Modern Applied Science; Vol. 10, No. 10; 2016
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

World City Network in China: A Network Analysis of Air Transportation Network

Zeyun Li[1] & Sharifah Rohayah Sheikh Dawood[1]

[1] Geography Section, School of Humanities, Universiti Sains Malaysia, Penang, Malaysia

Correspondence: Zeyun Li, Geography Section, School of Humanities, Universiti Sains Malaysia, 11800 USM, Penang, Malaysia. Tel: 6-018-461-8530. E-mail: lizeyun@yahoo.com

Received: May 16, 2016 Accepted: June 18, 2016 Online Published: July 27, 2016

doi:10.5539/mas.v10n10p213 URL: http://dx.doi.org/10.5539/mas.v10n10p213

Abstract

World city network formation is one of the most robust trends in the context of globalization. The unprecedented economic transformation and infrastructure restructuring enable China to integrate in world city network overwhelmingly. The purpose of this paper is aiming to conduct a network analysis of Chinese air transportation network based upon large-scale collected data of inter-city air passengers' volume thereby identifying the world city network of Chinese cities, as well as the internal cooperative relationship and hierarchical structure of these articulations in the network. There are 80 sample cities are enclosed in this air transportation network model using UCINET, which is pioneering social network analytical software. Clearly, UCINET is applied to manipulate the matrix of inter-city air passengers flows in order to elaborate analyze of density of the whole network, to calculate multiple centrality of each node cities, which strives to identify the dominance of each cities' hierarchical power and positions. In addition, NetDraw program in UCINET is designed to visualize the whole network whereas CONCOR program is operationalized to classify major subgroups within national air transportation network of China. Based on the analysis, we can find that Beijing, Shanghai and Guangzhou play a dominant role in this network, and it is evident that there exist some robust cooperative relationships within and between subgroups arisen from overall air transportation network. Overall, these findings consolidate a concrete cornerstone of Chinese world city network formation.

Keywords: world city network, air transportation network, air passengers flows, UCINET, network analysis, China

1. Introduction

In the context of globalization and world cities' interconnection, the metropolises in China are playing dominant roles in the world city network formation. These indispensable nodes in the global urban hierarchy notably embedded in the contemporary world city network. The largely connected Chinese big cities in the globalization circumstances are incorporating into the intertwined connectivity of globalism and localism characteristics, which illustrates the dominant orientations of them with respect to the world city network (Ben Derudder et al., 2013). In terms of Chinese inter-city network development within the national scale, it is substantial relied on government reformation strategies and transportation infrastructure restructuring to some extent. Since the salient uneven development between Chinese urban territories, transportation network and economic network are complementary and inseparable (Lao, Zhang, Shen, & Skitmore, 2016). This trend of mutual interactions within two networks is an integral part of urban structure transformation in China, which curtails the urban spatial disparities between core and peripheral cities. Air passengers' traffic flow is the major composition of transportation network; it remarkably configures the premier Chinese world cities integrating in the world cities network, Shanghai and Beijing as the undisputed pre-eminent world cities, their irreplaceable articulations within Chinese urban hierarchy are ideally embodied in the global centripetal forces and national government's policies (Ma & Timberlake, 2008). Apart from the deep analysis of global network of transportation and economy, the world cities network of internet backbone has also attracted some attentions of a bunch of scholars; London and New York are most connected dyad embedded in global information flows of internet (Choi, Barnett, & Chon, 2006).

Peter Taylor is the pioneering scholar who initiated the Globalization and world cities research network (GaWC). GaWC has provided most advanced and unified platform for world cities network research and a series of updated research findings are available for the interactive communication of scholars globally in this area, this cohesive network integrated into the world cities research's trajectory are largely enlarging the contemporary world cities research. Taylor's unprecedented discovery of world cities network are derived from Castell's previous research on the space of flows (Castells, 1996), whereby a network society with reference to advancing of information and communication technologies are significantly inducing the space flows of information, labor, commodity and knowledge. Saskia Sassen is a another renowned scholar who made the robust contribution to world city or global city research, admittedly, her fundamental study of advanced producer service firms (including banking/financing , advertising, legal service, accounting, business service and consultation) concerned about world cities, consolidating the extraordinary roles of advanced producer service industry for world cities formation (Sassen, 1991; 1994). Based on the seminal study of Sassen and Castell, Taylor outlined the interlocking network of world cities using quantitative method, this explicit research of advanced producer service firms pertaining to the world cities network intrinsically identify the pervasive structure of the global connectivity of world cities (Taylor, 2001; Taylor, P. J., Catalano, G., & Walker, D. R. F., 2002; Taylor, P. J., Catalano, G., & Walker, D. R. F., 2002). Apart from service centers' network of world cities, other scholars also carried out a handful of multifarious research in terms of some other streams of world cities network. The mainstream of contemporary research is widely divided into two spectrums, which are air traffic space flows of world cities (Choi et al., 2006; Derudder, B., & Witlox, 2005; Mahutga, Ma, Smith, & Timberlake, 2010; Smith & Timberlake, 2001) and internet flows of world cities (Townsend, 2001; Vinciguerra, Frenken, & Valente, 2010; Zook, 2003). These two streams of research play a crucial role in sustaining the world city network.

The most notable discovery with regard to the world city research is traced back to the empirical study of Sir Peter Hall and John Friedmann. Based on the previous scholars' research of world cities, Hall (1966) rectified ambiguous and deficient aspects of study. Practically, he conducted the holistic study of major world cities in the world based upon their distinctive characteristics, which covered from economic, social cultural, political and urban features. He typologically qualified the major world cites into several vivid identities, some world cities are deemed as the financial centers, political centers and business service centers, whereas the others are identified to be a trading and manufacturing center, as well as the transportation and information hubs. In contrast to previous research of world cities, Hall reconfigured the dominances of major cities within global urban hierarchy and emphasized the political mechanism of world cities formation. In addition to Hall's contributions, Friedmann and Wolff (1982) deployed some comprehensive research on the world cities formation, they concentrated on the new international division of labor , the imperatives of new spatial organization of labor market and productions of cities are major driving forces of global capitalism restructuring. On the other hand, world cities as the top control and command articulations of global urban hierarchy, they are premised upon the predominant regions with the agglomeration of business services and financial firms, especially some multination companies (MNC) (Friedmann, 1986). Since the early scholars focus less on the relations and rankings among the world cities' hierarchy, Beaverstock, Smith, and Taylor (1999) proposed a roster of the ranking of world cities using quantitative methods. The roster of world cities is embodied upon the numbers of advanced producer services (accounting, finance, advertising and law) firms in each city. The roster of world cities are systematically classified into three levels based upon aggregate scores of each global services center.

By reviewing the major trajectory of world cities research, we can clearly find that the majority of previous empirical study about world city network only concentrates on global scale, only a small number of scholars implement a profound research with regard to insights of East Asia and China (Ben Derudder et al., 2013; Lao et al., 2016; Ma & Timberlake, 2008). In order to rectify this research gap, in this research, we focus on China as the study area, to construct a world city network of Chinese cities based upon the data of Chinese air transportation network. Since China is experiencing unprecedented economic transformation and infrastructure restructuring in this contemporary era, it is increasingly integrating into world city network. Likewise, Globalization, urbanization and foreign direct investment (FDI) have become another three indispensable driving forces to enable the research of world city network of Chinese cities as well (Zhao & Zhang, 2007).

Air transportation network model as well as air traffic data are regarded as one of most straightforward criterions to evaluate the development status of world city network; this assessment is recognized by many scholars (Derudde, B., & Witlox, 2005). Lin (2012) emphasize the aviation network model is best characterized by overcoming the limitations of geographical and spatial constraints; this topological network is simple to explore the spatial mechanism in the complex network in this regard. Most importantly, since Chinese world cities entail the most pronounced capabilities related to the world system, a spatial-temporal air traffic network analysis inferred from world city network trajectory systematically assess the national urban structure of Chinese cities (Ma & Timberlake, 2008). In terms of research, as collections of air transportation data is easier compared to other sources, thus, we utilize these data to conduct a network analysis of China air transportation linkage thereby identifying a world city network of Chinese cities. The major purposes of this article are aiming to explore following:

(1) To construct a world city network of Chinese cities derived from air passengers' flows data and air transportation network.

(2) To conduct a network analysis of Chinese air transportation network using UCINET thereby identifying the internal cooperative relationship of cities in this network.

(3) To classify the potential dominant cities in this network, and assess their connections with other cities, as well as their hierarchical status of world city network.

2. Data and Methodology

Since collection of relational data is not a simple procedure, not surprisingly, network research of Chinese cities integrated into world cities network is hampered by the deficiency of sources data. Generally, some data are conspicuous available in a range of sources , such as air traffic flows data, migration flows data and internet backbone flows data, while a portion of data are deemed as dearth of collective sources, the most obvious example is the advanced producer services flows data. The disproportionate sources of relational data in the cities' network research have brought about some obstacles; hence a multifaceted research method should be carried out in order to enlarge the spectrum of data collected. In this research, we utilized a synthetically data collection method to collect the required data. The major sources of data are derived from 'Statistical Data on Civil Aviation of China 2013' (China, 2013), which is a dominant statistical referential material published by Civil Aviation Administration of China. There is no doubt that this pattern of preliminary data collected method is embodied by some vulnerabilities, this is due to the fact that huge quantities of cities within China air transportation network. In order to avoid the problematic circumstances, we only choose the cities with national airports, and accommodate at least one scheduled airline to paired city with passengers' volume of aggregate flights are above 50000 in 2012. Eventually, there are 80 sample cities are enclosed in this research, these air hubs tend to are capital cities of each provinces, vice-provincial city, municipalities and renowned tourist destinations. Hong Kong and Macau are not considered in this research due to their special administrative position of Chinese urban system. Besides that, only direct flights are considered in this research, stop-over flights and transit hub cities are not recognized in this article. Clearly, this roster of Chinese cities incorporated into Chinese air transportation network are characterized by two features, which entail the salient dominance of Chinese political, economic, cultural and social powers, and cohesive connection with world city network and global economy.

In this article, we explore the vibrant inter-city air passengers' volume of different cities (nodes) within the Chinese air transportation network. Clearly, based upon the quantity of air passengers flows, we set up a matrix to epitomize an interrelationship of different cities in the Chinese urban territory. Not surprisingly, the incoming and outgoing flights of two paired cities are embodied some slight distinctions. Some cities attract a huge number of incoming air passengers from corresponding paired cities; meanwhile, they might deliver a relative less amount of departure passengers to the same paired cities. In order to cope with this conspicuous problem in the air transportation research, and also avoiding the deficiency of paired data of air passengers flows, we elucidate a symmetrical air passenger's pattern for this research thereby enhancing the underlying matrices straightforwardly.

UCINET6 is pioneering social network research software (Borgatti, Everett, & Freeman, 2002), it is deemed as the best gateway for our air transportation network analyses. In this research, we utilize Excel to set up the matrix of intercity connections based upon collected data of air passengers' volume; UCINET is applied subsequently to underpin the matrix in order to elaborate analyze of density of the whole network, to calculate multiple centrality of each node cities, which strives to identify the dominance of each cities' hierarchical power and positions. In addition, NetDraw program is designed to visualize the whole network whereas CONCOR program is operationalized to classify major subgroups within national air traffic network of China.

3. Results and Analysis

3.1 Whole Network Density Analysis

```
BLOCK DENSITIES OR AVERAGES
------------------------------------------------------------------------------

Input dataset:                      aa_GT_0 (C:\Users\DELL\Desktop\aa_GT_0)

Relation: Sheet1

Density (matrix average) = 0.1839
Standard deviation = 0.3874

Use MATRIX>TRANSFORM>DICHOTOMIZE procedure to get binary image matrix.
Density table(s) saved as dataset Density
Standard deviations saved as dataset DensitySD
Actor-by-actor pre-image matrix saved as dataset DensityModel

----------------------------------------
```

Figure 1. Whole network density output

Note. Source: Compiled and analyzed from Statistical Data on Civil Aviation of China (2013).

Density analysis is an indispensable measurement technique for network analysis. Since this is a binary network framework, the major formula is designed to calculate the actual total quantities of connected ties in this network divided by theoretical maximum numbers of underlying ties in the network; the overall density of the whole network is equivalent to the average value of the whole relational binary matrix (Liu, 2009). Generally speaking, this technique is patterned to evaluate cohesive interconnected relationships between all of the nodes embedded in the network. In this article, we utilized fundamental whole network density analysis technique to discover the density status of overall air passengers flow network. The major criterion in the analytical procedure is to evaluate the connections between major air hubs in this network, basically, since this is a whole network analytical process, we should examine all of cities together in order to embody aggregate distributions of a multitude of inter-city flights. In this comprehensive inter-city network, if the whole network is configured by high quantities of inter-city flights, the whole network should be represented as high density network. Instead, contrary to this situation, a network is conceptualized as low density network in the context of fewer quantities of inter-city flights in this network.

In terms of this research, we can easily find that the density of this whole network is 0.1839 based upon UCINET output in Figure 1, which is a moderate density value compared to other prevailing network, and standard deviation is 0.3874. Overall, this network is considerable to be deemed as a tight inter-city air transportation linkage network, the majority of air hubs in China are embodied in a cohesive linked and cooperative network. Thus, as the moderate density network of nodes in China, the paradigm of Chinese air passenger network is gradually transformed in this millennium with reference to its close interconnection and cooperation intrinsically. In contrast, since this network is gauged with acceptable density, and individual city (node) is an integral part of this network, the whole network also has a remarkable implication on the nodes' variation and collaboration. Specifically, the intimate whole network is not only the cornerstone that diffuses information and resources to corresponding nodes, but also considering as a restricted force to constrain the development of internal nodes in this network (Liu, 2009; Wasserman & Faust, 1994).

3.2 Centrality Analysis

In addition to density analysis, centrality analysis is applied to identify the single node's position in the network. Generally, centrality analysis is a basic network analysis indicator within UCINET, which topologically distinguishes dominance of hierarchical position and structure of each node in the network. Since each node is not isolated in the tremendous spatial system, they tend to impose a relational network with other homogeneous node. This pattern of relational network is attributed to the power status of relevant nodes, in other words, power is characterized by the dependencies of other nodes (Liu, 2009). In this regard, despite some scholars have made certain distinctions between centrality and power empirically (Neal, 2011), we propose the identical definitions of this two concepts for this research. Centrality research is a dominant research orientation in the social network research area which possesses a brilliant trajectory. Freeman was a pioneering scholar who concentrated on this area; his seminal research was associated with uncovering notions and intrinsic relations between point centrality and graph centrality, which examined the fundamental structural centrality of point and whole network respectively (Freeman, 1978; 2004). Following the breakthrough of Freeman's discovery, quantitative method became one of the most critical methods to enhance the social network research. Most importantly, these sophisticated methods are booming with a number of statistical techniques and mathematical models, which eventually clarified the consistent results with Freeman's hypotheses (Carrington, Scott, & Wasserman, 2005; Scott, 2012; Wasserman & Faust, 1994).

In this article, centrality of selected cities are measured based upon the volume of inter-city air passengers flows. Reasonably, only notable direct flights between paired cities are qualified in this research, stop-over or indirect flights are not considered for us due to the fact that inherent constraints of deficient data and problematic vulnerability of applicable techniques within this research. Thus, we conduct a multiple analysis to identify the centrality indexes of selected cities based upon elaborate network analysis of degree, betweenness and closeness centrality. These three centrality indexes are most widespread application of centrality in the social network research (Luo & Zhong, 2015).

Degree centrality is normally conceptualized as a most common used centrality within social network study, which mainly associates to elucidate quantities of networks of each articulation that possesses.

The higher degree centrality demonstrates that the actors have more incoming or outgoing ties with other nodes in overall network, which states the advantageous power potential of this node to acquire resources and targeted needs (Ma & Timberlake, 2008). This index is composed of in-degree centrality and out-degree centrality. The basic formula (Lee, Lee, Taylor, & Lee, 2011) is presented as following:

$$C_D = \frac{\sum_{i=1}^{A}[C_D(n^*) - C_D(n_i)]}{max \sum_{i=1}^{A}[C_D(n^*) - C_D(n_i)]} \tag{1}$$

In contrast to degree centrality, closeness centrality traditionally illustrates the distance of paths between paired nodes. In specific, if a node has a relative high proximity to other nodes embedded in the network, this means that this node is much easier to disseminate information to other nodes, which demonstrates the high centrality of this node. Formula of closeness centrality is summarized as below:

$$C_C(n_i) = \left[\sum_{j=1}^{g} d_{i,j}\right]^{-1} \tag{2}$$

Where $d_{i,j}$ indicates the shortest distance between two nodes i and j.

As compared to previous two critical criterions, betweenness centrality is originally proposed by Freeman (Freeman, 1977), it is noticeably measuring the intensity of a node where situates at center of other nodes, which means this node basically signify as gateway function of whole network. Accordingly, if a node has a high circumstance of betweenness centrality index, this node tends to have higher power to coordinate resources.

Based on the measurement of normalized centrality scores and ranking of a roster of Chinese major cities, we only summarized 20 pre-eminent cities out of total 80 sample cities in Table 1. As we can see from this table, this system of Chinese air hubs' ranking greatly relies on the rankings of degree centrality, taking together with degree centrality, we also display the closeness centrality, betweenness centrality and eigenvector centrality of relevant cities simultaneously.

Not surprisingly, we can find that Beijing, Shanghai and Guangzhou have highest centrality scores and overwhelming discrepancy against other cities, they are deemed as the most predominant nodes in the Chinese air transportation network on account of their strategic location, powerful economy base and robust government preferential policies. Following the three vanguards, Chengdu, Shenzhen, Chongqing, Kunming, and Changsha are considered as second tier of Chinese air passengers' network with reference to its coordinating capabilities, renowned reputations for tourists and national political dominance. Apart from aforementioned cities, the remaining cities of 20 gauged samples are generally depicted as third level of hierarchy; they tend to conceive as prevailing regional centers of each province, whilst some cities are adjacent metropolises of Beijing, Shanghai and Guangzhou. Lastly, 60 cities that are not presented in this table, they pertain to forth tier of Chinese air traffic network; these cities are less competitive and dominant in cooperating information and resources of air traffic network.

As we make the general comparison between first three centrality indexes in this table, we can find that the first two indexes have robust coincidences in the centrality rankings, which are degree centrality and closeness centrality. Specifically, if a city has a higher ranking in degree centrality, this city tends to have similar ranking in closeness centrality as well. In other words, a city where situates at a powerful position with a vast number of ties with other cities in the network tends to be more close to other cities in the network, and more convenient to diffuse information and sources to other neighboring cities. There are two major exceptions in these comparative rankings, which are Hangzhou and Tianjin. These two cities maintain inconsistent rankings of degree and closeness centrality, the prime reason may ascribes to their close distance to two most dominant metropolises and air hubs in China, which are Shanghai and Beijing. Shanghai and Beijing already exerted a huge quantity of global flights in China, Hangzhou and Tianjin only can retain complementary hinterlands in the Chinese air transportation network. In terms of betweenness centrality, Xiamen and Zhengzhou are two exceptions in this ranking. Xiamen is a crucial gateway city for Taiwan and south China whereas Zhengzhou is an indispensable hub to moderate flights in Middle and West China; hence they are both irreplaceable gateways in the Chinese transportation network with regard to betweenness centrality index.

Table 1. Multiple measures of centrality

Ranking	City	Degree	Closeness	Betweenness	Eigenvector
1	Beijing	86.076	87.778	31.070	34.411
2	Shanghai	72.152	78.218	14.881	32.237
3	Guangzhou	67.089	75.238	9.436	32.454
4	Chengdu	56.962	69.912	6.542	30.943
5	Xi'an	53.165	68.103	5.982	29.982
6	Shenzhen	51.899	67.521	3.468	29.436
7	Chongqing	51.899	67.521	4.281	29.123
8	Kunming	44.304	63.200	2.458	27.272
9	Changsha	41.772	63.200	1.039	26.790
10	Wuhan	39.241	62.205	0.857	25.258
11	Hangzhou	36.709	59.848	0.473	24.723
12	Xiamen	37.975	60.769	1.280	24.789
13	Zhengzhou	37.975	61.240	1.050	24.147
14	Nanjing	35.443	59.398	0.635	23.010
15	Qingdao	31.646	58.519	0.459	22.686
16	Sanya	31.646	58.519	0.159	23.389
17	Haikou	31.646	58.519	0.312	22.304
18	Tianjin	30.380	56.429	0.351	20.827
19	Dalian	29.114	57.664	0.282	20.211
20	Fuzhou	29.114	57.664	0.089	22.049

Note. Source: Compiled and analyzed from Statistical Data on Civil Aviation of China (2013).

3.3 Graph Visualization

Apart from centrality analysis, in order to generate much more visualization results of Chinese air passengers' network using 1-model network data, we utilized NetDraw program in the UCINET to construct topological diagram of Chinese air passengers' network, this diagram is clearly indicated in the above Figure2. Visualizing a network is an effective procedure to exchange information, transmit ideas and diversify research methods. NetDraw is characterized as a most common technique to visualize graph. As diagram is an intuitive feeling for the users, in terms of the network research area, a vivid diagram can immediately generate opportunities for readers to understand the interconnection and interaction of nodes, ties and subgroups embedded in the network, which are the most critical characteristics of overall network structure (Hanneman & Riddle, 2005).

As we can see from the graph, the topological diagram maps the structural relationships and attributes among all of air hubs in Chinese air traffic network. The city possesses the higher centrality score; it is operationalized in the bigger node in the network structural graph. Besides that, a node has more interconnections with other air hubs in China or much more flights to other cities; they tend to concentration in the core area of this diagram. Whereas less flights connected cities are decentralized in the peripheral area of the diagram due to their relative lower dominance. In general, since this is a basic application of graphic representation of air passengers' network, NetDraw still has some inadequate capabilities to discover the subgroups' relationship between all of nodes; in this situation, CONCOR program is extensively displayed to explore subgroups' cooperative relationship.

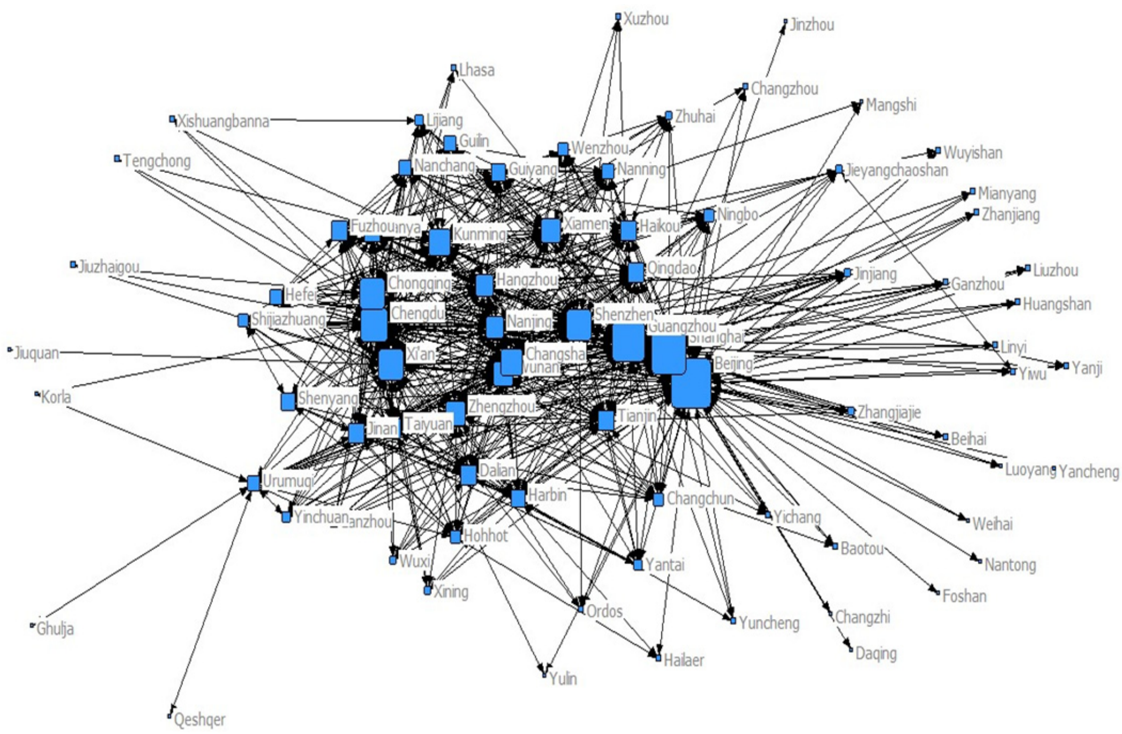

Figure 2. Topological diagram of China air transportation network

Note. Source: Compiled and analyzed from Statistical Data on Civil Aviation of China (2013).

3.4 Subgroup Analysis

In the discovery of dominance of each cities incorporated into Chinese air traffic network based upon centrality method and visualization graph, we cannot simplify the extensive cooperative relationship of subgroups, and explore network structure of underlying subgroups. In order to deal with this conundrum, we manipulated CONCOR technique in the UCINET to identify the basic similarity of collaborative nodes in this network thereby consolidating the proximity and similarity of each interconnected nodes. CONCOR is also called CONvergence of iterated CORrelations , which is a powerful function in the UCINET to analysis equivalent structure based upon partitions network data (Borgatti et al., 2002), meanwhile, this is also a predominant technique to analysis roles and positions of hierarchical structure in the social network (Ko, Hsung, & Lu, 2012; Wasserman & Faust, 1994).

In terms of this research, we are going to identify the rigorous subgroups of whole network to facilitate the salient cooperative relationship between each node. In order to tackle this issues explicitly, we decouple the fundamental subgroups from the whole network whereby we identify several cooperative clusters based upon CONCOR method. Subsequently, the density matrix and cluster dendrogram are displayed from CONCOR output clearly. As we can see from Figure 3, there are 8 subgroups are indicated in the dengrogram, intrinsic cooperation and similarity within each subgroup and inter-group relationships both are recognized here. The first subgroup includes cities of Beijing, Zhangjiajie, Chengdu, Guangzhou, Xiamen, Huangshan, Nanning, Jieyangchaoshan, Chongqing, Sanya, Wuhan and some other metropolises of each province and renowned tourism cities, these metropolises tend to close Beijing and Guangzhou. Subgroup two encompasses Nanjing, Guiyang, Shanghai, Yiwu, Hangzhou, Kunming and some other big cities and tourism cities, these big cities are located near Shanghai. Similarly, subgroup three and four are two mixed groups with irregular spatial distributions of cities in Chinese territory. Besides, subgroup five, six, seven, eight all are cities within border provinces from south and west regions of China. Therefore, based on the analogy and cooperation classification of subgroups of Chinese air traffic network, we can find that three prestigious cities, which are Beijing, Shanghai and Guangzhou, play a dominant role in affecting the subgroups formation in the structural network. Apart from hidden subgroups discovery, If we focus on the interaction and cooperation among each group, we can find that subgroup 1 and subgroup 2 have tight relationship, subgroup 3 and subgroup 4 exist similar cooperation, whereas subgroup 5 , 6, 7, 8 constitute another cluster of cooperative relationship.

Generally, the inter-city cooperation within internal of subgroup and inter-group cooperation within the whole network are both explicitly explained in this graph. Overall, this part demonstrates that intrinsic cooperative relationship within subgroup and mutual cooperation of their corresponding groups within the whole network both emphasizes the robust cooperative relationship. In other words, the inter-city connections of air passengers flow in China also endeavor to constitute a consistent intercity cooperative relationship.

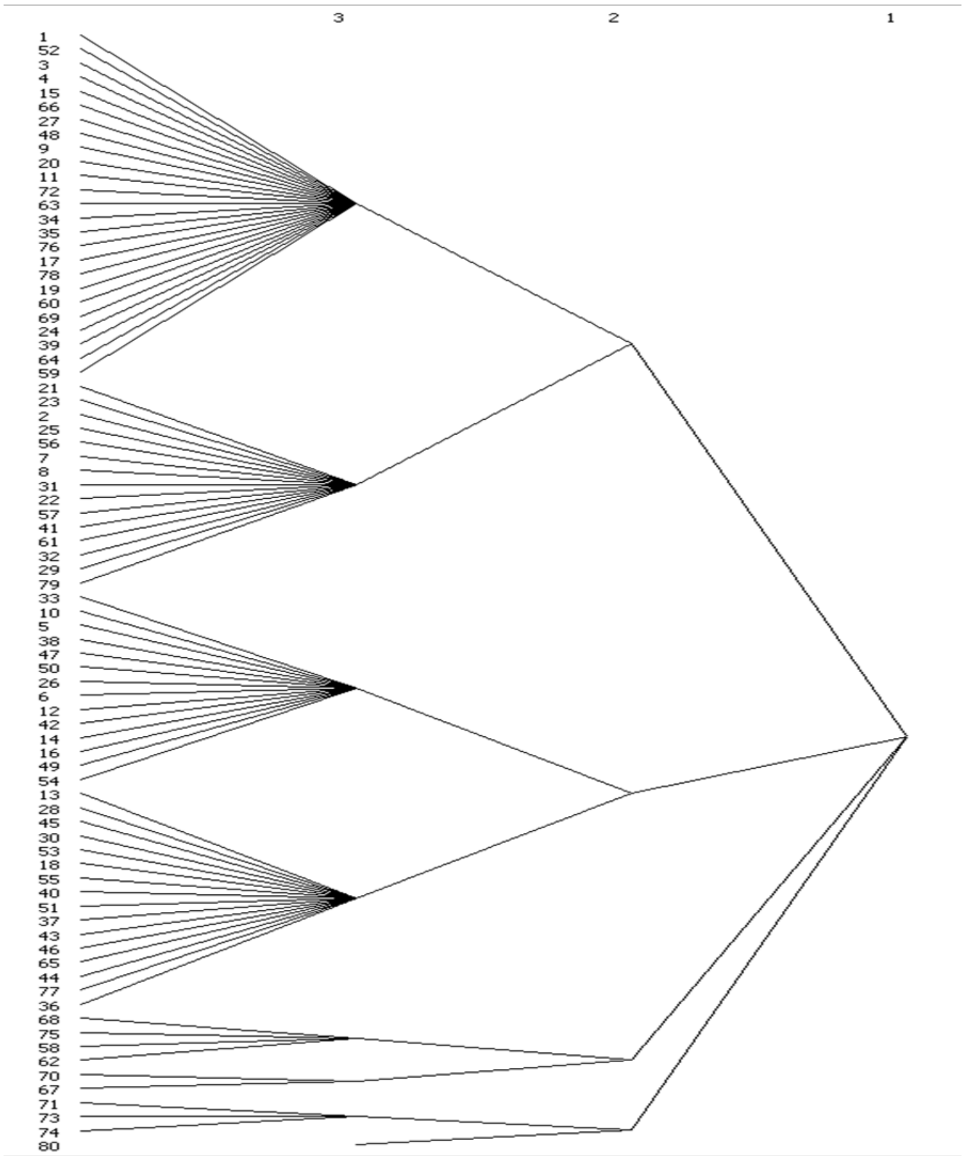

Figure 3. Dengrogram of subgroup analysis

Note. Source: Compiled and analyzed from Statistical Data on Civil Aviation of China (2013).

1.Beijing 2.Shanghai 3.Chengdu 4.Guangzhou 5.Shenzhen 6.Xi'an 7.Hangzhou 8.Kunming 9.Chongqing 10.Dalian 11.Wuhan 12.Changsha 13.Urumuqi 14.Harbin 15.Xiamen 16.Changchun 17.Qingdao 18.Hohhot 19.Shenyang 20.Sanya 21.Nanjing 22.Haikou 23.Guiyang 24.Fuzhou 25.Zhengzhou 26.Lanzhou 27.Nanning 28.Yinchuan 29.Nanchang 30.Baotou 31.Ningbo 32.Hefei 33.Yantai 34.Taiyuan 35.Wenzhou 36.Ordos 37.Xining 38.Zhuhai 39.Guilin 40.Hailaer 41.Wuxi 42.Weihai 43.Daqing 44.Yanji 45.Yuncheng 46.Changzhi 47.Yichang 48.Jieyangchaoshan 49.Luoyang50.Linyi 51.Yulin 52.Zhangjiajie 53.Foshan 54.Mianyang 55.Nantong 56.Yiwu 57.Jinan 58.Lijiang 59.Beihai 60.Ganzhou 61.Zhanjiang 62.Mangshi 63.Wuyishan 64.Liuzhou 65.Yancheng 66.Huangshan 67.Lhasa 68.Xishuangbanna 69.Tianjin 70.Jiuzhaigou 71.Qeshqer 72.Shijiazhuang 73.Korla 74.Ghulja 75.Tengchong 76.Jinjiang 77.Changzhou 78.Jinzhou 79.Xuzhou 80.Jiuquan.

4. Discussion and Conclusion

Based on the previous rigorous network analysis of Chinese air transportation network using UCINET, we can enhance our understating and insights of inter-city connection and cooperation of Chinese air traffic hubs embedded in the world city network. Specifically, density analysis is recognized as a holistic analysis of the whole network of Chinese cities, we could find that Chinese air transport network have a moderate density connection, intimate relationship of overall air transportation network contributes to world city network formation in China. In terms of centrality analysis, it is clearly found that Beijing, Shanghai and Guangzhou play most dominant roles in the Chinese air transportation network. They are the heart cities, as well as gateway cities for coordinating and commanding the Chinese air transportation network, hence they should be deemed as the apex world cities in Chinese urban hierarchy, and core articulations of Chinese world city network. Apart from density and centrality analysis, visualization provides a platform for us to deep understanding of visible relationship of Chinese air transportation network. Lastly, subgroup analysis is another important spectrum for us to research; there are many evidences from subgroup analysis to show that robust cooperative relationships within and between subgroups arisen from overall air transportation network, Beijing, Shanghai, Guangzhou as three leading world cities in China, they are largely associated with subgroups' formation and cooperation.

In concluding, this article is a systematical research with regard to the world city network of Chinese cities. Most importantly, in order to constitute this immense world city network in China straightforwardly, we depart from air transportation network approach, which concentrate on large-scale air passengers' inter-city data in China. Clearly, this method is a reasonable methodology orienting towards constructing a mainstream of inter-city air passenger flows in the context of world city network's research trajectory. Ideally, a social network approach based on the application of UCINET is concisely analysis a huge quantity of relational data which derived from some official referential materials in China. Despite some inevitable obstacles of data collection and data analysis, we elaborate analyze of Chinese air transportation network through the whole network density analysis, centrality analysis, subgroup analysis and graph visualization method based upon the UCINET software, which consolidate a new blueprint of Chinese transportation network. On the other hand, this paper coincides with reality Chinese development status, but it still has some limitations. Since air traffic data is not the only sources of transportation network, railways and highways data also take up a dominant role in the transportation network analysis, in this situation, we will conduct a comprehensive comparative analysis of multiple transportation networks in future articles.

Acknowledgements

The authors would like to thank Universiti Sains Malaysia for providing financial assistance through the USM Fellowship to conduct this research smoothly.

References

Beaverstock, J. V., Smith, R. G., & Taylor, P. J. (1999). A roster of world cities. *Cities, 16*(6), 445-458. http://doi:10.1016/s0264-2751(99)00042-6

Borgatti, S. P., Everett, M. G., & Freeman, L. C. (2002). *Ucinet for Windows: Software for social network analysis*.

Carrington, P. J., Scott, J., & Wasserman, S. (2005). *Models and Methods in Social Network Analysis*, *28*. Cambridge University Press.

Castells, M. (1996). *Rise of the Network Society*. Blackwell Publishers, Inc.

China, C. A. A. O. (2013). *Statistical Data on Civil Aviation of China.* China: Civil Aviation Press.

Choi, J. H., Barnett, G. A., & Chon, B. S. (2006). Comparing world city networks: A network analysis of Internet backbone and air transport intercity linkages. *Global Networks-a Journal of Transnational Affairs, 6*(1), 81-99. http://doi:10.1111/j.1471-0374.2006.00134.x

Derudder, B., Taylor, P. J., Hoyler, M., Ni, P., Liu, X., Zhao, M. … Witlox, F. (2013). Measurement and interpretation of connectivity of Chinese cities in world city network, 2010. *Chinese Geographical Science, 23*(3), 261-273. http://doi:10.1007/s11769-013-0604-y

Derudder, B., & Witlox, F. (2005). An appraisal of the use of airline data in assessing the world city network: A research note on data. *Urban Studies, 42*(13), 2371-2388. http://doi:10.1080/00420980500379479

Freeman, L. C. (1977). A set of measures of centrality based on betweenness. *Sociometry*, 35-41.

Freeman, L. C. (1978). Centrality in social networks conceptual clarification. *Social networks, 1*(3), 215-239.

Freeman, L. C. (2004). *The development of social network analysis*. A Study in the Sociology of Science.

Friedmann, J. (1986). The World City Hypothesis. *Development and Change, 17*(1), 69-83. http://doi:10.1111/j.1467-7660.1986.tb00231.x

Friedmann, J., & Wolff, G. (1982). World city formation: An agenda for research and action. *International Journal of Urban and Regional Research, 6*(3), 309-344. http://doi:10.1111/j.1468-2427.1982.tb00384.x

Hall, P. M. (1966). *The world cities*. London: Weidenfeld & Nicolson Publishing.

Hanneman, R. A., & Riddle, M. (2005). *Introduction to social network methods*. University of California Riverside.

Ko, P. C., Hsung, R. M., & Lu, K. W. (2012). A Network Analysis of Inter-Journal Citations of Sociology Journals in Taiwan. *Journal of Educational Media and Library Sciences, 49*(4).

Lao, X., Zhang, X., Shen, T., & Skitmore, M. (2016). Comparing China's city transportation and economic networks. *Cities, 53*, 43-50. http://doi:10.1016/j.cities.2016.01.006

Lee, H. J., Lee, D. H., Taylor, C. R., & Lee, J. H. (2011). Do online brand communities help build and maintain relationships with consumers [quest] a network theory approach? *J. Brand Manag, 19*(3), 213-227. http://doi:10.1057/bm.2011.33

Lin, J. (2012). Network analysis of China's aviation system, statistical and spatial structure. *Journal of Transport Geography, 22*, 109-117. http://dx.doi.org/10.1016/j.jtrangeo.2011.12.002

Liu, J. (2009). *Lectures on whole network approach: A practical guide to UCINET.* Truth & Wisdom Press, Shanghai People's publishing House, Shanghai.

Luo, Q., & Zhong, D. (2015). Using social network analysis to explain communication characteristics of travel-related electronic word-of-mouth on social networking sites. *Tourism Management, 46*, 274-282. http://doi:10.1016/j.tourman.2014.07.007

Ma, X., & Timberlake, M. F. (2008). Identifying China's leading world city: a network approach. *Geo Journal, 71*(1), 19-35. http://doi:10.1007/s10708-008-9146-8

Mahutga, M. C., Ma, X. L., Smith, D. A., & Timberlake, M. (2010). Economic Globalisation and the Structure of the World City System: The Case of Airline Passenger Data. *Urban Studies, 47*(9), 1925-1947. http://doi:10.1177/0042098010372684

Neal, Z. (2011). Differentiating Centrality and Power in the World City Network. *Urban Studies, 48*(13), 2733-2748. http://doi:10.1177/0042098010388954

Sassen, S. (1991). *The Global City*. Princeton University Press.

Sassen, S. (1994). *Cities in a World Economy Sage*, CA: Thousand Oaks.

Scott, J. (2012). *Social network analysis*: Sage.

Smith, D. A., & Timberlake, M. F. (2001). World City Networks and Hierarchies, 1977-1997. An empirical analysis of global air travel links. *American Behavioral Scientist, 44*(10), 1656-1678. http://doi:10.1177/00027640121958104

Taylor, P. J. (2001). Specification of the world city network. *Geographical Analysis, 33*(2), 181-194. http://doi: 10.1111/j.1538-4632.2001.tb00443.x

Taylor, P. J., Catalano, G., & Walker, D. R. F. (2002). Exploratory Analysis of the World City Network. *Urban Studies, 39*(13), 2377-2394. http://doi:10.1080/0042098022000027013

Taylor, P. J., Catalano, G., & Walker, D. R. F. (2002). Measurement of the world city network. *Urban Studies, 39*(13), 2367-2376. http://doi:10.1080/00420980220080011

Townsend, A. M. (2001). The Internet and the Rise of the New Network Cities, 1969–1999. *Environment and Planning B: Planning and Design, 28*(1), 39-58. http://doi:10.1068/b2688

Vinciguerra, S., Frenken, K., & Valente, M. (2010). The Geography of Internet Infrastructure: An Evolutionary Simulation Approach Based on Preferential Attachment. *Urban Studies, 47*(9), 1969-1984. http://doi:10.1177/0042098010372685

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*, *8*. Cambridge University Press.

Zhao, S. X. B., & Zhang, L. (2007). Foreign Direct Investment and the Formation of Global City-Regions in China. *Regional Studies, 41*(7), 979-994. http://doi:10.1080/00343400701281634

Zook, M. A. (2003). Underground Globalization: Mapping the Space of Flows of the Internet Adult Industry. *Environment and Planning A, 35*(7), 1261-1286. http://doi:10.1068/a35105