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Q1 # Analysis of the Chinese provincial air transportation network

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HIGHLIGHTS

- We examine the Chinese provincial air transportation network via the complex network theory.
- We investigate the variation of flight flow within 24 h.
- We found an obvious tide phenomenon in the dynamics of the Chinese provincial ATN for high output level of tertiary industry.

ARTICLE INFO

ABSTRACT

The air transportation system is of a great impact on the economy and globalization of a country. In this paper, we analyze the Chinese air transportation network (ATN) from a provincial perspective via the complex network framework, where all airports located in one province are abstracted as a single node and flights between two provinces are denoted by a link. The results show that the network exhibits small-world property, homogeneous structure and disassortative mixing. The variation of the flight flow within 24 h is investigated and an obvious tide phenomenon is found in the dynamics of Chinese provincial ATN for high output level of tertiary industry. Our work will offer a novel approach for understanding the characteristic of the Chinese air transportation network.

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1. Introduction

In the past twenty years, the theory and application of complex networks have attracted a great deal of attention from different scientific communities [1–3], such as network modelling [4–6], cascading failures [7–10], evolutionary games [11–14], traffic dynamics [15–17] and optimization [18–23]. As a crucial infrastructure with an enormous impact on local, national, and international economies, air transportation network (ATN) has been extensively studied via complex network framework in recent years [24–27]. Guimerà et al. [28] studied the worldwide ATN and found that the network is a scale-free small-world network. They suggested that the community structure of the worldwide ATN cannot be explained solely based on geographical constraints and that geopolitical considerations must be taken into account. Barrat et al. [29] examined the weighted worldwide ATN and found that high-degree airports have a progressive tendency to form interconnected groups with high-traffic links. Li and Cai [30] examined the airport network of China. The result reveals that the Chinese airport
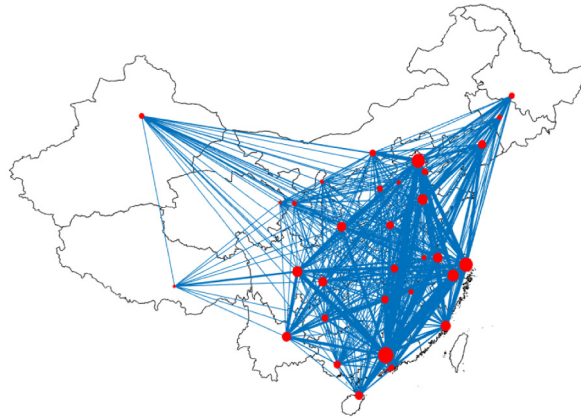
Fig. 1. The structure of the weighted Chinese provincial ATN, *where all airports within one province are abstracted as a single node and flights between two provinces are denoted by a link. Here the network contains N = 33 nodes and M = 462 links, and the size of nodes and the width of links are proportional to the number of flights.*

network shows small-world property, and the cumulative degree distribution of Chinese airport network (both directed and undirected) obeys a two-regime power law.

In most previous studies, air transportation networks are primarily investigated with three different scales: world-wide [31,32], continental [33,34] and national [35–37]. In the case of national scales, some major countries, such as US [38–42], China [43–46], India [47] and Brazil [48], are extensively investigated. The results of these studies show that national ATNs can display different features, such as two-regime power-laws degree distribution, rich-club phenomenon and small-world property and so on. Commonly, a node denotes an individual airport or aggregated airports within the same city. It is well known that air transportation network is sensitive to the economical distribution and geopolitical constraints [28], and provinces can effectively reflect these properties in China. Consequently, it is natural to investigate Chinese ATN in the province level. Meanwhile, provinces of China have exhibited heterogeneous economical developing levels and formed diverse regional airline networks. Hence it is meaningful to identify the roles of provinces in Chinese ATN and analyze how the air traffic interactions between provinces are organized. In this paper, we investigate the features of the Chinese provincial ATN and the variation of flight flow within one day. The results show that the network displays small-world property, disassortative mixing level and is heavily affected by the output of tertiary industry.

The paper is organized as follows. In Section 2 we demonstrate the Chinese provincial ATN and the related network properties in detail. In Section 3, simulation results and correspondent theoretical analysis are provided. Finally, the work is summarized in Section 4.

2. The model

2.1. The Chinese provincial ATN

The data used in this paper are provided by the Air Traffic Management Bureau (ATMB) of China. We consider the data within one week, from June 1, 2015 to June 7, 2015. In the Chinese provincial air transportation network, all airports located in a province are denoted as a single node. It is noteworthy that municipalities, such as Beijing, Shanghai, Tianjin and Chongqing, are also considered as a single node. Table 1 displays the number of airports N_a in each province with decreasing order. One can see that Xinjiang has the maximum number of airports ($N_a = 17$) while the value of N_a corresponding to Tianjin, Hong Kong and Macao is only one. We establish link between node pairs if there are direct flights between them. Fig. 1 shows the structure of the weighted Chinese provincial ATN, which contains $N = 33$ nodes and $M = 462$ links, *and the size of nodes and the width of links are proportional to the number of flights.* The average degree of the network is 28, the average shortest path length of the network is 1.13 and the clustering coefficient is 0.883, indicating that Chinese ATN is a densely connected small-world network. The diameter of the network is 2, and over 85% province pairs are directly connected. *Table 2 displays a comparison between the basic network parameters of the Chinese provincial ATN and the Chinese ATN [37] whose nodes are airports and links are direct flights. This shows that the Chinese provincial ATN is smaller and denser than the Chinese ATN.*

2.2. Network properties

To examine the features of the Chinese provincial ATN, we investigate some properties commonly used in complex network literatures [1,2], including the cumulative degree distribution, degree correlation and the node strength.