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The Competitive Position of Primary Airports in the Asia/Pacific Rim

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Abstract: This paper measures and compares the network performance and hub competitive position of primary airports in the Asia/Pacific rim, taking into account the quantity and quality of both direct and indirect connections. The results reveal that Tokyo has the best network performance and hub competitive position. The most striking growth of network development is found at Chinese airports, while network performance deteriorates at Oceanian airports. Finally, the results show that the position of Oneworld and Star Alliance is stronger, whereas SkyTeam has an innegligible position especially at Japanese airports, owing to fifth and sixth freedom rights.

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1. Introduction

Problems of hub location and network configuration are one of the main items that are frequently discussed. These topics draw considerable attention, particularly in the Asia/Pacific rim. This region has witnessed intense competition among major airports to become key international air traffic hubs. Especially after the 1990's, new international airports started up one after another in this region: Shenzhen (1991), Osaka/Kansai (1994), Macau (1995), Kuala Lumpur (1998), Hong Kong (1998), Shanghai/Pudong (1999), Seoul/Incheon (2001), Guangzhou (2004), Nagoya/Chubu (2005), Tianjin (2005) and Bangkok (2006), while Tokyo/Narita, Singapore, Taipei etc. have expanded their runways or terminals. Beijing is also announced to start constructing a new international airport in 2010.

To date, many studies have analyzed hub-and-spoke networks. One branch of research is from the viewpoint of economic perspectives, which mainly focus on economies of density and scope (Brueckner & Spiller, 1994; Caves, Christensen & Tretheway, 1984), hub premiums (Borenstein, 1989; Oum, Zhang & Zhang, 1995), entry deterrence (Zhang, 1995), and the role of hub-and-spoke networks in airline alliances (Oum, Park

& Zhang, 2000; Pels, 2001). Another branch of research is in the field of operations research, which aims spatial optimization of air networks from the cost-minimizing approach (Kuby & Gray, 1993; O'Kelly & Miller, 1994; O'Kelly & Bryan, 1998). A third branch chooses the geographical approach, in which the structures, performance and spatial dimension of hub-and-spoke networks are analyzed empirically (Bania, Bauer & Zlatoper, 1998; Burghouwt, Hakfoort & Ritsema-Van Eck, 2003; Ivy, 1993; Shaw, 1993). These studies, however, have taken up international air traffic flows just from the standpoint of the demand-aspect, not capturing airline network structures, schedule coordination and the resulting hub performance from the supply-aspect. Consequently, some studies have included the level of schedule coordination in the measurement of performance and structure of hub-and-spoke networks. Veldhuis (1997) analyzed Amsterdam/Schiphol, focusing on the quality and frequency of indirect connections. Burghouwt and Veldhuis (2006) evaluated the competitive position of West European airports in the transatlantic market from this viewpoint.

The main objective of this paper is to extend this approach to the Asia/Pacific rim, where airline networks are progressively transforming into hub-and-spoke networks, as international aviation markets become increasingly liberalized. Meanwhile, formation of global airline alliances strongly stimulates these network configurations.

2. Measurement of Network Quality

2.1 Three Types of Network Connectivity

Here in this article, three types of connectivity are distinguished as described in Figure 1.

1. Direct Connectivity: flights between A and B without a hub transfer
2. Indirect Connectivity: flights from A to B, but with a transfer at H
3. Hub Connectivity: connections via (with a transfer at) A between C and B

Figure 1

Three Types of Connectivity

Note: This paper does not consider Onward Connectivity, namely the connections via (with a transfer at) B between A and D.

The quality of an indirect connection between A and B with a transfer at H is not equal to the quality of a direct connection between A and B. In other words, the passenger traveling indirectly will experience additional costs due to longer travel times, consisting of detour time and transfer time.

The measurement of indirect connectivity is particularly important from the perspective of consumer welfare; how many direct and indirect connections are available to consumers between A and B? The concept of hub connectivity is particularly important for measuring the competitive position of airline hubs in a certain market; how does A perform as a hub in the market between C and B?

2.2 Concept of Connectivity Units (CNU's)

Many passengers transfer at hub airports to their final destinations, even in case good direct connections are available. Passengers' choices depend on the attractiveness of the available alternatives. Attractiveness is often expressed in utility functions, where variables such as available frequencies, their travel time and fares are weighted. Other factors like comfort, loyalty to airlines, special preferences for certain airports or airlines do also play a certain role. Data for the latter ones are hardly systematically available and even difficult to measure, so we only consider – when measuring the attractiveness of a certain alternative – frequencies and travel time. Fares on certain routes change, sometimes by the day. Advanced yield management systems, used by full service carriers, result in substantial fare differences. So a systematic and coherent fare information system, representing the actual fares paid, is neither available. However, there may be some systematic characteristics in fare differentiation. Fares on direct routes are generally higher than those on indirect routes between two airports. Fares on indirect routes are generally lower for on-line (or code-shared) connections than for interline connections. Fares on a route are generally lower if more competitors are operating on these routes. And finally fares are 'carrier-specific' and are depending on the ability of carriers to compete on fares. It can be concluded that fares are generally depending on the number of competitors on the route and the product characteristics, like travel time, number of transfers, kind of connection (on-line or interline) and the carrier operating on the route. So – although explicit fare information is not available – fare differentiation is partly reflected in the route characteristics.

The route characteristics mentioned are to be operationalized in a variable indicating connectivity, expressed in 'connectivity units (CNU's). This variable is a function of frequencies, travel time and the necessity of a transfer.

2.3 Methodology: NetScan Model[Appendix A)]

The NetScan Model has been applied here to quantify the quality of an indirect connection and scale it to the quality of a theoretical direct connection (Veldhuis (1997), IATA (2000)).

First, direct connections and indirect connections have been retrieved from OAG flight schedules. The former are directly available from the OAG flight schedules. The latter have been constructed using an algorithm, which identifies for each incoming flight at an airport the number of outgoing flights that connect to it. The algorithm takes into account the minimum connecting time and puts a limit on the maximum connecting time and routing factor. In our case, we assume 30 minutes between domestic connections, and 45 minutes between domestic and international connections and between international connections for the minimum connecting time, 1.440 minutes for the maximum connecting time, and 170 % for the maximum routing factor.

Next, NetScan assigns a quality index to every individual connection, ranging between 0 and 1. A direct, non-stop flight is given the maximum quality index of 1. The quality index of an indirect connection will always be lower than 1 since extra travel time is added due to transfer time and detour time for the passenger. The same holds true for a direct multi-stop connection: passenger face a lower network quality because of en-route stops compared to a non-stop direct connection. If the additional travel time of an indirect connection exceeds a certain threshold, the quality index of the connection equals 0. The threshold between two airports depends on the travel time of a theoretical direct connection between these two airports. In other words, the longer the theoretical direct travel time between two airports, the longer the maximum indirect travel time can be. The travel time of a theoretical direct connection is determined by the geographical coordinates of origin and destination airport and assumptions on flight speed and time needed for take-off and landing. Furthermore, additional time penalties for transfer time have been included in this model. Passengers generally perceive transfer time as more inconvenient than flying time, as additional risks exist of missing connections and loss of baggage.

By taking the product of the quality index and the frequency of the connection per time unit (day, week, and year), the total number of connections or connectivity units (CNU's) can be derived.

2.4 Data and Classification

The data used in this analysis are from OAG flight schedules in the third week of September in 2001, 2004 and 2007. In this study, only online connections are considered as viable connections. In other words, the passenger transfer has to take place between flights of the same airline or global airline alliance. For the years 2004 and 2007, three global airline alliances are distinguished: Oneworld, SkyTeam and Star Alliance. For the year 2001, an additional alliance, Wings Alliance is also distinguished, which submerged into SkyTeam in 2004.

The study area is specified as the Asia/Pacific rim, which includes East Asia, Southeast Asia and Oceania. The airports, selected and analyzed in our study, are sixteen primary airports in this area. The analysis considers the connectivity between or via these airports and airports worldwide.

3. Comparison of Network Performance and Hub Competitive Position among Primary Airports in the Asia/Pacific Rim

3.1 Total Network Connectivity

Figure 2 shows the total connectivity split up in direct, indirect and hub connectivity at the primary Asia/Pacific rim airports in 2007. As for direct connectivity, Chinese airports definitely provided many direct connections; Beijing (3,918 CNU), Hong Kong (2,745 CNU), Guangzhou (2,743 CNU) and Shanghai (2,152 CNU), most of which were domestic ones at the three airports in Mainland China. Jakarta was the second largest airport in this region with regard to direct connectivity and accommodated 3,025 direct flights in this year. Furthermore, Sydney, Kuala Lumpur, Bangkok and Singapore offered more than 2,000 direct frequencies. On the other hand, the remarkably largest indirect connectivity was found at Tokyo, which was 14,821 CNU in 2007, followed by Hong Kong, Singapore, Bangkok and Seoul.

With respect to hub connectivity, Sydney and Tokyo were in the first tier, with 5,066 CNU and 5,042 CNU, respectively. Beijing, Singapore, Bangkok, Seoul, Hong Kong and Kuala Lumpur were in the second tier. Indirect and hub connectivity at the three airports in Mainland China and Jakarta, in general, were not so high, compared with direct connectivity. This was because Air China, China Eastern Airlines, China Southern

Airlines and Garuda Indonesia, that base their respective hubs at Beijing, Shanghai, Guangzhou and Jakarta, didn't belong to any global airline alliances at this time. As a consequence, on-line connections with other airlines were not provided at these airports.

Figure 2

Total Network Connectivity at Primary Asia/Pacific Rim Airports, 2007

Table 1 shows the percentage growth in these types of connectivity between 2001 and 2007. The highest growth percentages can be found, through all types of connectivity, at the three airports in Mainland China. In particular, the figure of hub connectivity at Shanghai increased about 1,450 percent, and that of indirect connectivity at Guangzhou increased about 690 percent between these years. One reason concerns the opening of a new international airport in 1999 and in 2004, in each of both cities. In addition, these two airports had very low levels in 2001. Seoul and Jakarta experienced remarkable growth levels, especially in terms of hub connectivity. The high growth of indirect and hub connectivity at Seoul can be largely attributed to Asiana Airlines becoming a Star Alliance partner in 2003. In addition, Tokyo demonstrated rather high growth in hub connectivity. On the contrary, some airports showed negative growth rates, such as

Osaka and the three Oceanian airports. Osaka decreased its direct connectivity around 22 percent between 2001 and 2004, and indirect and hub connectivity around 19 percent and 15 percent between 2004 and 2007, respectively. This can partly be explained by the opening of the second runway in Tokyo in 2002, which enabled some airlines to move their flights from Osaka to Tokyo, owing to the economic recession in the Kansai Area. The two Australian airports experienced the highest negative growth percentages. It was because Ansett Australia ceased all operations in 2002 as a consequence of its bankruptcy.

Table 1

Percentage Growth in Direct, Indirect and Hub Connectivity at Primary Asia/Pacific Rim Airports, 2001-2007

3.2 Onward Connectivity Ratio and Hub Connectivity Ratio

The onward connectivity ratio indicates the average number of onward connections beyond another hub per direct connection from the airport considered. The hub connectivity ratio, on the other hand, means the average number of hub connections via the hub per direct connection.

Table 2 illustrates the ratios of both connectivity at the primary Asia/Pacific rim airports in 2001, 2004 and 2007. The largest one can be found at Tokyo both in onward and hub connectivity ratios, which were 8.79 CNU 2.99 CNU in 2007, respectively. In other words, each direct flight from Tokyo generated on average 8.79 connections beyond (with a transfer at) another hub and 2.99 connections via (with a transfer at) Tokyo. The former was mainly developed by transfers in North America, and the latter was brought about partly by the extra territorial hub operation of foreign airlines. In the same year, others, such as Osaka, Seoul, Hong Kong, Bangkok and Singapore showed a relatively high onward connectivity ratio, and Seoul, Kuala Lumpur, Singapore, Sydney and Auckland demonstrated a comparatively high hub connectivity ratio. The three airports in Mainland China, on the other hand, showed the low levels in this measurement, due to lack of on-line connections with other airlines.

Table 2

Onward Connectivity Ratio and Hub Connectivity Ratio at Primary Asia/Pacific Rim Airports, 2001, 2004 and 2007

4. Effects of Airline Alliances on Network Performance and Hub Competitive Position

4.1 Network Connectivity by Alliances

In this section, the network connectivity at the primary Asia/Pacific rim airports in 2007 is discussed from the standpoint of global airline alliances. As for direct connectivity, non-alliance carriers are the largest players in this region. Their shares are remarkably high especially at the three airports in Mainland China, Taipei, Manila, Kuala Lumpur and Jakarta. This is partly a symptom of the emergence of regional carriers or low-cost carriers in this region.

Other airports are roughly classified into three alliance groups; Oneworld (Hong Kong, Sydney and Melbourne), Star Alliance (Bangkok, Singapore and Auckland), Oneworld & Star Alliance (Tokyo and Osaka) and Star Alliance & SkyTeam (Seoul). This rough classification much better clarifies hub connectivity by alliances. This is because the share of each alliance group at an airport depends on the alliance the home based airline belongs to. For example, Oneworld accounts for 88.0 percent of hub connectivity at

Hong Kong the home base of Cathay Pacific Airways. Star Alliance shows the percentage of 94.6 percent at Bangkok with Thai Airways International, and 90.8 percent at Singapore with Singapore Airlines. With regard to Tokyo and Osaka, Japan Airlines, which joined Oneworld in 2007, and All Nippon Airways, which is a member of Star Alliance, have high shares. As for Seoul, Korean Air, which is one of the founders of SkyTeam, and Asiana Airlines, which joined Star Alliance in 2003, are the predominant carriers for hub connectivity. The shares of Star Alliance are quite low at Sydney and Melbourne, where Ansett Australia, a former member of this Alliance, ceased all operations in 2002.

Besides, it is remarkable that SkyTeam accounts for quite a large share of hub connectivity especially at Tokyo, owing to the fifth freedom rights of US airlines out of Tokyo. Northwest Airlines, one of its members, operates a substantial number of beyond rights. It is also interesting that the shares of SkyTeam for indirect connectivity at these two Japanese airports are quite high, although a Japan-based SkyTeam member is missing. SkyTeam members such as Korean Air or Northwest Airlines, coordinate their flight schedule between incoming flights from Japan and outgoing flights from their own airports, like Seoul or Los Angeles, boosting its share in indirect connectivity at these two Japanese airports. Another example can be found in the share of Oneworld for hub connectivity at Singapore. Qantas Airways operates a hub at Singapore based on seventh freedom rights, as well as British Airways.

Note that Air China and Shanghai Airlines joined Star Alliance in December, 2007, and China Southern Airlines joined SkyTeam in November, 2007. Others, such as China Eastern Airlines or Malaysia Airlines System, are expected to join one of the global airline alliances in the future. These future alliance members will drastically change the balance among the three incumbent alliances.

4.2 Changing Share Levels of Alliances

Table 3 summarizes the percentage share of alliances by network connectivity in the Asia/Pacific Rim in 2001, 2004 and 2007. This clearly describes the rise in the share of SkyTeam and non-alliance members over this period, mainly because of the integration of Wings Alliance into SkyTeam in 2004 and the recent upsurge of regional carriers and low-cost carriers. The increase in SkyTeam’s share in indirect and hub connectivity reflects the effect of the network strategy by SkyTeam members, as mentioned above.

Table 3

Percentage Share of Alliances by Network Connectivity in the Asia/Pacific Rim, 2001, 2004 and 2007

Note: Calculated from the sum of the sixteen Asia/Pacific rim primary airports.

5. Summary and Conclusion

This paper measures and compares the network performance and hub competitive position of sixteen primary airports in the Asia/Pacific rim between 2001 and 2007. After decomposing network connectivity into three items -direct, indirect and hub connectivity, this paper takes into account the quantity and quality of both direct and indirect connections to measure the network performance in hub-and-spoke systems.

The results reveal that Tokyo has the best network performance and hub competitive position. The most striking growth of network development is found at three Chinese airports, while network performance deteriorates at three Oceanian airports. Finally, the results show that the position of Oneworld and Star Alliance is stronger, whereas

SkyTeam has an innegligible position especially at two Japanese airports, owing to fifth and sixth freedom rights.

The analysis presented in this paper may be helpful for airports or airlines in identifying their network performance or diversity, and competitive position in relation to competing airports or airlines.

Appendix A

Summarizing, the following formulas have been applied for each individual (direct, indirect or hub) connection;

(1) $NST = (40 + 0.068 * \mathrm{gcd}\, km) / 60$

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

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

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

(5) $CNU = QLX * NOP$

Where,

NST: non-stop travel time in hours

gcd km: great-circle distance in kilometers

MXT: maximum perceived travel time in hours

PTT: perceived travel time in hours

FLT: flying time in hours

TRT: transfer time in hours

QLX: quality index of a connection

CNU: number of connectivity units

NOP: number of operations

In Formula (1), it is assumed that flight speed is 1/0.068 (=14.7) kilometers per minute, and time needed for take-off and landing is 20 minutes each. Formula (2) is empirically derived from the trip data and inquiries on travel patterns and traffic behaviors intra-Europe. The basic idea under this is that MXT increases with the increase of NST, but with the decreasing incremental ratio, so the estimated model was specified as a quadratic function. PTT, which is composed of flying time and transfer time, is calculated by Formula (3). Additional time penalty for transfer time has been included in this formula to reflect its inconveniences. After making a global check with actual route choices based on passenger inquiries at Amsterdam Airport Schiphol, we assumed time penalty will decrease in accordance with flying distance, which means a larger time penalty for short-haul flights and a smaller for long-haul ones. By Formula (4), a quality index has been assigned to every individual connection, ranging between 0 and

1. A non-stop direct connection is given the maximum quality index of 1. The quality index of an indirect connection with PTT over MXT is 0. Appendix-Figure 1 shows a simple example of the route between origin airport A via intermediate hub H and destination airport B. NST is 3 in this example (QLX=1). MXT is calculated from Formula (2), that is 8.33 (QLX=0). If a passenger chooses an indirect flight and transfers at H, FLT between A and H and between H and B are 1.5 and 2.5, respectively. Assuming 0.75 for TRT, 6.08 is obtained for PTT from Formula (3). If a quality index is assumed to be inversely proportional to total travel time, QLX of 0.42 is assigned, by Formula (4), to this example (Appendix-Figure 2). Finally, CNU is obtained from Formula (5).

Appendix-Figure 1

Route between Origin Airport A via Intermediate Hub H and Destination Airport B

Appendix-Figure 2

Calculation of QLX

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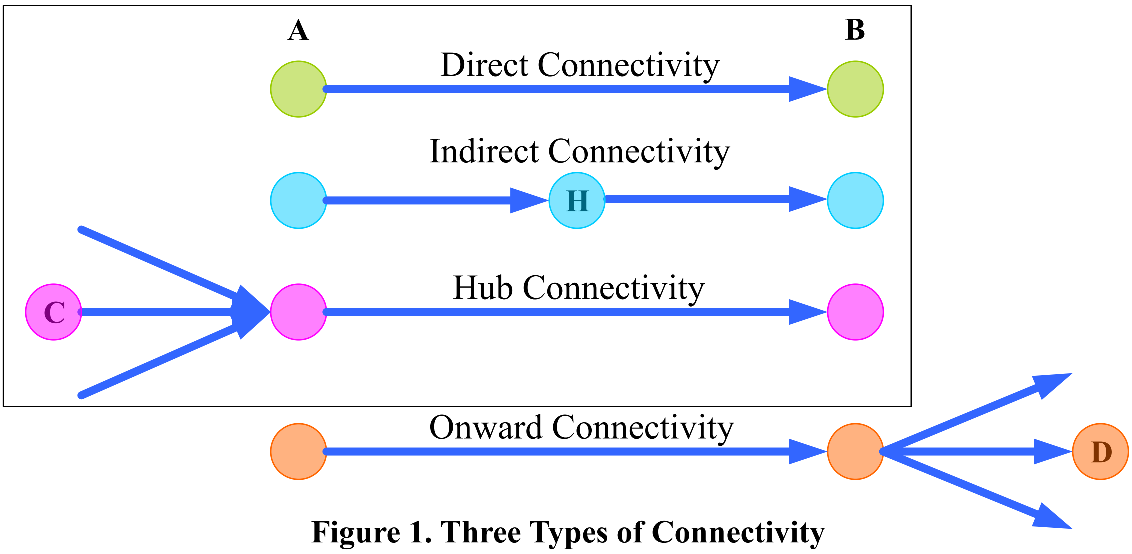


Figure 1. Three Types of Connectivity

Note: This paper does not consider Onward Connectivity, namely the connections via (with a transfer at) B between A and D.

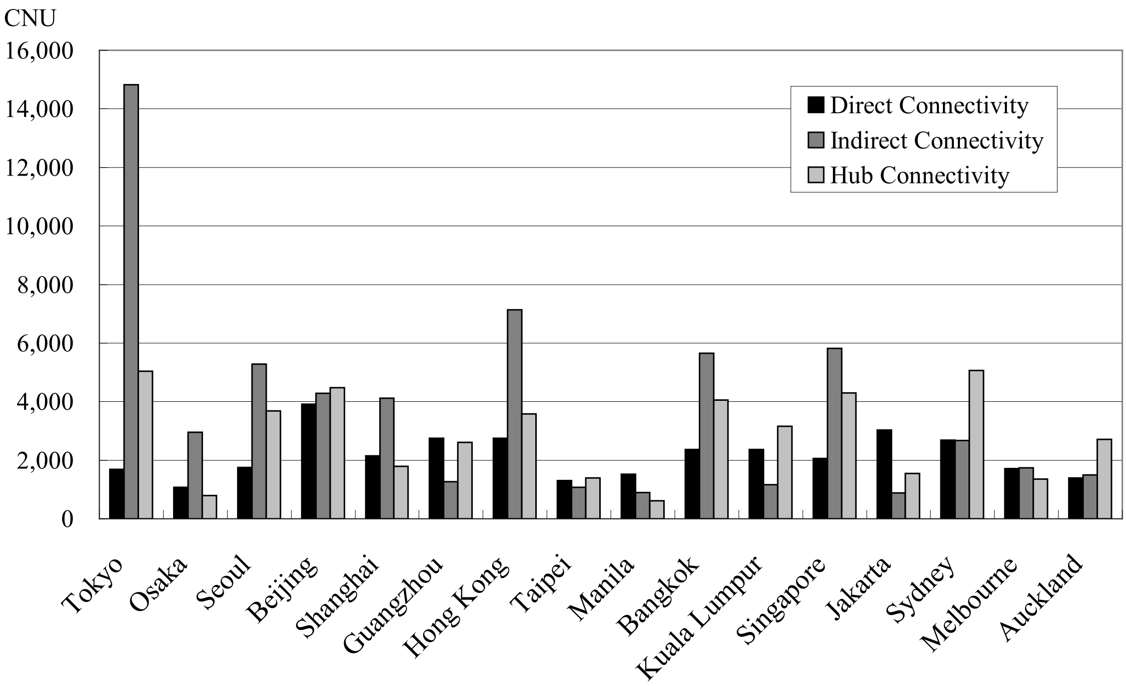


Figure 2. Total Network Connectivity at Primary Asia/Pacific Rim Airports, 2007

Table 1 Percentage Growth in Direct, Indirect and Hub Connectivity at Primary Asia/Pacific Rim Airports, 2001-2007

Airport	Direct Connectivity			Indirect Connectivity			Hub Connectivity		
	2001-2004	2004-2007	2001-2007	2001-2004	2004-2007	2001-2007	2001-2004	2004-2007	2001-2007
Tokyo	29.0	4.2	34.3	10.4	15.9	28.0	**102.1**	9.3	**121.0**
Osaka	-21.6	16.0	-9.1	17.5	-18.6	-4.4	6.8	-15.0	-9.2
Seoul	23.8	43.1	77.2	87.7	37.9	**158.9**	90.3	73.9	**230.9**
Beijing	49.0	26.6	88.7	31.3	48.8	95.5	**300.2**	24.2	**396.8**
Shanghai	**161.3**	37.6	**259.6**	82.9	99.0	**263.9**	**983.1**	43.2	**1450.5**
Guangzhou	51.2	50.4	**127.5**	**385.5**	62.6	**689.3**	**109.4**	**102.0**	**323.0**
Hong Kong	17.4	25.7	47.5	-4.3	30.9	25.2	22.2	39.7	70.7
Taipei	11.9	6.7	19.4	-44.5	34.8	-25.3	31.4	8.8	43.1
Manila	0.9	30.9	32.1	-3.5	46.3	41.1	12.3	71.9	93.0
Bangkok	29.7	0.8	30.7	10.1	16.8	28.7	12.9	7.2	21.1
Kuala Lumpur	45.3	41.6	**105.7**	51.8	8.8	65.2	27.9	-2.2	25.1
Singapore	0.8	14.1	15.0	4.7	7.4	12.5	-0.7	13.5	12.7
Jakarta	73.3	37.0	**137.5**	27.4	10.8	41.2	**133.2**	76.1	**310.6**
Sydney	-10.9	2.6	-8.6	-26.3	9.8	-19.2	-45.1	7.6	-40.9
Melbourne	-10.9	-0.7	-11.5	-9.6	4.2	-5.8	-28.5	-20.2	-42.9
Auckland	14.7	-1.5	13.0	-17.2	1.0	-16.4	40.2	-5.1	33.0

Table 2 Onward Connectivity Ratio and Hub Connectivity Ratio at Primary Asia/Pacific Rim Airports, 2001, 2004 and 2007

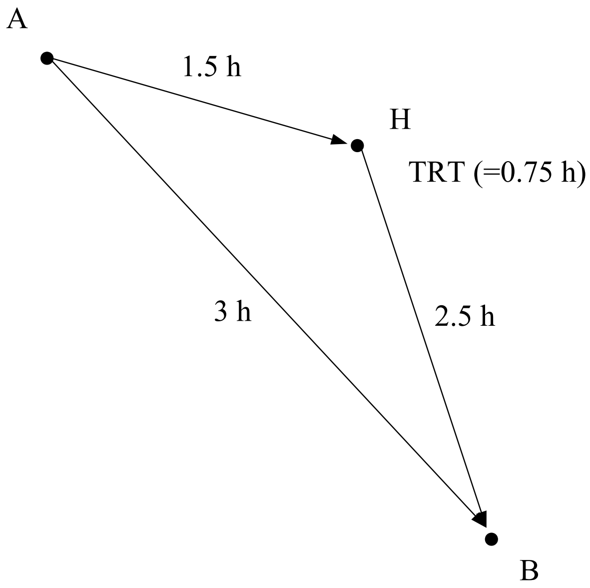
Airport	Onward Connectivity Ratio			Hub Connectivity Ratio		
	2001	2004	2007	2001	2004	2007
Tokyo	**9.23**	**7.90**	**8.79**	1.82	**2.85**	**2.99**
Osaka	**2.61**	**3.92**	**2.75**	0.74	1.00	0.74
Seoul	**2.07**	**3.14**	**3.03**	1.13	1.74	**2.11**
Beijing	1.06	0.93	1.09	0.43	1.17	1.14
Shanghai	1.89	1.32	1.91	0.19	0.80	0.83
Guangzhou	0.13	0.43	0.46	0.51	0.71	0.95
Hong Kong	**3.06**	**2.50**	**2.60**	1.13	1.17	1.30
Taipei	1.32	0.66	0.83	0.89	1.05	1.07
Manila	0.55	0.53	0.59	0.28	0.31	0.40
Bangkok	**2.42**	**2.06**	**2.39**	1.85	1.61	1.71
Kuala Lumpur	0.61	0.64	0.49	**2.19**	1.93	1.33
Singapore	**2.88**	**2.99**	**2.82**	**2.12**	**2.09**	**2.08**
Jakarta	0.49	0.36	0.29	0.30	0.40	0.51
Sydney	1.13	0.93	1.00	**2.92**	1.80	1.89
Melbourne	0.95	0.97	1.01	1.22	0.98	0.79
Auckland	1.46	1.05	1.08	1.65	**2.02**	1.95

Table 3 Percentage Share of Alliances by Network Connectivity in the Asia/Pacific Rim, 2001, 2004 and 2007

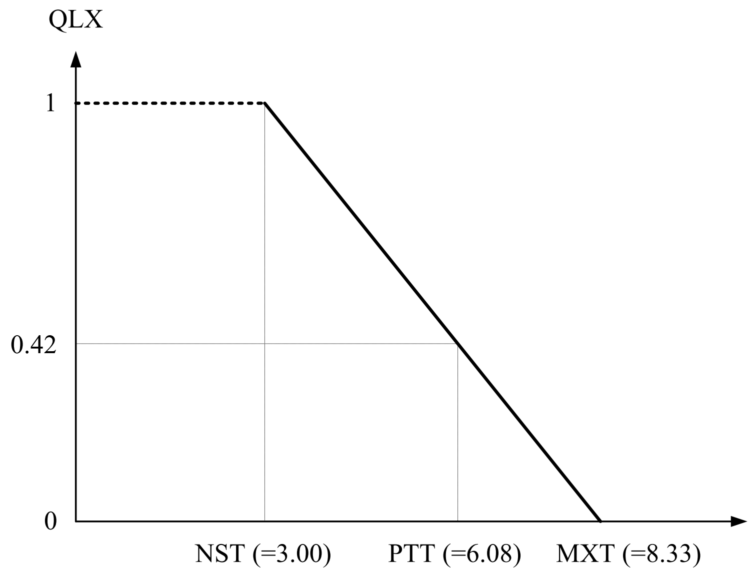
Alliance	Direct Connectivity			Indirect Connectivity			Hub Connectivity		
	2001	2004	2007	2001	2004	2007	2001	2004	2007
One World	15.4%	11.9%	12.1%	21.0%	19.3%	21.5%	26.9%	21.2%	22.8%
Star Alliance	26.3%	17.9%	15.2%	49.1%	43.6%	43.7%	45.9%	36.2%	33.8%
Sky Team	**2.5%**	**4.2%**	**4.2%**	**9.0%**	**25.2%**	**23.4%**	**2.4%**	**6.2%**	**7.4%**
Wings Alliance	2.2%	0.0%	0.0%	11.6%	0.0%	0.0%	1.7%	0.0%	0.0%
Non-alliance	**53.5%**	**66.0%**	**68.6%**	**9.3%**	**11.9%**	**11.4%**	**23.1%**	**36.4%**	**36.0%**
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Calculated from the sum of the sixteen primary Asia/Pacific rim airports.

Appendix A



Appendix-Figure 1. Route between Origin Airport A via Intermediate Hub H and Destination Airport B



Appendix-Figure 2. Calculation of QLX