THE RESPONSES OF CHINESE DEDICATED AIR CARGO INDUSTRY TO E-COMMERCE BOOM AND COVID-19: NETWORK DEVELOPMENT AND SERVICES

A thesis submitted by

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ABSTRACT

China has achieved remarkable economic growth from 1978. In recent years, the country has become the world's number two economy and is turning to a consumption-driven orientation with its booming e-commerce market. These circumstances are expected to drive the development of the domestic cargo market and create opportunities for the local integrator in China. However, the industry has been considered inefficient because it is operating with less focus on freight transport compared to passenger one. Especially in the domestic market, cargo delivery highly relies on belly-capacity of passenger traffic which is dominated by combination airlines because of the unbalanced air route network with much higher traffic density in the east coast of China. During 2020 the global pandemic caused by COVID-19 led to most passenger flights being grounded. The crisis raised the importance of networks and services the all-cargo flights.

The rapid developments of the e-commerce markets increased the demands on the air express service industry substantially, and so the air express integrators became the biggest market players. The integrators' networks underwent great development after one year of the COVID-19 outbreak. By comparing their network indices values with ones of the world-leading carriers in the EU, it is found that the EU carriers with their preponderance of hub-and-spoke structures have a higher degree of centralization. In contrast, China's integrators have hub-and-spoke and point-to-point structures, which make the network less centralized and more complex.

It also found that the Chinese scheduled freighter network (CSFN) displayed small-world and scale-free network properties in 2020. The CNT analysis demonstrated that the CSFN is not a random type of network and maintains a good coverage of the nation. The CSFN is unbalanced like the form of the air passenger traffic in relying on three eastern mega-city clusters. However, the network appears to have a clear layering feature consisting of national and intermediate level hubs as well as many small nodes (peripheral cities). The national hubs for the dedicated cargo carriers are Shenzhen in the Pearl River delta, and Hangzhou and Nanjing in the Yangtze River delta for the CSFN, instead of Guangzhou and Shanghai as in the case of China's air passenger

network. The increase in direct freighter routes among cities such as Wuhan, Beijing, Tianjin and Guangzhou in the early period of the pandemic increased the density and transitivity of the CSFN. Since China's air passenger traffic had quickly restored in the second half of 2020, we argue that the changes in the CSFN during COVID-19 were unlikely to be a result of the substitution effect between freighter and passenger aircraft. It was more likely a result of the higher air cargo demand during the pandemic and airlines' realisation of the importance of freighter operations in China.

To meet the rising aviation demands driven by the development of China's economy, the domestic air cargo network in the coming decades will have strategic development opportunities. The air freight industry will benefit from transforming and upgrading the existing large domestic cargo airports. The trend of the national network development is foreseeable. In the long run, China's domestic air cargo network pattern will be altered to a real hub-and-spoke network by an integrator such as SF Express who will implement its integration strategies to reinforce its advantages in the premium price and Promised delivery time (PDT) service strategies.

A conceptual model with six evaluating dimensions is developed for the air freight express industry in China's e-logistics market. The fields of preferential pricing, customer experience, safety/risk cover and air freight capacity are positively associated with customer satisfaction. When e-commerce firms choose an Air express service provider (AESP), they are more sensitive to cost and after sales service than the operational capacity and the overall industrial performance claimed. Significantly, this suggests that customers expect and value air freight capacity. When an AESP increased its investments in aircraft and airport infrastructure substantially in recent years, these investment projects increased the AESP's competitiveness on the customers' perceived service quality.

CERTIFICATION OF THESIS

This Thesis is the work of Yu Deng except where otherwise acknowledged, with the majority of the authorship of the papers presented as a Thesis by Publications undertaken by the student. The work is original and has not previously been submitted for any other award, except where acknowledged.

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Student and supervisors signatures of endorsement are held at the University of Southern Queensland (USQ).

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STATEMENT OF CONTRIBUTION

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The overall contribution of Yu Deng was 75 per cent to the concept development, methodology, data analysis, visualization, writing – original draft. Yahua Zhang and Frank Elston contributed the other 25 per cent to supervision, Conceptualization, Writing – review & editing

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The overall contribution of Yu Deng was 80 per cent to the concept development, methodology, data analysis, visualization, writing – original draft. Yahua Zhang contributed the other 20 per cent to supervision, Conceptualization, Writing – review & editing

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LIST OF ABBREVIATIONS

AESP	Air express service provider
AFT	Available freight tonnes
B2B	Business to business
B2C	Business to customer
CAAC	Civil Aviation Administration of China
CFA	Confirmatory factor analysis
CNT	Complex network theory
CSFN	Chinese scheduled freighter network
EDI	Electronic data interchange
EMS	Express Mail Service
EU	European Union
FSC	Full service carrier
IATA	International Air Transportation Association
LCC	Low cost carrier
PDT	Promised delivery time
SEM	Structural equation modelling
TPL	Third party logistics
US	United States

CHAPTER 1 : INTRODUCTION

1.1 Background

The development of a global manufacturing supply chain, especially after China entered the World Trade Organization in November 2001, has spurred China's air cargo tonnage growth (Hui, Hui & Zhang, 2004). Following consecutive decades of economic growth in China since 1978, the expanding middle class with increasing disposable income has contributed to the growth of Chinese commodity consumption (Boeing, 2016). As a result, the Chinese economy is evolving to a consumption-driven one. With the second largest domestic market after the United States (US) and the largest e-commerce market in the world, China is expected to have the world's fastest-growing regional air cargo market (Boeing, 2018). E-commerce is playing a significant role in the progress of the Chinese air cargo industry. E-commerce, especially Business to customer (B2C), has been accepted widely and has changed the public's shopping behaviour. Without the need to visit to a physical store, shopping online breaks space and time barriers and offers many customers more convenient access to products (Wang & Xiao, 2015). Through e-commerce, the choices of several categories of products such as electronics and even fresh food are not limited to local production. Relying on air cargo services for safe and speedy delivery, products can be sold cross-provinces and even cross-borders.

But online purchasing relies heavily on express delivery services, particularly by air because it can fulfil the needs of e-commerce buyers. The three e-commerce giants – Amazon, Alibaba and eBay – rely on express delivery services by air to send high value and fragile items like electronic devices to their online customers (IATA, 2018). According to Allen et al. (2018), customers have a high expectation of fast delivery with a timeliness guarantee, and the latest trackable delivery status and estimated time of arrival online. Timeliness is the primary consideration for customers in choosing an e-commerce store and platform to buy from (Preston's Friends, 2016). Beside late deliveries, negative customer experiences such as damaged and lost parcels, offensive manners from couriers and tedious return procedures conceivably cause credibility and brand name damage for e-commerce firms and shops too (Jie et al., 2015). In terms of service quality, when customers are not satisfied with the delivery service they would rather complain to the seller than blame the logistics providers. They indirectly reduce their willingness to buy products on that platform and shift their search to rival platforms with a perceived better delivery service (Kearney 2011).

However, most airports and air cargo networks in China are not suitable for the current air mode logistics. The industry has been inefficient and has operated with limited focus on freight transport since the early era of China aviation deregulation and the economic boom driven by manufacturing. Economic growth has led to the development of coastal cities with vast populations and major export processing zones within the catchment areas of these cities. The air corridors linking Beijing, Shanghai and Guangzhou contain the largest market share of the domestic cargo traffic (Hui, Hui & Zhang, 2004). This 'golden triangle' of air routes connecting these three mega cities is almost saturated because of the unbalanced air route network and the intensive traffic on the east coast of China. The main airports in this 'golden triangle' are reaching maximum capacity (Zhang & Zhao, 2015). Tensions relating to traffic capacity and congestion arise frequently for the airports along the prime air transport corridors (Jennings, 2017).

Consequently, the lack of support from airports for dedicated cargo areas means air cargo transport does not function as an effective network. In managing transport capacity, the cargo airlines' planning suffers from the complexity of mixed rental aircraft bellies and freighters (Yu, Yang & Yu, 2017). Some of the cargo airlines are small in scale and they need to overcome technical and resource issues when obtaining terminal space and facilities in a gateway airport. The network patterns have limited the development of air cargo transport. The recent soaring demand for air cargo has been challenging for Chinese airports (Li, 2020a).

Cargo delivery relies heavily on the belly capacity of passenger aircraft and so it is dominated by passenger airlines because of the unbalanced air route network. Cargo was long considered to be an adjunct to an airline's main business – carrying passengers – which mainly served the passengers' preferences. During 2020 the global pandemic caused by COVID-19 led to most passenger flights being grounded. The crisis raised the importance of the networks and services of all-cargo flights, which provided valuable development opportunities for this sector.

1.2 Motivation for the study

The appeal of e-commerce for people across China and the world is proving to be a continuous boom for air freight demand. While this is a great opportunity for the industry, air cargo logistics operations have to deal with some e-commerce challenges (Kearney, 2011). Fortunately, inter-city highway express freight companies have increased their substantial investments in aircraft, airport infrastructure and other areas. These new investment projects are expected to boost air cargo express service competitiveness (Xiao, 2011). These have become common strategies by Chinese express companies which intend to use dedicated air cargo services to improve or ensure their committed lead time to their customers. For instance, in January 2019 SF International Airport, also known as Ezhou Airport, was approved by the National Development and Reform Commission. SF Express intends to use the airport to set up a genuine hub-and-spoke air route network (SF Express, 2018a). The project is the core of SF Express's air transport system in the company's strategic planning. SF Express will use Ezhou Airport to build a nationwide and global airline network to support product timeliness improvements, guarantee service stability, create high-end comprehensive logistics service capacity and enhance customer satisfaction (SF Express, 2018b). SF Express will be the first air transport company in China to operate a self-built dedicated cargo airport (Kauffman, 2017). Similar projects have been launched by other Chinese private transport companies. YTO Express, which maintains a self-built fleet of 10 all-cargo freighters, has started to build an air logistics hub at Jiaxing in the eastern province of Zhejiang. The total investment is more than USD1 billion. Given growing freighter fleets and more productive airport support services, it is predicted that an actual hub-and-spoke cargo network will emerge in China eventually (Gong et al., 2018).

While the leading express transport companies have been applying strategies to build their own fleets and networks to improve supply chain performance, after the COVID-19 pandemic outbreak in 2020 the National Development and Reform Commission and the Civil Aviation Administration of China (CAAC) issued a memorandum on measures to facilitate China's air cargo transport infrastructure development. The memorandum reinforced the need for cargo airlines to expand their fleets and to develop all-cargo aircraft transport. It is necessary for stakeholders, such as scholars, authorities and the industry practitioners, to understand how the networks and services for dedicated air cargo in China both develop to meet the e-commerce boom and respond to public health hazards.

1.3 Research aims and objectives

The purpose of this research is to explore the development of dedicated air cargo networks and services in China. To understand the development of networks, this study applies complex network theory (CNT) to investigate the networks and to assess their evolution during the pandemic period. Thus, the research addresses several principal questions. Who are the main market players in China? How have their air cargo networks developed? What is the status of China's dedicated air cargo networks? What has changed for the networks since the pandemic's outbreak?

In the domestic market, the transportation of air cargo mainly relied on the belly-hold of passenger flights rather than dedicated all-cargo freighters. However, with most of the passenger flights being grounded during the pandemic, the capacity for air cargo substantially decreased, while at the same time, the demand for e-commerce was soaring. Chinese air express companies had to allocate more resources to develop their self-built air cargo networks to maintain their services and meet the consumers' demand. Their network development was significant and noticeable in the first year of the COVID-19 pandemic. Given that the dedicated air cargo industry is the main focus of this research, China's three integrators, namely, SF Express, China Post and YTO Express, are selected to analyse the network development and examine the evolution of the networks during the pandemic period.

To provide more insights into the country's dedicated air cargo networks, this research evaluates the Chinese scheduled freighter network (CSFN) via its topological properties and explores the changes to it since the COVID-19 outbreak. Part of this research targets matters such as the importance of individual airports or cities in the national network, whether there is a substitution effect between full cargo and belly transport in the network's evolution and so on.

As discussed, online order deliveries are an important market for air express companies. In terms of service, online sellers and e-commerce giants are critical clients. From a marketing perspective, the satisfaction they give the customer is most important. What are the factors, and their relative importance, that influence the adoption of an air express delivery service? What is the impact of air express quality factors on logistics service performance? Service quality has attracted the most attention in researching this field of business (Campos-Soria et al., 2005). The authors add that good performance on customer satisfaction can improve the competitiveness of an enterprise. In order to meet the fast developing online market, air express cargo companies, and the freight industry in general, need to understand better the expectations of Chinese firms (consignors) and end customers (consignees) of the express services. Therefore, this study develops a model with service quality dimensions for air express service providers (AESPs). Through these dimensions, the AESPs are capable of identifying the relative strengths and weaknesses of the factors that influence their performance.

Understanding the perceived importance of these factors is vital for an AESP to survive and to strengthen its competitiveness.

1.4 Contribution of research

As most of literature has investigated global express companies in the US and the international trade market, this study fills a gap in the literature on the development of air express cargo companies in China, including their scheduled freighter network and business strategies. This study illustrates the potential for China's air express cargo business with its recognized significance and its foreseeable future growth. SF Express's network in the Chinese domestic market developed topological features unique from its Chinese and foreign counterparts. This may imply that China's current booming e-commerce market benefits the express company with a good balance of the cargo demand and the flow of its scheduled all cargo flights. This aspect of e-commerce growth has not been discussed in the literature before.

Dedicated air freight services have different network patterns to passenger flight services. Compared with the academic literature on passenger airline networks, publications about dedicated cargo airlines are scarce. This study analyses the cargo network in one of the most important markets in the world. This is thought to be the first study of the changes in a national scheduled dedicated air cargo network during the COVID-19 pandemic. The most significant contribution of this analysis is not investigating the impact of COVID-19, but revealing unique network patterns in China, the leading e-commerce market in the world. It has been reported that the world's revenues in e-commerce has grown dramatically in the past two years due to the pandemic, because buying from home is a main option for people needing to be isolated voluntarily or compulsorily to protect themselves from the COVID-19 virus (Bhatti et al., 2020) The pandemic has changed the purchasing behaviour of consumers in retail outlets and accelerated a shift to e-commerce (Guthrie, Fosso-Wamba & Arnaud, 2021). It is expected that e-commerce will keep growing around the world and so play a more important role in the air cargo industry in a post-pandemic future. This study will encourage other scholars in this area to investigate more deeply how dedicated air cargo networks in other countries or markets have been impacted by e-commerce and the pandemic.

In terms of service quality, the competitiveness of the air cargo express carriers involves factors that influence the choice of an air express service (Park, Choi & Zhang, 2009). Haryanto and Chang (2018) suggest that logistics providers should seek to improve their service quality continually, both for their clients and the end customers who receive and use their clients' products. Third-party logistics (TPL) providers present not only their company's behaviour to the consumer, but they also represent the e-commerce firms. This research explores the relative importance of the dimensions that influence the selection of an air express delivery service in China. In addition, it examines and proves that the service quality dimensions are associated with the competitiveness in customer satisfaction of the air express services. The results offer useful implications for Chinese service providers, the e-commerce giants and policy makers.

1.5 Thesis Structure

This thesis is organized in five chapters. Following this chapter, which, so far, has explained the motivation, aim and the contribution of the research, there are one previously published, and two articles submitted for publication on related topics are included as chapters to address the research topic. The final chapter concludes the findings from these three chapters and discusses future study opportunities.

Chinese air cargo express companies which use their self-built in-house air freight capacity are defined as 'Integrators' in Chapter 2. The study of this aspect analyses the geography of the integrators using CNT. The research explores the individual integrators' network developments and compares these with the networks of the world-class integrators in the European Union (EU). It is found that SF Express operates more bidirectional routes in its domestic networks. This may imply that the e-commerce market can provide a good balance of the cargo traffic between two destinations in the CSFN.

Chapter 3 analyses the CSFN via its topological properties. In addition, the study presents the changes in 2020 and discusses the impact of the COVID-19 pandemic. The result demonstrates that the CSFN has been enhanced since the pandemic's outbreak. The improvements have been in the increased network average degree, the clustering coefficient and closeness, and the reduced average path. The changes were driven by the major hub cities whose centralities had been strengthened with more routes being developed. It is argued that the changes in the CSFN during the pandemic were unlikely to have been caused by the substitution effect between freighter and passenger aircraft. More likely, it was in response to soaring air cargo demand and the airlines' realisation of the importance of freighter operations in China.

Chapter 4 is an empirical study applying service quality theories and SERVQUAL, which is a multiple-item scale for measuring service quality for air express service organizations in assessing consumer expectations and perceptions of service quality. The current study assesses the relationship between the service performance aspects of air express third-party logistics and service quality dimensions in the context of the Chinese e-logistics market. In particular, it analyses the latent relationship between the service dimensions and performance of the AESPs through the structural equation modelling (SEM) approach. It gives an insight as to how the service quality factors influence the air cargo express service company's performance. It can help firms achieve competitiveness through identifying gaps requiring managerial attention and action to improve service quality.

Chapter 5 summarizes the research findings and identifies the implications and suggestions for future research opportunities. Based on the findings of Chapters 2 to 4, an overall conclusion is drawn about the Chinese dedicated air cargo industry's response to the e-commerce boom and the concurrent COVID-19 pandemic.

CHAPTER 2 (PAPER 1) THE DEVELOPMENT OF CHINESE AIR EXPRESS INTEGRATORS

Abstract

Despite the significance of the China e-commerce economy and the rapidly increasing air express service, there are few publications on the development of Chinese integrators that are significant contributors to the e-commerce boom. This research explores the network development of China's three integrators, namely, SF Express, YTO Express and China Post, and assesses the evolution of the networks during the pandemic period. Also, their domestic networks are compared with the networks of the world-class integrators in the EU. It is found that the Chinese integrators operate networks with both hub-and-spoke and point-to-point features at their principal hubs (Hangzhou and Shenzhen of SF express, and Nanjing of China Post). SF Express' network in the Chinese domestic market demonstrates different topological features from the ones of its Chinese counterparts and the foreign integrators in Europe, with fewer one-way flights and at a higher density.

Keywords: Integrator; China express industry; network; air freight

2.1 Introduction

In the air cargo industry, integrators are defined as a type of market players which provide an end-to-end air express service with time guaranteed with the flight and land transport, including goods collection and delivery for end-customers, for example, FedEx, UPS, and DHL, which are global leading integrators. (Bowen Jr., 2012; Kupfer et al., 2017; Malighetti et al., 2019b). The rapid development in the e-commerce markets drives the demand of the air express service industry. (Van Asch et al., 2020; Park, Choi & Zhang, 2009). In 2020 after the COVID-19 pandemic outbreak, because of the forced isolation, the sales of online shopping gained unrivaled growth in categories, such as medical, baby products, food, and drink items. (Bombelli, 2020). The COVID-19 pandemic has accelerated the growing importance of e-commerce on the air cargo market, especially in the air express segment. By the end of September of 2020, integrators achieved a traffic increase of 14% (Boeing, 2020). It is foreseen that the air freight operated by integrators would take the significant lead in the competition under the current market environment, even though the development of air freight remains uncertain in the post-pandemic era. (Suau-Sanchez, Voltes-Dorta & Cugueró-Escofet, 2020)

Currently, China is the largest e-commerce market with US$1.5 trillion in revenue in 2019 (Boeing, 2020). In 2019 China's express industry delivered 63.52 billion orders, worth a value of RMB749.78 billion (State Post Bureau, 2020). There is no doubt that e-commerce is the primary driver for the increase in China's air cargo volume and revenue. How the air cargo industry meets the e-commerce boom has been on the spotlight and aroused interests and attentions in academia. For example, Xiao (2011) applies a SWOT framework to analyze Post Express Service with private and foreign air express firms in China and points out the main service problems of the state-owned express company. Farooq et al. (2019) state that customer retention and loyalty can create a massive profit. A strong brand reputation has a positive effect on customer retention. Also, proper management is positively related to service delivery quality. Liu & Kang (2015) conduct a case study of Chinese leading integrator SF Express with in-depth analysis of its operational model. It interprets that SF Express achieves competitive strength through distinct delivery service with promptness and mature network coverage. These studies offer an overview of Chinese express industry and feature of delivery service performance. However, studies on the integrators' network remain rare, when compared with that for other integrators in the world.

Malighetti et al. (2019a) and Bowen Jr (2012) highlight the key positions of Chinese airports as the Asian gateways for global integrators. Some research has conducted network analyses with topological measures for global and regional air cargo markets with a focus on the global integrators (Bombelli, Santos & Tavasszy, 2020; Malighetti et al., 2019a; Bowen Jr, 2012). However, there is a lack of research on China's integrators and their network development. To fill the gap, this study will use the complex network theory (CNT) to examine the scheduled freighter network of China's integrators. The development progress and business strategies of individual integrators will be discussed.

This chapter is structured as follows. The background of China's integrators is reviewed in Section 2. The methodology is presented in Section 3. Section 4 analyses the networks of Chinese three integrators. Section 5 offers further topological measures and changes during the pandemic period. The comparison with peers in European market is in Sections 6. Section 7 contains discussion and concluding remarks.

2.2 The development of China's integrators

Running own air freight and the land transport in their parcels' delivery service, three express companies (Table 2.1) in China fulfill the definition of integrators discussed above. China Post is wholly state-owned, while as SF Express and YTO Express are private companies. When online retailers emerged in China, most online orders were delivered by Chinese private express enterprises. These local logistics operators developed from inter-city highway express freight companies which included a 'door-to-door' service (Wang & Xiao, 2015). In terms of delivery orders of parcels, the private express delivery companies play a significant role by occupying over 80% market share of the Chinese parcel delivery business in 2019 (State Post Bureau, 2020). The fast-expanding market encouraged two local express companies, SF Express and YTO Express, to invest in self-owned air cargo fleets and operate scheduled freighter flights. (Li, 2020b). In 2005 the civil aviation sector was opened to private capital, and private airlines started to develop (Wang et al., 2016). In 2009 SF Express established its cargo airline for the expanding local market. More recently, YTO Express initiated its self-run air cargo flights service in 2015.

By the end of 2020, these three integrators had operated scheduled all-cargo flights in China, under the brand of China Postal Airlines, SF Airlines and YTO Cargo Airlines, respectively. Table 2.1 provides the fleet and hub information of the integrators.

Table 2.1: Three Chinese integrators.

Integrators	Name of the Carriers	Year established	Fleet	Hub
SF Express	SF Airlines	2009	61 (B737, B747, B757, B767)	Shenzhen, Hangzhou
YTO Express	YTO Cargo Airlines	2015	10 (B737, B757)	Hangzhou
China Post Group Corporation	China Postal Airlines	1996	28 (B737, B757)	Nanjing

Source: Civil Aviation Administration of China (CAAC) reports, the company financial reports and publications.

2.2.1 SF Express

SF Express is China's number one logistics company with an annual revenue of RMB112.19 billion in 2019, which was much higher than any other express logistic company in China. What distinguishes SF Express from its domestic peers is that it offers an express professional service with a promised delivery time (PDT) to customers,[1] which brings a higher brand premium (SF Holding, 2019). According to the 2019 annual report of SF Holding (2020), the PDT service contributed RMB56.521 billion, occupied over 50% annual revenue of SF Express, and this part has a close connection with air freight in long-distance delivery.

As the leading domestic integrator, SF Express has been developing its subsidiary, SF

[1] SF Express provides different categories of PDT services, including 'SF the Same Day Delivery' and 'SF Next Morning Delivery', based on the delivery destination and pickup time. In the 'Same Day Delivery' commitment, within the designated destinations and pickup time, the delivery will be completed by 8 p.m. on the same day. The committed timeline for 'SF Next Morning Delivery' is the next morning before noon. These PDT services are guaranteed with full refunds or other monetary compensation to customers if delivery is not fulfilled on time. PDT has been regarded as an advanced service offering in the air freight business, which can give the parcel express firm a competitive advantage (Niu, Dai & Zhuo, 2019).

Airlines, rapidly. Although its size is not comparable to the state-owned ‘Big Three’ passenger airline backed cargo airlines or international peers such as UPS or FedEx, SF Airlines has the most potential to be the largest integrated carrier in China’s air cargo market. After ten years of aggressive fleet development (Fig. 2.1), SF Airlines owned 61 all-cargo freighters at the end of 2020. With this inhouse air freight support, SF Express achieves ‘next day arrival’ for major cities in mainland China. With placing its Airport Operation Centre in Shenzhen Airport, SF Airlines has built a nationwide ‘dual-core’ transportation network with Shenzhen and Hangzhou as its main hubs (Chen, 2017).

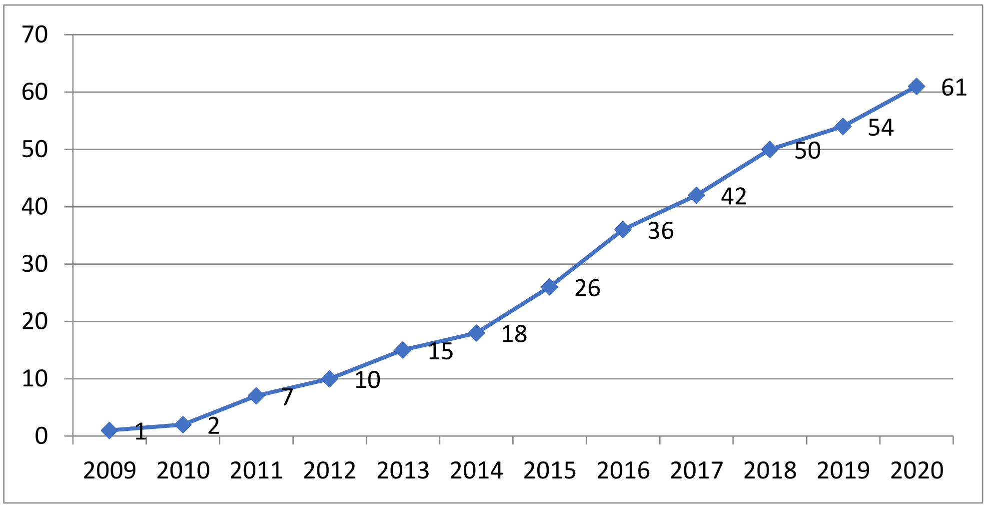


Figure 2.1: SF Airlines fleet development, 2009–20.

2.2.2 YTO Express

YTO Express was founded in 1999. Its annual revenue reached RMB31.15 billion in 2019 (State Post Bureau, 2020). To survive the fierce competition in the express delivery sector, it not only applied the franchise business model like other local express companies to capture market share rapidly, but it also cooperated with an e-commerce platform to ensure parcel order quantity. Meanwhile, Taobao.com, which is the online Business-to-Business (B2B) and Business-to-Customer (B2C) platform developed by the Chinese e-commerce giant Alibaba Group, handled any unsatisfied performance on order fulfilment service. In 2005 YTO Express was the first express company to sign an official cooperation agreement with the Alibaba Group, and it then became the recommended logistics service provider for all e-sellers on Taobao.com (Wang & Xiao, 2015). Afterwards, YTO Express was on the fast track of development with Alibaba's e-commerce platform. The Alibaba Group invested in YTO Express in 2015 and 2019, becoming its second largest shareholder with a 22.5% stake. YTO Cargo Airlines, the wholly owned subsidiary of YTO Express, has Hangzhou Xiaoshan International Airport as its administrative headquarters and main operation base. At present, there are ten domestic destinations for YTO Cargo Airlines' regular domestic flights. By the end of 2019 the carrier maintained its own fleet of twelve all-cargo freighters – five B757-200s and seven B737-300s.

2.2.3 China Post

China Post, China's state-owned official postal service, launched its Express Mail Service (EMS) in 1985 and it was the exclusive express service operation for more than a decade (Wang & Xiao, 2015). The integrators in China initially provided express delivery services for business documents and mail such as contracts, invoices, customs report cards and even design samples for manufacturers and purchasing agents. China Postal Airlines was established in 1995. It officially commenced cargo operations in February 1997. It was the first domestic specialised cargo airline in express mail and cargo transportation. The carrier is wholly owned by China Post and mainly handles air freight for it. Nanjing Lukou International Airport serves as its hub airport. This cargo airline has formed a mature scheduled all-cargo network with 27 key aviation cities around the country being connected.

2.3 Methodology

2.3.1 Complex network theory (CNT)

To address the problem of understanding Chinese integrators local freight network capacity, we apply the CNT approach to analyse the scheduled air freight network. The CNT can evaluate the structural properties of the networks by describing them in nodes and edges, which are the basic data elements, and so define the overall classification (regular, random, small-world and scale-free). The network characteristics are outlined with indices, which can be used to diagnose the inefficient connections and identify the importance or roles of nodes. The knowledge achieved can support further improvement of the networks (Hossain & Alam, 2017).

The CNT indices allow comparisons between the networks at different locations or the status of networks at different points in their timeline (Ducruet & Rodrigue, 2013). Even more importantly, the method assists the understanding of the spatial structure of the logistics networks, the importance of location and the real traffic flows (Wang et al., 2011). On international routes the Chinese passenger carriers are considered deficient in competitiveness when compared with foreign airlines (Cao et al., 2011; Fang, Wang & Gao, 2009). It would be interesting to determine the characteristics or indicators illustrating the domestic network efficiency gap between Chinese integrators and their counterparts such as DHL, UPS and FedEx in comparable domestic markets, such as North America and Europe.

Following Malighetti et al. (2019b), we model each integrator's network as a directed graph G = (V, E), where V is the set of nodes (cities) and E is the set of directed edges. As each edge represents the route between city *i* and city *j*, each edge has forward and backward two directional edges and all connected city pairs with one or two links have both outward and inward directions (Malighetti et al., 2019b). As the existing studies discovered, the air cargo industry usually operates flights in circle routes under imbalances of cargo traffic. Thus, the directed graph more aligns with actual circumstances than the undirected one.

For each Chinese integrator, the indices used to measure the network include degree distribution, the average path length and the clustering coefficient. The topological indices such as μ, α, γ and β are also applied to evaluate the network structure to find the changes of topological properties during the COVID-19 pandemic and compare their domestic network with the foreign integrators' network in Europe. Table 2.2 lists all the network variables and the indices.

Table 2.2: List of network indices.

Index	**Description**
k_i	degree of node *i*
$\langle k \rangle$	average degree of the network
d_{ij}	shortest distance between nodes *i* to *j*
D	diameter of a network; the longest shortest path in the graph
L	average shortest path length or characteristic path length
C_i	clustering coefficient of node *i*
C	clustering coefficient of the network
n	number of nodes (cities)
m	number of edges (routes)
μ	number of cycles in a network
α	ratio of the number of cycles in a network to the maximum number of cycles in the network
γ	the ratio of the number of actual routes to the maximal feasible number of routes
β	average air routes of each node
g	number of disconnected subgraphs

- Degree of node i: k_i

Degree is the number of directed (in and out) connections that a node bond with others. Degree k_i is defined as the number of these connections.

- Average degree of the network

If there are n nodes, the average degree of all nodes $\langle k \rangle$ can be calculated as:

$$\langle k \rangle = \frac{1}{n} \sum_{i=1}^{N} k_i \tag{1}$$

- Average path length

The distance between node *i* and *j* in a network is defined as the number of connections passed from node *i* to *j*. There are some possible paths including direct or indirect between them. The distance d_{ij} is the shortest path with the minimum number of edges between node *i* and *j*. The average path length (L) represents the mean distance of any two nodes of a network, which can be expressed as:

$$L = \frac{1}{\frac{1}{2}\mathrm{n}(\mathrm{n}-1)} \sum_{i>j} d_{ij} \tag{2}$$

- The diameter of a network: *D*

The diameter *D* is defined as the maximum value of all possible the shortest distance of node pairs in a network.

- Clustering coefficient: *C*

C_i represents the clustering coefficient of node *i*. It is the rate of the connected edges (E_i) with all its neighbours to the number of all possible edges. The clustering coefficient of a network (C) is the mean value of all the single nodes, which is expressed as:

$$C = \frac{1}{n}\sum_{v_i \in V} \frac{E_i}{k_i(k_i - 1)/2} \quad (3)$$

This index reflects the clustering degree of all nodes in the network (Wu et al., 2020), With the larger the value of clustering coefficient, the nodes cohere with each other by paths with fewer edges (Wang et al., 2011).

- Number of disconnected subgraphs: g

A graph is disconnected if two nodes are not connected by a path. The number of disconnected sub-graphs is denoted as g.

- Number of cycles in a network: μ[2]

$$\mu = m/2 - n + g \quad (4)$$

It reflects the complex rate and the maturity of the network.

- Alpha index: the ratio of the number of cycles in a network to the maximal feasible number or

$$\alpha = \mu / (2n-5) \quad (5)$$

A higher alpha index indicates that there are more options for the user to travel from one place to another.

[2] μ is calculated with undirected edges, therefore, the number of undirected edges in the chapter is defined as a half of number of direct edges: m/2.

- Gamma Index: the ratio of actual routes to the maximal feasible number of routes Following Bombelli's (2020), the maximal feasible number of edges is (n*(n-1)).

$$\gamma = m/[n(n-1)] \tag{6}$$

This index represents the concentration degree of a network.

- Beta Index: the average routes of each node.

$$\beta = m/n \tag{7}$$

Overall, larger values of α, γ, or β indicates a better connectivity.

2.3.2 The data

The data were obtained from the 2020 flight timetables published by CAAC. The CAAC issues two timetables a year – the summer/autumn timetable (from late March to late October) and the winter/spring timetable (from late October to late March of the next year) (Wu et. al., 2020). Due to the COVID-19 outbreak, the summer/autumn timetable was revised in May 2020. The study considers the three integrators' networks for a period from October 2019 to March 2021. In our study, a node represents a navigable city instead of an airport. The data are combined for cities with two airports such as Beijing and Shanghai.

The available freight tonnes (AFT) are applied to estimate and to compare air freight capacity between integrators and airports (Malighetti et al., 2019b; Bombelli, 2020; Bombelli, Santos & Tavasszy,2020). The AFT of a flight is equal to the maximum payload of the related operating freighter. In unit time frame, mostly weekly, the AFT is the flight frequencies within the period multiplied by a flight's AFT.

In their seasonal flight plans the integrators report the proposed aircraft type in the approved scheduled routes. On some routes there would be a change to another size of freighter according to the actual transportation volume. Usually, the listed type of aircraft on the schedule is the minimum size of the aircraft that the cargo airline can operate. We list aircraft types with the payload tonnes in Table 2.3, according to the technical specifications obtained from Boeing's website (Boeing, 2021). The cargo fleets of China's airlines for the domestic market are dominated by Boeing freighters.

Table 2.3: Cargo tonnage by aircraft type.

Freighter Type	**Payload (tonnes)**
B747-400F	112.00
B777F	102.00
B767-300F	52.48
B757-200F	35.00
B737-400F	20.50

Source: https://www.boeing.com/commercial/freighters/, accessed 22/03/2021.

2.4 China's integrators' freighter networks

Table 2.4 reports the indices showing the structure characteristics of each Chinese integrator network. SF Express has the biggest network with 125 routes, which is almost double the routes of China Post. It also has larger average degree, smaller average path and diameter. All these indices together reflect better connectivity compared to other domestic competitors. But SF Express' network has less cohesiveness than the one of China Post according to its lower clustering coefficient value. YTO Express' network is small in scale in regards of the numbers of nodes and edges. Therefore, it is not surprising that this network with the lower clustering coefficient has less cohesiveness than the other integrators.

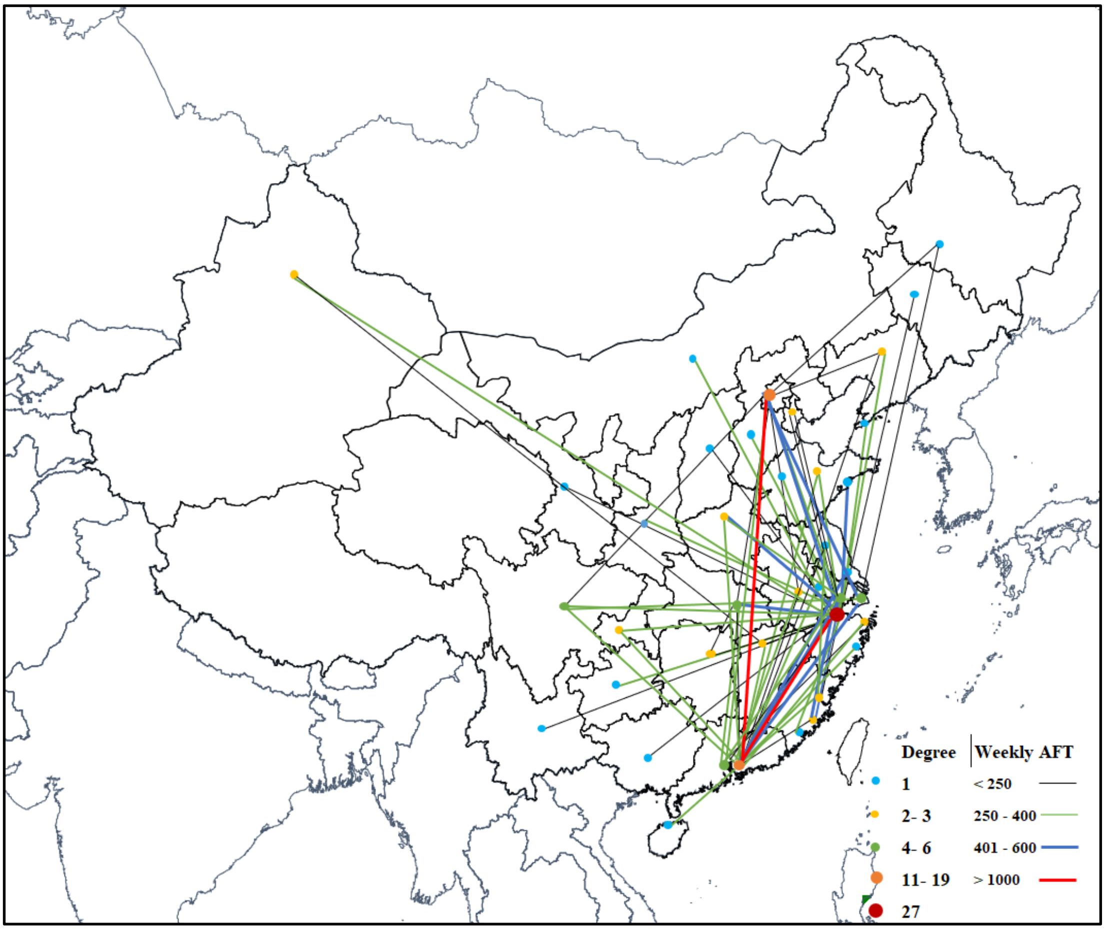
Table 2.4: Characteristics of integrators' network structures

Integrators	**No. nodes (n)**	**No. edges (m)**	**Average degree <*K*>**	**Average path length (L)**	**Diameter (D)**	**Clustering coefficient (C)**
SF Express	39	125	6.41	2.20	4	0.307
China Post	27	66	4.89	2.45	5	0.383
YTO Express	10	20	4	1.97	4	0.192

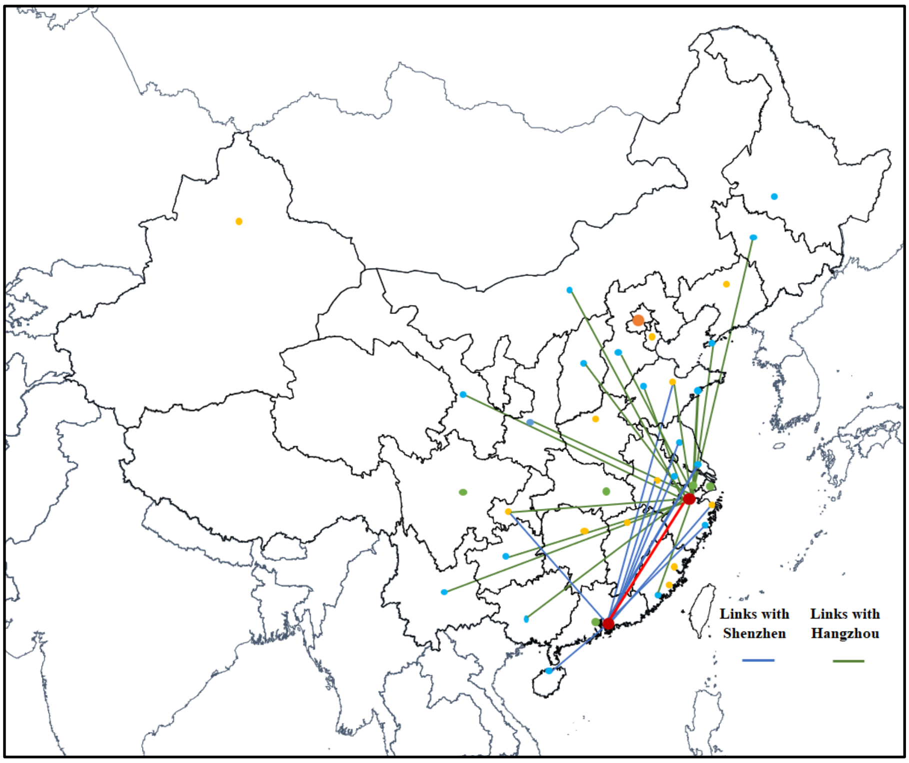
Figures 2.2–2.4 show the structure and size of the individual integrators through the number of connections to a city and the weekly AFT of a route of pair cities. The proportional colour circles represent different ranges of the connections (routes) number to a city in the figures. The wide colour lines correspond to the different scales of routes' weekly AFT. For visual clarity, lines representing edges are undirected. Therefore, the corresponding circles and lines in the figures represent the same scale of the connection number and weekly AFT to enable an easier comparison of the carriers.

Stable and massive express delivery and other air freight volume support SF Express' scheduled freighter network. At the end of 2020, for the sake of SF Express' premium delivery service, especially PDT business, 39 cities were covered in SF Express' network. Its network is based on a hub-and-spoke model to optimise the speed of delivery from any local area to all parts of the country (SF Airlines, 2017). In practice, with two main national hub airports in Hangzhou and Shenzhen, SF Airlines' network combines point-to-point and hub-and-spoke structures (Fig. 2.2). Most of its navigable cities connect with these two hubs: 17 cities have a sole connection with Hangzhou or Shenzhen, and four cities connect with both hubs. The two separate systems function independently, or they can work as one through the Hangzhou–Shenzhen route. As the two national hubs play the critical role in SF Airlines' network, the Hangzhou–Shenzhen route is shown in all the charts in Figure 2.2.

(a) The overall network



(b) Hub-and-spoke structure



(c) Point-to-point structure

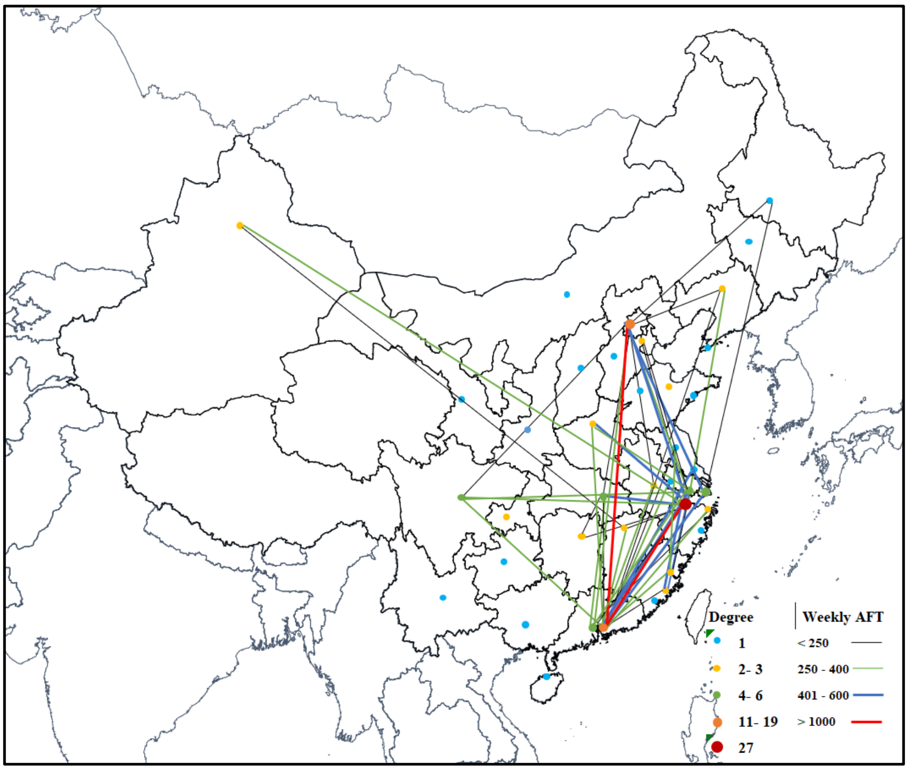


Figure 2.2: SF Express' Network.

The network of China Post has a similar feature to that of SF Airlines. Although most of its flights originate from and end at Nanjing, its main hub, this integrator also operates direct flights linking Beijing, Hangzhou and Guangzhou (Fig. 2.3). Circle routes are operated within the network, for example, Nanjing–Shenyang–Dalian–Weifang–Nanjing, Nanjing–Fuzhou–Xiamen–Nanjing and Nanjing–Fuzhou–Wenzhou–Xiamen–Nanjing. Some airports are in-transit airports between Nanjing and the far north and southwest cities. For example, Taiyuan, Nanchang and Changsha are intermediate airports connecting Hohhot, Nanning and Chongqing, respectively, in the network.

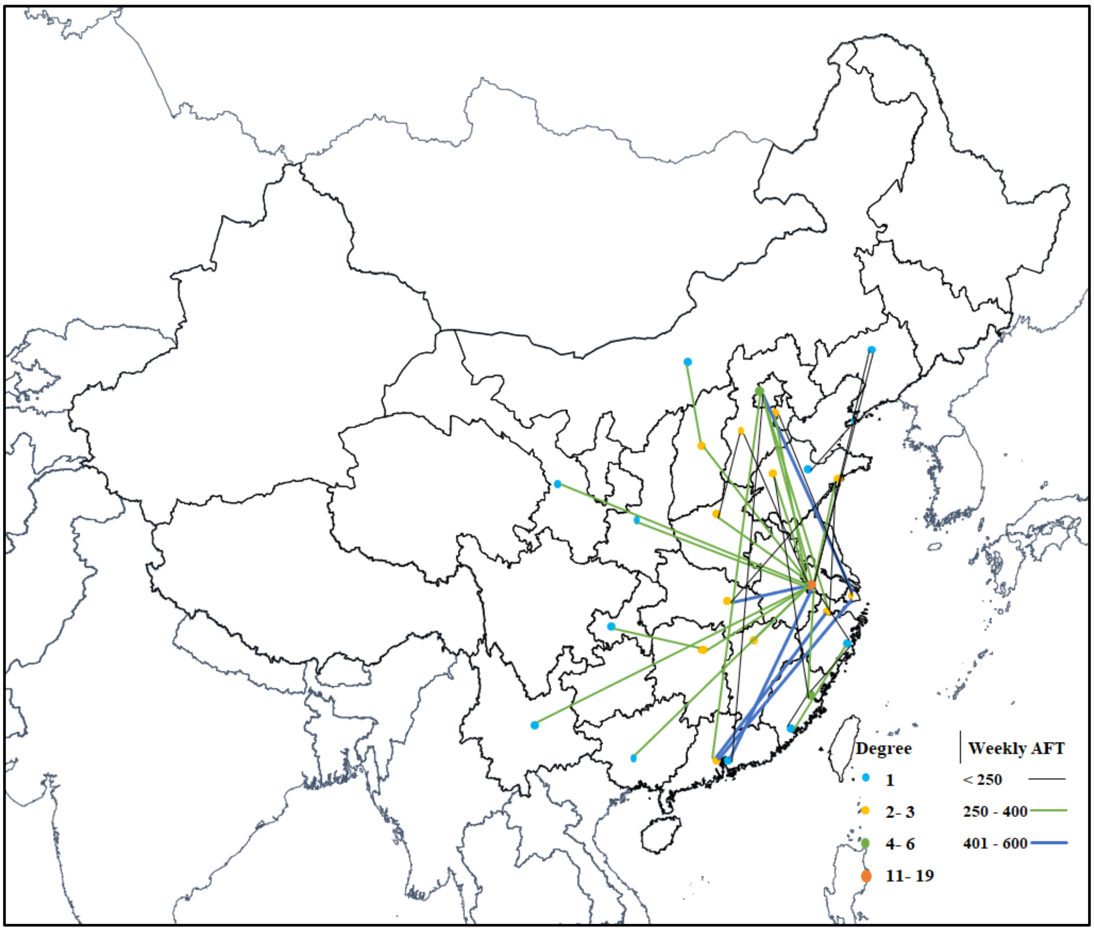


Figure 2.3: China Post's Network.

Although the network of YTO Express is small in scale, it covers the most economically developed areas in China. It operates with a basic functional structure that is less dependent on the mega-cities of Beijing, Shanghai and Guangzhou (Fig. 2.4). YTO Express' regular domestic flights service ten domestic destinations: provincial capitals, the economically developed coastal city of Wuxi and peripheral cities in central and western China such as Yulin in Shanxi Province. The network hierarchy has Hangzhou as a main hub and Xi'an, Shijiazhuang and Shenzhen as secondary regional hubs. Xi'an acts as an intermediate node to connect remote cities such as Yulin and Yinchuan accordingly. There are also connections between regional hubs such as Xi'an–Shijiazhuang and Shijiazhuang–Shenzhen. As an integrator, its coverage and capacity are insignificant.

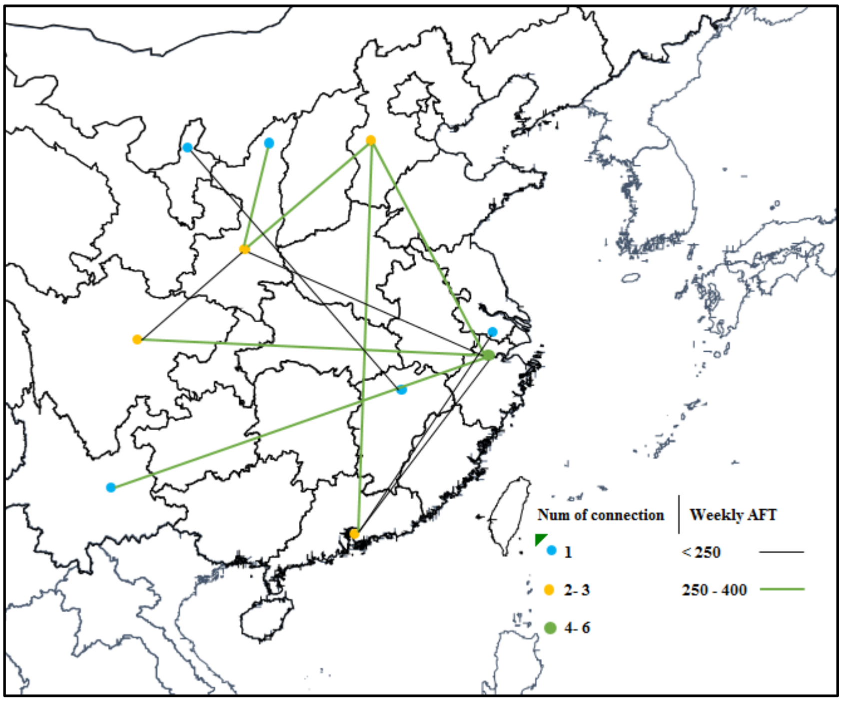


Figure 2.4: YTO Express' Network.

As the analysis above shows, to achieve national coverage Chinese integrators have developed routes between Beijing, Shanghai, Guangzhou, Chengdu and cities around them to cover the most economically developed areas of China. Few carriers developed flights to cities in the northeast, Xinjiang and Inner Mongolia. In the networks of SF Express and China Post, most cities in the peripheral areas or with lower cargo demand connect directly to their main national hubs rather than secondary regional ones. Based on their different strategies and backgrounds, small-scale carriers will focus on density areas rather than national coverage. Regional airports play crucial roles in those networks. The choice of nodes for small integrators depends on their development strategies and the level of cooperation with the local authorities.

2.5 Topological measures and changes during the COVID-19 pandemic

Examining the results of the topological measures in Table 2.5, we can see that the structures of the individual air express carriers in the Chinese domestic market underwent various adjustments during the pandemic. SF Express, China Post and YTO Express expanded their networks to more cities with significant route developments. Mainly operating in the private sector, SF Express increased the number of routes by 30% to 125, while YTO Express doubled the size of its network. SF Express expanded its air cargo network to Huai'an, Xiamen and Taiyuan. The connection to these cities with a similar degree and closeness value helped SF Express to enhance its network coverage. As a new airport in Beijing, Daxing, commenced operation, SF Express developed new routes to connect Beijing with Hefei and the hub cities of Shenzhen, Chengdu and Wuhan. These cities and new routes increased SF Express' connectivity in 2020. YTO Express developed routes to the peripheral nodes of Shijiazhuang, Kunming and Yulin and to Nanchang on the east coast. The new routes enhanced the hub function of Xi'an. The isolated Guangzhou–Tianjin route was removed. Consequently, all cities in its network are now connected in one graph, and connectivity is optimised. At the same time, China Post improved its network by adding one node and revising the route between Dalian and Qingdao.

Overall, the integrators have developed their networks significantly in the pandemic period. Private integrators have played the main role in driving the whole nation's scheduled freighter network optimisation. The index μ column in Table 2.5 suggests that SF Express operates the most developed networks in the country. The α ratios of SF Express and YTO Express increased. The γ values of YTO Express and China Post fell from 2019 to 2020 when the cohesiveness of these carriers decreased slightly. These developments reflect the situation whereby the integrators' networks are developing with nodes increasing faster than route developments, and so the density of the network becomes lower. According to the β column, SF Express maintains the best connectivity with the biggest network scale. With the lowest γ of 0.084, and considering the much larger scale of the network than other Chinese integrators, the network's density is still relatively scattered, and the level of centralisation is the highest.

In terms of weekly cargo AFT, all integrators enlarged their capacity in the first year after the pandemic outbreak. After network restructuring from remote cities in the southwest region to the central and east coast areas, with more routes operating in the 2020 winter/spring timetable, YTO Express doubled its weekly AFT to 5412 t. With support from air express volume, SF Express and China Post enhanced their weekly capacity by 28.4% and 3.1%, respectively.

Table 2.5: The network structure index by winter/spring schedules.

Airline	**Year**	***n***	***m***	**μ**	**α**	**γ**	**β**	**Weekly AFT**
SF Express	2019	36	96	13	0.194	0.076	2.667	30586
	2020	39	125	24	0.329	0.084	3.205	39278
China Post	2019	26	64	7	0.149	0.098	2.462	18245
	2020	27	66	7	0.143	0.094	2.444	18819
YTO Express	2019	8	10	0	0	0.357	1.25	2624
	2020	10	20	2	0.133	0.222	2.000	5412

2.6 Comparison with integrators in Europe

According to the World Bank (2020), in 2019 the European Union's gross domestic product reached USD15.626 trillion while mainland China's was USD14.28 trillion. These two markets have similar economic volumes and geographical areas. To understand the variations in network efficiency and capability between domestic and foreign carriers, we compare the topological indices and weekly AFT of carriers in these two markets. There are four dominating integrators – DHL, FedEx, TNT and UPS, in the European market (Malighetti et al., 2019b). In Table 2.6 Navigable cities (n), edges (m), 'one-way flights percentage' and 'Weekly AFT' of four foreign carriers in the European market are collected and calculated by Malighetti et al. (2019b) from one-week scheduled flights in 2015.

Table 2.6: Comparing Chinese carriers' domestic networks with four European counterparts.

Carriers	n	m	β	γ	One-way flights %[3]	Weekly AFT
DHL (in Europe)	87	265	3.05	0.035	48.0%	59590
FedEx (in Europe)	40	85	2.13	0.054	43.0%	26023
TNT (in Europe)	51	121	2.37	0.047	55.0%	13250
UPS (in Europe)	35	74	2.11	0.062	20.0%	32693
SF Express	39	125	3.21	0.084	9.0%	39278
China Post	27	66	2.44	0.094	30.8%	18819
YTO Express	10	20	2.00	0.222	18.2%	5412

[3] The percentage of one-way flights is the ratio of the number of the city pairs with a sole direction link to the number of all connected city pairs.

In regard to the navigable cities (n) and links (m) in Table 2.6, the four European carriers have significant network size and coverage. SF Express and China Post are the two leading carriers in the Chinese domestic market with good-sized national networks. Unlike the European carriers' oligopolistic market position (Malighetti et al., 2019b), the Chinese air freight industry has fierce competition from numerous highway freight companies. In terms of weekly AFT, with a massive cargo demand SF Express and China Post together have more than 60% of the market share in the scheduled air freighter flights. The other Chinese domestic carriers have small and fragmented portions only.

The β and γ indices can reflect the connectivity and centralisation of networks. In a network with a certain number of nodes, the maximal feasible number of links is determined. The higher the number of connections, the more paths are ready to connect nodes (Ducruet & Rodrigue, 2013). In this case, larger values of β and γ indicate better connectivity. Typically, however, airlines' networks with hub-and-spoke structures attribution illustrate low β index and γ index values. In contrast, networks with point-to-point systems in the main have a larger value of these indices. Thus, networks inclined to centralisation have lower values of these indices (Malighetti et al., 2019b). Chinese integrators' β and γ are much higher than those of FedEx and UPS, which have a similar number of nodes. These facts reflect the higher degree of centralisation among the European carriers as compared to the Chinese ones.

SF Express' network shows the largest β with 3.21 in Table 2.6. It reflects a better connectivity with more direct routes between city pairs. First, SF Express has a lower percentage of one-way flights. Most city pairs are connected with two direction links between them. Furthermore, SF Express with two national hubs has both hub-and-spoke and point-to-point structures. The result is a more complex and less centralised network. The values of the indices are according to the pattern shown in Figure 3. The complexity increased in 2020 when SF Express' network increased by only three nodes but with 29 edges. Most of the new links are between Beijing, Shanghai, Guangzhou, Wuhan and Chengdu, which are the country's regional aviation centres.

In terms of the β, compared with UPS and FedEx, China Post has a smaller number of nodes but a larger β. It suggests that China Post' network structure is similar to that of SF Express, a mix of hub-and-spoke and point-to-point features. The result is consistent with Figure 4. Beijing, Shanghai, Guangzhou and Hangzhou are connected and form the point-to-point pattern. They also serve as spoke cities with Nanjing being the main hub. However, in terms of one-way flight percentages, the value of China Post is between UPS and FedEx. Given that evidence, its network shown is more like a conventional integrator's air cargo network. To avoid empty backhauling in an uneven demand pattern, especially in the dedicated cargo networks of the air express freight industry, substantial proportions of flights run in one direction on round paths to make capacity utilisation more efficient (Malighetti et al., 2019b; Bombelli et al., 2020).

2.7 Discussion and conclusion

The analysis in this chapter has revealed the characteristics of the Chinese integrators' networks. These integrators were all looking to a national coverage, including YTO express whose network was still small in scale. There is certainly competition between the three integrators, but it appears that they have deliberately chosen the hubs and developed their networks in a way to avoid head-to-head competition. As a leading private express company with stable and massive express delivery volumes, SF Express has developed the largest scheduled freighter network with better connectivity among the three integrators to support its premium PDT commitment. SF Express operates two main national hubs in Hangzhou and Shenzhen, which host the headquarters of many e-commerce giant enterprises. This has enforced its dominant position in the booming online order delivery market. As a state-owned company, China Post relies on its EMS business more than the emerging online order delivery service. China Post has developed a hub-and-spoke structure with a national hub in Nanjing, a key city in the Yangtze Delta region, which gives it an enormous opportunity to grow its business. The thriving e-commerce market encouraged YTO Express to expand self-owned air cargo fleets and operate scheduled freighter flights. The carrier has adopted a low-price strategy with a strong commitment in delivery time (Wang & Xiao, 2015). Given its relatively small network, it has to use the services of trucks and belly-hold of passenger flights to complement its air express services. There is potential for YTO Express to use other integrators' service at this stage.

In the part of the comparison of Chinese integrators with their European counterparts in topological measures and AFT, in general, their network pattern reflects the companies' business strategies and focus. It is found that SF Express is the key player in the domestic market and formed its air cargo network different to other competitors. To support its national premium express delivery service, the carrier's network covers most of the cities, which currently are running schedule freighter flights, with the most being bidirectional routes. This characteristic in China of bidirectional routes contrasts with the situation in Europe where there is a high proportion of one-direction flights. The unique symmetric network pattern of SF Express shows that its cargo operation is distinct from the rest of its domestic and global competitors.

As discussed, the air freight operations often present 'big circle' or 'triangular' routes around a few destinations. This asymmetry is the result of imbalances in cargo demand (Zhang & Zhang, 2002; Bombelli, Santos & Tavasszy, 2020). Traffic imbalance is a big challenge in the air freight industry, and it can only be resolved through adjusting 'import/export imbalances' with the implementation of some long-term economic policies (Zhang & Zhang, 2002). The scheduled air freighter network of SF Express shows almost symmetry with a relatively small one-way flight percentage shown in Table 2.6. SF Express enjoys the most significant annual revenue with its primary growth coming from the e-commerce industry. Therefore, it appears that with the increase in consumption and the boom in e-commerce, when parts and goods are dispatched from manufacturing sites to consignees, air cargo demand imbalance challenges could be mitigated or overcome through filling the return flights with consumer products.

E-commerce, especially B2C, has been widely accepted and has changed public shopping behaviours, which in turn drives the development of China's air cargo industry. Without any visit to physical stores, shopping online breaks the space and time barriers and offers customers more convenient access to products (Wang & Xiao, 2015). With the help of e-commerce, choices of several categories of products such as electronics and even fresh food are not limited to local production. Relying on air cargo services for safe and speedy delivery, those products can be sold cross-province and even cross-border. As reported by SF Airlines (2019) in 2019, within the annual shopping festival 'Double 11', SF Airlines achieved an almost 30% year-on-year growth in freight volume, among which includes a large proportion of electronics products and fresh food products.

Unlike global competitors such as FedEx and UPS in the US, which developed and dominated their market share before the e-commerce era, Chinese freight express firms emerged and developed during the e-commerce boom from 2006 to 2013 when online commerce caused extraordinary growth in parcel delivery volumes (Wang & Xiao, 2015). SF Express is one of them and puts a lot of volume on its inhouse cargo airlines to support its PDT and fresh food delivery business. In the Chinese domestic market, air freight still depends highly on the belly capacity of passenger flights with which all-cargo flights face fierce competition. Only with adequate demand can the carriers develop dedicated cargo flight routes and networks (Gong et al., 2018). The operation of bidirectional routes may imply that the cargo demand and the flow of SF Express's scheduled all cargo flights have reached a good balance thanks to the boom in the e-commerce market.

In sum, the paper applies topological measures to analyse China's three integrators. Referring to carriers' business development strategies, the paper explains how the network patterns shaped the current main national hubs and the function of the chosen secondary or regional hubs. The Chinese integrators have undergone great development in their networks one year after the COVID-19 pandemic outbreak. Private integrators investment was the main force in driving the whole nation's scheduled freighter network optimisation. By comparing their network indices values with the ones of world-leading integrators in the European market, we see that the European carriers with their preponderance of hub-and-spoke structure have a higher degree of centralisation. In contrast, China's integrators have both hub-and-spoke and point-to-point structures, which make the network less centralised and more complex. We also found that SF Express' scheduled air freighter network, with its fewer one-way flights at a higher density, demonstrates different topological features from its counterparts in the Chinese domestic market and the European market. With massive delivery volume from e-commerce orders, the air cargo demand and flow of SF Express reach a good balance in the network. In the post Covid-19 outbreak period, the influence of e-commerce on air cargo would become more significant. Integrators are the main operators positioned to gain from the growth of e-commerce.

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CHAPTER 3 (PAPER 2) AN ANALYSIS OF THE CHINESE SCHEDULED FREIGHTER NETWORK DURING THE FIRST YEAR OF THE COVID-19 PANDEMIC

Abstract

COVID-19 caused the vast majority of passenger flights to be grounded, but the crisis raised the importance of the network of dedicated cargo flights and, therefore, interest in its development. This chapter aims to evaluate the Chinese scheduled freighter network (CSFN) via its topological properties and to explore its changes following the COVID-19 pandemic. Using spatial analysis with the complex network theory (CNT), the paper found that the CSFN displays small-world and scale-free network properties, similar to that of air passenger network. Hangzhou, Shenzhen and Nanjing are the dominant national hubs in the CSFN because they host the headquarters of many e-commerce giant enterprises and have relatively underutilized airport capacities. The CSFN has improved since the COVID-19 pandemic, with increased network average degree, clustering coefficient, and closeness, and reduced average path. These improvements were mainly driven by major hub cities whose centralities had been strengthened with more route connections. Since China's air passenger traffic had quickly restored in the second half of 2020, we argue that the changes in the CSFN during COVID-19 were unlikely to be a result of the substitution effect between freighter and passenger aircraft. It was more likely a result of the higher air cargo demand during the pandemic and airlines' realisation of the importance of freighter operations in China.

Keywords: Freighter network, China, COVID-19, Complex network theory, Cargo carriers

3.1 Introduction

The development of China's air freight market commenced a few decades ago in conjunction with the country's rapid economic growth. This increase is attributed to the development of global manufacturing supply chains, especially after China's entry into the World Trade Organisation (WTO) in November 2001 (Hui, Hui & Zhang, 2004). In recent years China has become the largest e-commerce market, selling US$1.5 trillion worth of goods in 2019 (Boeing, 2020). Shopping online became the primary driver for China's air cargo volume and revenue. From 2012 to 2017 the increase in the number of parcels and turnover was 48% and 33%, respectively (Boeing, 2018). According to Boeing's World Air Cargo Forecast (Boeing, 2020), as a key participant in this market, China is expected to have the fastest growing regional air cargo market with an expected average 4.3% annual growth in the coming 20 years by 2039.

The years of rapid economic growth created a severe imbalance in regional development: more than 70% of the air cargo and mail volume is still concentrated in the eastern part of the country (CAAC, 2020c). However, recent increases in labour costs in the eastern coastal area and foreign capital investment moving to inland China, with support from the Chinese government, have accelerated the infrastructure development of the air freight industry and network in inland cities such as Zhengzhou (Walcott & Fan, 2017). Also, Chinese cargo airlines lack dedicated freighter aircraft whereas in the USA, for example, UPS and FedEx operate more than 1000 dedicated freighter aircraft (Fang, Wang & Gao, 2009). Therefore, Chinese airlines rely on passenger aircraft carrying cargo in their 'belly' compartment (the cargo hold).

While a large amount of the domestic air cargo is transported via the belly capacity in passenger flights, the geographic pattern of the cargo network depends on the nature of aircraft and the passenger flight timetable (Jiang, Ren & Hansman, 2003). The top 20 mail and cargo airports are almost the same as the top 20 passenger airports. The air corridors linking the three main international gateway airports – Beijing, Shanghai and

Guangzhou – contain the largest market share with more than 40% of the total cargo and mail traffic. The unbalanced air route network and the intensive traffic in the east coast means the 'golden triangle' of air routes connecting these three mega-cities is almost saturated, with the main airports in this area nearing maximum capacity (Zhang & Zhang, 2016; Ma, Wang, Yang, Zhang & Zhang, 2019).

In early 2020 the vast majority of passenger flights were grounded as a possible measure to control COVID-19 spreading (Zhang, Zhang & Wang, 2020; Tisdall, Zhang & Zhang, 2021). This resulted in a significant shrinkage of the overall cargo capacity initially because of the reliance on the carrying capacity of passenger flights. The COVID-19 pandemic reinforced the desperate need for specialised freight aircraft and airport infrastructure to increase air cargo capacity (Li, 2020a). Amid the crisis the authorities recognised a deficiency in emergency logistics caused by an inadequate dedicated air cargo transport system with restricted services such as a scarcity of specialised cargo airports and the absence of very large logistics companies with international standardisation. The virus outbreak exposed the crucial role of logistics in tackling public health emergencies (Wang, Ou & Shi, 2020). A seamless air cargo service is critical for fulfilling the prompt delivery of supplies when reacting rapidly to public health events (MERICS, 2020). The obstacles in air cargo capacity should be removed (Li, 2020b).

Therefore, how the air cargo industry meets the e-commerce boom and responds quickly to public health hazards has received extensive attention from Chinese authorities. In August 2020 the National Development and Reform Commission and the Civil Aviation Administration of China (CAAC) issued a memorandum with opinions on how to develop China's air cargo transport facilities. The memorandum pointed out that cargo airlines should expand their fleets and develop dedicated aircraft transport. Specifically, it gave explicit directions on developing specialised air cargo enterprises. It encouraged the current air freight operators, which are broadly speaking state-owned passenger airlines' subsidiaries or their cargo business division, to establish dedicated cargo airlines by breaking state ownership restrictions and attracting more investment from the private sector. Private logistics companies were welcome to build their cargo capacity with in-house fleets and lead the planning, construction and operation of professional cargo hub airports. With large express logistics enterprises as the main body, Chinese cargo airlines were expected to be the primary entity to construct and operate the air freight network.

Despite the recognised significance of dedicated air cargo capacity in the foreseeable future growth of China's air transport industry, the literature on Chinese cargo airlines and their network is scarce when compared with that for all-passenger airlines in China. The collapse of the air passenger network in the initial stage of the COVID-19 pandemic implies an insufficient cargo capacity and thus a disruption in the just-in-time global supply chains. With the high demand for medical and essential items, and the encouragement of government policies, operating dedicated cargo flights has been a significant source of revenue for many airlines and saved them from bankruptcy. China's air freight sector has been developing very fast in the last two decades and the pandemic provides it with another growth opportunity. However, little attention has been paid to China's air freighter operators and their network development. This research aims to address this topic and fill the literature gap. Specifically, first, this chapter will review the development of the dedicated cargo carriers in China. Second, we will conduct a spatial analysis using the complex network theory (CNT) to examine their network properties before and after the outbreak of the pandemic. Third, this study will identify the significant nodes and assess the performance of the CSFN during the pandemic period. This chapter has seven sections. Section 1 introduces the study. The literature on dedicated air freight services and their networks is reviewed in Section 2. The background of Chinese cargo airlines is given in Section 3. Section 4 introduces the methodology and the data collection procedure. An overview of the current status of the CSFN is presented in section 5. Section 6 examines the changes in key indicators of the CSFN during the pandemic period. Section 7 concludes.

3.2 Literature Review

The belly compartment's capacity in combination with passenger services was the initial entrant in the air cargo market, with air freight providing an income supplement (Van Asch et al., 2020). In the latter half of the twentieth century dedicated freight-only airlines and specialist air freighter services began to emerge (Van Asch et al., 2020; Budd & Ison, 2017). Even though both types of traffic require identical airport-to-airport transport services, they operate in different modes in terms of cost structures, management features and spatial supply-demand patterns (Budd & Ison, 2017). Fundamentally, the requirements for human beings and cargo being transported on board are different. Zhang and Zhang (2002) compared the different characteristics of air cargo and passenger services. First, the preference for flight take-off time and route choice (to travel directly or to pass through two or more airports) is distinctive and not harmonious. Second, travellers commute between two destinations, while shippers often pass cargos to others. Finally, manufacturing and logistics centres can be located in sparsely populated areas, not locations that will attract tourism traffic. These factors influence dedicated air freight services and give them distinct characteristics from that of the passenger flights with belly cargo which generally considers passenger customers ahead of freight requirements (Scholz & Cossel, 2011; Lange, 2019).

The network patterns of passenger flights are different to those of dedicated air freight services (Zhang & Zhang, 2002; Scholz & Cossel, 2011). The dedicated cargo operations often show "big circle" routes connecting a few destinations, while passenger carriers often utilise hub and spoke services (Zhang & Zhang, 2002). Since cargo traffic has a unique routing pattern and different requirements to passenger traffic, the flight schedules and routes of passenger services are not suited to cargo operations. Moreover, Lange (2019) found an increasing risk of departure delays because of the more complicated operation when handling passengers and cargo at the one time. As a result, passenger flights need to consider how the volume of cargo being shipped impacts on passenger service quality. In contrast, dedicated cargo airlines fly aircraft to airports with networks and schedules that suit air freight requests (Merkert et al., 2017). Hence, dedicated cargo carriers provide better control of take-off and landing time, shipping amounts and journey, utilisation of specialised cargo airports and the disposition of hazardous and outsized shipments that cannot be loaded on passenger aircraft. These advantages are favourable for shippers and cargo airlines (Budd & Ison, 2017; Van Asch et al., 2020).

Despite this essential role for dedicated air cargo carriers in the air freight services sector, the academic literature on dedicated cargo airline scheduled networks is scarce. In studies about the passenger business, air cargo sometimes exists simply as a counterpart or auxiliary service (Zhang & Zhang, 2002; Zhang, Hui & Leung, 2004; Hong & Zhang, 2010). The literature focuses on the choice of airport and the network centrality of individual carriers (Gardiner et al., 2005; Gardiner & Ison, 2008; Scholz & Cossel, 2011; Kupfer et al., 2016), rather than evaluating the whole network with comprehensive topological indices to reflect the overall structure. Some studies have evaluated the air cargo network containing combined and dedicated cargo routes together (Scholz & Cossel, 2011; Bombelli, Santos & Tavasszy, 2020), while Boonekamp and Burghouwt (2017) apply a connectivity model to analyse the networks of seven European airports with the main cargo volume shipped in the region. Lin and Chen (2003) investigated mainland China's air cargo network, but their study focused on the air cargo flows to and from China's gateway airports, with no mentioning of the air cargo network in the domestic market.

Some studies have provided a network analysis of global and regional air cargo markets using an international cargo traffic dataset (Bombelli, Santos & Tavasszy, 2020; Malighetti et al., 2019b; Bowen, 2012). The all-cargo service network literature primarily focuses on global logistics companies, the US and the international trade market (Bowen, 2012; Malighetti et al., 2019a). Malighetti et al. (2019a). Bowen (2012) pointed out the important roles of Chinese airports as the main hubs in Asia for global logistics companies. However, no reference is made to the air freight network patterns of the dedicated cargo carriers in China. Therefore, it is worth taking a closer look at Chinese cargo carriers and the trend of their development in the world's biggest e-commerce and consumption market.

3.3 Dedicated air freight services in China

At the end of 2020 there were nine carriers operating scheduled dedicated air cargo flights in China. Table 3.1 shows general information about these cargo carriers, including the size of their own fleet (all carriers are using Boeing aircraft), ownership and hub airports. The scheduled freighter networks they have built are the focus of this chapter.

Table 3.1: The Chinese carriers operating with a local freighter timetable in 2020.[4]

Carriers	**CAAC approval (year)**	**Freighter Fleet**	**Ownership**	**Hub**
China Postal Airlines	1996	28 (B737F, B757F)	China Post Group Corporation	Nanjing
Suparna Airlines	2002	14(B737F, B747F)	Hainan Airlines	Shanghai Pudong
Air China Cargo	2003	15(B747F, B777F, B757f)	China National Aviation Holding, Cathay Pacific	Beijing Capital, Shanghai Pudong, Guangzhou
SF Airlines	2009	61 (B737F, B747F, B757F, B767F)	SF Express	ShenZhen, HangZhou

[4] Related information was updated to the end of 2020 from CAAC reports, the latest financial reports and company publications.

Loong Air	2012	3 (B737F)	Zhejiang Loong Airlines	HangZhou
YTO Cargo Airlines	2015	10 (B737F, B757F)	YTO Express	HangZhou
Longhao Airlines	2016	6 (B737F)	Henan Civil Aviation Development and Investment	Zhengzhou, Guangzhou
Tianjin Air Cargo	2018	4 (B737F)	Hainan Airlines	Tianjin
Central Airlines	2020	3 (B737F)	Central Airlines	Zhengzhou

The International Air Transportation Association (IATA) considers e-commerce growth to be one of the primary drivers of air cargo industry developments (IATA, 2018). China Postal Airlines, SF Airlines and YTO Cargo Airlines are the cargo-only carriers of three local logistics companies, respectively: China Post Group, SF Express and YTO Express. Founded in 1996, China Postal Airlines is wholly state-owned. SF Airlines and YTO Cargo Airlines are owned by private investors.

According to the State Post Bureau (2020), in 2019 China's express delivery volume[5] reached 63.52 billion orders and the total industry revenue reached RMB749.78 billion (approximate US$110 billion). The sub-total market share of delivery orders of the top six express logistics companies, which are all listed private sector firms, reached 80.37%. Only two of them, SF Express and YTO Express, operate self-owned air cargo fleets and scheduled flights within these top six express logistics companies. SF Express is a leading logistics company in China with an annual revenue of RMB112.19 billion (approximate US$16.74 billion) for 2019, which was far higher than other top players,

[5] The express delivery volume is measured by the number of letters and parcels delivered with the fastest form of shipping and delivery.

while YTO Express's annual revenue was RMB31.15 billion (approximate US$4.65 billion) (Fig. 3.1).

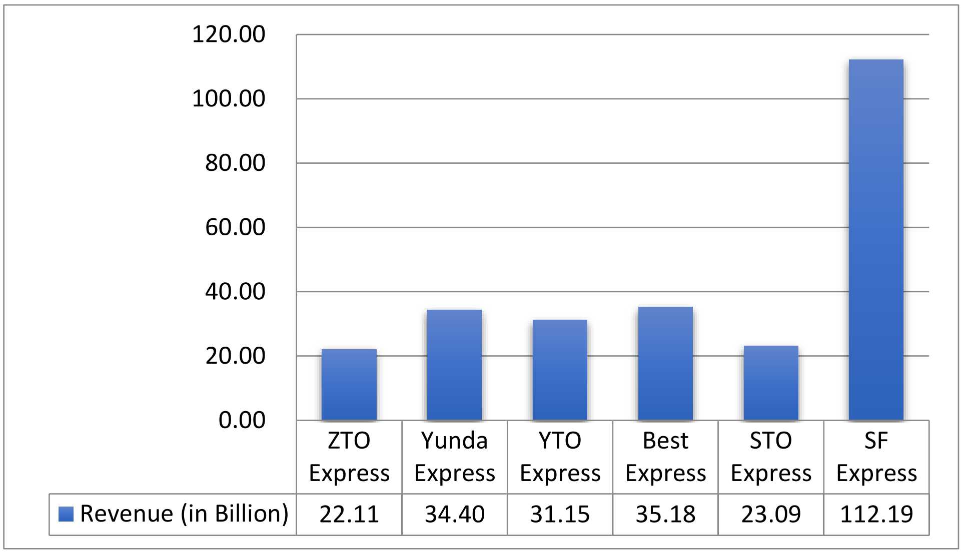

Figure 3.1: The top six express logistics companies by revenue, 2019. (Source: State Post Bureau, 2020)

Air China Cargo was established in March 2003 by Air China based in Beijing Capital International Airport. By the end of 2020, Air China Cargo's freighter fleet comprises three B747-400s, eight B777Fs and four 757-200SFs. The wide-body aircraft are mainly deployed in the international market. In 2010 Air China Cargo became a joint venture between Air China and Cathay Pacific Airways. Currently China National Aviation Holding owns 45% of its shares with Cathay Pacific Cargo and Langxing being the second and third largest stake holders, respectively.

Suparna Airlines and Tianjin Air Cargo are both majority-owned by the Hainan Airlines Group. It was formerly known as Yangtze River Airlines, which had developed from Yangtze River Express which was founded as a cargo-only airline in January 2003. The airline was rebranded as Suparna Airlines on 7 July 2017. Yangtze River Express had offered a dedicated air cargo service to SF Express, FedEx and UPS in the Chinese domestic market. From 2003 and before SF Express set up its own aircraft fleet in 2009, Yangtze River Express was the contractor used by SF Express to make it the first private parcel express company using dedicated cargo flights in China. In 2010 Yangtze River Express operated three B737s for FedEx at Hangzhou Xiaoshan International Airport, while UPS worked with the airline to build a hub for its domestic express services network at Pudong International Airport in Shanghai (Bowen, 2012). Using Pudong as its hub, Suparna Airlines' dedicated air cargo network now covers the main corridors of Shanghai–Beijing–Tianjin and Shanghai–Guangzhou on the east coast.

Tianjin Air Cargo launched its maiden flight in 2018. The airline was founded in 2016 as a joint venture between the Tianjin municipal government and Hainan Airlines. The carrier chose Tianjin as its only hub with an expectation of taking advantage of its proximity to the capital city Beijing. Using Tianjin Air Cargo, the Tianjin municipal government intended to develop an air cargo hub in north China at Tianjin International Airport to alleviate congestion at Beijing Capital International Airport. However, it is operating at a small scale compared with the competing full-freighter airlines. The network is not yet formed, with the only regular domestic all-cargo flights being on the Zhengzhou–Nanchang and Tianjin–Weihai routes.

Recently, as the result of increasing labour costs in the eastern part in China, some foreign capital investment moved to inland China (Walcott & Fan, 2017). An experimental Zhengzhou Airport Economic Zone was created, with a purpose to develop a logistics-based economy in the capital of Henan Province. The Henan local authority is enthusiastic about introducing air freight services, and to base dedicated cargo carriers at Zhengzhou Xinzheng International Airport. The airport, which is also the hub of Cargolux in China, is now the base for two cargo airlines – Longhao Airlines and Central Airlines – serving the domestic market.

Longhao Airlines is a private and dedicated cargo carrier which has been expanding rapidly. In 2015 it was founded by the Longhao Group which is based in Guangdong Province. The Longhao Group transferred its majority stake in the airline to Henan Civil Aviation Development and Investment Company Ltd in May 2019. The airline's full company name was then changed from Guangdong Longhao Airlines to China Central Longhao Airlines. It plans to build up a double hub system including Zhengzhou and Guangzhou Airports. In 2020 the airline aggressively doubled its network of cities by opening five new domestic destinations. Except for Shenzhen, Guangzhou, Lianyungang and Quanzhou, all of its destinations are provincial and regional cities in the middle of China.

Central Airlines is the first dedicated cargo carrier in Henan Province. Its main operating base is Zhengzhou Xinzheng International Airport. Formerly known as Zhongzhou Airlines, the airline is majority-owned by a local freight agent, Henan Zhongzhou Tengfei International Freight Forwarding Co. Ltd. The joint venture was founded in 2016 but only started air freight operations in May 2020. It managed to put all three aircraft into operation within six months of its first flight. Operating its own fleet of three B737-300Fs, the carrier maintains a scheduled all-cargo flight network covering seven cities and seven city-pair routes.

Founded in 2011, Loong Air, like Suparna Airlines, is a local carrier operating scheduled passenger and cargo services. Previously known as CDI Cargo Airlines, the airline launched scheduled passenger flights in December 2013 with narrow-body aircraft, Airbus's A320s. Loong Air is based in Hangzhou, the capital city of Zhejiang Province in eastern China. Taking advantage of Hangzhou's position as the headquarters of an e-commerce giant and an important national logistics hub in the Yangtze River delta area, Loong Air focuses on the potential volume of cargo in the province. Loong Air has not increased its all-cargo fleet of three freighters in recent years, but its passenger fleet continues to proliferate. Compared with its aggressive cargo competitors, it may no longer consider all-cargo flights to be its core business.

3.4 Methodology and Data Collection

3.4.1 Complex network theory (CNT)

To understand Chinese domestic freighter network structure and the impact of COVID-19, we adopt the CNT approach and compare the results before and after the COVID-19 pandemic. The CNT has been widely applied to analyse a country's overall air passenger network (Wang et al., 2011; Hossain & Alam, 2017) and an individual airline's network to understand the strategy and competitiveness of the airlines (Jiao & Wang, 2014; Jiang et al., 2017; Wu et al., 2020). A recent paper by Bombelli, Santos and Tavasszy (2020) used the CNT to evaluate a worldwide air cargo network.

This chapter uses centrality measures – degree, closeness and betweenness – to evaluate the role that hubs and spoke cities play within the networks. It also applies the structure measures to analyse the networks through indices, including degree distribution, the average path length and the clustering coefficient. We list all these variables and the indices used to analyse the networks in Table 3.2.

Table 3.2: List of network indices.

Index	Description
k_i	degree of node *i*
$\langle k \rangle$	average degree of the network
$p(k)$	degree distribution
d_{ij}	shortest distance between nodes *i* to *j*
D	diameter of a network; the longest shortest path in the graph
L	average shortest path length or characteristic path length
C_i	clustering coefficient of node *i*
C	clustering coefficient of the network
$C_C(i)$	closeness centrality of node *i*
$C_B(i)$	betweenness centrality of node *i*

$C_B^w(i)$	weighted betweenness centrality of node i
$\overline{K(k)}$	average degree of all k-degree nodes' neighbours
$C(k)$	average clustering coefficient of all k-degree nodes

3.4.2 Data collection

The data were collected from the CAAC in 2020 (CAAC, 2020b). Normally, the CAAC issues two seasonal flight plans a year – the summer timetable (effective from late March to late October) and the winter timetable (effective from late October to late March of the next year) (Wu et. al., 2020). The flight plan separates passengers and all-cargo flights. Due to the COVID-19 outbreak, the summer timetable was reviewed in May 2020. The study area includes cities in mainland China (excluding Hong Kong, Macao and Taiwan) with airports operating scheduled all-cargo flights from 28 October 2019 to 29 March 2021. The routes in the network are operated by the dedicated cargo carriers discussed previously and listed in Table 3.1.

A node in this study represents a city rather than an airport. Most cities in the data set have a single airport. For mega-cities like Beijing and Shanghai which have more than one airport, the data from the same cities are combined. The data were only obtained for regular all-cargo flights. Passenger and charter flights are not included.

3.5 An overview of the Chinese scheduled freighter network (CSFN) in 2020

3.5.1 The CSFN in 2020

Unlike other countries' cargo networks reported in the literature where a cargo flight tends to have multiple destinations, and may or may not return to its departure airport, it is found that about 90% of the city-pair routes in China are operated by return cargo flights. Therefore, to assess the network structure of the CSFN, we simplify it as a connected vertices and undirected lines graph $G = (V, E)$, where $V = v_i : i = 1,2, \dots, n; n = |V|$ is the number of nodes (navigable cities) and $E = e_i$: $i = 1,2, \dots, m$, $m = |E|$ the number of edges (routes). The network is described as a connectivity (adjacency) symmetric matrix $A_{n \times n}$, where an element $a_{ij} = 1$ if a flight route exists between node i and j, otherwise $a_{ij} = 0$. When $a_{ij} = 1$, connected two nodes are considered as neighbours. The CSFN is composed of 45 cities and 132 unique air routes as at the end of 2020 (Fig. 3.2). Table A1 in the appendix lists the cities in the CSFN in the 2019 winter and the 2020 winter schedules, respectively, with indices including degree (*k*), clustering coefficient (*C*), closeness and betweenness.

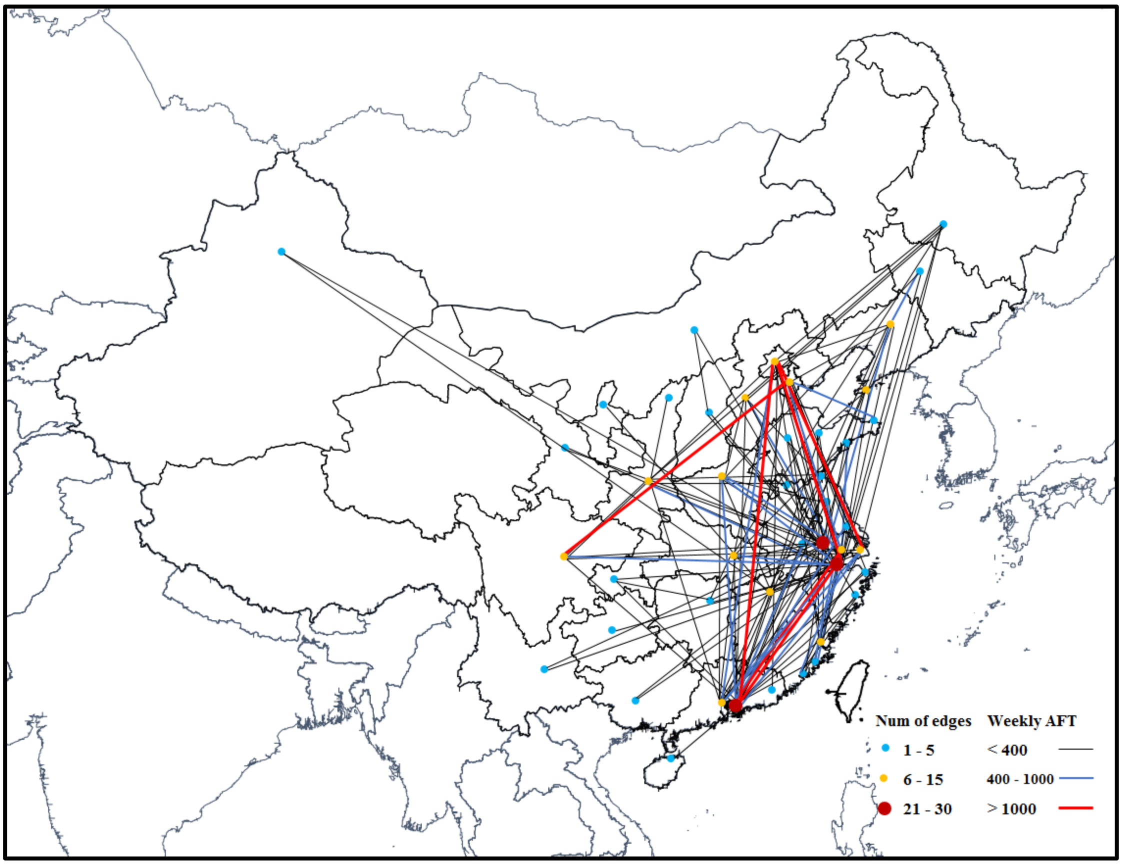

Figure 3.2: The Chinese scheduled freighter network and capacity measured by available freight tonnes (AFT) in 2020 winter

3.5.2 Centrality measures

This subsection is dedicated to the analysis of the centrality of different cities in the CSFN, measured by the closeness and betweenness indices using the 2020 winter data. Such centrality measures illustrate the importance of each city (i.e, node) in the network. The degree is also a useful measurement of the node's centrality and is thus discussed in this subsection for different cities. The indices of the top 20 cities in the 2020 winter are listed in Table 3.3. The top three positions in each of the centrality measurements are filled by the cities with national level freighter airline hubs in the CSFN. Hangzhou with its Xiaoshan International Airport is in first place on all indicators, followed by Shenzhen/Bao'an and Nanjing/Lukou. Guangzhou, Beijing and Tianjin can be classified as regional level freighter hubs in the CSFN, ranking in the 4th to 7th places. Interestingly, China's gateways cities, Beijing, Shanghai and Guangzhou are not the top-ranking cities in the CSFN, although these cities are the top three air passenger markets in China. This suggests that the country's freighter network does not necessarily align well with its air passenger network. In addition, Hangzhou and Shenzhen are the headquarters of China's internet and e-commerce giant enterprises, Alibaba and Tencent, respectively, which obviously influences the outcome here.

Eastern and southern cities play key roles in the CSFN. Beijing and Tianjin are important regional hubs in the north, while Wuhan and Zhengzhou are ones in the central region. Like the passenger-oriented network, the CSFN relies on the east coast area. Other outstanding cities are Chengdu, Shijiazhuang, Fuzhou and Nanchang. Chengdu is the core city in the west. Shijiazhuang is the important node after Beijing and Tianjin in the Jing-Jin-Ji Metropolitan Region, which is also known as the Beijing-Tianjin-Hebei Economic Zone. Zhengzhou in central China has been developing rapidly in recent years (Walcott & Fan, 2017). Interestingly, according to the 2020 winter timetable Nanchang has good degree and betweenness with connections to the main hubs in China such as Hangzhou, Shenzhen, Shanghai and Zhengzhou, and to key international hubs such as Hong Kong, Liege, Anchorage, Osaka and Moscow.

Clearly, the ranks for degree, closeness and betweenness are similar in the top 20 cities: fifteen cities appear repeatedly in all three centrality assessments. Providing more insight, the cities' rankings on betweenness can be far less than their performances on degree and closeness (Wang et al., 2011). Cities with higher values of degree and closeness tend to have better connectivity in the network with relatively more scheduled dedicated cargo flights and more convenient access with shorter paths. However, some cities with fewer connections can act as important transit nodes. For example, Xi'an and Nanchang rank fourth and seventh for betweenness, respectively, but they have much lower ranks for degree or closeness. These two cities are both connected with important hubs, such as Nanjing and Hangzhou. They play roles as "bridge" airports, which Bombelli, Santos & Tavasszy (2020) defined as connecting two or more hub-and-spoke sub-structures in the whole network.

Table 3.3: The top 20 cities/airports in China by degree, closeness and betweenness.

Rank	Degree	Closeness	Betweenness
1	Hangzhou/Xiaoshan	Hangzhou/Xiaoshan	Hangzhou/Xiaoshan
2	Nanjing/Lukou	Nanjing/Lukou	Shenzhen/Bao'an
3	Shenzhen/Bao'an	Shenzhen/Bao'an	Nanjing/Lukou
4	Beijing/Capital+Daxing	Beijing/Capital+Daxing	Xi'an/Xianyang
5	Guangzhou/Baiyun	Guangzhou/Baiyun	Beijing/Capital+Daxing
6	Tianjin/Binhai	Chengdu/Shuangliu	Tianjin/Binhai
7	Zhengzhou/Xinzheng	Tianjin/Binhai	Nanchang/Changbei
8	Wuhan/Tianhe	Zhengzhou/Xinzheng	Guangzhou/Baiyun
9	Shanghai/Pudong	Wuhan/Tianhe	Shijiazhuang/Zhengding
10	Nanchang/Changbei	Shijiazhuang/Zhengding	Zhengzhou/Xinzheng
11	Xi'an/Xianyang	Nanchang/Changbei	Shanghai/Pudong
12	Chengdu/Shuangliu	Shenyang/Taoxian	Wuhan/Tianhe
13	Shijiazhuang/Zhengding	Xi'an/Xianyang	Fuzhou/Changle

14	Shenyang/Taoxian	Fuzhou/Changle	Chengdu/Shuangliu
15	Fuzhou/Changle	Dalian/Zhoushuizi	Quanzhou/Jinjiang
16	Dalian/Zhoushuizi	Shanghai/Pudong	Wuxi/Shuofang
17	Wuxi/Shuofang	Quanzhou/Jinjiang	Shenyang/Taoxian
18	Harbin/Taiping	Weifang/Weifang	Xiamen/Gaoqi
19	Xiamen/Gaoqi	Chongqing/Jiangbei	Harbin/Taiping
20	Quanzhou/Jinjiang	Harbin/Taiping	Dalian/Zhoushuizi

Overall, cities along the east coast and in the central area have the best connectivity in the CSFN with higher degree and closeness (Fig. 3.3). In terms of betweenness, with the fourth highest value, Xi'an serves as an important transfer hub for north western and inland cities. In terms of degree and closeness, cities in peripheral areas such as Guiyang, Haikou, Weihai, Yinchuan, Xuzhou, Yulin and Jieyang have only one degree, and one freight flight to hub cities. Almost all these cities have the lowest value of accessibility. Several stopovers are needed before a shipment arrives at its destination in the network. Given the single contact with one hub city, their betweenness value is zero, which implies that they are not in the middle of the shortest paths between any city-pairs.

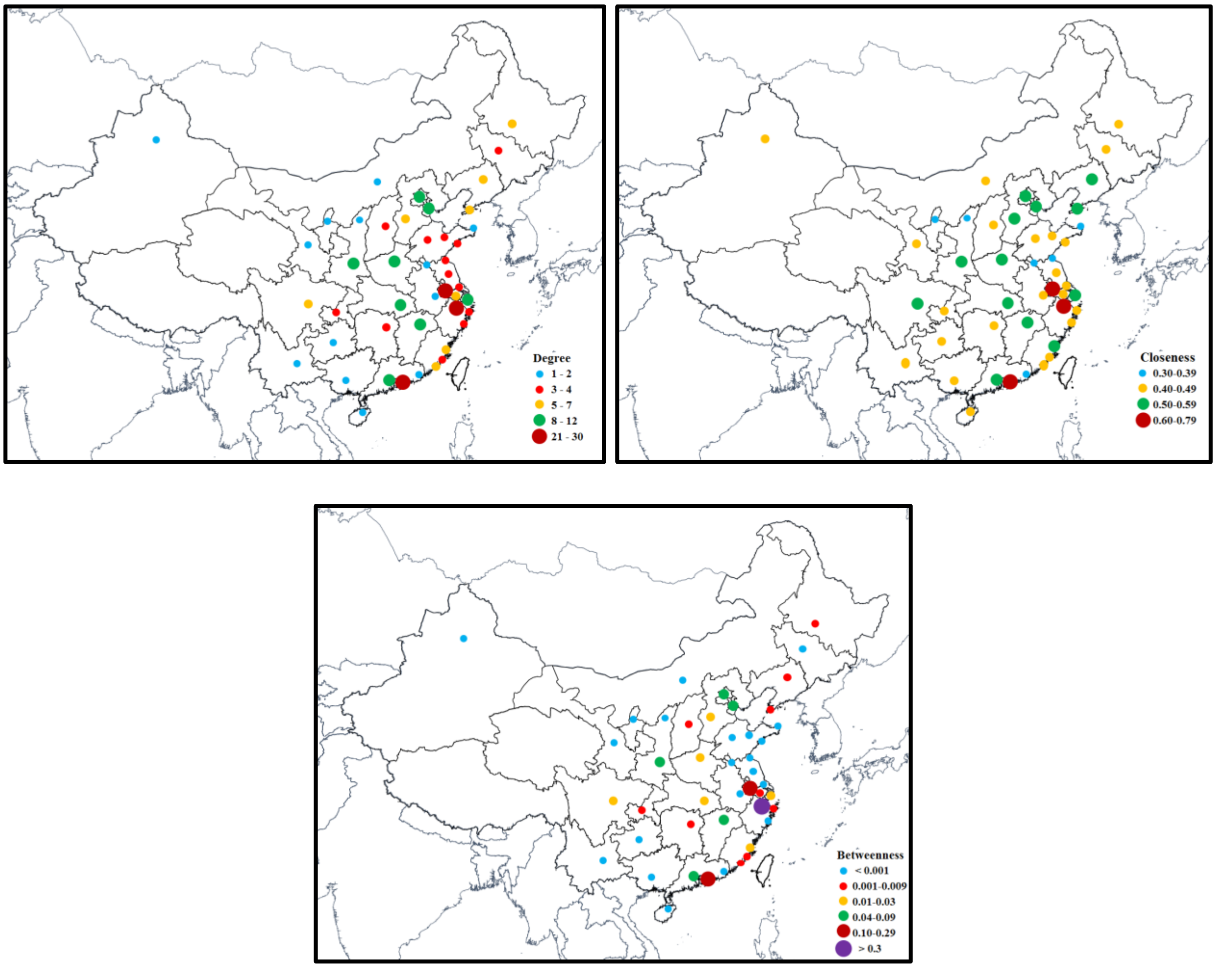

Figure 3.3: Spatial distributions of degree, closeness and betweenness in the CSFN.

So far, our betweenness measure treats the edges equally as long as there are direct freighter flights operating on it. This ignores the capacity of each route, which may not capture the differences in importance between routes. Thus, we can weight each edge in the network by its freight capacity to differentiate their importance for the nodes and the entire network. Following Opsahl, Agneessens and Skvoretz (2010) and Bombelli, Santos and Tavasszy (2020), the weighted betweenness is calculated with a consideration of the number of weekly cargo flights. The weighted and the unweighted betweenness are compared in Table 3.4.

Table 3.4: Unweighted and weighted betweenness centrality

Rank	Unweighted network		Weighted network	
	Node	C_B	Node	$C_B^w(i)$
1	Hangzhou/Xiaoshan	0.374	Hangzhou/Xiaoshan	0.615
2	Shenzhen/Bao'an	0.211	Shenzhen/Bao'an	0.430
3	Nanjing/Lukou	0.176	Nanjing/Lukou	0.095
4	Xi'an/Xianyang	0.099	Xi'an/Xianyang	0.090
5	Beijing/Capital+Daxing	0.069	Wuxi/Shuofang	0.087
6	Tianjin/Binhai	0.066	Beijing/Capital+Daxing	0.086
7	Nanchang/Changbei	0.059	Nanchang/Changbei	0.047
8	Guangzhou/Baiyun	0.046	Tianjin/Binhai	0.046
9	Shijiazhuang/Zhengding	0.022	Guangzhou/Baiyun	0.041
10	Zhengzhou/Xinzheng	0.020	Shanghai/Pudong	0.004
11	Shanghai/Pudong	0.016	Shijiazhuang/Zhengding	0.001
12	Wuhan/Tianhe	0.013	Zhengzhou/Xinzheng	0.001
13	Fuzhou/Changle	0.012	Wuhan/Tianhe	0.000
14	Chengdu/Shuangliu	0.011	Fuzhou/Changle	0.000
15	Quanzhou/Jinjiang	0.005	Chengdu/Shuangliu	0.000
16	Wuxi/Shuofang	0.005	Quanzhou/Jinjiang	0.000
17	Shenyang/Taoxian	0.004	Shenyang/Taoxian	0.000
18	Xiamen/Gaoqi	0.004	Xiamen/Gaoqi	0.000
19	Harbin/Taiping	0.002	Harbin/Taiping	0.000
20	Dalian/Zhoushuizi	0.001	Dalian/Zhoushuizi	0.000

The weighted betweenness centrality measure does not change the ranking significantly. However, the results computed with weighted edges show that the betweenness scores of a few highly ranked cities record a substantial increase. This is because the number of shortest paths between two cities will decrease after the frequency is used as weight. For example, the shortest paths from city A to B can be A-C-D-B and A-E-F-B with no consideration of the edge weighting. However, when the edges are weighted based on flight frequencies, there will be only one route counted as the pair's shortest path.

5.3 Correlation analysis

Correlation analysis in the CNT evaluates the nodes' neighbours' connectivity to reflect the function of the same degree nodes in the network. A correlation assessment summarises the average degree and clustering coefficient of their direct connection points to all nodes with the same k-degree. These indices reflect how connected nodes depend on each other (Hossain & Alam, 2017). A neighbour node with higher degree and clustering coefficient provides more support than the rest of the nodes in the direct connection graphs. If strong connectivity nodes with high degree connect with strong ones, the pattern of the network is assortativity (Wang et al., 2011; Hossain & Alam, 2017). Otherwise, it is disassortative and means that the low-degree nodes rely on the high-degree ones as their transit stops.

Figure 3.4 was created using the 2020 winter timetable data. It shows that the nodes can be clearly grouped into three clusters. The degree correlation illustrates a negative tendency, implying that high-degree nodes tend to run direct flights with low-degree ones. It implies that the CSFN is disassortative. In the first group where the node degree values are over 20 including national level hubs such as Hangzhou, Shenzhen and Nanjing (see Table A1), the highest k degree values (29 and 23) correspond to the lowest values of average degree of connected cities (5.97 and 7.26). Cities in the range of 12-degree to 8-degree (the second group) are mainly regional sub-hubs[6] in the CSFN and their degree generally follows a negative correlation with $\overline{K(k)}$. The 9-degree city, Shanghai, is an exception. Unlike other sub-hubs, Shanghai is in the Yangtze River delta region adjacent to the high degree hubs of Hangzhou and Nanjing and does not connect

[6] As shown in section 5.2, Hangzhou, Shenzhen and Nanjing can be classified as national logistics hubs. Here we call other provincial capital cities intermediate regional sub-hubs.

to them with direct cargo flights. Within the lowest degree group (the third group), the 2-degree nodes have the largest $\overline{K(k)}$ value of 20.42, followed by 4- and 3-degree cities with 16.6 and 15.67, respectively. Among the individual cities, the 2-degree cities of Kunming and Lanzhou have the equal value of K(i) (the average neighbour nodes' degree of the city), 26. Both cities are connected with Hangzhou and Nanjing which have the high degree values in the CSFN. The $\overline{K(k)}$ value for 1-degree nodes shrunk to 14. Most 1-degree cities directly connect with sub-hubs with small-scale dedicated cargo carriers such as Yulin (which connects to Xi'an by YTO Cargo) and Xuzhou (which is connected to Xi'an by Longhao Airlines). This disassortative mixing with lower degree cities surrounding higher degree cities in the CSFN demonstrates that the national level hubs and the regional sub-hubs support the connectivity to remote cities.

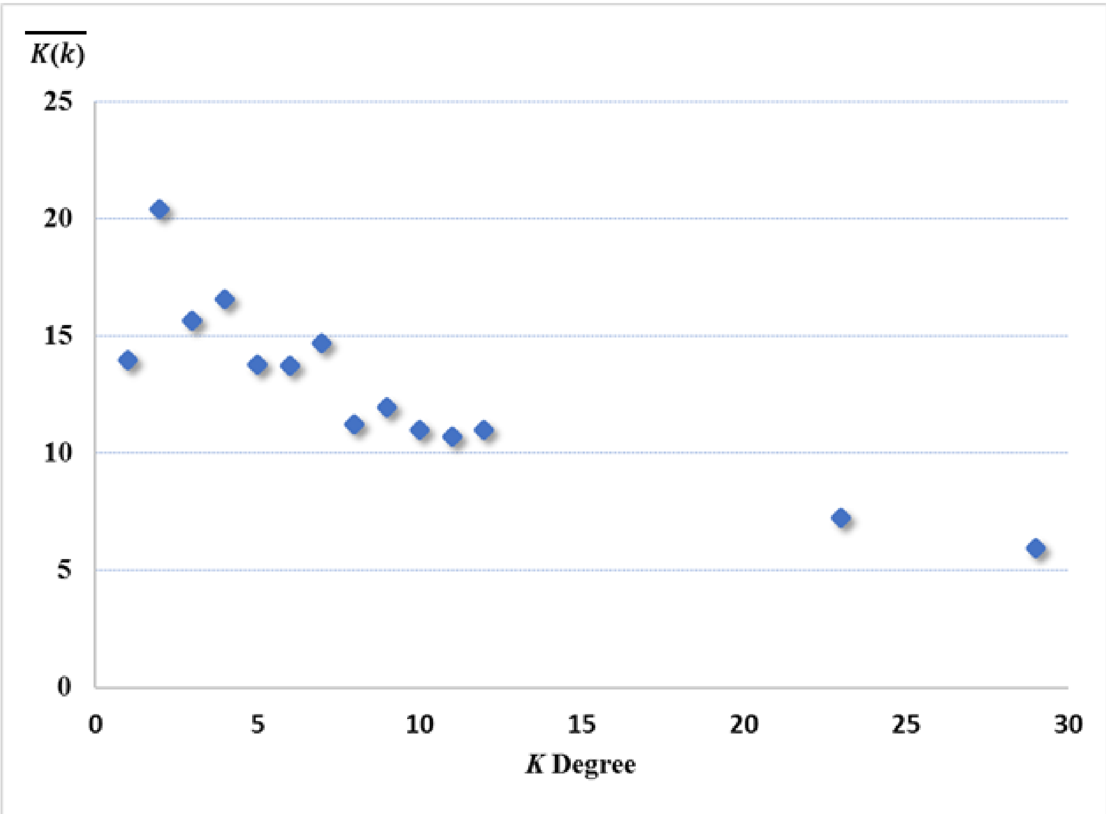

Figure 3.4: Degree correlation

The clustering degree correlation provides more evidence on how national and regional level hub nodes provide connectivity to peripheral nodes in the CSFN (Fig. 3.5). The relationship between the clustering coefficients and degrees tend to be negative linear. In this negative linear correlation, higher degree hubs tend to directly support lower clustering coefficient cities. In contrast, lower degree cities are inclined to connect with higher clustering coefficient hubs.

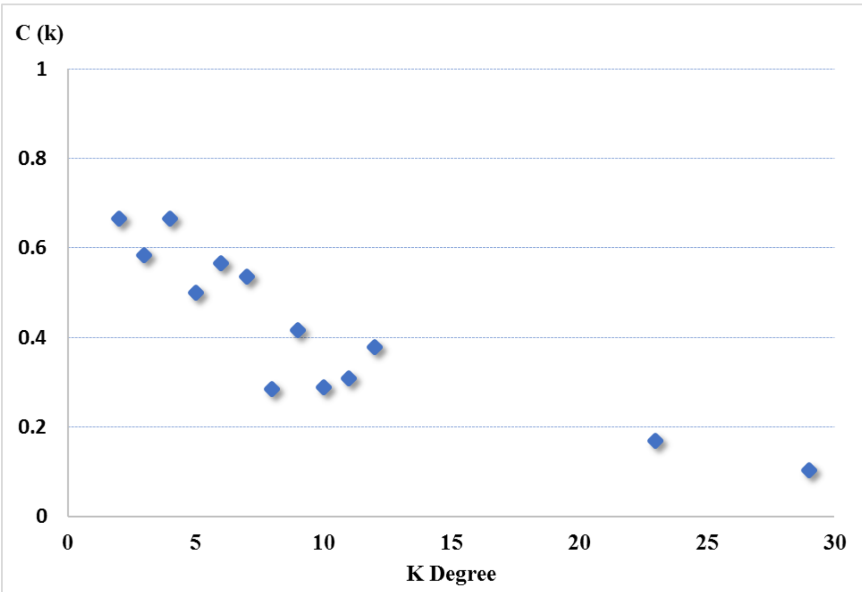

Figure 3.5: Correlations between degree and clustering coefficient

3.6 Analysis of network development during the COVID-19 period

Table 3.5 shows the overall network structure measures by the different timetable schedules. Overall, during the COVID-19 pandemic, the number of nodes reduced by one (2019 Winter vs. 2020 Winter), but the number of edges (i.e., the number of routes) increased by nearly 30%, which reflects the high demand for dedicated cargo services during the pandemic. The average degree and the clustering coefficient also increased, while the average path length fell. The average path length measures the convenience of navigation in a related network. The clustering coefficient is a ratio that measures the degree of connection density around a node: a higher cohesiveness in the node's neighbourhood provides a more efficient pathway with fewer transit points (Wang et al., 2011; Hossain & Alam, 2017). The model shows the growth of the CSFN with more origin-destination (OD) flights between the navigable cities in 2020 since the outbreak of COVID-19. It also shows that the overall structure of the CSFN improved from 2019 to 2020. More detailed analyses by different indices are presented in the following subsections.

Table 3.5: Changes of the CSFN structure by the scheduled timetable periods.

Schedule	**Effective period**	**No. nodes (n)**	**No. edges (m)**	**Average degree <K>**	**Average path length (L)**	**Clustering coefficient**
2019 Winter	Oct 2019-Mar 2020	46	104	4.52	2.26	0.293
2020 Summer	Mar–May 2020	47	108	4.60	2.26	0.317
2020 Summer revised	May–Oct 2020	45	123	5.47	2.18	0.415
2020 Winter	Oct 2020-Mar 2021	45	132	5.87	2.17	0.434

3.6.1 Degree distribution

As shown in Table 3.5, in the 2019 winter, the average degree was 4.52 in the CSFN with a maximum value of 28). The CSFN's cumulative degree distribution follows an exponential or a power function also as $P(k) = 0.7055e^{-0.133k}$ ($R^2 = 0.9071$), $P(k) = 1.659k^{-1.189}$ ($R^2 = 0.9518$), respectively, as shown in the upper panel of Figure 3. It means that a small number of the busiest cities/airports in the CSFN constitute the nodes of most of the all-cargo routes. They linked to a small number of hubs, and resembled the characteristics of a scale-free network. In late 2020 the exponential function was updated to $P(k) = 0.7871e^{-0.13k}$ ($R^2 = 0.8949$) or the power function became $y = 2.0108x^{-1.133}$ ($R^2 = 0.8899$), as shown in the lower panel of Figure 3.6. The average degree increased to 5.87 (Table 3.5), as more cities launched new all-cargo routes, which can be seen in Figure 3.7. Table 3.6 and Table A1 of the appendix suggest that some provincial capital cities, or intermediate regional sub-hubs, such as Chengdu, Wuhan and Zhengzhou operated more direct routes between each other in the CSFN in 2020. They also play roles as transit points between the central hub and peripheral cities in the network. It appears that during the pandemic, the distribution pattern of the CSFN developed into a network with more small-world properties. This will become clearer as we look at the changes in clustering coefficient and average path length next.

Based on the degree rankings in the 2019 Winter, Chinese cities are further grouped into categories of "top 10", "top 11-20" and "others", such that the heterogenous impacts of COVID-19 on different groups of airports can be investigated with a paired *t*-test. The results have been collated in Table A2. As can be seen, the increases in the network degree were mainly driven by the top 20 cities. More direct air freight routes were added to larger airports, further enhancing the small-world nature of the CSFN in China. This reflected the booming air cargo demand during the COVID-19 period for e-commerce goods and essential medical supplies which were mainly produced and consumed in key economic centers in China. On the other hand, we did not see a reduction in the degree of nodes in smaller airports, suggesting little or no impact of

COVID-19 on smaller airports' air freight network.

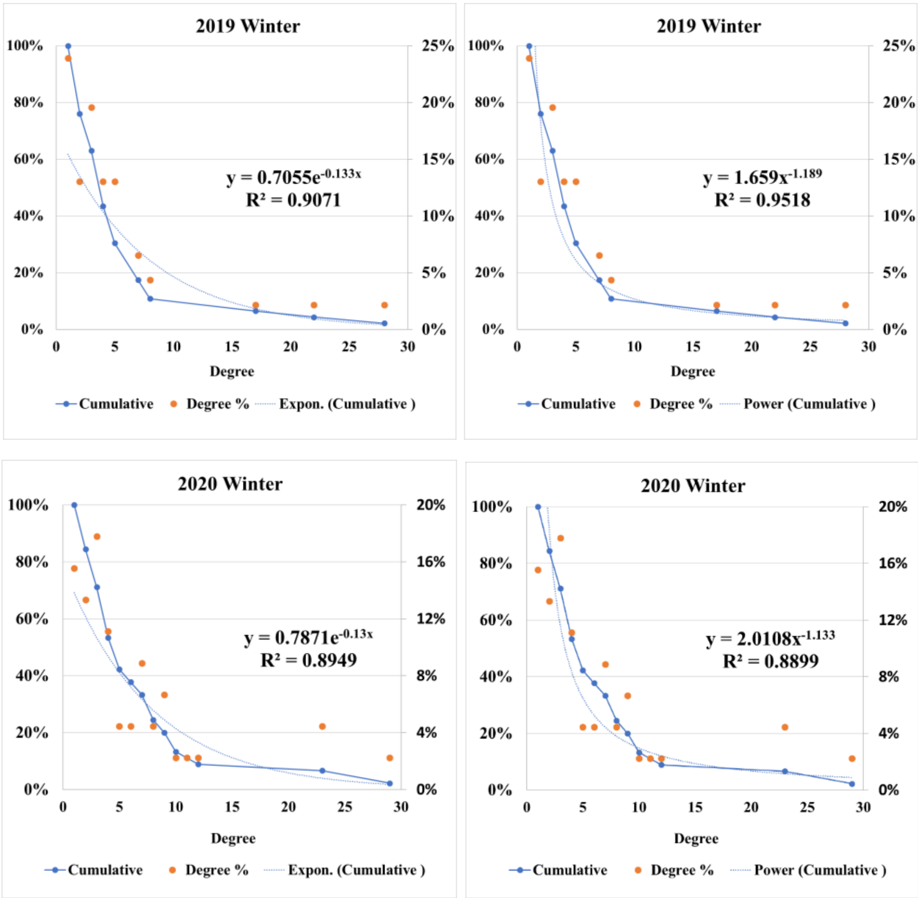

Figure 3.6: The cumulative degree distribution for the 2019 and 2020 winter timetables.

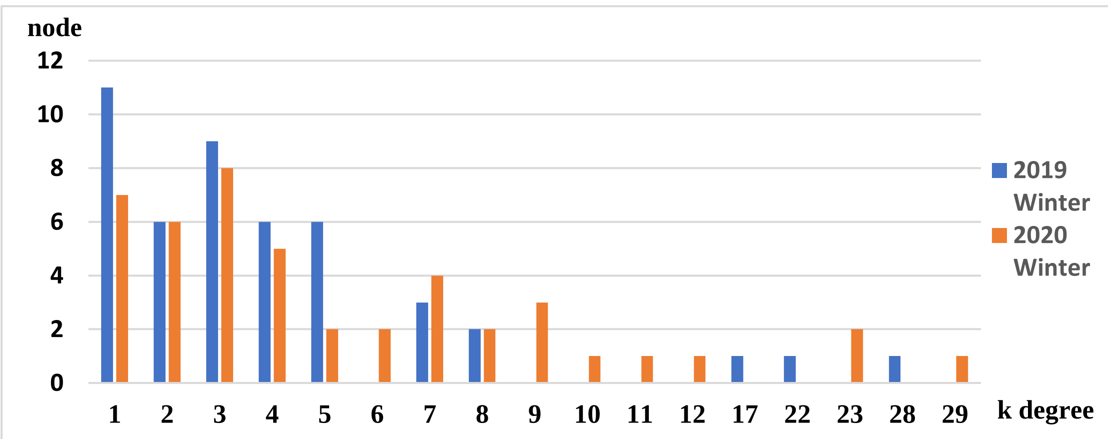

Figure 3.7: A comparison of the *k* degree by the number of nodes for the winter schedules of 2019 and 2020.

3.6.2 Average path length and clustering coefficient

The CSFN's average path length was 2.17 in the 2020 winter, which was slightly smaller than in 2019 for the same period (Table 3.6). This value is less than that of the air passenger network of China, 2.23, measured by Wang et al. (2011). Compared with the passenger flights that are still subject to a certain degree of regulation, the dedicated cargo carriers have more freedom to enter and exit a route. They could design a more efficient network with smaller average path length to minimise the transit times based on the historical cargo flow data. Table 3.6 summarises the distribution of the shortest paths among all city-pairs in the CSFN for 2019 and 2020. In 2019 about 11% of the city-pairs were connected by direct flights. About 67% of the city-pairs were connected with no more than one stop. About 96% of the city-pairs were connected with no more than two stops. In 2020 the figures show an apparent improvement given the shorter average path length value, and fewer transit points needed for a consignment to reach its destination in China's air freighter network. As shown in Table 3.6, 72% of the city-pairs were connected by direct all-cargo flights or one transit in 2020.

Table 3.6: The distribution of air freighter routes by the number of connecting flights

Shortest path	**No. of paths**	**Percentage of air routes**	**Cumulative percentage of air routes**	**No. of stopovers**
2019 winter timetable				
1	208	10.98	10.98	0
2	1066	56.28	67.27	1
3	544	28.72	95.99	2
4	76	4.01	100	3
2020 winter timetable				
1	264	13.33	13.33	0
2	1156	58.38	71.72	1
3	522	26.36	98.08	2
4	38	1.92	100.00	3

In the 2020 winter, the value of the clustering coefficient was 0.434 (Table 3.7), representing an increase of almost 50% from the same period in 2019. This implies that the topological distance for shipping a parcel from one airport to another became much shorter during the pandemic. To the best of our knowledge, there are no other studies on a nation's scheduled freighter network that allow us to compare this value. Therefore, to understand the transitivity and cohesiveness of the CSFN, we compare its clustering coefficient with air passenger transport networks (Table 3.7), including China's full-service (FSC) and low-cost carrier (LCC) networks (Table 3.8). Considering that there are fewer nodes and edges, it is not surprising that the CSFN is less cohesive than most of the air passenger networks (i.e., most nodes can be reached by fewer edges in the passenger networks). For instance, the clustering coefficient of the CSFN is much lower than those of the passenger networks of China, India, and the US, but much higher than that of Italy. Although there is a concentration of the cargo traffic among a few large logistics hubs, the ties between the peripheral cities in the cargo network are relatively weak compared with those in the passenger network. However, the CSFN's average path length is quite comparable with those of many of the passenger networks. As shown in Table 3.6, the CSFN's clustering coefficient (0.434) is close to the values of China's major LCCs, namely Spring Airlines, China United, West Air and Lucky Air. This makes sense as they all serve a small number of markets at this stage, focusing on a few busy airports and their link to some regional airports. Based on the degree distributions, the relatively small average path length and large clustering coefficient, we can argue that the CSFN has developed more apparent features of a small-world and scale-free network since the outbreak of the COVID-19 pandemic.

Table 3.7: A comparison of the CSFN with air passenger networks

Author	**Country/network**	**Average path length (L)**	**Clustering coefficient (C)**
Bagler (2008)	India	2.26	0.66

Guida & Maria (2007)	Italy	1.98–2.14	0.07–0.1
Xu & Harriss (2008)	USA	1.84–1.93	0.73–0.78
Wang et al. (2011)	China	2.23	0.69
Hossain & Alam (2017)	Australia	2.9	0.5
Our thesis	CSFN	2.17	0.434

Table 3.8: A comparison of the CSFN with Chinese low-cost carriers' domestic networks

Airline/network	**Average path length (L)**	**Clustering coefficient (C)**
Spring Airlines	2.33	0.49
West Air	2.22	0.40
China United	2.28	0.56
Jiuyuan Airlines	2.51	0.23
Lucky Air	2.46	0.45
CSFN (in this thesis)	2.17	0.434

Source: Wu et al. (2020).

As shown in Table A2, the increase in clustering coefficient since the COVID-19 pandemic was mainly driven by the small airport cohort. This might be because that the small cities tend to be linked with the large airports (especially the few hub airports), whose degrees have improved since the COVID-19 pandemic. As the clustering coefficient measures the strength of the connected or neighbouring nodes for one particular node, this index for the small airports has also improved. In addition, we found that air freighter services in some remote cities with poor clustering coefficients have discontinued since 2020. New air freighter services have been added to some small airports with higher clustering coefficients, which also contributes to the increase in the overall clustering coefficient. However, we should be cautious to attribute all these changes to the change in demand for cargo services during the pandemic, as they may also be a re-adjustment of the dedicated air cargo industry towards a greater cluster degree of the local network as it grows.

3.7 Conclusion

This chapter has evaluated the current CSFN via topological properties and has explored how this system changed after the COVID-19 pandemic outbreak. Using spatial analysis with the CNT, the chapter found that the CSFN displayed small-world and scale-free network properties amid the COVID-19 pandemic. It showed a cumulative degree distribution that aligned more with an exponential function, with an average path length of 2.17 and an increased clustering coefficient of 0.434 by the end of 2020. In terms of network patterns, the CSFN almost duplicates the air passenger traffic imbalance in relying on three eastern mega-city clusters. However, the national hubs for dedicated cargo carriers are Shenzhen in the Pearl River delta, and Hangzhou and Nanjing in the Yangtze River delta for the CSFN, instead of Guangzhou and Shanghai as in the case of China's air passenger network. The CNT analysis suggests that the CSFN is not a randomly formed network and has offered a good coverage of the country. The network appears to have a clear layering feature consisting of national and intermediate level hubs as well as many small nodes (peripheral cities). Most peripheral cities with low degree airports are directly linked to the national hubs that have the best centrality. Intermediate airports function as regional sub-hubs in the CSFN through developing direct routes between each other and playing roles as transit points between the central hub and peripheral cities. In particular, intermediate airports such as Beijing, Tianjin, Xi'an and Nanchang play roles as transit points between the national level hubs and the peripheral cities in the network. The increase in the direct freighter routes among the cities such as Wuhan, Beijing, Tianjin and Guangzhou in the first year of the COVID-19 pandemic had enhanced the density and transitivity of the CSFN.

Many researchers have studied the performance of China's passenger market in the COVID pandemic. For example, Xue et al., (2021) report that one month after the reopening of Wuhan, a fast and strong recovery rate of air travel was observed. This was also the case for Beijing after its reopening in July 2020 (it went into lockdown in June 2020). The authors claim that China's successful control of COVID-19 in 2020 led to an almost full recovery of the domestic air demand by the end of 2020. Therefore, we can argue with confidence that the COVID-19 pandemic has not had a damaging impact on the CSFN. On the contrary, the CSFN has improved since the COVID-19 pandemic, with increased network average degree, clustering coefficient, closeness and reduced average path. Such improvement is mainly driven by major hub cities whose centralities have been strengthened with more route connections. Since China's air passenger traffic had resumed quite quickly in the second half of 2020, the CSFN's better performance amid the COVID-19 pandemic was not likely due to the substitution effect from a reduction in belly cargo on passenger aircraft. Rather, it was more likely a result of the higher air cargo demand during the pandemic and airlines' realisation of the importance of freighter operations in China.

China's big three gateway cities (Beijing, Shanghai and Guangzhou) are important passenger and cargo markets. However, they are not the top-ranking cities in the CSFN, probably because there have been a large number of passenger flights with belly cargo to and from these cities. This chapter only considers the dedicated cargo carriers and excludes the passenger flights, which may underestimate the role of these cities in the domestic air freight market. This constitutes a limitation of this study. It is worth noting that the international all-cargo routes to/from China could have had an impact on the domestic freighter network. The national level hubs and most regional sub-hubs identified in the Chinese scheduled freighter network (CSFN) have hosted international all-cargo flights. However, studying the international dedicated cargo carriers and flights is beyond the scope of this research, and can be a future research area. The next-step research should give a closer look at the individual cargo carriers' network developments and compare them with those of the world-class dedicated cargo carriers in the EU and US. It is also necessary to establish the link between China's cargo carriers' network development and the e-commerce evolution patterns, which can generate important policy implications for both carriers and government agencies.

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CHAPTER 4 (PAPER 3) SERVICE QUALITY DIMENSIONS OF AIR EXPRESS SERVICE PROVIDERS IN CHINA'S E-LOGISTICS MARKET

Abstract

As shopping online is booming in both the domestic and cross-border markets in China, air express service providers have developed their capability to provide a wholly integrated end-to-end logistics service. This chapter develops a conceptual model with six service quality dimensions – delivery performance operational capability, preferential pricing, safety/risk cover, delivery performance, customer's experience and air freight capacity. It then applies structural equation modelling to examine the relationships between the dimensions and Chinese air express service third-party performance, which is based on perceived service quality, in the e-logistics market. Empirical evidence shows that preferential pricing, safety/risk cover, delivery performance, customer's experience and air freight capacity have significant positive influences on perceived service quality.

4.1 Introduction

The rapid development of domestic and cross-border e-commerce has caused high demand for air express services in China, especially after China became the largest retail e-commerce market in the world since 2013. In 2018, China's online retail sales reached RMB7019.8 billion (National Bureau of Statistics, 2019). According to China customs statistics, the total import and export volume of China's cross-border e-commerce retail reached RMB134.7 billion in 2018, a year-on-year growth of 50% (ec.com, 2019). Online purchasing relies heavily on air express delivery services because these can fulfil the requirements of e-commerce buyers. According to Allen et al. (2018), customers have high expectations of fast delivery with a timeliness guarantee, the latest trackable delivery status advice and the estimated time of arrival being given online. Timeliness is the primary consideration for customers choosing an e-commerce store and a platform on which to buy (Preston's Friends, 2016). Apart from late deliveries, negative customer experiences such as damaged or lost parcels, offensive service manners from couriers and tedious return procedures conceivably cause credibility and brand name damage for e-commerce corporations (Jie et al., 2015). In terms of service quality, when customers are not satisfied with the delivery service, they would rather complain to the seller than blame the logistics providers. They indirectly reduce their willingness to buy products on the current platform and shift their search to rival platforms with a better delivery service (Kearney, 2011). Therefore, the three e-commerce giants – Amazon, Alibaba and eBay – rely on air express delivery services for sending high value and fragile items like electronic devices to their online customers (IATA, 2018).

E-commerce logistics, which is known as e-logistics, is the end-to-end online purchasing orders fulfilment service (Kawa 2017; Haryanto & Chang 2018). Generally, in order to fulfil the needs of the fast-developing online market, most of the e-commerce platforms and sellers outsource the delivery service to air express service providers (AESPs), or third-party logistics (TPL) companies. The AESPs are not limited to air express companies but can include integrated express solution providers such as e-platform logistics-arms and forwarder-airline alliances in China (Xiao, 2011; Farooq et al., 2019). While this is great opportunity for the industry, competition is fierce among the AESPs. In providing the fully integrated door-to-door service, the competitors become more focused on the needs of the end-users and apply further integration to improve competitiveness.

Subramanian et al. (2014) advise that in their case of e-retailers' services in China, order fulfilment service and other logistics functions have played a more important role than other intangible factors. Choosing a proper third-party logistics (TPL) company has gradually become a more important tactical issue for firms wanting to optimise their logistics capacity (Meng et al., 2010). Improving logistics service performance according to the needs of the customers is the main objective for every TPL company to gain a customer's satisfaction and retention (Aguezzoul, 2014; Gürcan et al., 2016).

To the best of our knowledge, the existing literature has not revealed any discussion about the relationship between the performance of air express third-party companies and the service quality dimensions in the context of the Chinese e-logistics market. A noticeable feature of the literature on cargo airline services is the scarcity of a comprehensive assessment of performance based on a multiple-factor scale measuring the service quality of the AESPs. To fill this gap, the current study gives an insight to how service quality factors influence the e-logistics company's performance in terms of perceived service quality. In particular, it analyses the latent relationship between the service dimensions and the performance of airlines through a structural equation modelling (SEM) approach. Therefore, this study fills a gap in the literature by comprehensively identifying the service factors behind the decision to select an AESP in China. The Chapter will examine the impact of these service factors on AESPs' perceived service quality in the context of the Chinese e-logistics market.

In sum, this research will develop a criteria model and investigate the criteria's relationships with the performance based on the e-commerce companies' perception of the service received. The model is a framework of these dimensions, with which AESPs are capable of identifying the relative strengths and weaknesses impacting on their service performance. Understanding the comparative perceived importance of these factors is vital for an AESP to survive and to strengthen its competitiveness

The chapter consists of eight sections. Section 1 introduces the study. Section 2 provides the literature review based on the SERVQUAL model. The conceptual model and the research hypotheses designs are given in Section 3. Section 4 explains the methodology and data collection procedure. Measurement of data and analysis of the hypothesised model is interpreted in Sections 5 and 6. Section 7 discusses the theoretical and managerial implications. The last section concludes.

4.2 Literature review

4.2.1 SERVQUAL model

In a competitive environment it is of great importance to deliver high service quality for establishing and sustaining long-term relationships with customers (Chatterjee & Yilmaz, 1993). Service quality has received much attention in the field of business research (Campos-Soria, García & García, 2005). Service quality is widely defined as the difference between the customers' expectations and their perception of the experience received. The expectation of a service would come from the user's antecedent experience, the service provider's image and the charge for the service, while the customer's perception of the service received is based on their latest experience. Perception is exactly what the user experiences (Parasuraman, Zeithaml & Berry, 1985; Grönroos, 1984). Parasuraman, Zeithaml and Berry (1988) added the rationale of how consumers judge the company's performance. The SERVQUAL model developed by Parasuraman, Zeithaml and Berry (1988) is one of the most popular measures for evaluating service quality levels (Hong & Jun, 2006; Saurina & Coenders, 2002; Subramanian et al., 2014; Huang & Hsu, 2016). Their SERVQUAL model measures the gap between the consumers' expectations and their perceptions of the service received. Table 4.1 lists the five dimensions of their SERVQUAL service quality model.

Table 4.1: SERVQUAL's five dimensions.

Tangibles	'Physical facilities, equipment, and appearance of personnel'
Reliability	'Ability to perform the promised service dependably and accurately'
Responsiveness	'Willingness to help customers and provide prompt service'
Assurance	'Knowledge and courtesy of employees and their ability to inspire trust and confidence'
Empathy	'Caring, individualized attention the firm provides to its customers'

Source: Parasuraman, Zeithaml & Berry, 1988, p.23

4.2.2 Service quality factors related to third-party logistics and air freight industry

Many studies have demonstrated the importance of service quality in the TPL sector. For instance, Lu and Yang (2006) identified the key logistics capabilities – customer response, innovation, economic scale, and flexible operation and logistics knowledge – for any international distribution centre. Hong, Chin and Liu (2004) summarised the factors related to customer satisfaction: price level, on-time delivery, number of service offerings, logistics information systems, responsiveness, personnel quality, error rates, and loss and damage rates. A review of 87 international journal articles about supply chains and logistics in the period from 1994 to 2013 found 67 of them referring to specific factors for the success of TPL customer relationships (Aguezzoul, 2014). The most commonly used dimensions of these are cost, relationship, variety of services and quality of them.

Service quality is a type of competitiveness in air freight industry, and a group of characteristics affect users' selection of air freight service providers[7] (Park, Choi & Zhang, 2009; Huang, Tseng & Hsu, 2016; Yoon & Park, 2015; Hsu et al., 2009; Wang, 2007; Cheng & Yeh 2007, Tsai, Wen & Chen, 2007, Meng et al., 2010, Wen, Tsai & Lin, 2011; Hsu et al, 2009; Durak & Yılmaz, 2016). For instance, Hsu et al. (2009) classified and measured six factors – product characteristics, values, inventory cost, shipping charges, shipping distance and time – which influence multinational companies in choosing an air freight service provider. Their study concluded that the service requirements of shippers with a high-value product and a short delivery distance are lower shipping charges and more frequent flights. Park, Choi and Zhang (2009) identified six main factors – promptness, accuracy, safety, convenience, preferential

[7] Air freight service providers include air freight carriers and air freight forwarders or other brokers providing air freight services but without air fleet.

pricing and dependability – with 26 attributes, and found that the attribute of quick delivery or promptness is the most influential factor.

Yoon and Park (2015) concluded that price, promptness, reliability, convenience and speciality are the influential service factors when forwarders select freight airlines in the Korean international trading market. Tsai, Wen and Chen (2007) studied the factors influencing the high-technology industry in making a choice between express-based and forwarder-based types of air freight service providers. They classified 15 variables into four underlying dimensions – service cost, service performance, value-added services and perceived capability. The found that high-tech manufacturers with high sale volumes or small shipments tend to use express services. Cheng and Yeh (2007) confirmed the positive relationship between three criteria – resources, capabilities and logistics services – and the sustainable competitive advantage of forwarders in the global air freight business. Staff capability is considered as a critical factor. Others, for instance, Durak and Yılmaz (2016), found price and speed are the first priorities that affect the choice of air freight airline, with reliability, flexibility, risk and sociality being another four criteria. The service quality factors in the literature related to TPL and the air freight industry have been summarised in Table 4.2 and grouped into SERVQUAL dimensions.

Table 4.2: Summary of the literature on the criteria for the adoption of the air express service provider.

Attribute	SERVQUAL Dimension	Item	Sub-criteria	Definition	References
Delivery performance	Reliability	DP1	Prompt on-time delivery	Quick and delivery on-time as promised from pick-up point	Park, Choi & Zhang (2009); Hong & Jun (2006); Jharkharia & Shankar (2007); Wen, Tsai & Lin (2011); Tsai, Wen & Chen (2007); Wang, (2007); Aguezzoul (2014); Meng et al. (2010); Lu & Yang (2006); Chan et al. (2006); Durak & Yılmaz (2016)
		DP2	Accurate delivery	Accurate delivery to address of shipment (right place right product)	Park, Choi & Zhang (2009); Jharkharia & Shankar (2007); Tsai, Wen & Chen (2007); Wen, Tsai & Lin (2011); Wang, (2007); Aguezzoul (2014); Chan et al. (2006)
		DP3	Prompt on-time pick-up	On-time and quick pick-up from booking point, as per customer's request	Park, Choi & Zhang (2009); Jharkharia & Shankar (2007); Aguezzoul (2014); Lu & Yang (2006); Chan et al. (2006)
Operational capability	Tangibles	OC1	Logistics network	Wide and quick transportation networking	Park, Choi & Zhang (2009); Hong & Jun (2006); Jharkharia & Shankar (2007); Tsai, Wen & Chen (2007); Aguezzoul (2014); Meng et al. (2010)
		OC2	Physical facility	New, tidy facility with state-of-the-art technology; enough, flexible operational warehouse space	Park, Choi & Zhang (2009); Hong & Jun (2006); Aguezzoul (2014); Meng et al. (2010); Lu & Yang (2006); Wang, (2007);
		OC3	Information system	ITC systems for logistics process	Park, Choi & Zhang (2009); Hong & Jun (2006); Jharkharia & Shankar (2007); Wen, Tsai & Lin (2011); Aguezzoul (2014); Lu & Yang (2006);
		OC4	Professional personnel	Specialized team; presence of workforce	Hong & Jun (2006); Lu & Yang (2006); Tsai, Wen & Chen (2007);
Preferential pricing		PP1	Variety rate with moderate price	Offer many class rates and basic low price option	Park, Choi & Zhang (2009); Hong & Jun (2006); Jharkharia & Shankar (2007); Tsai, Wen & Chen (2007); Aguezzoul (2014); Lu & Yang (2006); Chan et al. (2006)

		PP2	Flexibility in billing and payment	Flexibility in billing and payment conditions increases goodwill between the user and the provider	Jharkharia & Shankar (2007);
		PP3	Competitive price	Relatively lower price for same volume and/or weight to other rivals	Park, Choi & Zhang (2009); Hong & Jun (2006); Tsai, Wen & Chen (2007); Wen, Tsai & Lin (2011); Durak & Yılmaz (2016)
		PP4	Price markdown	Price markdown based on the certain amount freight; level of rate concession	Park, Choi & Zhang (2009); Hong & Jun (2006); Tsai, Wen & Chen (2007); Aguezzoul (2014); LU & YANG (2006);
Customer's experience (for end-consumers)	Responsiveness	CE1	Quick response	Quick response to customer's request by internet or telephone	Park, Choi & Zhang (2009); Meng et al. (2010); Lu & Yang (2006)
	Empathy	CE2	Image and reputation	Image and reputation of the carrier	Park, Choi & Zhang (2009); Aguezzoul (2014); Jharkharia & Shankar (2007)
		CE3	Customs clearance	Seamless customs clearance	Park, Choi & Zhang (2009); Wang, (2007)
Safety/risk cover	Assurance	SR1	Well cargo handling	Cargo protection; handling by proper characteristics based on the product features; able to handle unusual cargo	Park, Choi & Zhang (2009); Meng et al. (2010); Lu & Yang (2006); Wang, (2007)
	Reliability	SR2	Compensation/claim	Compensation policy	Park, Choi & Zhang (2009); Hong & Jun (2006); Wen, Tsai & Lin (2011); Tsai, Wen & Chen (2007); Meng et al. (2010)
		SR3	Willing to help; problem solving	Willingness to help solve customer's problems	Park, Choi & Zhang (2009); Hong & Jun (2006); Wen, Tsai & Lin (2011); Tsai, Wen & Chen (2007); Aguezzoul (2014); Wang, (2007)
		SR4	Low damage and loss rate	Low cargo damage or loss rate	Park, Choi & Zhang (2009); Wen, Tsai & Lin (2011); Lu & Yang (2006)
Air freight capacity		AC1	Inter-connectivity with land transportation system	Multi-modal connections and connectivity radiations of transport infrastructure	Hong & Jun (2006)
		AC2	Promised delivery time guarantee	Money back guarantee	
	Tangibles	AC3	Self-built air fleet	Maintain and operate own aircraft	

4.3 Model development and hypotheses

In order to evaluate the service performance of AESPs in China's e-logistics market, the current research use the SERVQUAL theory, together with existing studies, to develop the most important service dimensions that would influence customers' decisions when choosing a TPL company. The conceptual model in Figure 4.1 shows the proposed hypotheses and the latent relationships between customer satisfaction (perceived service quality) and six variables –delivery performance, operational capability, preferential pricing, customer's experience, safety/risk cover, and air freight capacity. According to the purpose of this chapter, perceived service quality is a dependent variable while the six other variables are independent.

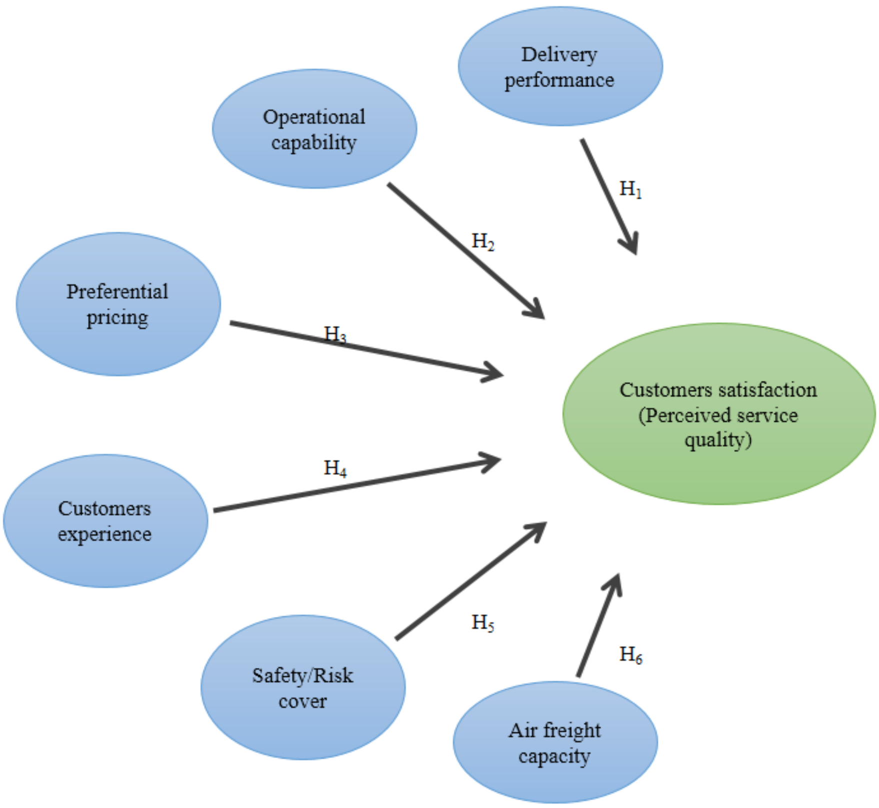

Figure 4.1: The hypothesised structural model in this study.

4.3.1 Delivery performance

When considering the factor of reliability in air freight express services, delivery performance is related to the capability to offer a logistics service correctly, speedily and steadily. Delivery performance includes three sub-criteria – prompt on-time delivery, accurate delivery and on-time pick-up. According to Meng et al. (2010), there is a significant link between delivery performance and reliability. Valaei, Rezaei and Shahijan (2016) summarise speediness or on-time as a critical indicator of service reliability. Speed is the most common and vital sub-criteria of delivery performance. Prompt on-time delivery is essentially required for an air freight express service (e.g., Park, Choi & Zhang, 2009; Hong & Jun, 2006; Jharkharia & Shankar 2007; Wen, Tsai & Lin, 2011; Tsai, Wen & Chen, 2007; Wang, 2007; Aguezzoul 2014; Meng et al., 2010; Lu & Yang, 2006; Chan et al., 2006). Accurate delivery to the shipping address, that is, the right place and the right product, completes the delivery service (Park, Choi & Zhang, 2009; Jharkharia & Shankar, 2007; Tsai, Wen & Chen, 2007; Wen, Tsai & Lin, 2011; Wang, 2007; Aguezzoul, 2014; Chan et al., 2006).

Because air freight express is an end-to-end service (Zhang et al., 2007), service quality should cover the phases from pick-up to sign-for. On-time and quick pick-up from the booking point, as per a customer's request, should not be ignored (Park, Choi & Zhang, 2009; Jharkharia & Shankar, 2007; Aguezzoul, 2014; Lu & Yang 2006; Chan et al., 2006). According to Chan et al. (2006), this is the customer response time required for the processing of the parcel after the point in time of placing orders or leaving items at the collecting point. Therefore, it is hypothesized that:

$H_{1:}$ Delivery performance is positively associated with perceived service quality.

4.3.2 Operational capability

Hong and Jun (2006) regard supply capability as a tangible dimension in international air freight service. This capability relies on the presence of the fundamental infrastructure for air freight services. According to Parasuraman, Zeithaml and Berry (1988), a tangible dimension is about the means of production, which includes concrete facilities, devices and human resources. These fundamental elements give AESPs operational capability. While physical facilities and professional personnel are generally needed in most service sectors, the logistics network and information system are incredibly vital for TPL providers, not only in the air freight express industry. Tsai, Wen and Chen (2007) interpret the logistics network as ‘service channels and destinations’, while Park, Choi and Zhang (2009) describe it as ‘service area’ or ‘branch’, which has the capability for creating convenience for customers.

In TPL selection studies, the information system refers to the hardware and software systems that function to facilitate communication between the TPL company and its customers, and for handling the physical materials. The essential software systems include Electronic Data Interchange (EDI), tracking/tracing of items, communication terminals, and other information accessibility. (Aguezzoul, 2014). Jayaram and Tan (2010) state that firms and their TPL companies rely on information and communication technology to coordinate decisions and activities. Their hypotheses testing showed integration carried on information technology had positive impact on firm performance. In the e-logistics market the cargo tracing service has become critical to customers’ satisfaction. Allen et al. (2018) state that the online trackable delivery status and the estimated time of arrival are important parts of timeliness, which is the primary consideration for customers choosing an e-commerce store and platform. Information systems are the fundamental infrastructure for AESPs to fulfil this requirement and to help e-commerce traders communicate with their customers for a better experience too. To sum up, operational capability is the primary physical means to support the freight service and to improve customer satisfaction. Therefore, it is hypothesised that:

$H_{2:}$ Operational capability is positively associated with perceived service quality.

4.3.3 Preferential pricing

According to Aguezzoul (2014), 46 of the 67 articles published in the two decades to 2013 evaluated the impact of cost in choosing a TPL company. For the air freight industry, the actual expense paid for the service is considered in the SERVQUAL model simultaneously (Hong & Jun, 2006; Park, Choi & Zhang, 2009). A premium quality service offered with low rates can alleviate the users’ pressure on their transportation costs (Hong & Jun, 2006). The most important dimension can be a low charge borne by the users, rather than being dominated by punctuality and speediness (Park, Choi & Zhang, 2009).

Preferential pricing in this study includes 'variety rate with a moderate price', 'flexibility in billing and payment', 'competitive price' and 'price markdown'. Not only is the low price compared with other competitors but markdown also should be considered in some circumstances. Flexible payment terms and a different rate based on the service categories also provide preferential pricing to users. As a result, Park, Choi and Zhang (2009) emphasise that measurement of the price factor is as vital as the non-price factors. Therefore, it is hypothesised that:

H_3: Preferential pricing is positively associated with perceived service quality.

4.3.4 Customer's experience

To respond the responsiveness and empathy, customer's experience is introduced. During the service delivery, there is usually contact and cooperation between the customer and the courier. Gurski (2014) suggests that customer experience is how value is generated during the interaction between the customer and the service provider. Service providers need to respond to customer feedback with an understanding of their feelings. Customers require responsiveness and empathy to detailed interactions. The ability to tackle problems efficiently and to answer customers is important (Parasuraman, Zeithaml & Malhotra, 2005). The responses from providers must be perceived by the customers to show empathy for their concerns and an understanding of their needs. This is aimed at giving consumers the experience of individualised caring and attention by the service provider (Kumar & Dash, 2015). Customer experience in this model measures the air freight express firms' capability to provide quick responses and appropriate problem-solving to their customers based on understanding their concerns and needs.

Customer experience in the service provided is positively associated with customer satisfaction and their positive behaviour in the future (Valaei, Rezaei & Shahijan, 2016). In the e-logistics market the AESPs serve both business clients and ordinary consumers. The online shopping experience includes the logistics service. Beside late deliveries, negative customer experiences such as troublesome booking and pick-up processes, unsolved problems with damaged and lost parcels, offensive manners from couriers and tedious return procedures conceivably cause credibility and brand name damage for the e-commerce corporations (Jie et al., 2015). Unpleasant difficulties encountered bring about negative word-of-mouth comments and expose the drawbacks of the providers among the customers. The quality of the experience, as reflected in past experiences, is as critical as the quality of the product and service for online customers (Shafiee & Bazargan, 2018). Thus, carriers with a better public image and reputation are considered to offer a higher quality service in a customer's perception. Consequently, the quality of the customer's experience influences customer loyalty (Gurski, 2014). Given the advantage of a positive impact on customers, it is hypothesised that:

H_4: Customer's experience is positively associated with perceived service quality.

4.3.5 Safety/risk cover

Safety/risk cover offers assurance to customers. The assurance dimension means the employee knowledge base which induces customer trust and confidence (Kumar & Dash, 2015). In the air freight industry or TPL companies, the knowledge of an employee is often not enough to gain the confidence of customers. Some form of compensation or insurance is required to cover any loss which may happen (Hong & Jun, 2006; Wen, Tsai & Lin, 2011; Tsai, Wen & Chen, 2007). Furthermore, the damage and loss rate which reflect the safety performance need to be kept low at all times (Park, Choi & Zhang, 2009; Wen, Tsai & Lin, 2011; Lu & Yang, 2006). Thus, Park, Choi and Zhang (2009) suggest that safety refers to protection during the process of cargo handling, the reimbursement of customers' loss claims, and the damage/loss figures being kept small. In the courier service industry, safety ensures the parcels are shipped and handed over to end-users with good packing and in a ready-to-use condition (Valaei, Rezaei & Shahijan, 2016). Safety is one of the most influential service quality dimensions in air cargo transport (Chao et al., 2013). Therefore, it is hypothesised that:

H_5: Safety/risk cover is positively associated with perceived service quality.

4.3.6 Air freight capacity

Air freight express service is a type of delivery that generally goes through varied sections such as line-haul transport provided by a passenger airline or a carrier's own fleet from airport to airport and with truck transport to the customer's door. Air freight capacity refers to the delivery service provided by air transport within the whole process. According to an assessment of previous studies, three sub-criteria are considered having strong links to air freight capability – inter-connectivity with land transportation systems, a promised delivery time (PDT) guarantee and a self-built air fleet.

When the air service is responsible for long-distance transport, there can be cooperation between airline and railway operators because high speed rail can connect airports and cities (Zhang et al., 2017). Also, road and rail services can be integrated into the multi-modal operation organized by the AESPs as part of the door-to-door transport to connect airports and destinations (Zhang et al., 2007; Jiang, D'Alfonso & Wan, 2017). Therefore, inter-connectivity with land transportation systems is a critical function of the e-commerce chain. PDT is a premium professional service for customers. PDT has been considered to offer an advanced advantage in the air freight business. When late delivery happens there is some loss not only directly financially, but also to the reputation of the companies involved.

Enlarging its self-built air fleet was a strategic action for the Chinese air freight express company SF Airlines. Reported by Shao and Sun (2016), 72.6% of total cargo volume was delivered in the belly hold of passenger flights in 2013. When its freight fleet cannot provide enough capacity, SF Express looks for cooperation with passenger airlines. Under this model, SF Airlines directly manages its transport capacity, but suffers from the complex of mixed network planning (Yu, Yang & Yu, 2017). For example, rental passenger aircraft transport follows the airline's routes and schedules which normally travel in the morning and early evening because of passengers' preferences. However, overnight ground operations can save costs and the lead-time for cargo services (Zhang & Zhang, 2002). As a short and constant lead-time is critical for delivery performance and adopting a PDT strategy, maintaining a self-built air freight fleet can ensure service quality. To sum up, it is hypothesised that:

H_6: Air freight capacity is positively associated with perceived service quality.

4.4 Methodology and data collection

4.4.1 Data collection

The survey questionnaire in this research was designed in accordance with the model described above with six service factors and the perceived service quality variable, including the 27 sub-items developed through the literature review. Two academics and an executive from each of an e-logistics and e-commerce company reviewed and modified the questionnaire. Then a pilot survey was conducted to test the questions and its user-friendly features on 22 senior professionals in the Chinese e-logistics market. The questionnaire was used to collect data on the Likert-type five-point rating scale. The level of importance (satisfaction) is from 1 for strongly disagree (very unsatisfied) to 5 for strongly agree (very satisfied).

The target respondents are full-time managers who have full knowledge of, or responsibility for, e-logistics operations. He or she should understand the service quality requirement in the air freight express industry. The respondents are from three main categories of responsibility. First, operations: daily jobs related to cargo packing, handling and handover, confirmation with the system's operation or paperwork. Second, management: planning, problem-solving, service quality control. Third, decision-making: a participant in third party selection, and/or making company strategies or policies. Some responsibilities may involve more than one category, so respondents were asked to choose the category with their most working hours or the essential part of their duties.

Conducting the survey was outsourced to an online survey agent which maintains a register of more than 10,000 activated accounts whose occupation is registered as logistics and supply chain management. To meet the target category of samples, the proposed respondents were filtered by various criteria. For example, industry experience was to be more than five years or the employer was an e-commerce or related TPL company. After two weeks of online launching, a total of 273 respondents was collected by the online survey agent. After filtering the data, 73 returned questionnaires were discarded because of incomplete information or invalid scores. Two hundred valid usable respondents were adopted for further data analysis. Two hundred observed cases is the minimum number for a 'large' considered sample size (Kline, 2005). Therefore, the number met the minimum requirement for SEM. The sample size of the data is considered acceptable. Moreover, further examination will be conducted to check if the number of respondents is enough.

Of the 200 completed questionnaires, 56.5% of the respondents were from shippers/e-commerce operators, of which 16.81% were from consumer electronics (mobile phones and digital diversions) companies, 10.62% were from household appliances and furniture companies, and 34.51% were from fashion and clothing companies. The other portions of the total cases were 13.5% for e-logistics firms, 23% for integrator/carriers with self-built or charter fleets and 7% for forwarder/supply chain solution provider/land transport express operators. Therefore, there does not seem to have been any obvious clustering in one particular company group. The results show that 46% of the survey participants had more than ten years of industry experience; 51.5% were in a management position; 27.5% were in charge of process management and decision making; and 21% were in operation positions. This finding was important since management and decision making may involve and focus on the TPL service performance and selection decision in their responsibility. A high percentage of responses from these groups and those with more industry experience supported the reliability of the survey's results on service quality criteria. General information about the demographic profile of the respondents is presented in Table 4.3 and Table 4.4 lists the mean value of service dimensions' perceived importance.

Table 4.3: The demographic characteristics of the respondents.

Variable	Number of respondents	Percentage (%)
Type of company		
Shippers/e-commerce operators	113	56.5%
e-platform logistics arm	27	13.5%
Integrator/carriers with self-built or charter fleet	46	23.0%

Forwarder/supply chain solution provider/land transport express	14	7.0%
City where located		
Beijing	30	15.0%
Shanghai	30	15.0%
Guangzhou	30	15.0%
Shenzhen	20	10.0%
Hangzhou	20	10.0%
Wuhan	20	10.0%
Nanjing	10	5.0%
Chengdu	10	5.0%
Other	30	15.0%
Type of commercial		
Consumer electronics (mobile phones, digital diversions)	19	16.8%
Household appliances and furniture	12	10.6%
Cosmetics and skincare	6	5.3%
Fresh food with temperature control	11	9.7%
Food, vitamins and supplements	23	20.4%
Fashion and clothing	39	34.5%
Other	3	2.7%
Main responsibilities		
Management (administration, customer service and inventory control)	103	51.5%
Cargo operation	42	21.0%
Process management and decision making	55	27.5%
Industry experience		
Over 5 but within 10 years	168	84.0%
Over 10 years	32	16.0%
Focus market		
Domestic (excluding Hong Kong, Macao and Taiwan regions)	113	56.5%
Cross border	5	2.5%
Both of them	82	41.0%
Number of employees		
Less than 250 persons	101	50.5%
250 persons or above	99	49.5%

Years of operation		
Less than 10 years	108	54.0%
10 years or above	92	46.0%
Destination		
Domestic (excluding Hong Kong, Macao and Taiwan regions)	167	83.5%
Hong Kong, Macao and Taiwan regions	5	2.5%
Southeast Asian	16	8.0%
North America	4	2.0%
European	8	4.0%
Average weight per parcel		
Less than 5 kg	84	42.0%
Among 5 to 100 kg	102	51.0%
Over 100 kg	14	7.0%

Table 4.4: Perceived importance of service dimensions.

Service dimensions	Mean	Standard Deviation	Rank
Delivery performance			
Prompt on-time delivery	4.73	0.49	1
Accurate delivery	4.71	0.52	2
Prompt on-time pick-up	4.29	0.65	16
Operational capability			
Logistics network	4.63	0.60	3
Physical facility	4.51	0.58	7
Information system	4.55	0.62	6
Professional personnel	4.46	0.67	9
Preferential pricing			
Variety rate with moderate price	4.36	0.60	13
Flexibility in billing and payment	4.23	0.67	17
Competitive price	4.56	0.59	5
Price markdown	4.19	0.73	20
Customer’s experience			
Quick response	4.35	0.57	14
Image and reputation	4.21	0.56	19

Customs clearance	4.22	0.62	18
Safety/risk cover			
Cargo handling	4.48	0.66	8
Compensation/claim	4.37	0.58	12
Willing to help, problem solving	4.32	0.58	15
Damage and loss rate	4.43	0.62	11
Air freight capacity			
Inter-connectivity with land transport system	4.45	0.59	10
Promised delivery time guarantee	4.58	0.57	4
Self-built air fleet/airlines schedule	4.13	0.48	21

4.4.2 Structural Equation Modelling

Structural equation modelling is capable of analysing the latent relationships among factors which could be either observed directly or indirectly (Gefen, Straub & Boudreau, 2000; Kline, 2005; Cheng & Yeh, 2007; Subramanian et al., 2014; Kumar & Dash, 2015). The SEM technique combining measurement and structural models was adopted in the early 1990s to investigate customer satisfaction (Fornell, 1992; Jie et al., 2015; Subramanian et al., 2014). Compared with first-generation regression techniques such as linear regression and ANOVA, SEM can analyse factors and examine hypotheses synchronously (Cheng & Yeh, 2007). Given these advantages, SEM has been adopted as a second-generation technique (Devaraj, Fan & Kohli, 2002; Gefen, Straub & Boudreau, 2000). Saurina and Coenders (2002) summarise that SEM is able to model complex systems with linear models where underlying associations are modelled between directly or indirectly observed variables or a mixture of these. For example, SEM is applied to simultaneous and reciprocal relationships between quality and satisfaction, and model relationships among latent variables such as the dimensions in the SERVQUAL model. With its simplicity and ability to model complex systems, SEM has been widely used in the social sciences and marketing literature (Jie et al., 2015; Subramanian et al., 2014; Saurina & Coenders, 2002; Devaraj et al., 2002).

The confirmatory factor analysis (CFA) model, a specified core technique of SEM, is used to measure relationships from latent to observable variables. The model of this study (Figure 1) is an overall structural equation model that integrates six independent variables to customer's satisfaction (perceived service quality). The latent variables are the seven perception dimensions and the 27 observed variables (Table 4.5). The relationships among the latent variables, which are perceived service quality and the six service quality factors, will be tested when a good-matching CFA model is identified. The validity of the correlations between the variables underlying the proposed analytic hierarchy is measured. Simultaneously, the hypotheses of each multiple relationships between a pair of variables are examined and analysed (Gefen, Straub & Boudreau, 2000; Saurina & Coenders, 2002; Devaraj et al., 2002; Kline, 2005; Cheng & Yeh, 2007; Subramanian et al., 2014; Jie et al., 2015; Kumar & Dash, 2015).

Table 4.5: The dimensions scaling.

Attribute	Item	Sub-criteria	Definition
Delivery performance	DP1	Prompt on-time delivery	Quick and delivery on-time as promised from pick-up point
	DP2	Accurate delivery	Accurate delivery to address of shipment (right place right product)
	DP3	Prompt on-time pick-up	On-time and quick pick-up from booking point, as per customer's request
Operational capability	OC1	Logistics network	Wide and quick transportation networking
	OC2	Physical facility	New, tidy facility with state-of-the-art technology; Enough, flexible operational warehouse space
	OC3	Information system	ITC systems for logistics process
	OC4	Professional personnel	Specialized team; presence of workforce
Preferential pricing	PP1	Variety rate with moderate price	Offer many class rates and basic low price option
	PP2	Flexibility in billing and payment	Flexibility in billing and payment conditions increases goodwill between the user and the provider
	PP3	Competitive price	Relatively lower price for same volume and/or weight to other rivals
	PP4	Price markdown	Price markdown based on the certain amount freight; level of rate concession

Customer's experience	CE1	Quick response	Quick response to customer's request by internet or telephone
	CE2	Image and reputation	Image and reputation of the carrier
	CE3	Customs clearance	Seamless customs clearance
Safety/risk cover	SR1	Well cargo handling	Cargo protection; Handling by proper characteristics based on the product features; Able to handle unusual cargo
	SR2	Compensation/claim	Compensation policy
	SR3	Willing to help; Problem solving	Willingness to help solve customer problems
	SR4	Low damage and loss rate	Low cargo damage or loss rate
Air freight capacity	AC1	Inter-connectivity with land transportation system	Multi-modal connections and connectivity radiations of transport infrastructure
	AC2	Promised delivery time guarantee	Money back guarantee
	AC3	Self-built air fleet	Maintain and operate own aircraft
Customer's satisfaction (Perceived service quality)	CS_DP	Delivery performance	Performance on delivery performance
	CS_OC	Operational capability	Performance on operational capability
	CS_PP	Preferential pricing	Performance on preferential pricing
	CS_CE	Customer's experience	Performance on customer's experience
	CS_SR	Safety/risk cover	Performance on safety/risk cover
	CS_AC	Air freight capacity	Performance on air freight capacity

Some measurements are applied for the goodness of fit. For example, the study examines estimates of the statistical and confirmed validity. This assessment ensures no estimates are outside of the acceptable area, and that there are no negative variances or correlations larger than 1 in this case. Other measurements include the convergence of the estimation procedure, the empirical identification of the model, the statistical significance of the parameters, and the goodness of fit to the covariance matrix (Saurina & Coenders, 2002). The root mean squared error of approximation is used to measure the degree of approximation between the model and the population covariance matrix. If the values are not larger than 0.05, the approximation is usually considered acceptable. (Browne & Cudeck, cited in Saurina & Coenders (2002).

4.5 Results

The Cronbach's α of customer's satisfaction (perceived service quality), operational capability, preferential pricing, safety/risk cover, delivery performance, customer's experience and air freight capacity are 0.822, 0.78, 0.735, 0.705, 0.771, 0.736 and 0.688, respectively (Table 4.7) and most of them are > 0.70. The values larger than 0.65 suggest that the measurement scales are acceptable (Jayaram & Tan, 2010). When the value of the variables is higher than 0.70, the measurement items and constructs are with adequate reliability (Nunnally, cited in Lu & Yang, 2006, p.22). All constructs have received high and good values, and are thus reliable to be applied for later analysis.

The study conducts principal CFA with Varimax rotation to evaluate the seven constructs individually. At the same time, only self-built air fleet/airlines schedule in air freight capacity has a factor loading of 0.487. The figure over 0.60 is suggesting good convergent and discriminant validity for each latent variable (Jayaram & Tan, 2010). With the principal components extracted, the Varimax of orthogonal rotation obtains the rotated coefficients for the seven variables and the component matrix (Table 4.6). The results show that most of the indicator items loaded high above 0.5 on their respective factors and all the other factors are below 0.40. The figures suggest convergence and that discriminant validity for each latent variable is acceptable. Table 4.7 shows the summary of the CFA and that the eigenvalues of the seven variables are greater than 1. The results indicated that the seven variables accounted for approximately 62.51% of the total variance.

Table 4.6: Rotated component matrix.

Latent construct	**Item**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**	**Factor 7**
Customer's satisfaction	CS_AC	0.730	0.046	0.107	-0.054	0.069	0.105	0.124
	CS_DP	0.685	0.178	0.119	0.181	-0.002	0.283	0.208
	CS_PP	0.674	0.051	0.070	0.154	0.008	0.088	-0.048
	CS_CE	0.646	0.133	0.022	0.172	0.048	0.284	0.103
	CS_SR	0.629	0.178	0.032	0.179	0.222	0.110	0.143
	CS_OC	0.584	0.152	0.085	0.134	0.311	0.038	0.181
Operational capability	OC1	0.006	0.778	0.047	0.059	0.229	0.163	0.014
	OC3	0.204	0.757	0.052	0.199	0.149	0.249	0.076
	OC2	0.165	0.748	-0.010	0.141	0.138	0.098	0.177

	OC4	0.298	0.507	0.205	0.283	0.044	-0.087	0.096
Preferential pricing	PP1	0.059	0.084	0.790	0.157	0.014	0.185	-0.017
	PP3	-0.071	-0.086	0.784	0.129	0.165	-0.099	0.101
	PP2	0.260	0.086	0.771	-0.109	0.044	0.094	0.092
	PP4	0.293	0.345	0.509	-0.128	-0.123	0.196	0.075
Safety/risk cover	SR2	0.124	0.121	-0.064	0.741	0.039	0.162	0.025
	SR4	0.110	0.233	0.113	0.720	0.146	-0.055	0.147
	SR1	0.215	0.229	0.024	0.635	0.288	0.118	0.052
	SR3	0.128	-0.053	0.091	0.487	-0.033	0.394	0.035
Delivery performance	DP2	0.029	0.128	0.086	0.131	0.869	0.069	0.085
	DP1	0.130	0.339	0.026	0.129	0.779	0.108	0.104
	DP3	0.370	0.074	0.060	0.048	0.601	0.268	-0.007
Customer's experience	CE3	0.222	0.104	0.073	0.144	0.094	0.737	0.086
	CE1	0.151	0.182	0.062	-0.038	0.223	0.728	0.103
	CE2	0.241	0.181	0.110	0.253	0.071	0.601	0.102
Air freight capacity	AC2	0.114	0.193	0.039	0.075	0.110	0.086	0.868
	AC1	0.185	0.101	0.080	0.036	0.146	0.158	0.860
	AC3	0.259	-0.033	0.161	0.263	-0.147	0.042	0.385

Table 4.7: Factor analysis of the research model.

Latent construct	**Item**	**Loading**	**Cronbach's α**	**Eigenvalue**	**% of Variance (Cumulative %)**
Customer's satisfaction (Perceived service quality)			0.822	7.628	28.25% (28.25%)
Air freight capacity	CS_AC	0.73			
Delivery performance	CS_DP	0.69			
Preferential pricing	CS_PP	0.67			
Customer's experience	CS_CE	0.65			
Safety/risk cover	CS_SR	0.63			
Operational capability	CS_OC	0.58			
Operational capability			0.780	2.114	7.83% (36.08%)
Logistics network	OC1	0.78			
Information system	OC3	0.76			
Physical facility	OC2	0.75			

Professional personnel	OC4	0.51			
Preferential pricing			0.735	1.77	6.56% (42.64%)
Flexibility in billing and payment	PP2	0.79			
Variety rate with moderate price	PP1	0.78			
Competitive price	PP3	0.77			
Price markdown	PP4	0.51			
Safety/risk cover			0.705	1.478	5.47% (48.11%)
Damage and loss rate	SR4	0.74			
Cargo handling	SR1	0.72			
Willing to help; problem solving	SR3	0.64			
Compensation/claim	SR2	0.49			
Delivery performance			0.771	1.412	5.23% (53.34%)
Accurate delivery	DP2	0.87			
Prompt on-time delivery	DP1	0.78			
Prompt on-time pick-up	DP3	0.60			
Customer's experience			0.736	1.294	4.79% (58.14%)
Customs clearance	CE3	0.74			
Quick response	CE1	0.73			
Image and reputation	CE2	0.60			
Air freight capacity			0.688	1.181	4.38% (62.51%)
Inter-connectivity with land transportation system	AC1	0.87			
Promised delivery time guarantee	AC2	0.86			
Self-built air fleet/airlines schedule	AC3	0.39			

4.6 Hypotheses testing

4.6.1 The goodness of fit evaluation

First, the measurement models with the six factors are tested by the CFA, which is conducted in AMOS 26.0. Fit indices are shown in Table 4.8. The results indicate strong empirical evidence of their validity. The critical ratio (C.R.) values shown in

Table 4.9 for the loading were high, indicating sufficient convergent validity. The values for the fit indexes recommended are as follows: Chi-square is a statistical test of significance and with at least 0.05 significance level recommended as accepted (Kumar & Dash, 2015). The relative Chi-square (Chi-square/df) value should be between 1 and 5 (Hair et al., cited in Kumar & Dash, 2015, p.298). The GFI index with a higher value represents a better fit (Hair et al., cited in Kumar & Dash, 2015, p.298) and > 0.90 (good fit) is recommended (Schermelleh-Engel et al., cited in Kumar & Dash, 2015, p.298). Kumar & Dash (2015) advise that for RMSEA the value recommended is < 0.05 for a good model fit, and for CFI the value should be above 0.95 to indicate well-fitting. A score for NNFI (TLI) of 0.90 and a higher value is required for the status of a good fit. The detailed results of these indexes of the measurement model is in Table 4.8. All of the indices indicate a good model fit.

Table 4.8: CFA fit indices.

Criteria	Results
Chi-square	229.498
DF	167
CMIN/DF	1.374
P-value	0.001
RMSEA	0.043
CFI	0.955
GFI	0.902
NNFI (TLI)	0.943

Table 4.9: Regression weights.

	βEstimate	S.E.	C.R.	P-value	Result
AC1 <--- AC	1				
AC2 <--- AC	0.904	0.106	8.497	***	Significant
AC3 <--- AC	0.264	0.07	3.781	***	Significant
CE3 <--- CE	1				
CE1 <--- CE	0.799	0.107	7.487	***	Significant
CE2 <--- CE	0.85	0.109	7.819	***	Significant

DP1 <--- DP	1				
DP2 <--- DP	0.756	0.09	8.442	***	Significant
DP3 <--- DP	0.88	0.108	8.122	***	Significant
PP1 <--- PP	1.112	0.159	6.987	***	Significant
PP2 <--- PP	1				
PP3 <--- PP	0.843	0.125	6.722	***	Significant
PP4 <--- PP	1.33	0.242	5.494	***	Significant
OC3 <--- OC	1				
OC1 <--- OC	0.8	0.075	10.65	***	Significant
OC2 <--- OC	0.73	0.072	10.205	***	Significant
OC4 <--- OC	0.8	0.104	7.66	***	Significant
SR1 <--- SR	1				
SR2 <--- SR	0.68	0.096	7.087	***	Significant
SR3 <--- SR	0.419	0.098	4.272	***	Significant
SR4 <--- SR	0.762	0.104	7.298	***	Significant

4.6.2 Structural model: path analysis

The integral fit indices of measurement for the structural model are provided in Table 4.10. The results show that the research model is a good fit overall, aligning with the recommended values under the review.

Table 4.10: Fit indices of measurement for the structural model.

Criteria	Results
Chi-square	388.984
DF	297
CMIN/DF	1.31
P-value	0.000
RMSEA	0.039
CFI	0.951
GFI	0.876
NNFI (TLI)	0.942

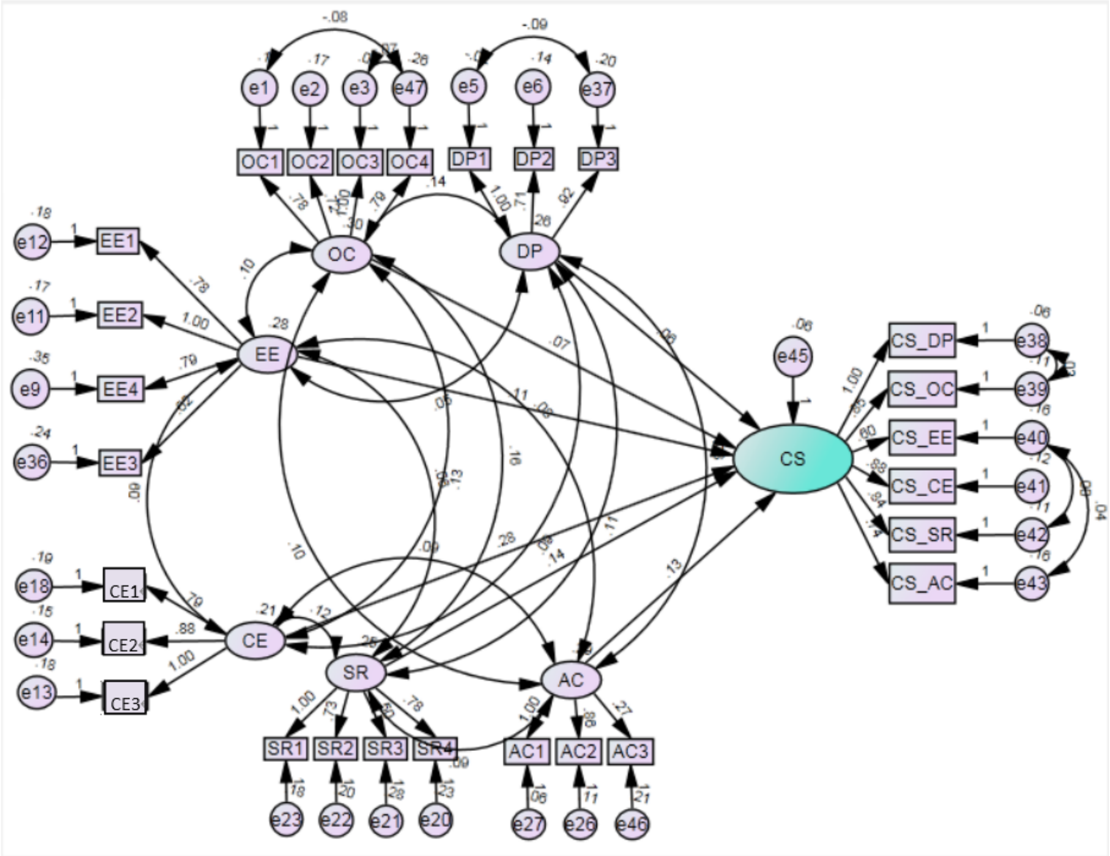

Figure 4.2: Path analysis of measurement and structural model

Figure 4.2 shows the path analysis of the hypothesised measurement and structural model of perceived service quality. The hypothesised relationships are examined by the estimates of the path coefficients. The results show that perceived service quality is significantly influenced positively by preferential pricing (H3: β = 0.105, t = 2.036, p=0.042), customer experience (H4: β = 0.282, t = 3.485, p < 0.0001), safety/risk cover (H5: β =0.142, t = 1.972, p = 0.049) and air freight capacity (H6: β = 0.131, t = 2.694, p = 0.007), but not by delivery performance (H1: β = 0.064, t = 1.435, p = 0.151) or operational capability (H2: β = 0.067, t = 1.164, p = 0.245). Thus, H1 and H2 are rejected. To sum up, there is a significant positive relationship between perceived service quality, preferential pricing, customer experience, safety/risk cover and air freight capacity. Interestingly it is not a significant positive relationship with delivery performance and operational capability. Details of the hypothesis testing results are given in Table 4.11.

Table 4.11: Hypothesis testing results.

	βEstimate	**S.E.**	**C.R.**	**P-value**	**Result**
CS <--- DP	0.064	0.045	1.435	0.151	Not significant
CS <--- OC	0.067	0.058	1.164	0.245	Not significant
CS <--- PP	0.105	0.052	2.036	0.042	Significant
CS <--- CE	0.282	0.081	3.485	***	Significant
CS <---S R	0.142	0.072	1.972	0.049	Significant
CS <--- AC	0.131	0.048	2.694	0.007	Significant

4.7 Discussion

Following research about TPL company selection and service quality, this chapter explores a series of evaluating dimensions for the air freight express industry in the Chinese e-logistics market. Referring to the SERVQUAL model theory and other studies in the literature, a hypothesised structural model was developed to assess empirically each relationship between an essential service dimension and customer satisfaction, which is referred to as perceived service quality, as this would influence a customer's decision on the AESP selected. The results of the factor analysis support the selection of the essential items as the key sub-criteria of each service dimension. This is functional for decision makers responsible for long-term outsourcing operations with air freight express services in the e-logistics market to use to review their air freight express service quality dimensions through specific items. For example, the research identified four sub-criteria to satisfy the operating capacity: logistics network, physical facility, information systems and professional personnel

This study reveals that air freight express service quality dimensions are valued by stakeholders and lead to better service performance of the AESPs. The air freight express companies should meet customers' demands in the fields of preferential pricing, customer experience, safety/risk cover and air freight capacity. The hypothesis testing results illustrate that these four service quality dimensions are positively associated with perceived service quality. Air freight express services are an end-user orientation market, and are different from other TPL outsourcing companies, as the end users experience maintains a great power and influence on the decision selection. Cost and loss protection are the most concerning issues. The overall customer experience is reflected in the capability of the air freight express companies to offer a quick response and the rightful problem-solving to customers, based on the understanding of their concerns and desires. Therefore, any investment to improve these dimensions is proper. As a core capability, air freight capacity is approval for end-users to believe the air express service will be covered for sure.

Interestingly, referring to the result from Table 4.11, there was no statistically significant positive association between perceived service quality and delivery performance, nor perceived service quality and operational capability. Thus, Hypotheses 1 and 2 were not supported. Valaei, Rezaei and Shahijan (2016) interpreted results which do not significantly support the hypotheses as being less influential on the perceived service quality from the (business client) customers' viewpoint. Jayaram and Tan (2010) explained that when the factors are shown to be fundamentally important to the outcome being evaluated but are found to not support a positive relationship, then it needs to be seen if ignored factors in the empirical study act as an 'assumed given' or 'an order qualifier' to the optimal performance, such as information integration working to firm performance studied in their study. Thus, our finding is not surprising, considering that the delivery performance and operational capability dimensions are supposed to be the key criteria for air freight express services based on the literature review on other TPL markets (Park, Choi & Zhang, 2009; Tsai, Wen & Chen, 2007; Meng et al., 2010). These results show that consumers in the Chinese e-logistic market are not sensitive to the overall industrial performance and think it is less important for their choice of an AESP. They focus more on cost and after sales service than the operation capacity claimed. Air freight capacity with PDT will be more specific for customers to refer to and rely on. PDT is More critical than general delivery performance and personnel and network scope.

To sum up, the unique features of the e-logistics market make air freight express different from other TPL outsourcing operations. Customer satisfaction of end users is the concern for air freight express third parties and their clients. An online order is the whole matter for its individual buyer. It is not the situation where a firm evaluates its TPL operation through a ratio of the bulk of orders delivered within a period. A unique character of Internet consumer satisfaction is that the customer experience affects word-of-mouth responses. A small thing can be magnified greatly, and a mistake can often cause huge problems for the TPL company's client. When it is impossible to achieve 100% zero error conditions, assisting the customer in solving the problem and compensation to cover the financial loss of the customer are things that the company should be concerned about. Due to the homogeneous competition in e-logistics operations, the scale and fast service of land transport networks can no longer provide great advantages in the market. Air transport capacity has become a capability that differentiates the scale of operations. It shows that there are differences between freight express companies in this, and companies with advantages can get better outcomes. The findings also support the strategy of companies focusing on building their own air freight cargo capacity.

4.8 Conclusion

This research offers empirical evidence to support the activities of AESPs and is the first study on the service quality of China's air express freight industry. Based on the results of the analysis, preferential pricing, customer's experience, safety/risk cover and air freight capacity maintain a strong positive relationship with perceived service quality, which indicates that decision-makers are better off not only focusing on overall delivery performance and operation capability, but also take into account the detailed service quality dimensions which benefit customers. For instance, offering comparatively low prices to other competitors with even further markdowns based on a given volume of delivery orders, improving a customer's experience through a quick response with a solution for the customer's concern, financial compensation or insurance to cover lost parcel or delivery delay, and better air freight infrastructure can provide a higher level of perceived service quality. By doing so, AESPs will achieve more competitive advantages in the e-logistics market. There can be a wide application of the model proposed in this study to examine the perceived service quality, customer loyalty and customer satisfaction through SEM analysis.

One limitation in this research is that the model developed in this study is only for AESPs in China's e-logistics market. Future research should examine the proposed model in other countries or for different demographic groups since e-commerce is developing globally and has become a component of daily commercial activity. A comparative study between some major e-commerce countries with different demographic variables, such as cultural background, gender and age, may provide different evidence. Finally, other dimensions might exist and their influence on perceived service quality needs to be evaluated to increase the body of our knowledge.

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CHAPTER 5 : CONCLUSION

5.1 The development of Chinese dedicated air cargo industry

This thesis explores air route networks and services in the air freight industry and evaluates the relationship between air freight capacity and competitiveness, which is customer satisfaction in this case. This thesis presents the development of China's dedicated air cargo industry while considering the impact of the e-commerce boom and the COVID-19 pandemic. The results help to fill a gap in the relevant literature and will help policy makers and company decision makers to understand the current state of developments in the networks and services. Specifically, the contributions of this thesis are summarized:

- It explores the impact of the e-commerce boom and the COVID-19 pandemic on China's dedicated air cargo industry through CNT and service quality theory. The study helps to fill a gap in the literature by applying these methodologies.

- One chapter investigated several individual carriers during the pandemic period, and another examined the national network. These chapters are the earliest investigations into the impact of the global pandemic on a country's domestic air cargo network.

- Rather than applying a topological index alone, these two studies of the transport network indicate the network's spatial scale and its air cargo capacity through comparisons of individual companies with their European counterparts and of the national network with other nations' passenger flight networks and low cost carriers' national networks.

- The chapter about air express services has developed a conceptual model of service quality dimensions that can be used to evaluate the service performance of ASEPs in China's e-logistics market.

- The air fleet planning and infrastructure development has been discussed and considered in the service dimensions in Chapter 4. It shows that air freight capacity is positively associated with the whole service performance.

The contributions have tangibly achieved the research aim and objectives of the thesis. The results from the thesis offer quantitative measurements for network development and air express service quality. The three chapters address the research questions raised in the introduction.

First, how is the networks development of the main market players? The rapid developments of the e-commerce markets increased the demands on the air express service industry substantially, and so the integrators became the biggest market players. Chapter 2 applied topological measures to investigate individual air express integrators' domestic CSFN. The integrators' networks underwent great development after one year of the COVID-19 outbreak. By comparing their network indices values with ones of the world-leading carriers in the EU, it is found that the EU carriers with their preponderance of hub-and-spoke structures have a higher degree of centralization. In contrast, China's integrators have hub-and-spoke and point-to-point structures, which make the network less centralized and more complex.

Further, what is the status of China's dedicated air cargo networks? Chapter 3 applied comprehensive CNT measures to the networks. This chapter described the CSFN's topological properties and investigated the changes in this system during the pandemic. It found that the CSFN displayed small-world and scale-free network properties in 2020. The CNT analysis demonstrated that the CSFN is not a random type of network and maintains a good coverage of the nation. The average path length was 2.17 and an increased clustering coefficient was 0.434 at the end of 2020. The CSFN is unbalanced like the form of the air passenger traffic in relying on three eastern mega-city clusters. However, the network appears to have a clear layering feature consisting of national and intermediate level hubs as well as many small nodes (peripheral cities). The national hubs for the dedicated cargo carriers are Shenzhen in the Pearl River delta, and Hangzhou and Nanjing in the Yangtze River delta for the CSFN, instead of Guangzhou and Shanghai as in the case of China's air passenger network. The increase in direct freighter routes among cities such as Wuhan, Beijing, Tianjin and Guangzhou in the early period of the pandemic increased the density and transitivity of the CSFN.

In a severe regional development imbalance after rapid economic growth, Chinese domestic air cargo traffic is concentrated in gateway airports in coastal metropolitan areas. To meet the rising aviation demands driven by the development of China's economy, the domestic air cargo network in the coming decades will have strategic development opportunities. The air freight industry will benefit from transforming and upgrading the existing large domestic cargo airports. According to the findings in Chapters Two and Three, the trend of the national network development is foreseeable. In the long run, China's domestic air cargo network pattern will be altered to a real hub-and-spoke network by an integrator such as SF Express who will implement its integration strategies to reinforce its advantages in the premium price and PDT service strategies.

Finally, what are the factors, and their relative importance, that influence the adoption of an air express delivery service? Following other studies in the literature about TPL company selection and the SERVQUAL model theory, Chapter 4 developed a conceptual model with six evaluating dimensions for the air freight express industry in China's e-logistics market. Each relationship between a service quality dimension and customer satisfaction was examined. The fields of preferential pricing, customer experience, safety/risk cover and air freight capacity are positively associated with customer satisfaction. These results show the inclinations of the Chinese consumers. When they choose an AESP, they are more sensitive to cost and after sales service than the operational capacity and the overall industrial performance claimed. Significantly, this suggests that customers expect and value air freight capacity. When an AESP increased its investments in aircraft and airport infrastructure substantially in recent years, these investment projects increased the AESP's competitiveness on the customers' perceived service quality. It is an encouraging result for the investors and policy makers in these infrastructure development projects.

5.2 The role of e-commerce and the impact of the COVID-19 pandemic

Since e-commerce became the primary driver for China's air cargo traffic industry, this thesis has highlighted some developmental features as a result of adapting to the online business model. First, Chinese integrators are the main group of operators to gain from the growth of e-commerce. By analysing the domestic market's scheduled air freighter network, it is seen that the individual integrators have dominated the domestic all-cargo network development in coverage and capacity. Chapter Two suggests that private integrators can impact on the hub-and-spoke network development by reshaping the network pattern. Second, SF Express was found to operate more bi-directional routes at a high density in its domestic network. This is different to what its counterparts in China and the EU domestic markets do. This may imply that the massive delivery volume from e-commerce orders made the integrator form this symmetric network pattern. Third, the national hubs for dedicated cargo carriers are not Guangzhou and Shanghai as in the case of China's air passenger network, but Shenzhen in the Pearl River delta, and Hangzhou and Nanjing in the Yangtze River delta. Hangzhou, Shenzhen and Nanjing host the headquarters of giant e-commerce enterprises but they have a relative excess in airport capacity.

In terms of service, satisfying the customer is the priority of air freight express companies and their clients. A particular characteristic of e-commerce consumer satisfaction is that the crucial word-of-mouth communication is associated with the customer's experience of the delivery service. A tiny error can be amplified greatly and, consequently, cause huge problems for the air express firm's clients. While it is rare to achieve 100% zero error conditions, assisting the customer in solving the problem and compensation to cover the financial loss incurred by the customer are things that the air express companies should implement.

The research suggests that the pandemic has not had a negative impact on the CSFN. Instead, the CSFN has improved since the COVID-19 outbreak, with an increased performance in all of the network properties evaluated in this thesis. As China's air passenger flights had reopened quite quickly in the latter half of 2020, it was more likely a result of the higher air cargo demand during the pandemic and the airlines' realisation of the importance of freighter operations in China, rather than the substitution effect from a reduction in belly cargo on passenger aircraft.

Unfortunately, the service quality model did not consider the impact of COVID-19. The draft of this part of the thesis was completed before the COVID-19 outbreak. The data collection and analysis were finished. However, based on a later literature review on the main impact of COVID-19 on e-commerce, it was found that the COVID-19 pandemic increased online shopping orders and revenues generally when people maintained social distance and stayed at home (Bhatti et al., 2020; Gu et al., 2021). The negative effects on e-commerce are uncertain customer demands and supply chain issues (Gu et al., 2021). It has not been reported that the order fulfilment service of the air express companies has been affected much. Restuputri, Indriani and Masudin (2021) conducted a study on the impact of logistics service quality on customer satisfaction during the pandemic. They reveal that it is important to protect consignments when they are delivered and passed on to the consumers. Logistics services must be highly responsive to customer requests. These dimensions are aligned with the results in this thesis of Chinese e-logistics customers being more sensitive to cost and after sales service. It can be argued confidently that the model presented here has considered these factors in respect to the impact of COVID-19.

The results above show that e-commerce impacted on the network's development and influenced customers' inclinations about perceived service quality. The COVID-19 pandemic accelerated the trend in these because of the growth in e-commerce. In a post-COVID-19 era, the role of e-commerce on air cargo development could be even more prominent as these features will be enhanced and consolidated. In the air cargo industry e-commerce is not only the driver of cargo traffic, but it also is imposing long-term effects on the industry. Adapting to the e-commerce market's requirements is the development path for the air cargo industry.

5.3 Limitations of the study and future research pathways

In sections 3.7 and 4.8 some limitations of this study and future research pathways were discussed from the perspectives of network analysis and the service quality model. This thesis was initiated to examine the development of Chinese air cargo industry in response to the e-commerce boom and added in the parts of the COVID-19 pandemic later after the outbreak, but the methodologies here can be applied to review the air cargo industry in other markets. There are potential breakthroughs about a nation's air cargo development that can be made by future research.

Chapter 2 has investigated individual cargo carriers, the air express integrators. Based on the findings, the massive parcel volume from online orders can make the main integrator form a symmetric network. The scope of the research methodology and a lack of data on the actual air cargo volume limits the research to explore more evidence to support this claim. But carriers have suffered from air cargo's uneven volumes in the last few decades, and so further research about the empirical link between cargo volume generated by e-commerce and the formation of a symmetric network could generate important managerial and policy implications for carriers and regulators.

Also, cross-border online markets create a massive demand for air cargo traffic. Due to the limitation on the scope of Chapter 3, the importance of cross-border cargo flights has not been considered. Therefore, international all-cargo routes to and from China should not be omitted in a future study. The new network model should cover all domestic and international destinations. Only cross-border flight routes passing gateway cities like Beijing, Shanghai and Guangzhou will be counted. The main target of this research would be to investigate the importance of these gateway cities through centrality measures. In addition, it is believed that the international flight frequency and weekly available freight tonnes of the gateway cities would have a positive impact on their domestic network. This is worth exploring in future research.

There are several limitations for this study which present the opportunities for future research. First, belly cargo is a significant part of the air cargo traffic, which is ignored in this study. Before the pandemic, the belly cargo mode was a main air cargo transportation method, which was examined in Gong et al. (2018). During the pandemic, with most passenger flights being grounded, all cargo carriers became the dominant operators in the air cargo market and their networks became more important than those of the passenger flights. In the post-Covid-19 period, it is expected that the belly cargo mode will regain its popularity and attention in air cargo research. Second, it is understood that CNT contains many indices that can give insight into the network characteristics. We only used part of these indices in this research and other network indices can be explored in the future research.

As mentioned above, the study presented in Chapter 4 was drafted before the pandemic outbreak. It means this part of the research missed a consideration of the impact of this global crisis. Future research about the impact of COVID-19 on the customers' perceived service quality can be conducted with a comparative study between two major e-commerce countries with different demographic variables such as cultural background, gender and age.

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APPENDICES

Table A1: The comparison of navigable cities in China's scheduled freighter network at the end of 2019 and in 2020.

City	2019 Winter				2020 Winter				CAAC Regional Admin	Airspace Class
	k	C	C_C	C_B	k	C	C_C	C_B		
Hangzhou	28	0.06	0.71	0.47	29	0.10	0.75	0.37	East China	4F
Nanjing	22	0.09	0.58	0.19	23	0.14	0.67	0.18	East China	4F
Shenzhen	17	0.14	0.56	0.18	23	0.20	0.66	0.21	Centrel and Southern	4F
Shanghai	8	0.18	0.42	0.01	9	0.33	0.50	0.02	East China	4F
Xi'an	8	0.21	0.49	0.13	8	0.29	0.51	0.10	Northwest	4F
Beijing	7	0.43	0.49	0.01	12	0.38	0.55	0.07	North China	4F
Guangzhou	7	0.43	0.50	0.02	11	0.31	0.54	0.05	Centrel and Southern	4F
Tianjin	7	0.19	0.48	0.03	10	0.29	0.53	0.07	North China	4E
Zhengzhou	5	0.50	0.48	0.01	9	0.42	0.53	0.02	Centrel and Southern	4F
Shenyang	5	0.60	0.48	0.00	7	0.62	0.52	0.00	Northeast	4E
Chengdu	5	0.50	0.50	0.01	7	0.62	0.54	0.01	Southwest	4F
Fuzhou	5	0.60	0.45	0.00	7	0.48	0.51	0.01	East China	4E
Wuxi	5	0.30	0.38	0.00	6	0.40	0.46	0.01	East China	4E
Xiamen	5	0.40	0.45	0.01	5	0.40	0.47	0.00	East China	4E
Wuhan	4	0.33	0.45	0.00	9	0.50	0.53	0.01	Centrel and Southern	4F
Dalian	4	0.67	0.44	0.00	6	0.73	0.51	0.00	Northeast	4E
Wenzhou	4	0.67	0.43	0.00	4	0.83	0.46	0.00	East China	4E
Quanzhou	4	0.50	0.47	0.01	4	0.50	0.49	0.01	East China	4D
Qingdao	4	0.67	0.45	0.00	3	0.67	0.45	0.00	East China	4E
Nantong	4	0.33	0.38	0.00	3	0.67	0.41	0.00	East China	4E
Nanchang	3	0.33	0.43	0.00	8	0.29	0.52	0.06	East China	4E
Shijiazhuang	3	0.67	0.44	0.00	7	0.43	0.52	0.02	North China	4E
Harbin	3	0.67	0.43	0.00	5	0.60	0.48	0.00	Northeast	4E
Changsha	3	0.33	0.44	0.00	4	0.50	0.46	0.00	Centrel and Southern	4E
Changchun	3	0.67	0.44	0.00	4	0.67	0.46	0.00	Northeast	4E
Ji'nan	3	0.67	0.44	0.00	3	0.67	0.45	0.00	East China	4E
Chongqing	3	0.67	0.46	0.00	3	0.67	0.48	0.00	Southwest	4F

Lanzhou	3	0.00	0.45	0.00	2	0.00	0.44	0.00	Northwest	4E
Jieyang	3	0.00	0.43	0.08	1	0.00	0.36	0.00	Centrel and Southern	4E
Weifang	2	1.00	0.46	0.00	4	0.83	0.49	0.00	East China	4D
Taiyuan	2	0.00	0.39	0.00	3	0.33	0.45	0.00	North China	4E
Ningbo	2	0.00	0.36	0.00	3	0.33	0.43	0.00	East China	4E
Nanning	2	0.00	0.42	0.00	2	1.00	0.45	0.00	Centrel and Southern	4E
Kunming	2	0.00	0.43	0.00	2	0.00	0.44	0.00	Southwest	4F
Hohhot	2	0.00	0.42	0.01	2	1.00	0.44	0.00	North China	4E
Huai'an	1	0.00	0.33	0.00	3	0.67	0.42	0.00	East China	4D
Urumqi	1	0.00	0.41	0.00	2	1.00	0.45	0.00	Xinjiang	4E
Hefei	1	0.00	0.35	0.00	2	1.00	0.42	0.00	East China	4E
Guiyang	1	0.00	0.41	0.00	1	0.00	0.43	0.00	Southwest	4E
Haikou	1	0.00	0.35	0.00	1	0.00	0.40	0.00	Centrel and Southern	4E
Yinchuan	1	0.00	0.33	0.00	1	0.00	0.34	0.00	Northwest	4E
Guilin	1	0.00	0.30	0.00	0	0.00	0.00	0.00	Centrel and Southern	4E
Luoyang	1	0.00	0.30	0.00	0	0.00	0.00	0.00	Centrel and Southern	4D
Xining	1	0.00	0.33	0.00	0	0.00	0.00	0.00	Northwest	4E
Xingyi	1	0.00	0.04	0.00	0	0.00	0.00	0.00	Southwest	4D
Zunyi	1	0.00	0.04	0.00	0	0.00	0.00	0.00	Southwest	4C
Lianyungang	0	0.00	0.00	0.00	3	0.67	0.39	0.00	East China	4D
Weihai	0	0.00	0.00	0.00	1	0.00	0.35	0.00	East China	4D
Xuzhou	0	0.00	0.00	0.00	1	0.00	0.34	0.00	East China	4D
Yulin	0	0.00	0.00	0.00	1	0.00	0.34	0.00	Northwest	4D

CAAC Regional Admin. and Airspace Class source: CAAC (2020a).

Notes:

1) CAAC organizes its administration through seven regional divisions based on the economic development level and geographic zoning. The ‘region’ column displays which regional authority the airport reports to (Jiang et al., 2017).

2) According to CAAC (2015), basically, the Chinese Airfield Area Class is aligned to the ICAO Aerodrome Reference Code included in ICAO Annex 14. The standards reflect the maximum space capacity that the airport can allow aircraft for takeoff and landing. The standard codes consist of numeric and letter parts. Generally, 4F is the highest class for the maximum with B747s, A380s and equivalent size aircraft. 4E is up to B777s and A330s, and 4D is for B767s and A310s.

Table A2 : The paired t-test for several network indices for 2020 Winter and 2019 Winter network

Category	**Degree**	**clustering coefficient**	**Closeness**	**Betweenness**
all	1.12***	0.1346***	0.0424**	0.001
	(0.261)	(0.0433)	(0.018)	(0.0034)
top 10	3.00***	0.04	0.061***	0.005
	(0.667)	(0.03)	(0.008)	(0.014)
top 11-20	2.00***	-0.001	0.056***	0.009
	(0.494)	(0.038)	(0.0075)	(0.006)
others	0.200	0.2113***	0.0317	-0.003
	(0.205)	(0.067)	(0.0304)	(0.0027)

Note:

1. The category of the cities are based on the ranking of degree in 2019 Winter network.

2. The paired-t test shows the difference of index (the change of 2020 Winter relative to 2019 Winter), and the number in the parenthesis is the standard deviation.

3. ***, **, * stand for significant level at 1%, 5% and 10%, respectively.