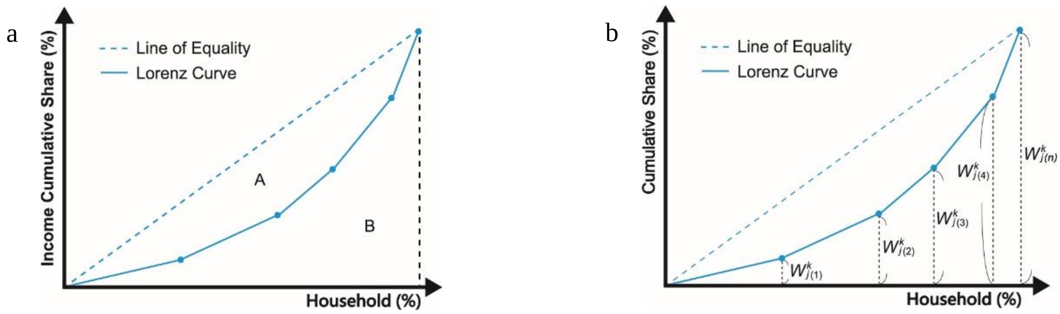

Figure 2.(a) Figure 2 (b)

Figure 2. Concept of the Gini coefficient

Koo et al. (2016) use it to design the relative Gini index value of an airport as defined in equation 2 and apply it to develop an airport dependency index (ADI) as shown in equation 3, where ADI for an airport k is the weighted combination of four sub-indexes, namely, f(airline), f(cities), f(countries) and f(seasonality).

$$G_k = 1 - \sum_{n-1}^{N} \frac{1}{N} \left[W_{j(n)}^{k} + W_{j(n-1)}^{k} \right] \tag{2}$$

where

- G_k denotes the relative Gini index value of airport k
- k is the target airport
- n represents the nodes/region connected to airport
- N is the total number of nodes/regions
- $W_{j(n)}^{k}$ is the cumulative share of the n^{th} node of airport k for node j (see Figure 4b for the details)

$$ADI_k = a \cdot f(airlines) + b \cdot f(cities) + c \cdot f(countries) + d \cdot (seasonality) \tag{3}$$
$$s.t.\ a + b + c + d = 1$$

According to the definition, when G_k=0, this means that the traffic share between airport k and region j has been equally distributed among all airports. Conversely, when G_k =1, this indicates that the traffic flows are unequally distributed with the majority of the traffic being concentrated within a few airports (Martin and Voltes-Dorta, 2009).

The results of Koo et al. (2016) show that airport traffic at European airports seems to be highly concentrated, and the mean ADI value is inversely related to capacity size. Among their recommendations, it is stressed that their proposed ADI has a number of limitations as it leaves some issues untouched, including airline global network dynamics, airport catchment areas and airport substitutability.

This study refers to the concept of Gini Coefficient and ADI to establish the airport transfer dependency index (ATDI) and airport transfer dependency index (ATDD). ATDI illustrate whether the airport has excess dependent on few hubs or routes for transfer; ATDD can compare the degree of dependency of airports rely on each other hubs or routes for transfer. The introduction of ATDI and ATDD are shown as the following section 3.2 and 3.3.

3.2 Airport Transfer Dependency Index

We consider an onward network for airport k:

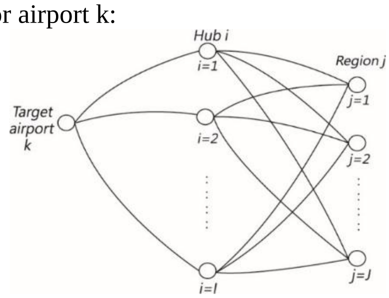

Figure 3 Research network of this study

The concept of ATDI is expressed in Figures 4(a) and 4(b), and the definition of ATDI is represented by equations 4 and 5. $ATDI^k$ measure the state, whether the airport k has excess dependent on the few hubs for transfer to all regions. The higher the value is, the more dependency the airport k have to all regions is; $ATDI^k_j$ measure the state, whether the airport k has excess dependent on the few hubs for transferring to region *j*. The higher the value is, the airport k have the more dependency to region j.

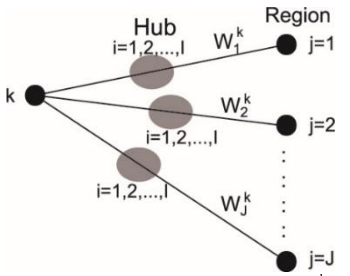

Figure 4(a) The concept of $ATDI^k$

$$ATDI^k = 1 - \frac{1}{J}\sum_{j=1}^{J}\left[w_j^k + w_{j-1}^k\right] \tag{4}$$

where

- J is the total number of regions j
- $ATDI^k$ is the transfer dependency index for airport k in relation to all regions
- w_j^k is the HCPI (Hub Connection Performance Index) cumulative share of the j^th^ region for airport k in relation to region j

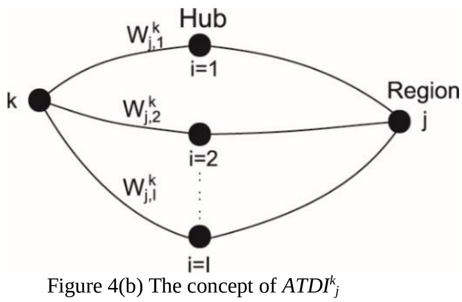

Figure 4(b) The concept of $ATDI^k_j$

$$ATDI_j^k = 1 - \frac{1}{I}\sum_{i=1}^{I}\left[w_{j,i}^k + w_{j,i-1}^k\right] \tag{5}$$

where

- n is the total number of airports i
- $ATDI_j^k$ is the transfer dependency index for airport k in relation to *region j*
- $w_{j,i}^k$ is the HCPI (Hub Connection Performance Index) cumulative share of the i^{th} hub of airport k in relation to region *j*

3.3 Airport Transfer Dependency Degree

Besides the Airport Transfer Dependency Index, this research has also designed an index entitled the Airport Transfer Dependency Degree (ATDD) to analyze an airport's degree of dependency on other airports. The concept of ATDD is depicted by Figures 5(a) and 5(b), and the definition is represented by equations 6 to 7. $ATDD^k_j$ measure the degree of dependency of airport k to region j. Researchers can use this index to compare the degree of dependency of airport k to each region j=1, 2, 3,..., J; $ATDD^{k\text{-}j}_i$ measure the degree of dependency of airport k transfer at hub i to region j. Researchers can using this index to compare the degree of dependency of airport k to region j transfer at each hub i=1, 2, 3,…, I. The higher the value, the airport k have the more serious dependency on this region/hub.

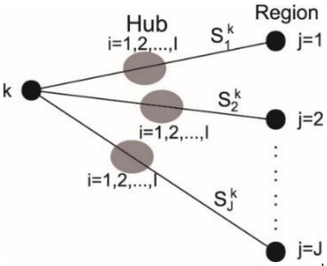

Figure 5(a) The concept of $ATDD^k_j$

$$ATDD_j^k = \frac{s_j^k}{J} \tag{6}$$

where

- $ATDD_j^k$ is the degree of dependency of airport k in relation to *region j*
- s_i^k is the HCPI (Hub Connection Performance Index) market share of routes from k to i for the j^{th} region.

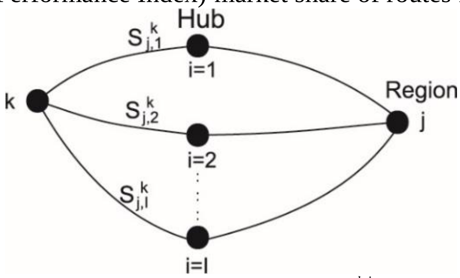

Figure 5(b) The concept of $ATDD^{k\text{-}j}_i$

$$ATDD_i^{k\text{-}j} = \frac{s_{j,i}^k}{I} \tag{7}$$

where

- $ATDD_i^{k-j}$ is the degree of dependency of airport k on airport i for routes to region j
- $s_{j,i}^k$ is the HCPI (Hub Connection Performance Index) cumulative share of the i^{th} node of airport k on airport i for routes to region j

3.4 Hub connectivity performance index

In this analysis, we use HCPI (Hub connectivity performance index) as the basement for calculating ATDI and ATDD. In other words, ATDI and ATDD are truly designed as the concentration of HCPI.

HCPI is proposed by Li, Miyoshi, and Pagliari (2012). This is the kind of method which measure the quality and quantity of flight connections. The HCPI is calculated by summarizing all QCI of each viable flight connection. The equation of HCPI is represented by equations 8:

$$HCPI = \sum_{conx=1}^{QVC} QCI_{conx} \tag{8}$$

QVC is the quantity of viable flight connections. A minimum transit time of 90 minutes and a maximum transit time of 300 minutes are required for viable flight connection in this analyse; QCI is the quality of a flight connection which is represented by equation 9 and it be calculated by the routing factor.

$$QCI_{conx} = \begin{cases} 1.5 - RF / 1.5 - 1.0, & if \ 1 < RF < 1.5 \\ 0 \quad , & if \ \geq 1.5 \end{cases} \tag{9}$$

$$RF = \frac{IDT}{DDT} \tag{10}$$

where

- QCI is the quality of connections
- RF is the routing factor
- IDT is the total travel time for indirect flights
- DDT is the estimated travel time if the flight is direct

4. Taoyuan Airport's transfer dependency on neighbouring hubs

We have adopted the Innovata worldwide flight schedules database covering the third week of September in the years 2004, 2008, 2012 and 2016 for our analysis. Two hundred major airports around the world have been selected as the sample in this research. For this research, we have also written computer programs to search for feasible transfer flights from Taoyuan Airport via its nine neighbouring hubs to five regions, including North America (NA), Europe (EU), the Middle East (ME), Oceania and Africa (AF) to facilitate further calculations. Before applying the algorithm to search for transfer flights, there are two steps that need to be taken. First, the names of the airport of origin and destination airport, as well as the departure and arrival times should be included for each flight. Secondly, the departure and arrival times for each flight need to be changed to Greenwich Mean Time.

4.1 Transfer dependency for the overall network

Figure 6 shows that Taoyuan Airport's transfer dependency on its nine neighbouring hubs to five different regions has increased over the period from 2004 to 2012. However, the value of ATDI fell in 2016. It means that Taoyuan Airport saw a reduction in its transfer dependency on neighbouring airports in 2016. TPE's HCPI depends on neighbouring hubs for transfer become more dispersed instead of concentrating on fewer routes.

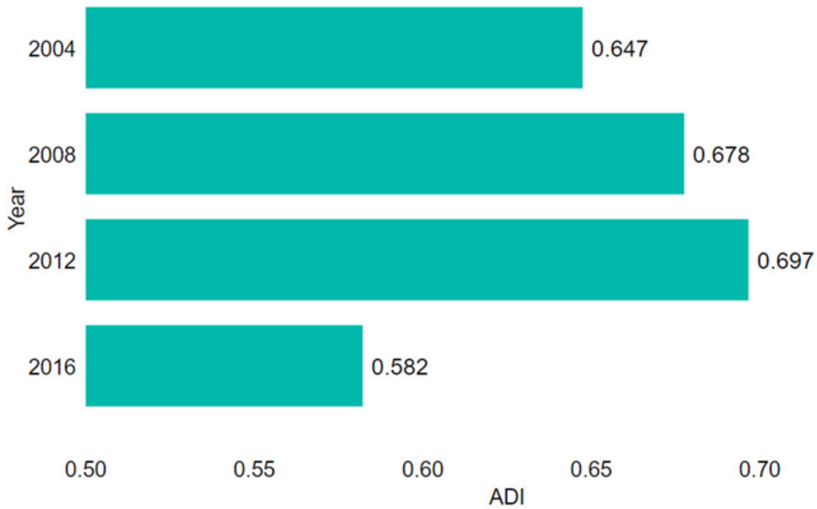

Figure 6 TPE's $ATDI^k$ in relation to neighbouring hubs for the overall network

We further depict Taoyuan Airport's degree of transfer dependency on its nine neighbors to five regions in Figure 7. This shows that Taoyuan Airport had the highest degree of transfer dependency on its nine neighbouring hubs for routes to North America from 2004 to 2016. In addition, Taoyuan Airport's degree of dependency on North American routes has begun to decrease in 2016, and its degree of dependency on the other four routes has increased.

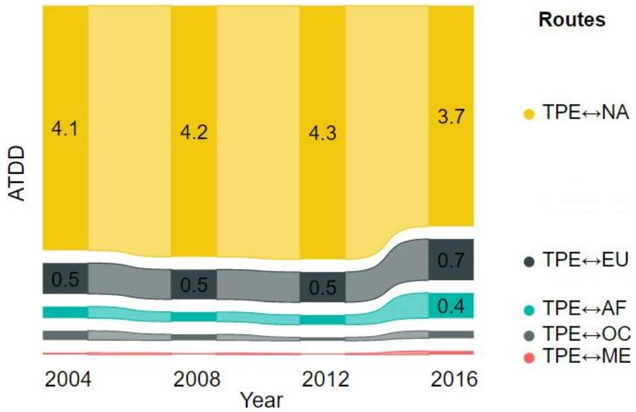

Figure 7 TPE's $ATDD^k_j$ in relation to neighbouring hubs

4.2 Transfer dependency for each regional network

This section analyzes Taoyuan airport's transfer dependency on its nine neighbouring airports for each regional route. Figure 8 shows that Taoyuan airport's ATDI declined for routes to North America from 2004 to 2016. It means that there are more choices of hubs for transfer to North America during 2004 to 2016; for routes to Europe, TPE's ATDI decreased from 2004 to 2012, then increased from 2012 to 2016. For routes to the Middle East, TPE's ATDI decreased from 2004 to 2008, then increased from 2008 to 2016. For routes to Africa, TPE's ATDI increased from 2004 to 2008, then decreased from 2008 to 2012, and increased again from 2012 to 2016. For routes to Oceania, TPE's ATDI remained quite stable from 2004 to 2016. Above of all, TPE has dependent on fewer hubs for transfer to Oceanic, Africa and Middle East in 2016.

b

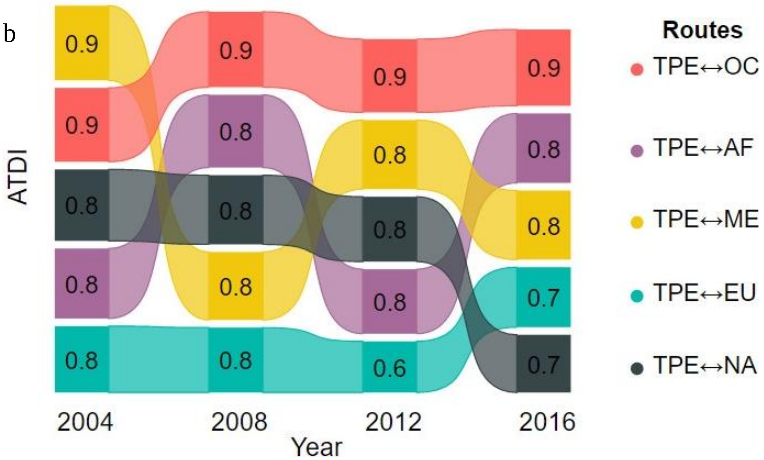

Figure 8 TPE's $ATDI^k_j$ in relation to neighbouring hubs for each regional network

4.2.1 North America routes

This research further measures the degree of Taoyuan airport's transfer dependency on its nine neighbouring hubs for routes to five regions. From Figure 9a, it can be seen that TPE has the highest degree of transfer dependency on NRT for routes to North America. However, the degree declined over the period from 2004 to 2016. On the other hand, TPE's ATDD in relation to HKG, ICN and PVG increased from 2004 to 2016. Despite TPE having the highest ATDD in relation to NRT, NRT also provides the highest HEI for transfer flights from TPE to North America (see Figure 9a for the details). This means that NRT not only serves the largest number of transfer connections, but also has the best quality.

4.2.2 European routes

Figure 9b shows that TPE had the highest ATDD in relation to HKG for EU routes from 2004 to 2016. It is interesting to mention that BKK used to have the second largest ATDD in 2004. However, the situation has significantly changed since 2008 with it being replaced by PEK, ICN and PVG. Similar to TPE's dependency on NRT for NA routes, HKG represents the most important position for transfer flights from TPE to EU (see Figure 9b for the details).

4.2.3 Africa, Middle East and Oceania routes

For flights from TPE to Africa, the Middle East and Oceania, the results show that HKG has the highest ATDD for routes to these regions (see Figures 9c, 9d and 9e for the details). This means that TPE is highly degree of dependency on HKG for most transfer routes.

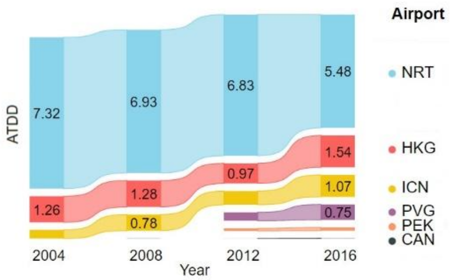

Figure 9(a) NA Routes

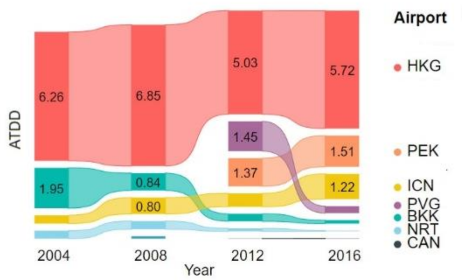

Figure 9 (b) EU Routes

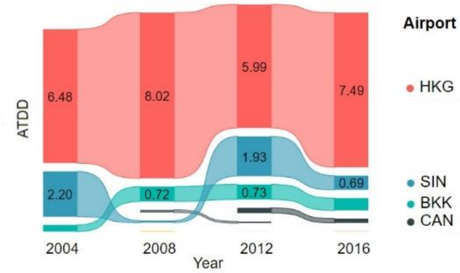

Figure 9(c) AF Routes

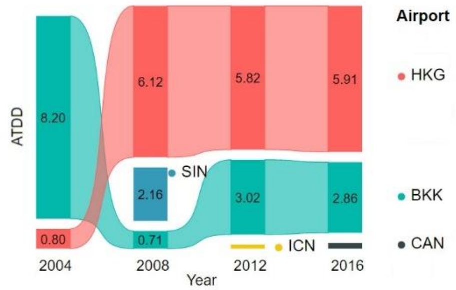

Figure 9 (d) ME Routes

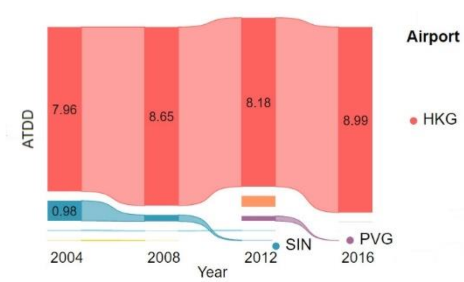

Figure 9(e) ATDD for OC Routes

Figure 9 ATDD

4.3 Summary

From the above analysis, it can be seen that Taoyuan airport's transfer dependency on its nine neighbouring hubs to all regions declined over the period from 2004 to 2016. However, its dependency on transfer flights to certain routes is strongly affected by particular airports, like NRT for North America routes and HKG for routes to the other four regions. If we look at the direct flights from TPE to its nine neighbouring hubs, it can be found that frequencies increased from 2004 to 2016 except to PEK and CAN. In particular, the number of flights between TPE and HKG increased from 298 in 2004 to 1,036 in 2016, more than twice the figure for flights to NRT (see Figure 10 for the details). This situation resulted in TPE's high degree of dependence on HKG for transfer flights to most regions.

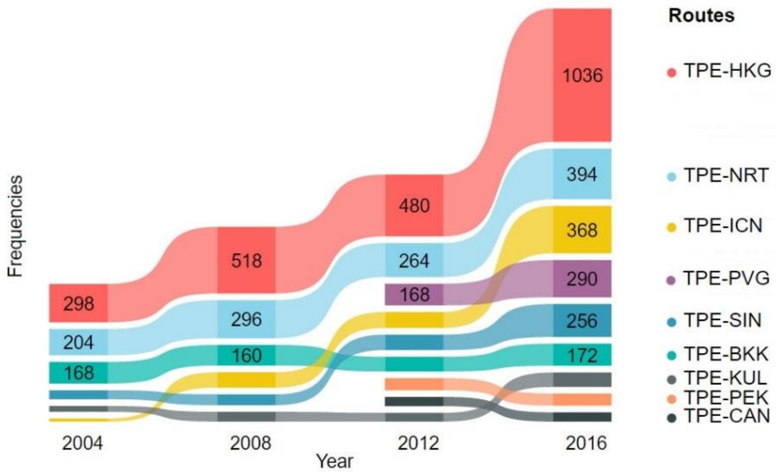

Figure 10 Flight frequencies between TPE and nine Asian hubs

5. Conclusions

As the liberalization of air transportation has become more widespread in Asia during the past two decades, air service agreements have given rise to more freedom between countries. Consequently, an airport's development will be influenced by the services that other airports offer that it cannot in order to meet passengers' demands.

To analyze an airport's transfer dependency on its neighbouring hubs, in this research, we have designed two indexes, namely, the Airport Transfer Dependency Index and Airport Transfer Dependency Degree, using Taoyuan Airport as a case study. The results show that TPE is highly dependent on HKG for most long-haul routes and has a high degree of dependency on NRT for North American routes.

As mentioned before, the airport has over-dependency on specific hubs or routes will be exposed at high risk. Once HKG has made drastic adjustments to its' Europe and South Africa routes, it will make a great impact for TPE's passengers who want to go these two regions, and this is the uncontrollable factor for Taoyuan Airport. That is detrimental to the long-haul networks' development of Taoyuan Airport. Therefore, to the routes which over-depending on the specific airport, the Taiwan's airlines should look for other airports as secondary hubs in order to improve the situation of over concentrate at specific hubs through flight supply adjustments or marketing strategy. For example, European routes can share their dependence on HKG to PEK, ICN, and PVG, and South Africa Airlines can decentralize the dependence to CAN, SIN, and BKK. In order to share dependency to the other hubs, Taiwan's airlines should proactively look for the cooperation with foreigner airlines of the other hubs to increase the connectivity such as add more flights, code share or reduce the waiting time for connecting.

The foregoing proposals mainly focus on the idea of diverting dependence to multiple hubs. From another perspective, if the passenger demand is sufficient, Taiwan's airlines can also launch the direct routes or increase flights to Europe or South Africa. This method can also reduce the risk that transfer excessively dependent on HKG.

This study has provided a way to measure an airport's transfer dependency on neighbouring hubs. The results could help airports to identify their market position and to plan the development of new routes. The airport authorities could therefore introduce incentive schemes to attract airlines to launch new routes and increase flight frequencies.

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