
China's Air Passenger Transport: An Analysis of Recent Trends

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Abstract: Two China-based transportation geographers examine trends and developments revealed by the release of the most recent official data on traffic and airport capacity within mainland China's domestic air passenger transport system. The focus of the study is the uneven spatial distribution of airports and airport service hinterlands, as well as the hierarchical nature of passenger flows centered within the axis Beijing–Shanghai–Guangzhou (Hong Kong, Macau, and Taiwan are not included in the analysis). Among the questions investigated are the efficiency/balance within the system, as well as the extent to which the distribution of airports and air passenger flow volumes reflect basic patterns of economic and urban development within the country, and conform with a hub-and-spoke model. *Journal of Economic Literature*, Classification Numbers: L50, L93, O18, R40. 5 figures, 5 tables, 30 references. Key words: airport system, aviation network, air passenger transport, service hinterlands, China.

INTRODUCTION

Recent years have witnessed a substantial increase in the number of air passengers worldwide. This has primarily been the result of increasing affluence in both developed and developing countries and government policies designed to improve services, increase competition, and reduce prices (e.g., deregulation, privatization, and liberalization of rules governing airline operations; see Graham, 1995; Chin, 1998; Park, 2003). The growth of air transport, in turn, has increasingly played an important role in overall social and economic development, and as such has been the subject of a growing volume of academic research.² Following the deregulation of civil aviation throughout most of the world, the focus of research has shifted in the direction of quantitative analysis of the spatial and economic characteristics of aviation networks, and particularly the evolution of hub-and-spoke networks.

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²A complete review of work on the subject lies beyond the scope of this brief report, but a partial listing of important recent contributions includes Fleming and Hayuth (1994), Shaw and Ivy (1994), Taaffe et al. (1996), Hooper (1997), O'Kelly (1998), Graham and Guyer (1999), Vowles (2000), Burghouwt and Hakfoort (2001), Goetz (2002), and Jin et al. (2004).

Table 1. Selected Indices of Mainland China's Civil Air Transportation System, 1980–2005

Indicator	1980	1985	1990	1995	2000	2005
Number of airports	77	80	92	116	139	142
Passenger traffic, mill. persons	3.4	7.5	16.6	51.2	67.2	138.3
Passenger traffic turnover, mill. person-km	39.6	116.7	230.5	681.3	970.5	2044.9
Freight traffic, thous. tons	90	200	370	1010	1970	3070
Freight traffic turnover, mill. ton-km	140.6	415.1	818.2	2229.8	5026.8	7889.5

Following the reforms and the opening-up policy in 1978, civil aviation in China has developed rapidly. Many new airports have been constructed and have started operations, and in the process the structure of the country's air passenger transport network has changed dramatically. Until recently, however, not much has been written about air transport in China, despite predictions that it is becoming the world's fastest-growing aviation market.³ Since the late 1990s, the void in the literature has been filled in part by a number of studies that have viewed China's civil aviation network from the prism of economic transition and contemporary models of transportation geography, often from a comparative, transnational perspective (e.g., Le, 1997; Zhang, 1998; Chen, 1999; Liu, 2000; Peng, 2000; Dougan, 2002; Wang et al., 2003; Zhang and Chen, 2003; Jin et al., 2004; Thomas, 2005, 2006; Zhou and Li, 2005; and most recently Boquet and Song, 2007). Instead of replicating the findings of this body of work, this research report focuses on extending our understanding of the present system by focusing on trends revealed by the release of the most recent official statistics (for 2005) for passenger traffic from the Civil Aviation Administration of China (2006). Coverage is limited here to domestic passenger flights to and from airports in mainland China (i.e., Hong Kong, Macau, and the airports of Taiwan are not included).

AIRPORTS AND SERVICE HINTERLANDS

Airports

Since the 1980s, the rate of growth in the number of air passengers has outstripped that of both the country's GDP and its overall population (Fig. 1). Reflecting this surge in aviation activity, a boom in airport construction has nearly doubled the number of airports serving commercial passenger traffic in mainland China, to 142 in 2005 (Table 1).

Not surprisingly, given the situation elsewhere in the world, the spatial pattern of these airports is characterized by regional inequality, both in terms of numbers as well as in terms of capacity (size). This pattern, however, is not immediately apparent when the focus is on the 60 Class 4D and 4E airports, low-capacity facilities serving smaller regional centers that constitute the bottom level of air passenger service hierarchy.⁴ 35 (ca. 58 percent of the total) of these are found in Eastern and Central China, a percentage share that is actually less than

³The number of passengers carried on domestic flights is on a pace to increase from 69.6 million (in 1999) to 214.7 million in 2014 (Granitsas, 2002).

⁴Class 4D airports have a runway length ≥ 1800 meters, can accommodate a maximum aircraft wingspan extending from 36 to 52 m, and an undercarriage track from 9 to 14 m. Class 4E airports have the same specifications except for the maximum wingspan, which is 52–60 m.

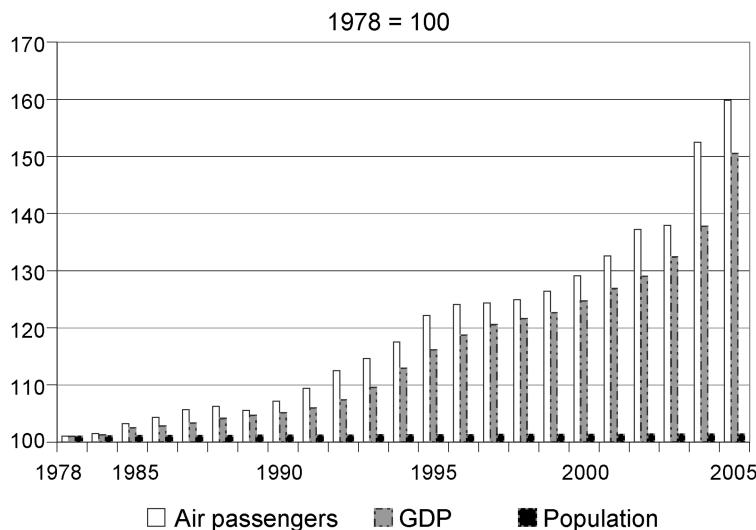


Fig. 1. Growth of population, GDP, and number of air passengers, 1978–2005.

the aggregate population share of these two “economic belts”⁵ in the 2000 census (77 percent; see Fan, 2002). However, when the focus shifts to larger facilities—and in particular airports with annual air passenger volumes exceeding 2 million—a pattern of increasing inequality in favor of economically powerful and populous eastern coastal provinces begins to emerge that does not deviate in any substantial way from patterns reflecting the distribution of population and economic activity.

Air passenger transport flows similarly are concentrated in China’s top 20 (largely eastern) cities, which accounted for nearly 80 percent of all domestic passenger traffic in 2005 (Civil, 2006). Since the 1980s, the three eastern cities of Beijing, Shanghai, and Guangzhou have occupied the peak of the flow pyramid (Wang et al., 2003), accounting in 2005 for roughly 37 percent of all passengers.⁶

Service Hinterlands

Our analysis of service hinterlands is based on data from the Civil Aviation Administration of China,⁷ and on two methods of delineating service areas—shortest distance and rational service range.

⁵The macroregions of China referred to in this study follow the now widely used regionalization scheme of three “economic belts”—Eastern, Central, and Western—delineated in the country’s Seventh Five-Year Plan (1986–1990). For a map detailing the provinces belonging to each region, see Fan (2002).

⁶The shares of the top 20 and top three cities in the system have diminished slightly over this period, however, indicating some strengthening of the position of small and medium-sized airports (e.g., the shares for the top 20 and top 3 in 2002 were 81.4 and 39.7 percent, respectively). Unless noted otherwise, all 2005 data reported here are from Civil Aviation Administration (2006).

⁷The most recent data available at a level of detail sufficient for the calculations embraced 141 airports located in 132 cities in 2002. Among the cities with more than one airport are Shanghai, Beijing, Chengdu, Hangzhou, Nanjing, Guilin, Fuzhou, Jinan, and Yinchuan.

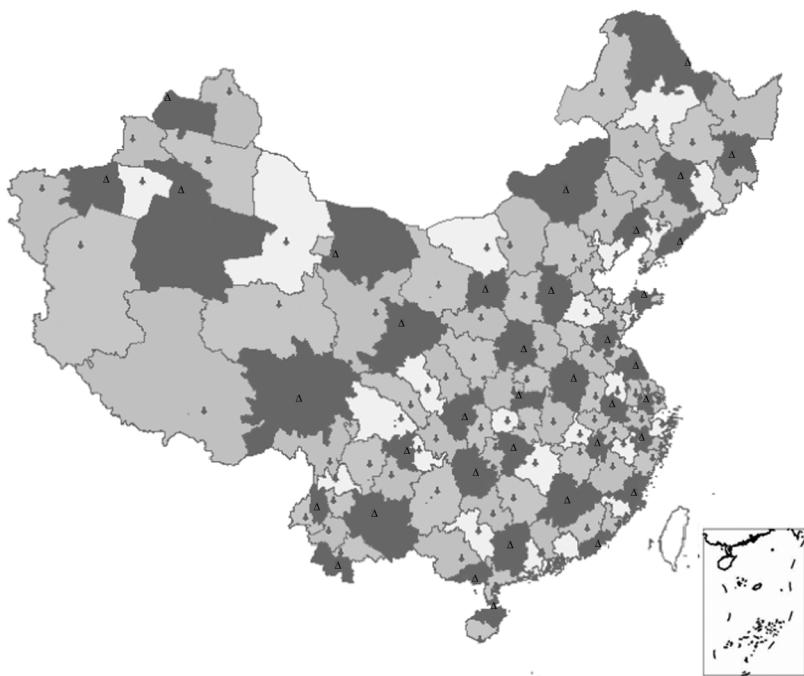


Fig. 2. Air service hinterlands defined by the shortest-distance method. The variously shaded areas typically consist of multiple counties served by the same nearest airport.

Shortest-Distance Method. The shortest-distance calculations use counties as the basic units of analysis, with “distance” defined as the geometric distance between the county administrative center and the nearest airport.⁸ Mathematically, this relationship can be expressed as:

$$L_{ik} = \text{Min}(L_{ij}) \quad (i = 1, \dots, m; j = 1, \dots, n), \quad (1)$$

where i is the county territory, j is the airport, L_{ij} is the geometric distance between i and j , k is the nearest airport to i , and L_{ik} is the shortest Euclidean distance. Every county is assigned to the hinterland of the nearest airport, regardless of whether it is served by an airport within its own borders. Figure 2 shows the service hinterlands consisting of counties served by nearest airports.

Rational Service Range. Surveys of air passengers indicate that convenient and rapid access to an airport is an important component of satisfaction with the overall travel experience (Chen, 1999; WCCAA, 2002). To gauge the extent to which airports in China are convenient and accessible to the flying public, and again using counties as basic units of statistical analysis, we sought to identify those parts of the country served by airports located no farther than 50 and 100 km from county administrative centers. As with the shortest-distance method, a county served by multiple airports is assigned to the hinterland of the nearest facility. The resulting pattern of “rational” service hinterlands is depicted in Figure 3.

Pattern Assessment. Examination of Figures 2 and 3 reveals some interesting distributions. Not unexpectedly, airport density tends to decrease from east to west, in conjunction

⁸If a county is served by several airports, it is assigned to the hinterland of the nearest facility.



Fig. 3. Counties served by airports within 50 km (darker grey shading) and 100 km (light grey shading).

with population density. Proceeding westward, shortest-distance service hinterlands increase in area (Fig. 2),⁹ while rational service hinterlands become much less numerous (Fig. 3). Clearly, the population of Eastern China as a whole enjoys superior service vis-à-vis the West, and to a lesser extent, Central China. The Yangtze and Zhujiang river deltas, the Beijing-Tianjin region, central and southern Liaoning Province, the Shandong Peninsula, the Wuhan-Changsha region, Chengdu-Chongqing, and southeastern Fujian Province all are well served by airports within 100 km distance, and the service areas of airports within 50 km distance are beginning to coalesce, particularly in the Yangtze River Delta. These regions contain numerous metropolitan areas and city belts, and the air transport demand generated by economic development has led to the expected concentration of airports.

Upon closer examination, however, the relationship between airport service areas and regional development/population density is not as straightforward as one might assume. In Table 2 we present, for each of China's three macroregions, information on the percentage of land area, population, and GDP falling within the rational service hinterlands depicted in Figure 3. Although as expected, Eastern China has decidedly higher shares of land area,

⁹Readers should note, however, that the shortest-distance method does not explicitly consider the spatial distribution of population within counties. For example, the distribution of population in some of the sparsely settled western regions (e.g., Xinjiang) tends to be highly concentrated in relatively compact urbanized areas served by local airports. Therefore, despite the impression of relatively large "shortest-distance" airport hinterlands in Western China depicted in Figure 2, a resident of Kashi or Kuerle may have a shorter trip to the nearest airport than many residents of southwestern Beijing, who commute to the airport located in the northeastern fringe of the city.

Table 2. Area, Population, and GDP Encompassed by 50 and 100 km Rational Service Hinterlands, 2002, in percent^a

Indicator:	50 km			100 km		
	Area	Population	GDP	Area	Population	GDP
Eastern	27.7	39.2	63.8	66.0	69.3	85.9
Central	14.4	24.2	31.7	44.6	56.5	56.0
Western	13.2	27.4	46.3	28.7	55.7	68.8
Mainland China	15.0	31.1	52.6	37.2	61.5	75.4

^aThe latest data available at a level of detail sufficient for the calculations were for 141 airports located in 132 cities in 2002 (see Fig. 3).

population, and GDP encompassed by the 50 and 100 km hinterlands than the other two regions (and consequently, China as a whole), Central China exhibits a pronounced “flyover pattern” (“traffic shadow”),¹⁰ with noticeably reduced coverage in terms of population and GDP than the even more sparsely populated West.

AIR PASSENGER FLOWS

The distribution of air passenger flows is closely interconnected with the location and hierarchy of China’s airports; the population, GDP, and economic functions of the cities in which airports are located;¹¹ and the assortment of air carriers and flights offered by particular airports. Conversely, the air transport demand generated by passenger flows affects the distribution and hierarchy of airports to some degree. Accordingly, most analyses of aviation networks also include an examination of passenger flows.

Spatial Structure

Relationship with Distance. We have analyzed 404 city pairs in China with an air passenger volume exceeding 50,000 in 2005, focusing on air transport distance. Figure 4, based on data compiled from Civil (2006), which plots passenger flows against air travel distance, shows that most passenger traffic occurred within a distance of 2400 km, with “peaks” at 500–600 km and 1100–1200 km and “valleys” at 700–800 and 1000 km. This pattern likely reflects a combination of factors, and particularly: (1) air transport, among all conventional modes, is most able to transcend physical distance, and this together with the discontinuous character of its transport infrastructure liberates it from a conventional distance-decay function; (2) the “flyover” or “traffic shadow” pattern of relative airport underdevelopment of Central China described above plays a role in the definition of the “valleys.”

Beijing–Shanghai–Guangzhou Axis. Our calculations of air passenger volumes of China’s cities and passenger flows for 2005 are summarized in Figure 5. It presents the familiar spatial concentration in Eastern China, but also highlights a pronounced triangular axis (Beijing–Shanghai–Guangzhou) and several individual subsystems (centered on

¹⁰For more on this flyover effect, see Wang et al. (2003).

¹¹Correlations between air passenger volumes in 105 cities with airports in China in 2002 (not including 27 special-purpose airports) and (a) GDP and (b) non-agricultural population of those cities are high, namely .88 and .77, respectively.

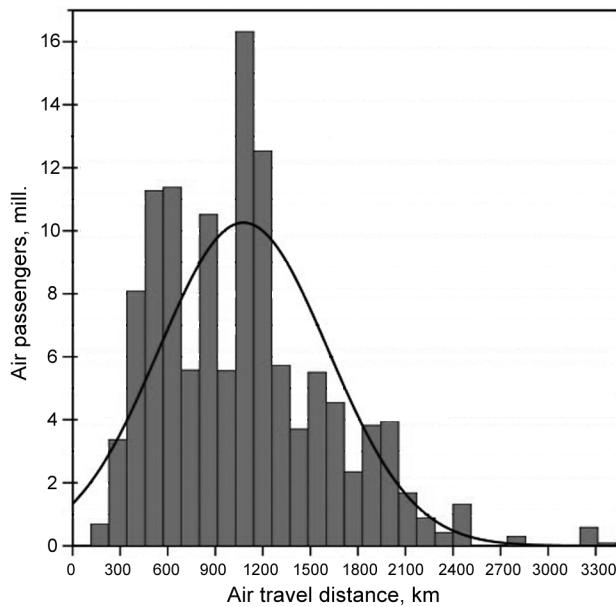


Fig. 4. Distribution of domestic air passenger flows (>50,000 annual passengers) by distance in 2005.

Table 3. National Shares of Area, Population, and GDP of the Three Nodes of China's Triangular Air Passenger Axis, 2005

Node	Area, thous km ²	Share of national total	Population, mill.	Share of national total	GDP, bill. yuan	Share of national total	Passenger volume, hundred thous.	Share of national total
Jing-Jin-Ji ^a	217.8	2.3	94.3	7.4	206.0	10.5	437.0	15.4
Yangtze River Delta ^b	97.7	1.1	80.7	6.3	326.1	16.6	589.0	20.7
Zhujiang River Delta ^c	54.9	0.6	27.1	2.1	181.2	9.2	405.0	14.2
Sum of three nodes	370.4	4.0	202.2	15.8	713.2	36.3	1431.0	50.3
Mainland China (total)	9295.9	100.0	1283.2	100.0	1965.6	100.0	2843.5	100.0

^aBeijing, Tianjin city, and Hebei Province.

^bShanghai, Nanjing, Ningbo, Hangzhou, Huzhou, Wuxi, Suzhou, Zhenjiang, Yangzhou, Taizhou, Changzhou, Nantong, Jiaxing, Shaoxing, and Zhoushan city.

^cGuangzhou, Shenzhen, Zhuhai, Foshan, Jiangmen, Dongguan, Zhongshan, Huizhou, and Zhaoqing city.

Chengdu, Wulumuqi, Haikou, etc.). As Table 3 documents, these patterns reflect the economic relationship of various city pairs, as well as their overall level of economic development. Tourism also increasingly plays a role, albeit largely seasonal.

Connection Intensity and Flow Analysis

Absolute Connection Intensity. One measure of the air transport connection between a pair of cities in terms of passenger flows is absolute connection intensity (T_{ij}):

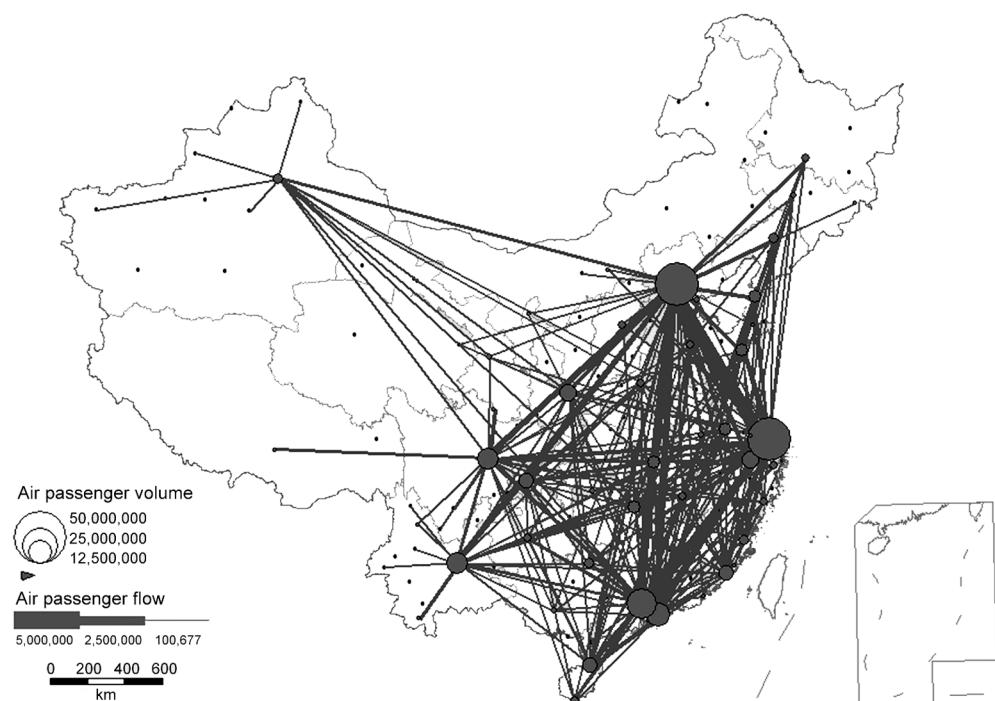


Fig. 5. Spatial pattern of domestic air passenger flows (>100,000 passengers) in 2005.

Table 4. Ranking of China's Air Routes According to Absolute Connection Intensity, 2005

T_{ij} category:	I	II	III	IV	V	Sum	Total ^a
Air passenger flow, persons ^b	> 2 mill.	1–2 mill.	200,000–1 mill.	100,000–200,000	50,000–100,000	—	—
Number of routes	3	18	147	108	128	404	1024
Air passengers, mill.	9.2	23.0	63.3	15.5	9.2	120.2	138.3
Percentage of all routes	0.3	1.8	14.4	10.5	12.5	39.5	100.0
Percentage of all passengers	6.6	16.6	45.8	11.2	6.7	86.9	100.0

^aIncludes routes with air passenger flow below 50,000 annually (i.e., not assigned to any category). Hence the entries in this column are larger than the sum of the entries for categories I–V ("Sum").

^bAverage annual number of passengers per route.

Source: Civil Aviation Administration of China (2006) and author calculations.

$$T_{ij} = I_{ij} + I_{ji} \quad (i, j = 1, \dots, n), \quad (2)$$

where I_{ij} and I_{ji} are air passenger flows from city i to city j and from j to i , respectively. With respect to air passenger transport, I_{ij} should basically equal I_{ji} .

Table 4, based on our recalculation of data in Civil (2006), classifies air routes with passenger flows exceeding 50,000 according to T_{ij} in 2005. It shows that spatial connections among cities are hierarchical in nature, with a far greater number of routes being characterized by small passenger flows rather than massive ones. Five categories of routes connecting

city pairs can be identified, with category I of highest connection intensity—consisting of the three routes Beijing–Shanghai, Beijing–Guangzhou, and Shanghai–Shenzhen (all with over 2 million passengers annually)—forming the framework of the aviation network. Because of the relatively low friction exerted by distance on air transport connections, connection intensity tends to reflect first and foremost economic relationships, with the three nodes of China's triangular air passenger transport axis all possessing very strong economic linkages. Nonetheless, the greatest number of passengers overall (45.8 percent) travel category III routes (147 routes, each averaging 200,000 to 1 million passengers annually).

The character of China's air passenger transport hierarchy is distinctly "top-down" in the sense that newly constructed small and intermediate-sized regional airports without fail first seek to establish connections with dominant facilities possessing the highest-level connectivity in the system. Only later do they seek connections with airports at marginally higher or equal levels in the hierarchy.

Dominant Flow Analysis. A method known as dominant flow analysis also can be utilized to examine the network structure of China's air transport system. Among all possible flows from one particular city and all other cities in a network, dominant flow analysis identifies only the largest flow from or to this city (Tian, 2000):

$$L_{ik} = \max \left\{ \frac{T_{ij} + T_{ji}}{O_i + D_i} \right\} \quad (j = 1, 2, 3, \dots, n \quad k \in n), \quad (3)$$

where T_{ij} and T_{ji} are air traffic flows from city i to j and from j to i , respectively; O_i and D_i are total air passengers from and to city i respectively; and L_{ik} is the "dominant flow ratio" of city i . Among the many linkages between i and j ($j = 1, 2, \dots, n$), the linkage $i \rightarrow k$ is the "priority linkage" containing the dominant flow.

Applying Equation (3) to air passenger flow data for all linkages involving 50,000 passengers in 2005, it was possible to identify four types of dominant flows: (1) strong connection ($L_{ik} \geq 0.6$, namely $i \Rightarrow k$); (2) sub-strong connection ($L_{ik} = 0.3–0.6$, or $i \Rightarrow k$); (3) weak connection ($L_{ik} < 0.3$, or $i \rightarrow k$); and (4) coupling connection (in which the intensity of flows is the largest one from i and also from k , $i \Leftrightarrow k$). Readers are advised that the interpretation of results may appear to be counterintuitive, in the sense that very "strong" connections tend to characterize dominant flow ratios between smaller cities and major hubs (e.g., Beijing, Shanghai, and Guangzhou),¹² whereas dominant flows between two major hubs will be characterized by much weaker connections (lower L_{ik}), as the dominant flows will be a smaller proportion of overall passenger volume ($O_i + D_i$).

Table 5, based on our perusal and compilation of relevant data from Civil (2006), shows the majority of dominant flows in China's air transport system in 2005 (distilled from 404 air routes among 88 cities). Beijing currently is seen to be the most important hub, not by virtue of the number of dominant flows reported (Shanghai has a total of 26 and Beijing 25), but due to the fact that it has a slightly higher number of strong connections and its network covers the entire country (although with strong and sub-strong connections concentrated in northern China). Shanghai's network, on the other hand, is more concentrated in the eastern coastal region and Yangtze River valley, whereas the network of the third hub, Guangzhou, is focused south of the Yangtze River. The dynamics in the system of dominant flows since

¹²The sum of the numerator $T_{ij} + T_{ji}$ will approach much more closely the sum of the denominator $O_i + D_i$.

Table 5. Categorization of Dominant Air Passenger Flows in China, 2005

City	Strong connection	Sub-strong connection	Weak connection	Coupling connection
Beijing	Baotou, Mudanjiang, Nantong, Changzhi, Hailar, Weihai, Huhehaote	Yanji, Changchun, Haerbin, Shenyang, Lanzhou	Dalian, Nanjing, Wulumuqi, Ningbo, Xian, Zhengzhou, Shanghai, Guiyang, Chengdu, Guangzhou, Kunming, Changsha	Shanghai
Shanghai	Huangyan, Mianyang, Lianyungang, Luoyang, Shijiazhuang, Xuzhou	Yantai, Tianjin, Huangshan, Yichang, Zhuhai, Zhangjiajie	Fuzhou, Wenzhou, Jinjiang, qingdao, Hefei, Xiamen, Guilin, Nanchang, wuhan, Jinan, Shenzhen, Beijing, Taizhou	Beijing
Guangzhou	Yiwu, Liuzhou	Linyi, Zhanjiang, Yibin, Shantou, Sanya	Wuxi, Hangzhou	—
Other cities	{Zhongdian, Baoshan, Mangshi, Lincang, Xishuangbanna, Dali, Lijiang} ⇒ Kunming {Kashi, Kuerle, Aertai, Hetian, Akesu, Yining} ⇒ Wulumuqi Yulin ⇒ Xian; Enshi ⇒ Wuhan Xichang, Lhasa, Panzhihua, Jiuzhaigou ⇒ Chengdu			

2002 is revealing: 11 more cities registered dominant flows to Shanghai in 2005, whereas Guangzhou's number of priority linkages fell by 3.

The pattern of dominant flows thus reinforces the picture of the triangular air passenger transport axis (Beijing–Shanghai–Guangzhou) described above, and provides early signs of the emergence of a hub-and-spoke system. Development of the latter at present is impeded by several factors: (1) China's commercial airlines at present for the most part do not have strong connections to specific hubs;¹³ (2) the number of feeder lines remains insufficient; and (3) transfers at hubs continue to be time-consuming and inefficient, and the number of connecting flights is relatively low.

CONCLUDING NOTES

The material presented in this brief study leads to a conclusion that the development of China's air passenger transport system is spatially uneven and hierarchical. The three top-level national hubs Beijing–Shanghai–Guangzhou form a triangular axis that dominates the network nationally (accounting for 37.3 percent of total passenger volume), supported by a network of sub-hubs that organize air transport at the regional level.

Airport location is governed by economic development, political factors, and a host of other reasons. The strong economic and social relationships among Beijing, Shanghai, and Guangzhou generate a high level of air travel demand, ensuring the durability of this triangular framework for the foreseeable future. The dominance of the “triangle” also is promoted

¹³Partial exceptions to this generalization are China's “big three” carriers (Air China, China East, and China South), with headquarters functions and a dominant presence in Beijing, Shanghai, and Guangzhou, respectively.

by continued rapid development of the economy and real estate market in the Beijing-Tianjin-Tangshan region, the Yangtze River Delta, and the Zhujiang River Delta.

Although domestic air passenger service in China has experienced rapid growth over the last two decades (the number of civilian airports nearly doubling between 1982 and 2005), the aviation network soon must transition from a period of expansion/extension to a stage of adjustment and optimization. The latter will require careful attention to a number of problems. Primarily, the task for the future will be to construct new airports at the appropriate scale in the right places (unserved and underserved locations), and to adjust service capacity at already-existing facilities (some airports have excess capacity, whereas others are over-used). An important factor, often overlooked, is the need for more rapid passenger access to terminal facilities via high-speed land transportation links. Also, whereas the number and capacity of airports in eastern coastal areas are basically sufficient, further expansion is warranted in Western and particularly Central China. Therefore regional equity considerations may dictate accelerated development in regions characterized by difficult natural conditions, remoteness, elevated levels of poverty, and a high percentage of minority populations.

Based on the analysis of air passenger flows, the aviation network in China continues to feature connections between city pairs, with some incipient characteristics of a hub-and-spoke system. Future construction of new subsidiary airports and feeder routes, as well as continued evolution of hierarchical relations among airports, may push the aviation network farther in the direction of a bona fide hub-and-spoke system. Following the deregulation of China's civil aviation industry, the strategies employed by commercial airline companies likely will play an increasingly important role in the configuration of the country's aviation network.

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