Journal of Air Transport Management 50 (2016) 12–20

Contents lists available at ScienceDirect

Journal of Air Transport Management

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

# Simulation analysis of factors affecting air route connection in China

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ARTICLE INFO

*Article history:*
Received 23 March 2015
Received in revised form
23 July 2015
Accepted 7 September 2015
Available online xxx

*Keywords:*
Simulation analysis
Connection probability
Influence factors
Tertiary industry
Degree
Spatial distance

ABSTRACT

In order to explore the impacts of various factors on air route connection, a probability model is constructed to simulate the Chinese airline network (CAN) in 2010, and the influences of tertiary industry output, degree and the spatial distance between two navigable cities on the analog results are discussed. Our research shows that, the opening of an air route is not completely determined by the potential air passenger flow of it, although the latter is playing a leading role. In addition, the connection probability of an air route is significantly affected by the tertiary industry outputs and degrees of corresponding two navigable cities, but little influenced by the spatial distance between them. Moreover, scale economies effect obtained from the increasing of degree is apparently greater than that brought by the developing of social economy, so CAN is more inclined to evolve into a hub-and-spoke network.



## 1. Introduction

With the development of social economy and people's living standards in China, civil aviation transportation industry develops rapidly. This leads to the increasingly fierce competition among airlines. Especially in recent years, the code-sharing flight and other new transportation forms appear one after another along with the recombination among airlines. In order to adapt to the development of civil aviation transportation industry, it is necessary to adjust the structure of airline network and optimize the resource allocations of civil aviation transportation industry. The factors affecting air route connection can aid understanding why the airline network has formed the current structure. Moreover, investigating the effects of those factors is the premise of optimization of airline network structure.

In recent years, many studies have analyzed the topological properties of airline network (Li and Cai, 2004; Guimerà and Amaral, 2004; Yu et al., 2006; Liu and Zhou, 2007; Bagler, 2008; Wang et al., 2009; Zeng et al., 2011). Also, based on the complex network theory, a few researches have systematically analyzed the structural characteristics of airline networks in China, America, India, and other countries under different historical stages (Zhou, 2006; Pan et al., 2009; Zhang et al., 2010; Jimenez et al., 2012; Neal, 2013; Wang and Mo, 2014; Wang et al., 2014; Jia et al., 2014). The findings from the above-mentioned studies suggested that the airline network is a small-world network since the number of direct connections to a given node (i.e., degree) exhibits a (two-stage) power-law distribution. For a given node, the number of its direct connections is not only influenced by the spatial location and social economic development level of it, but is also closely related to the management policies of Civil Aviation Administration and the development strategies of different airlines.

Although the aforementioned studies are of great significance to understand the variation tendencies and development laws of airline network, the root causes for structural characteristics of airline network can not be explained. Therefore, many scholars conducted a wealth of research on the simulation of the evolution of airline network according to defining the connection probability of each air route. Barabási and Albert (1999) first proposed the famous B-A model. Since then a variety of improved models which reappeared the power-law degree distribution characteristic of small-word network were established in succession (Pan and Wang, 2006; Li et al., 2006). However, these models could not completely explain the two-stage power-law distribution of node degree in airline network. Hence, one study selected four indicators – the population, GDP and tertiary industry output of navigable city, and the distance between navigable cities – to calculate the connection probability of air route and reproduced the degree distribution of airline network (two-stage power-law distribution) through simulation (Liu et al., 2009). The analog results showed

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http://dx.doi.org/10.1016/j.jairtraman.2015.09.002
0969-6997/

that the influences of population, GDP and distance on connection probability were not significant, but the tertiary industry output of navigable city was a significant factor of airline network structure (Liu et al., 2009; Liu et al., 2011). Qian and Han (2009) simulated CAN (Chinese airline network) using the gravity model and systematically analyzed the effects of each parameter on the degree distribution of artificial network. Meanwhile, Qian et al. (2011) assumed that the growth rate of GDP remains unchanged and developed a dynamic evolution model of airline network according to the exponential relationship between GDP and degree. Zeng et al. (2012) applied the gravity model to uncover the influences of various factors including population, per capita disposable income and tertiary industry output of navigable city on air route connection. It was found that the developing of tertiary industry is the main driving force for the evolution of CAN. Liu et al. (2013) adopted a utility model to explore the evolution of airline network through analyzing the influences of social economic development level and spatial location of navigable city on passenger flow. Zhang et al. (2014) developed a dynamic fluctuation model of weighted airline network to examine how the connection probabilities of air routes vary with each parameter.

Although the existing relevant studies on the evolution of airline network have obtained rich achievements and many probability models can reproduce the two-stage power-law distribution of degree, there are still some problems to be addressed:

Firstly, the most existing researches centered on statistical analysis, so it is difficult to clearly understand how these factors affect the structure of airline network. In addition, these factors do not necessarily impact air route connection even though they are mathematically related to some network performance metrics. Therefore, the results of statistical analysis may be unreliable.

Secondly, most scholars evaluated the simulated effect of probability models by comparing the degree distributions of simulated network with actual network. Nevertheless, the degree distribution does not reflect the structure characteristics of airline network comprehensively, and it does not mean that the analog results accord with the actual situations even though the degree distribution of simulated network is similar to that of actual network.

Thirdly, although some studies have explored the probability model of air route connection, it needs a more in-depth analysis on the parameters of probability model, especially for the stability of analog results and influence factors of each parameter.

The objective of this study was to measure the role of potential passenger flow of air route in the evolution of CAN and analyze the impacts of various factors via simulating the topological structure of CAN in 2010. Hence, the conclusions of this article can help us to deepen the understanding of the evolution of airline network, and provide reference for the optimization of airline network structure.

The remaining part of this paper is structured as follows: Section 2 describes the data sources and the methodology used in this article. The probability model of air route connection and the analog results of CAN in 2010 are presented in Section 3. Section 4 discusses the impacts of three parameters in probability model on the simulated effect. Subsequently, this paper is concluded with a brief summary.

## 2. Data and methodology

### 2.1. Data sources

The domestic data of China in 2010 is used for this analysis. It is worth pointing out that the airline network in this study is the civil aviation passenger transport network which does not include Taiwan, Hong Kong and Macao due to the different statistical calibers.

The topological network of CAN is constructed based on Chinese domestic flight schedules of each airport in 2010 and relevant data is processed as follows.

(1) Multiple airports in the same city are merged into one node, and the node means navigable city in this study.
(2) The airline network is treated as an undirected network, because the flights are commonly two-way.
(3) Two navigable cities are adjacent if there is at least one direct flight between them. Otherwise, they are nonadjacent.

After that, the adjacency matrix of CAN is obtained easily. And then the degree of each navigable city is calculated. Fig. 1 illustrates the degree distribution of CAN in 2010, and it follows a two-stage power-law distribution. This means that the degrees of a few nodes are very high but most nodes have a low degree. The degree of a network is the average degree of all nodes. There are 1188 edges and 161 nodes in CAN, so the degree of the network is 14.76. That is to say, there are 14.76 edges connected with each node on average.

We extract the data required for this study, including the air passenger flow (PF) of each route and air passenger throughput (PT) in each navigable city from *Statistical Data on Civil Aviation of China 2011*, which is provided by Civil Aviation Administration of China (CAAC). In addition, socio-economic indicators, i.e., tertiary industry output, gross domestic product (GDP), population, and tourist arrivals of each city, are obtained from *China Statistical Yearbook 2011*, which is published by National Bureau of Statistics of China. Table 1 shows a snapshot of part of the data required for this analysis.

Specifically, GDP is the sum of the added values of each industry. In this research, tertiary industry output represents the added value of service industry in a certain period (usually a year), which is an important part of GDP. Generally, tertiary industry includes all other industries except agriculture, industry and construction. It is mainly composed of transportation, wholesale and retail trade, hotel and restaurants, banking, and real estate in China. In addition, the population refers to the total population of a city at the year-end. The tourist arrivals consist of domestic and international travelers.

### 2.2. Methodology

The aims of this study are not to systematically and comprehensively analyze the statistical relationship between each influence factor and flight frequency (available seats or passenger flow), but to discuss the impacts of several major factors on air route connection and explore how these factors effect the topological structure of airline network. Therefore, the statistical analysis

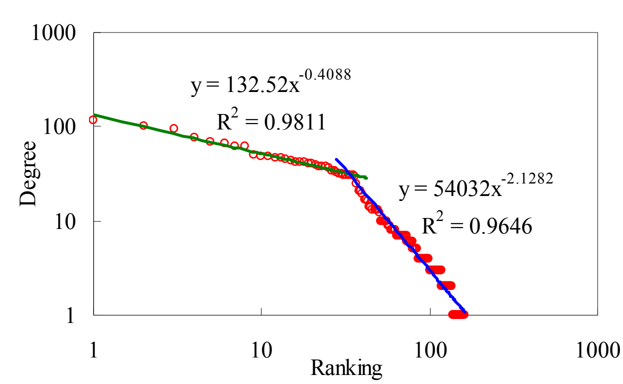


**Fig. 1.** Degree distribution of CAN in 2010.