Journal of Air Transport Management xxx (2016) 1–9

Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

Comparison of major air freight network hubs in the U.S. and China

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ARTICLE INFO

Article history:
Received 16 March 2015
Received in revised form
10 May 2016
Accepted 13 June 2016
Available online xxx

ABSTRACT

The increase in global economic connectivity spurred by ties between Chinese manufacturing and a global market, particularly in high value low weight goods, pushed establishment of air cargo networks. These remain under-examined but impactful particularly for second and third tier metropolitan hub cities. This research looks at the air freight connections within China, a major rapidly developing trade center, and use of the aerotropolis concept to accelerate growth in the lagging inland region. References are made to FedEx and UPS networks within their U.S. headquarter region and in China to note differences in political economic contexts and China's adaptation of developed world models. The theoretical framework includes global production networks strategically coupled by transport logistics linked to aerotropolis type development. Data comes from government aviation and transportation sources, research analyses, corporate and industry reports, and interviews with Chinese officials. Focus falls particularly on Zhengzhou, capital of Henan Province in central China and the country's first airport-centered economic zone. The conclusion finds that Chinese hub cities more closely correspond to major manufacturing and population centers and central policy directives for development dispersion.

1. Introduction

Commodity flows through air freight centers constitute an economically notable aspect of globalization. The trade-off of higher cost for faster speed favors high-value, technology-infused, low weight air cargo such as computer and medical goods, as well as time-sensitive items such as clothing and biological shipments (Ensign, 2014). Air cargo transport systems nevertheless remain under-examined in both theory and case studies (Bowen, 2004, 2012; Hesse and Rodrigue, 2006). The following study considers China's creation of an Airport Economic Zone at Zhengzhou (ZAEZ), capital of central Henan Province, as an experimental zone for an air cargo production and logistics-based economy. The pattern of leading U.S.-headquartered cargo companies FedEx and UPS is referenced as is the aerotropolis model of urban airport-centered development since both are central to Zhengzhou's aspirations (The Economist, 2015; personal communications, Zhengzhou development officials 2015).

This study hypothesizes that the locations of major air cargo integrators reflect development strategies in places targeted for transit-oriented activities as a tool to drive growth, particularly in lagging inland regions. Utilization of hub cities to strategically couple local economic strengths (particular products or services) within their related global production network (GPN) illustrates the further assertion that despite spatial pattern similarities, differences in air freight networks arise from the roles played by individuals and companies in the U.S. compared to the role of governments in China. This allows China to speedily implement ideas and examples from the U.S. to improve hub modernization and connectivity to these networks whose spatial fragmentation drives the restructuring of China's air freight network (Hui et al., 2004). At China's current stage as a rapidly developing economy, government policies accelerate the speed of integration by encouraging targeted foreign direct investment (FDI) to enhance export trade, strategically coupling local firms with global integrators, suppliers and markets (Mackinnon, 2012, 2013).

Networks globalize and accelerate the development trajectory of areas with a well-integrated intermodal transportation infrastructure location conducive to distribution functions, particularly in a nation's interior region. These cities frequently function as cross-docking sites where goods are sorted and redirected to various destinations via land-based infrastructure connected to a regional airport. Spreading development into less prosperous

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http://dx.doi.org/10.1016/j.jairtraman.2016.06.006
0969-6997/

regions expands spatial and policy impacts of air freight network locations. Hubs may be supplemented by functioning within a larger scale aerotropolis: "a new urban form where cities are built around airports speedily connecting time-sensitive suppliers, manufacturers, distributors, and business people to distant customers, clients, and marketplaces" (Kasarda, 2013; aerotropolis.com).

China seeks to geographically spread the benefits of its manufacturing prowess by building new facilities for shipping cargo by air, rail and roadways linked to global as well as domestic markets. Placing the country's first aerotropolis-centered economic zone in central China forms an integral part of the country's continuing geographic strategy of initially developing the east coast, followed by the western and now the central regions (Fan, 1995). Airfreight network locations assist urban economic growth based on a variety of similar factors including the established relationship between air cargo volume, GDP per capita, and growth in higher skill producer services (Oster et al., 1997; Bowen and Leinbach, 2003; Kay, 2004; Kasarda and Green, 2005; Alkaabi and Debbage, 2011). The exact relationship defies measurement due to data suppression at many sites, but one study of four FedEx hub metropolitan areas calculated the multiplier effect of an air freight hub to be around 1:3 (Oster et al., 1997). This is less than the multiplier for manufacturing but still notable, particularly in areas seeking to establish a new economic base or build higher skill level extensions of the existing base.

U.S. network examples noted in this research are related to FedEx's international corporate headquarters in Memphis, Tennessee or UPS' operational headquarters in Louisville, Kentucky, which is separate from the corporate headquarters in Atlanta, Georgia. China's globally-linked hubs include Shanghai-Pudong (with a new national FedEx hub) and Guangzhou on the east coast. Zhengzhou, capital of Henan province, exemplifies the next-stage push to develop inner China's central region. As in the U.S. air freight centers, this location is well served by rail and road networks but located inland from major shipping ports. The following sections set out the basic data used and the theoretical lens of global production networks enhancing regional development through strategic coupling with air cargo transit networks and aerotropolis development. A concluding discussion summarizes contributions from considering China's move to utilize integrator hubs in order to accelerate regional development.

2. Materials and method

Differences in the data available by various sources often complicate comparisons of countries when diverse items are measured, with varying degrees of transparency. The U.S. air freight network is largely served by FedEx and UPS, the world's two largest air freight carriers (Jermy, 2014). Chinese air cargo data is available for cities but not for separate companies, which tends to support the earlier assertion that companies drive growth in the U.S. but government bodies are the important factor in China. We therefore utilize figures from a range of sources. Numerous ZAEZ development officials were interviewed and studies gathered during two trips in 2015. These are referenced as personal communications.

Comparison of air freight traffic in major carrier cities at five year intervals from 2004 through 2014 shows the rise in prominence of Asian centers, with Hong Kong taking over from FedEx center Memphis since the Chinese port serves as a major entry point for three global carriers (Table 1). Two main advantages contribute to the success of Hong Kong (Fu, 2013). Hong Kong is an important bridge connecting Europe and America with other Asian countries due to its central location in Asian-Pacific region. Second, nearby manufacturing centers in the Pearl River Delta ensure the supply of air cargo. Hong Kong is not included in the following Tables and Figures reflecting predominantly Chinese government-driven domestic development.

Table 1
Top world airports in the U.S. and China based on global air cargo carried, 2004–2014.

City	2004 Rank	2009 Rank	2014 Rank	%Change, 13–14
Hong Kong	2	1	1	2.3
Memphis	1	2	2	4.0
Shanghai	14	3	3	8.6
Anchorage	4	6	5	−0.7
Louisville	12	7	7	2.7
Miami	9	12	12	5.1
Beijing	26	14	14	2.0
Los Angeles	6	13	15	2.3
Guangzhou	NA	21	18	11.0
Chicago	13	19	19	9.9
Additional China only ranking				
Shenzhen	4	4	4	5.5
Chengdu	5	5	5	8.7
Hangzhou	8	7	6	8.3
Zhengzhou	25	20	7	44.9

Source: Airports Council International, http://aci.aero; www.transtats.bts.gov; Civil Aviation Administration of China, http://www.caac.gov.cn/I1/K3/201504/t20150403_73469.html.

Rapid growth of the new Pudong airport in Shanghai propelled it to a steady third (from 14th) place. While FedEx hub Anchorage outranks UPS center Louisville, larger cargo airplane size permits longer flight times between refueling and will impact Anchorage's trans-continental centrality as a collection and distribution hub, shown in the negative percent change (Bowen, 2012). U.S. air cargo hub cities frequently differ from busy air passenger sites. Over the decade Beijing soared from 26th place to outrank Los Angeles, as did south China manufacturing center Guangzhou. Shenzhen and Hangzhou play supplementary roles as sub centers in the Pearl and Yangtze River deltas. Chengdu, west China's leader, was fifth in national rankings since 2004. As an emerging hub in central China, Zhengzhou considerably raised its position from 25th in 2004 to 7th in 2014, with an annual growth rate of over 40%.

A rapidly developing country with strong global oceanic trade and rail shipping links but relatively weak domestic highway and air accessibility, China works to extend infrastructure ties to inland areas and promote locational efficiency. Hong Kong SAR serves as the Asian regional hub for the three main global airfreight companies of FedEx, UPS, and DHL. Nearby Guangzhou and Shenzhen replaced the Philippines as Asia/China centers in the first decade of this century, capitalizing on proximity to Hong Kong and the manufacturing 'global factory' concentration in the Pearl River Delta. Overall, China's hub city distribution exhibits major strength in established east coast cities, plus the rise of Zhengzhou in the central region.

3. Strategically coupling global production network s and aerotropolis development

Air cargo pathways in the global network of distribution encourage regional economic development by connecting suppliers, producers, and consumers (Coe et al., 2004). The framework of global production networks (GPN) links actors to consequent economic impacts on contingent regions that their activities shape and integrate (Sturgeon, 2000; Henderson et al., 2002). However, this picture critically downplays the role of goods transporters. Holes in the research literature need to be spanned by examining the strategic coupling of firms and regional development, network dynamics, globalization, and transportation arrangements along

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competitively shifting routes at different scales. Private service providers such as FedEx and UPS largely decide hub and spoke locations in the global airfreight network (AFN). Classic site and situation considerations reflect the importance of intermediacy for coordinating functions in various transportation modes across a variety of suppliers and markets.

Supply chain management practices for different size cities provide access to a global production network that can accelerate regional development via foreign direct investment (Mackinnon, 2013). Connecting local production and service activities to a wider market through air cargo links tests the concept of strategically coupling global production network functions (Mackinnon, 2012). The operation of these networks in the U.S. and China highlights the different roles of key actors such as private firms and government officials. Regional development strategically links these concepts with the role of an aerotropolis: urban-economic activities drawn together to promote accelerated connectivity (Kasarda and Green, 2005). This co-located assemblage includes logistics, research, residential, corporate and core airport entities. Challenges to the aerotropolis concept rest on the notion of a *polis* as human rather than business centered, and perceived trade-offs between their interests (Charles et al., 2007). China views this strategy as providing higher skill jobs and attracting companies to boost lagging regional and metropolitan economies (Zhang and Cai, 2013).

A network of hubs collects items from producing areas via land and air transit, then distributes them to markets in regional centers. This creates a globalized "distribution economy" (Hesse, 2014, 337) connecting "transport cities" (Harris and Ullman, 1945, 8) in a classic urban pattern. The increase in distance spanned and volume carried by networks reflects globalization effects accelerating development in Asian manufacturing centers and the opening of domestic economies to penetration by foreign owned companies (Bowen, 2004). The location of airfreight centers reflects manufacturing concentrations but air passenger hubs reflect population centers, so they are not necessarily in the same places (Jin et al., 2004).

FedEx and UPS networks in the U.S. involve the role of agency in the bottom-up capitalist system of the U.S. for determining the hub locations. Though local incentives also influence the U.S. airline industry (Bowen, 2004), in China they play a far smaller role than the central government does regarding opening to global capitalism (Wei and Liefner, 2012). A variety of political-economic and personal forces shape the space of flows directing geographies of functional integration (Rodrigue, 2006; Loo, 2014).

4. Analysis: locating air freight networks

Several factors feature prominently in the selection of sites for air freight hubs, including moderate weather conditions, ease of access to a high demand market, lack of noise restrictions particularly for night flights, underutilized airports lacking other major airlines competing for space, highly accessible intermodal infrastructure links, room for expansion and a supportive political climate (Cosmas and Martini, 2007; Alkaabi and Debbage, 2011). The following sections look at strategies of regions seeking to accelerate their development via transport linkages.

4.1. Global air freight networks

The major centers of U.S. air cargo shipments involve the networks of FedEx and UPS, the two largest companies in this business. Table 2 shows the top metropolitan destinations of air cargo originating in FedEx corporate headquarters in Memphis, Tennessee and the UPS major shipping center in Louisville, Kentucky (Atlanta, Georgia serves as corporate headquarters).

Table 2
Top air cargo destinations from Louisville (UPS) & Memphis (FedEx) 11/2013–10/2014.

UPS	Mill lbs	FedEx	Mill lbs
Anchorage	506	Los Angeles	375
Dallas-Ft Worth	181	Newark	300
Newark	178	Anchorage	264
Ontario, CA	166	Oakland, CA	248
Philadelphia	163	Seattle	195
Miami	130	Miami	189
Chicago	104	Chicago	173
Houston	97	Dallas-Ft Worth	162
Seattle	97	Phoenix	158
		Philadelphia	148
		Houston	94
TOTAL	1622		2306

Source: www.transtats.bts.gov

Fig. 1 displays the location of the major U.S. cities handling air cargo in 2014. These should not be considered 'aerotropolis' centers. Anchorage, the busiest airport for UPS, is the closest U.S. point on the northern Great Circle route to Asia and a distribution center, unlike the Dallas/Las Colinas complex. While FedEx also uses this Alaskan business center, it is dwarfed in that system by the international gateway airports of Los Angeles, CA for the Pacific/West Coast jumping off point to Asia and Newark, NJ for the Atlantic/East Coast traffic. Both networks use Chicago in the north central region of the U.S., Dallas (DFW) in the south central, Houston as a close site to Mexico, Miami as a close site to the Caribbean, and Newark for the European launch point. Philadelphia serves as the central East Coast site, Seattle as the transfer link with Asia. FedEx utilizes western sites Los Angeles, Oakland and Phoenix, while UPS uses quieter Ontario airport east of Los Angeles.

Comparison of Figs. 1 and 2 demonstrates the national coverage of the internal air cargo network in the U.S. and China. Major hubs in the U.S. lie in the central section, linking to Europe in the east and Asia on the west coast, while China's core sites are on the east coast in large urban centers heavily engaged with international trade. The central spine reflects government policy targeting development in this lagging region via linking infrastructure networks. Visualizing the network provides more detail about its structure. The size of the hubs indicates the degree centrality of each city; the thickness of the lines shows the connectivity between any two cities. Beijing is the capital and has the highest connectivity in this network, which makes it the northern center. Shanghai is the core city of the Yangtze River Delta and center for eastern China. Guangzhou-Shenzhen is the southern major center. Chengdu has a significant high centrality in western China. Zhengzhou and Changsha have the same centrality in central China, but Zhengzhou carries a larger airfreight volume so is the regional center.

Freight logistics infrastructure in both sending and receiving countries connect urban and economic centers. FedEx entered China in 1984, followed four years later by UPS. By 2013 they both used hubs in Tianjin, Shanghai, Guangzhou and Shenzhen. UPS' west China hub was Xi'an, with FedEx using Chengdu in west China along with Zhengzhou in central China, Hangzhou (102 miles southwest of Shanghai), and Dalian in the northeast. The main international hub for FedEx in China is currently in Guangzhou, but scheduled to relocate to Shanghai-Pudong with completion of new facilities in 2017. Seventeen other Chinese cities serve as major FedEx cargo handling hubs (see Fig. 2).

Airfreight volume in China increased rapidly since the country's economic opening in 1978, mirroring the growing prominence of manufacturing. The total amount of air cargo for China in 1980 was

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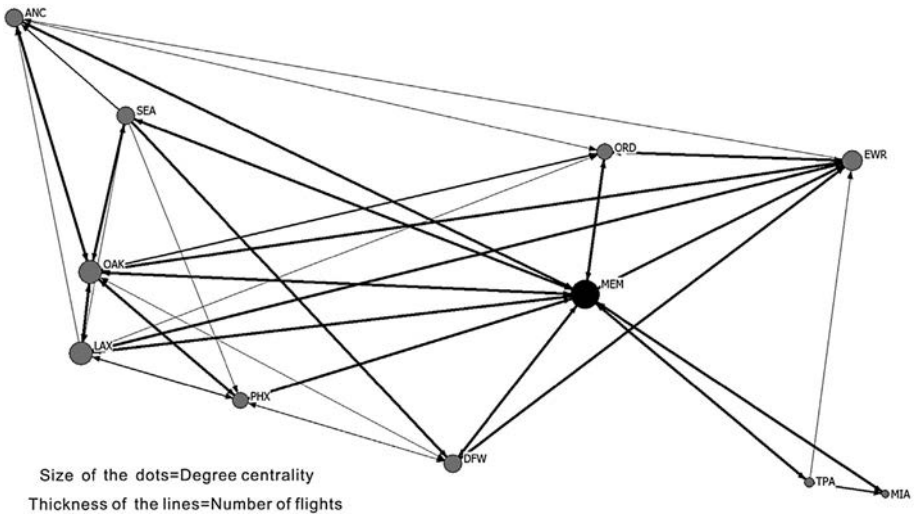

Fig. 1. Sample structure of U.S. air freight network based on FedEx Hubs.
Source: www.transtats.bts.gov

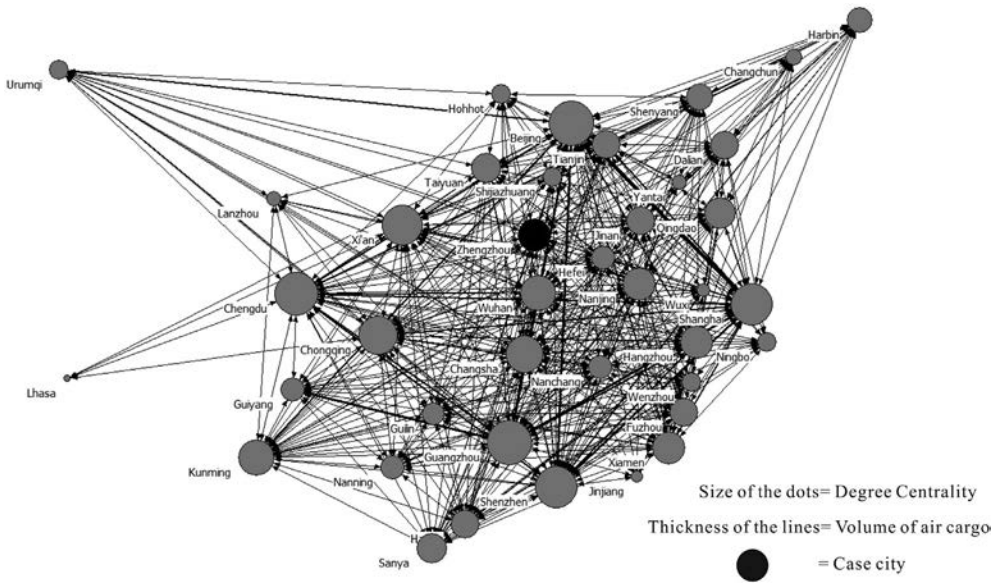

Fig. 2. Structure of Chinese air freight network in 2012. Author calculations based on statistical data, Civil Aviation of China 2013

only 157,900 tons, rising to 13.6 million tons in 2014, an increase of 75 times. Transportation infrastructure and air freight hubs are concentrated on major east coast export sites, reflecting China's development stage (Dang and Peng, 2012). Each of the three east coast hubs handled more than one million tons of airfreight volume in 2014, accounting for 51% of total for the whole country (CAAC, 2015). Beijing carries the most air passengers in China, commensurate with its position as the capital city. Shanghai ranks first in airfreight volume, reflecting its role as China's economic center. Other cities among the top ten air freight hubs in the country include economic centers along the east coast such as Shenzhen, Hangzhou, Xiamen and Nanjing (Fig. 3). East coast cities were the first to open in the 1980s since China limited participation in the global economy. These cities entered the globalization process in the 1990s by attracting foreign direct investment, leading to a rapidly growing metropolitan economy generating greater demand for air cargo transportation and funding expanded facilities.

The 2004 bilateral agreement between China and the United States allowed each country's carriers to service a carefully limited number of cities in the other country, opening the way for expansion of large global integrators in China. UPS moved its Asia-Pacific hub from the Philippines to Shenzhen in 2008, FedEx's Asia-Pacific hub shifted from the Philippines to Guangzhou in 2009, and DHL established a northeast Asian hub in Shanghai in 2012 (DHL, 2012). The Pearl River Delta was the first open area declared in China in the 1980s. Guangzhou and nearby Shenzhen are relatively convenient to both Northeast and Southeast Asia. FedEx and DHL chose Shanghai as their transcontinental hub due to its location close to European and North American flight paths to China and other major Asian destinations such as Japan and South Korea (Tang, 2008; Parcel and Post, 2012). FedEx established an international hub in Shanghai Pudong airport in 2004; a new logistics hub will open in 2017 (FedEx, 2012). Shanghai Pudong Airport features the country's most advanced infrastructure connections, a large fleet

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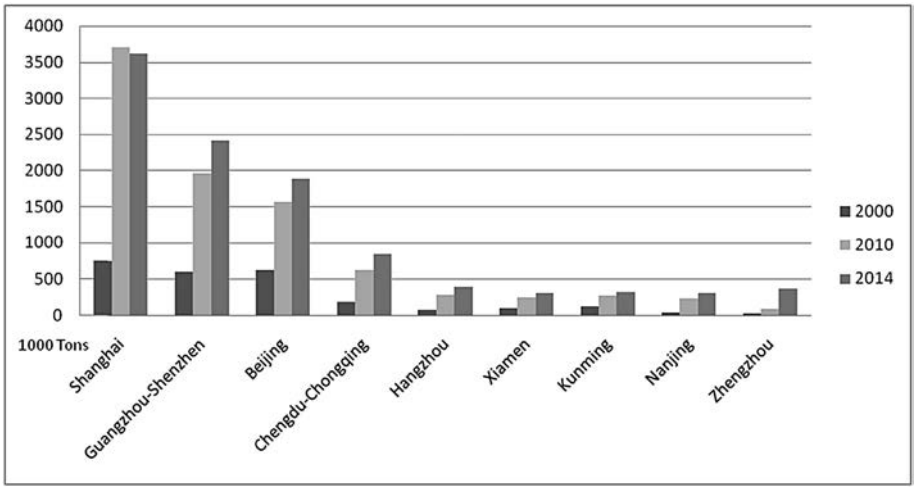

Fig. 3. Air cargo volume from 2000 to 2014 (1000 Tons).
Source: Statistical Data on Civil Aviation of Civil Aviation Administration of China, 2014) (2015)

and busy air route network (Pan et al., 2007; UPS, 2008; FedEx, 2012; Airports Council International, 2015).

4.2. National hubs

In China, foreign capital investment is shifting to interior regions in response to the growing cost of labor and land. Cities in western and central China utilize this opportunity to catch up with major eastern cities, a move advocated by central government policy since the year 2000. According to the growth rate of airfreight volume from 2010 to 2014, eastern cities with the highest growth rates during the past decade started to slow down while inland cities such as Zhengzhou, Chengdu and Chongqing continue to grow (CAPA, 2014). Tons of air cargo passing through Shanghai decreased from the year 2010–2014 (Fig. 4). The coastal dip reflected outcomes of central government policies encouraging the spread of economic growth to western and central regions, hence the rise of air cargo from production sites in Chengdu, nearby Chongqing and interior Zhengzhou. As the first city to establish an airport economic zone at the national level and an important hub in the strategy of "One Belt, One Road", Zhengzhou more than tripled air cargo during the last four years (Fig. 4). Plans for Zhengzhou fit the classic aerotropolis model (Fig. 5).

In order to fully identify the hierarchic structure of China's airfreight network, the 40 largest cargo hubs by total volume of air cargo were used to calculate centrality characteristics using data from the Civil Aviation of China (2003), 2013. Network analysis commonly focuses on three types of centrality. Degree Centrality constitutes the initial factor, since places with more ties present more interaction strengthening opportunities (Hanneman and Riddle, 2005). C_D (ni) reflects the degree centrality for an individual city i, n is total number of cities in this network, here namely 40. Degree Centrality of city i expresses the sum of its connections with other hubs (x_{ij}).

$$C_D(n_i) = \sum_j x_{ij}$$

The second measure of centrality is closeness centrality.

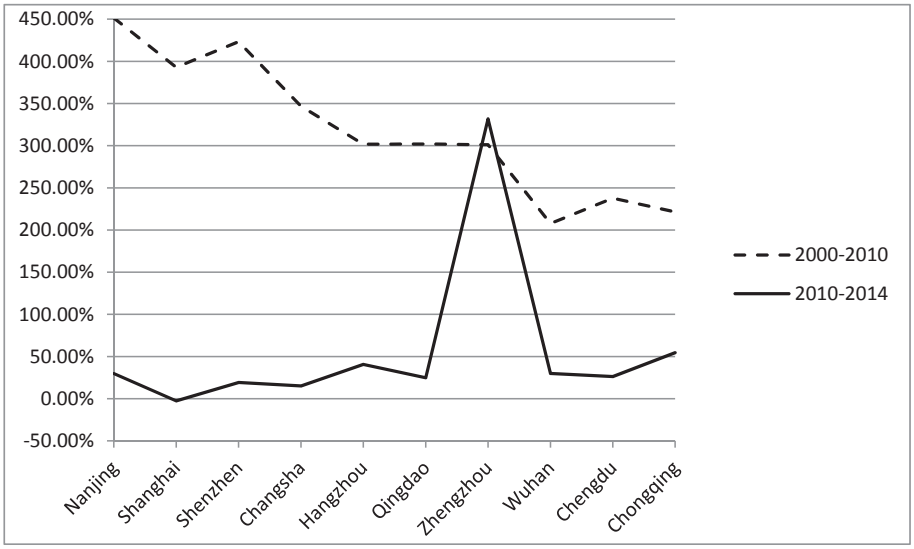

Fig. 4. Growth rate of air cargo volume in major cities.
Source: Civil Aviation Administration of China, 2014) (2015)

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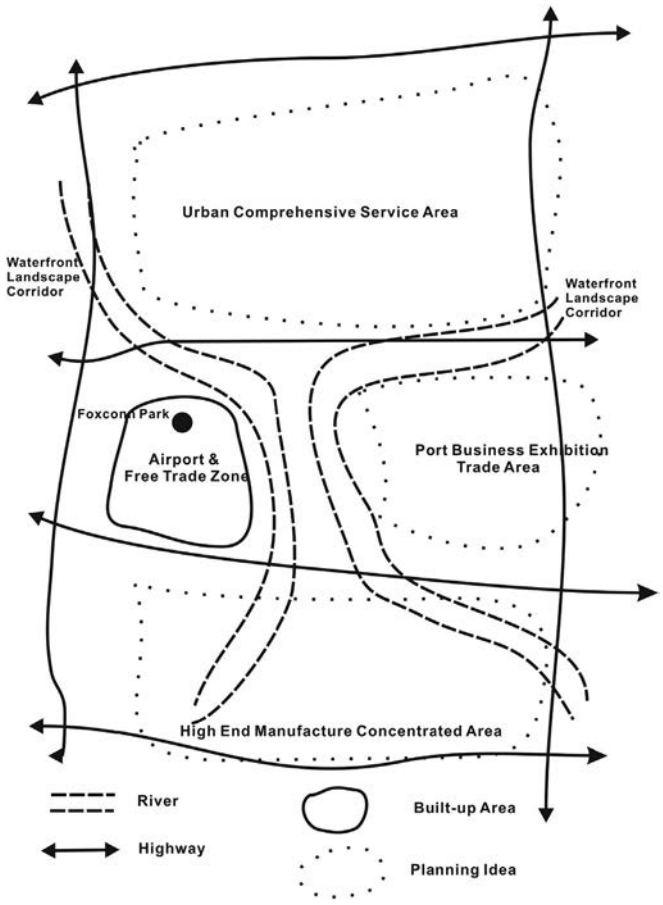

Fig. 5. Spatial structure of ZAEZ and location of Foxconn.
Source: Personal communication 2015

Closeness centrality of city i C_{APi}^{-1} can be considered as the sum of the distances between city i and other cities in the network (d_{ij}).

$$C_{APi}^{-1} = \sum_{j=1}^{n} d_{ij}$$

Another major consideration is the degree of betweenness centrality. Locating between two places promotes contacts among actors, with opportunities to isolate or prevent contacts with others. If the total number of shortest paths between city j and city k is g_{jk}, then $g_{jk}(i)$ is the number of those paths that pass through city i. The betweenness centrality of city i (C_{ABi}) is expressed in the following equation:

$$C_{ABi} = \sum_{j}^{n} \sum_{k}^{n} \frac{g_{jk}(i)}{g_{ik}}$$

$$j \neq k \neq i \text{ and } j < k$$

Network indexes were calculated using the UCINET (version 6.216) software program. NETDRAW (version 2.084, distributed with UCINET) is useful for visualizing network data.

Each of these approaches describes the location of an entity in terms of its closeness to the "center" of the action in a network. Definitions of what it means to be centrally located differ, however (Hanneman and Riddle, 2005). Table 3 displays the results for a calculation of the main urban centers of China in 2002 and 2012. It should be noted that rankings according to a) degree centrality and b) closeness centrality do not show great differences. This paper therefore uses the result of the degree of centrality to measure cities as air freight hubs in the network. Betweenness centrality, the third category, measures cities as airfreight transit hubs in the network.

Specific features of the network demonstrate that the largest two national centers, Beijing and Shanghai, attained different achievements in the past ten years. Beijing strengthened its dominant position in the network by remaining first in degree centrality and taking over the leading position in betweenness degree. Shanghai, the second largest air freight hub and largest air freight transit hub in 2002, dropped to fourth place in the two rankings. Several cities in mid-western China achieved higher positions in the ranking of degree centrality in 2012 including Chengdu (from 5th to 3rd), Chongqing (from 12th to 7th) and Zhengzhou (from 20th to 8th). According to betweenness centrality, Chengdu became the second largest air freight hub in the country following Beijing in 2012. For many years the economic center of China lay in large east coast cities, a trend increasing with the process of globalization. According to a recent study, Chengdu in west China is one of the "high sufficiency" category cities (GaWC, 2012). The rise of Chengdu in the world economy involved complex flows of people, goods, capital and commodities, carried by air transportation. At the same time, some eastern cities decreased in both degree centrality and betweenness centrality. The rapid growth of air transportation in central China indicates the westward shift of manufacturing from the east coast, the deliberate result of targeted funding policies by the central government (CAPA, 2013).

4.3. Regional hub connections and development

Both FedEx and UPS utilize the aerotropolis concept in their hub locations, resulting in great economic benefit for their U.S. headquarters' city (Kasarda and Green, 2005; Kasarda, 2008). Numerous companies leverage their proximity to rapid around-the-clock shipping on land set aside surrounding the corporate airport complex, resulting in savings for companies on shipping time to destination and competitive turn-around delivery. FedEx reportedly pours in $22.1 billion and more than 132,000 jobs to Memphis' economy, while UPS drew 150 firms to surround its site in Louisville (Economist 11/2/2013). The location of both cities is well connected with transport infrastructure to water, rail and major highways, as well as abundant and affordable land and non-union labor (Bowen, 2012).

An industrial real estate group report on air cargo handling operations and related land development functions provides another way of rating the importance of infrastructure supporting air cargo operations (Area Development, 2014). Their report highlights the need of airports to leverage proximate commercial real estate along logistics corridors linking them to a commodity network, ideally deriving up to 60% of their regional revenue from functions not directly related to airport activities such as advanced service functions, e.g., logistics and freight forwarders. The strategic integrative approach to surrounding land development adopted in the Memphis and Louisville hub cities magnifies the economic impact for the surrounding region, detailed in the aerotropolis concept (Kasarda, 2008). In order to combat "middle class flight, crime and blight" around Memphis' airport, the city and federal authorities are investing almost US$2 million for a more aerotropolis-like transformation of the proximate area (Joggi, 2015).

According to conversations with and documents supplied by ZAEZ personnel, and as evidenced by the competition among 51 cities to be the first airport-centered development zone, China sees

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Table 3
Centrality of air freight network in 2012 and 2002.

Rankings		2012			Rankings		2002		
		Degree	Closeness	Betweenness			Degree	Closeness	Betweenness
1	Beijing	94.872	95.122	5.214	1	Beijing	89.744	90.698	19.115
2	Guangzhou	94.872	95.122	4.279	2	Shanghai	87.179	88.636	20.561
3	Chengdu	92.308	92.857	4.317	3	Guangzhou	76.923	81.25	9.086
4	Shanghai	87.179	88.636	3.221	4	Shenzhen	61.538	72.222	4.946
5	Shenzhen	87.179	88.636	3.052	5	Chengdu	58.974	70.909	5.702
6	Xi'an	84.615	86.667	3.208	6	Changsha	51.282	67.241	1.482
7	Chongqing	82.051	84.783	3.089	7	Xi'an	48.718	66.102	1.387
8	Changsha	79.487	82.979	2.327	8	Hangzhou	48.718	65	1.161
9	Kunming	74.359	79.592	1.313	9	Haikou	46.154	65	1.287
10	Wuhan	74.359	79.592	2.039	10	Xiamen	43.59	62.903	1.122
11	Xiamen	69.231	76.471	1.246	11	Kunming	41.026	62.903	0.623
12	Hangzhou	69.231	76.471	1.359	12	Chongqing	41.026	62.903	0.631
13	Nanjing	66.667	75	1.589	13	Qingdao	41.026	62.903	1.266
14	Zhengzhou	66.667	75	1.141	14	Shenyang	38.462	61.905	2.609
15	Qingdao	64.103	73.585	0.802	15	Wuhan	38.462	61.905	0.514
16	Sanya	61.538	72.222	0.587	16	Nanjing	35.897	60	0.767
17	Taiyuan	61.538	72.222	0.649	17	Guilin	33.333	60	0.598
18	Fuzhou	58.974	70.909	0.383	18	Fuzhou	30.769	59.091	0.231
19	Dalian	56.41	69.643	0.982	19	Jinan	30.769	59.091	0.377
20	Haikou	56.41	69.643	0.453	20	Zhengzhou	28.205	58.209	0.274
21	Tianjin	56.41	69.643	0.885	21	Wenzhou	28.205	58.209	0.149
22	Jinan	56.41	69.643	0.819	22	Dalian	25.641	57.353	0.364
23	Shenyang	53.846	68.421	0.546	23	Guiyang	23.077	56.522	0.02
24	Harbin	51.282	67.241	0.443	24	Urumqi	20.513	55.714	0.115
25	Guiyang	48.718	66.102	0.139	25	Ningbo	20.513	54.93	0.038
26	Nanning	48.718	66.102	0.149	26	Sanya	17.949	54.93	0.006
27	Nanchang	48.718	66.102	0.272	27	Nanchang	17.949	54.93	0.022
28	Hefei	46.154	65	0.18	28	Harbin	15.385	54.167	0.033
29	Guilin	43.59	63.934	0.141	29	Nanning	15.385	53.425	0.129
30	Urumqi	38.462	61.905	0.172	30	Changchun	12.821	52.703	0.019
31	Hohhot	38.462	61.905	0.193	31	Lanzhou	12.821	53.425	0
32	Wenzhou	38.462	61.905	0.054	32	Hefei	12.821	52.703	0.006
33	Shijiazhuang	38.462	61.905	0.188	33	Wuxi	12.821	52.703	0.101
34	Ningbo	35.897	60.938	0.107	34	Taiyuan	7.692	51.316	0
35	Changchun	30.769	59.091	0.074	35	Tianjin	7.692	50.649	0.006
36	Lanzhou	25.641	57.353	0.019	36	Jinjiang	7.692	50.649	0.006
37	Yantai	25.641	57.353	0.057	37	Lhasa	5.128	44.828	0.012
38	Wuxi	23.077	56.522	0.023	38	Yantai	5.128	50.649	0
39	Jinjiang	20.513	55.714	0.032	39	Hohhot	2.564	48.148	0
40	Lhasa	10.256	52.703	0.004	40	Shijiazhuang	2.564	47.561	0

Source: author's calculation based on statistical data from Civil Aviation of China (2003), 2013.

constructing an aerotropolis for accelerating economic development as a useful model. Following the 2011 visit of aerotropolis expert Kasarda, Zhengzhou became particularly active with this model leveraging Foxconn's position in Apple's global production network. The distinction of aerotropolis construction in China lies in the ability of a development authority to build, upon approval from government authorities, an entirely new urban area linked to major extensions of existing airport facilities, creating the physical embodiment of an idealized aerotropolis (Economist, 2015). The Twelfth Five Year Plan in 2011 accelerated development of logistics, civil aviation, and distribution sectors in a series of hub-centric locations.

Local, provincial, and central government agencies provide support through land supply policies, free trade zones, tax incentives, and accelerated permitting (Kasarda and Appold, 2014). In late 2009, Apple contractor Foxconn announced that it was considering moving the majority of Apple's iPhone assembly from Shenzhen to Zhengzhou. Less than two years later, a special bonded zone near Zhengzhou international airport for the iPhone assembly was established. A massive factory complex includes dormitories and services for more than 300,000 workers.

Impressed with the speed of operations at Zhengzhou, Foxconn began assembling other digital products in its supply chain at a location adjacent to Zhengzhou International Airport, producing over 70 percent of Apple's iPhones worldwide in 2013. The same year the State Council and Cabinet approved Zhengzhou Airport Economic Zone (ZAEZ) as China's first experimental zone for an airport-based economy (Zhang and Cai, 2013).

Henan province and Zhengzhou lagged far behind the coastal areas since the reform and opening-up movement launched in 1980. For example, in 1990 Henan's neighboring province of Shandong registered a per capita GDP of US$334 compared to Henan's US$218. Due to its coastal location, Shandong started to take off in the 1990s while Henan remained an agricultural province. By the year 2014 Shandong's per capita GDP was US$ 9260 while Henan's was only US$ 5,569, demonstrating the persistently unequal regional economy. Establishment of ZAEZ in 2012 boosted growth and reduced the impact of China's current economic slowdown (see Table 4). Preferential policies are provided for Zhengzhou as a gateway to the development of central China's mid-west region (China.org, 2013). With the approval of the central government, the government of Henan province attracts manufacturing to generate sufficient air cargo. The current "Four Parks and Four Centers" scheme envisions airport, railroad and highway arteries branching off the central city ring road. From Zhengzhou, FedEx flies to Anchorage, Delhi and Guangzhou, while UPS connects to Almaty, Cologne, Seoul, Shanghai and Warsaw (UPS 2012, Wu 2012, Rimmer, 2015). Provincial authorities

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Table 4
Economic development data for Zhengzhou airport economic zone.

	2010	2014	Jan-Oct 2015
GDP(Billion RMB)	2.8	41.3	39
Government Revenue (Billion RMB)	0.45	19.5	26.5
Import and Export (Billion U.S. Dollar)	0.01	37.9	38.3
Volume of Passengers (Million)	8.7	15.8	14.6
Volume of Air Cargo (Thousand Tons)	86	370	313

Source: Provided by Zhengzhou city government, 2015

Table 5
Smart phone production in Zhengzhou Airport Economic Zone, 2014–15.

	2014	Jan-Oct 2015
Phone production in total (million)	143	170
iPhone production (million)	119	120
Other smart phone production (million)	24	50

Source: Provided by Zhengzhou city government, 2015

expanded the air cargo network to bring in global aviation logistic companies. Zhengzhou's airport now serves 20 cargo airlines (Tang, 2014). The 2014 joint venture between Luxembourg's Cargolux freight carrier and Henan Civil Aviation Company links Zhengzhou's inland location with destinations throughout Europe (CAPA, 2014).

Zhengzhou's prominence reflects its location advantage at the intersection of the two most important railways in China: the Beijing-Guangzhou railway running north-south and the Longhai railway connecting east-west. Major manufacturers such as Foxconn ship large components (e.g., computer casings, screens) by rail. With advanced ground transportation, Zhengzhou's integrated transport hub systemically couples China's industrialization and agricultural modernization (Zhang and Cai, 2013). Cargo transport networks basically follow separate paths: roadways link to both air and trains, but rail tends to be fixed and at a distance from air as well as serving primarily passengers and cargo heavier than that preferred for air. Microsoft, for example, uses trains to ship software CDs from their factory in the Pearl River Delta to Zhengzhou railway station. Trucks convey the CDs to the airport, where they are delivered to global markets. Microsoft chose this way due to subsidies from the local government of Zhengzhou (personal communications 2015).

Aerotropolis plans designate the smart device (primarily cell phone) industry as the leading focus of ZAEZ, including a bonded zone adjacent to the airport in the north for Foxconn. A new smart device industry park rises south of the airport. Currently 16 companies making cell phones or components produce in the park, while 103 other companies are building factory sites. (Table 5). Park developers anticipate that when companies are in production, a complete supply chain for iPhones and a smart device industry cluster will be established.

According to officials interviewed in 2015, Chinese city planners carefully consult the models of Memphis, Louisville and Frankfurt (Germany) as aerotropolis ventures. Development plans include integrating facilities and supplying training for aviation material manufacturing and maintenance, aviation logistics, integrated tax zones, bonded logistics centers and research institute, clustered production and service providers, and big data computer centers, enhancing GPN functionality. Lack of skilled and well-educated workers remains a problem for ZAEZ. Most of the workers come from Henan province, the most populous in China with 120 million residents. This creates a large and inexpensive local labor pool, but much training is required for work in the smart device factories. Foxconn established two technical colleges near their factory facilities to address this situation, providing targeted skills training along with courses at local universities leading to a BS degree.

Attracting more levels of labor skills to residential and employment sites would lessen pressure on east coast factory centers, bring jobs back to sending regions and assist workers transitioning from agriculture to the urban concentrations favored by government policies. Tension comes from the pace of these transitions: competition among political entities to reap development benefits, financing for numerous buildings needed, environmental disruptions from rapid construction, social stability stress, and coordinating policies among the various levels of government authorities involved. Nevertheless, local planners profiled in Zhengzhou remain committed in the face of the transformative possibilities of such a vast project in a region needing to add value to its existing agricultural products and vault into a globally prominent modernization role through enhanced air cargo functions (personal communications 2015).

5. Concluding summary

China and the United States are well linked internally and externally to each other through global air cargo trade networks of major corporate integrators such as FedEx and UPS. As in China many second tier nodal city sites share an airfreight network, showing the importance of intermediacy, or in-between-ness. Coordinating functions strategically couple transportation modes across a wide variety of distances among suppliers and markets in global production networks. In the air freight networks studied, these locations are increasingly supported by a combination of internal corporate facilities and proximate businesses, lowering costs through co-location in the hierarchically structured urban network and across global production networks such as the Apple/Foxconn center in Zhengzhou.

The central government process that selected Zhengzhou as the inland lagging region site for an air cargo development center responds to the two proposed hypotheses regarding the role of government-led development strategies for lifting regions by strategically coupling a local economic base to a global production network. In Zhengzhou's case the goal was to assist the transition to higher skilled occupations, from agriculture to food industry to service sector additions. Some core distinctions between the U.S. developed world model and the situation in rapidly developing

Table 6
Comparison of U.S. and Chinese Air Cargo Hub characteristics.

Factor	U.S.	China
Infrastructure link	Highways	Railroads & Highways
Distribution	2 coasts, central, even	East coast, few central or west
Link driver	Input, domestic	Output, export
Local connection	Logistics integrator center	Local industrial pillar focus
Planning	Corporate, bottom up	Central administrative, top down
Human input	Corporate decision makers	Local political leadership

Source: Authors

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China appear by contrasting similar elements in each country (Table 6).

Differences between hub locations include the siting of U.S. centers in peripheral locations with airports that are hungrier for business, have less crowded facilities, less expensive land, and are willing to live with more nightly noise. Different city hub sites chosen by the two major integrators demonstrate the U.S. corporate competition model. Chinese hub locations mirror manufacturing sites reflecting their GPN strength, operating out of pre-existing airports due to the high demand on capital for new construction. They are more amenable to the development of an aerotropolis due to the ability of the government to make land available for development. Networks in both countries take advantage of intermodal infrastructure to speed distribution of their cargo to a variety of regional destinations. The top-down flow of permission and finance in the Chinese system permits rapid adoption of development models such as an aerotropolis in the heart of the Central Plains. This experiment in new town construction and airport-centered development is intended to speed transition from agriculture to manufacturing and services. Further research needs to continue examination of an increasingly networked global urban-economic system and elements distinguishing place characteristics. Acknowledgement The authors are grateful for assistance from Prof. Ning Yuemin, East China Normal University, and support from Natural Science Foundation of China grants 41329001 and 41171145.

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Please cite this article in press as: Walcott, S.M., Fan, Z., Comparison of major air freight network hubs in the U.S. and China, Journal of Air Transport Management (2016), http://dx.doi.org/10.1016/j.jairtraman.2016.06.006