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Air transportation in China:
Temporal and spatial evolution and development forecasts

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Abstract: This paper analyses the features and dynamic changes of the spatial layout of air transportation utilization among different provinces in China. It makes use of data for the airport throughput and socio-economic development of every province throughout the country in the years 2006 and 2015, and employs airport passenger and cargo throughput per capita and per unit of GDP as measures of regional air transportation utilization, which is significant for refining indicators of regional air transportation scale and comparing against them. It also analyzes the spatial differences of coupling between the regional air transportation utilization indicators and the key influencing factors on regional air transportation demand and utilization, which include per capita GDP, urbanization rate, and population density. Based on these key influencing factors, it establishes a multiple linear regression model to conduct forecasting of each province's future airport passenger and cargo throughput as well as throughput growth rates. The findings of the study are as follows: (1) Between 2006 and 2015, every province throughout the country showed a trend of year on year growth in their airport passenger and cargo throughput per capita. Throughput per capita grew fastest in Hebei, with a rise of 780%, and slowest in Beijing, with a rise of 38%. Throughput per capita was relatively high in western and southeastern coastal regions, and relatively low in northern and central regions. Airport passenger and cargo throughput per unit of GDP showed growth in provinces with relatively slow economic development, and showed negative growth in provinces with relatively rapid economic development. Throughput per unit of GDP grew fastest in Hebei, rising 265% between 2006 and 2015, and Hunan had the fastest negative growth, with a fall of 44% in the same period. Southwestern regions had relatively high throughput per unit of GDP, while in central, northern, and northeastern regions it was relatively low. (2) Strong correlation exists between airport passenger and cargo throughput per capita and per capita GDP, urbanization rate, and population density. Throughput per capita has positive correlation with per capita GDP and urbanization rate in all regions, and positive correlation with population density in most regions. Meanwhile, there is weak correlation between airport passenger and cargo throughput per unit of GDP and per capita GDP, urbanization rate, and population density, with positive correlation in some regions and negative correlation in others. (3) Between 2015 and 2025, it is estimated that all provinces experience a trend of rapid growth in their airport passenger and cargo throughput. Inner Mongolia and Hebei will see the fastest growth, rising

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221% and 155%, respectively, while Yunnan, Sichuan, and Hubei will see the slowest growth, with increases of 62%, 63%, and 65%, respectively.

Keywords: air transportation utilization; temporal and spatial patterns; influencing factors; development forecasting; China

1 Introduction

A developed transportation industry serves as a backing for a region's social and economic prosperity. As an important component of transportation systems, air transportation is becoming more and more closely related to regional development. Therefore, understanding the relationship between air transportation development and the demands of socio-economic development in different regions is an important basis for rationally planning the development of airports, and even the aviation industry as a whole. In the 1970s, developed countries in the west began studying the relationship between air transportation and regional economic development. Angles of research ranged from narrow to broad, at first laying particular emphasis on investigating the relationship between air transport and development in local areas, and afterward expanding the scope of research to whole regions or the entire country. Research was primarily focused on carrying out empirical analysis of the relationship between air transportation and its related industries and regional development in countries such as the United States (Debbage, 1999; Bhadra, 2013), the United Kingdom (Papatheodorou and Lei, 2006; Zhang and Chen, 2018), and Australia (Brons *et al*., 2002). The results of these studies showed that clear correlation exists between air transportation and economic growth, population density, employment rate (Goetz, 1992), population growth (Yue, 1993), transportation of manufactured goods, tourism expenditure (Ken and Atef, 1994), and modes of transportation in different regions (Bhadra and Kee, 2008). At the same time, research outcomes also confirmed that the relationship between air transportation and development varied between regions (Chang and Chang, 2009).

In recent years, in the wake of the Chinese civil aviation industry's rapid development, the relationship between air transportation and regional development has gradually attracted the interest of Chinese scholars. These scholars are primarily focused on researching the structure of the airport system's spatial network (Jiang *et al*., 2010), the reachability and service range of airports (Pan and Cong, 2015), the population coverage of airports (Dai *et al*., 2014; Dai *et al*., 2014), and the connection between airport passenger throughput and regional economies (Zhang *et al*., 2010). The conclusions of most of these studies indicate that relatively strong correlation exists between China's air transportation industry and the national economy (Liu and Zhao, 2005; Yang and Wang, 2006; Xie *et al*., 2009). They further suggest that while the impact of regional economic development on air transportation is quite large, the impact is limited in reverse (Ye *et al*., 2005). In specific studies regarding the effect of various regional indicators on air transportation, common methods for extracting the primary influencing factors include principal component analysis (Jiao, 2005) and econometric modeling (Zhang and Zhang, 2007). It has thus been found that the major factors influencing air transportation include GDP (Tian and Li, 2015), GDP growth rate, population growth rate, total volume of imports and exports (Ge and Ge, 2005; Cui and Wu, 2017), average disposable income of urban residents, total volume of foreign trade, number of tourists entering China, average worker salary, and per capita consumption expenditure

(Xiong *et al*., 2006), as well as the new impetus for developing civil aviation brought through the constant advancement of urbanization (Shen and Cao, 2016) and improvement of high-speed rail (Ding *et al*., 2013). Studies indicate that the importance of different influencing factors varies between airports due to their different geographic locations (Wang *et al*., 2015; Wang and Guo, 2017).

In both domestic and international research, influencing factors on air transportation mainly include factors of regional economic and social development, among other factors. Most studies are concerned with researching air passenger throughput, but along with the vigorous growth of China's economy and foreign trade and the rapid development of air cargo transportation that has taken place in recent years, air cargo transportation has shown strong growth, while growth in the passenger air transportation market has slowed. The structure of the air transportation market has begun to transform, with hub airports for air cargo transportation already appearing. Therefore, air cargo throughput should be considered in studies of air transportation. Although researching the scale of air transportation and regional development has definite significance, we switch the measures of scale used in existing studies for a measure of efficiency – regional air transportation utilization – to show the actual degree to which regions utilize air transportation. This measure gives a fuller picture of the coupling between air transportation development and regional socio-economic development, and is better able to reflect the actual extent of the demand placed on air transportation by regional development. It thus supplements and furthers existing studies. In light of this, the present study, giving consideration to both passenger and cargo throughput, employs airport passenger and cargo throughput per capita and per unit of GDP as indicators of regional air transportation utilization in order to study the inherent relationship between air transportation development and regional development. Selecting provinces as its statistical unit and the years 2006 and 2015 as two specific temporal reference points, the study employs socio-economic data from various regions to study the regional air transportation utilization indicators. It also predicts future airport passenger and cargo throughput, in the hopes that this can provide a source of scientific reference for the development, planning, and construction of airports in the future.

2 Indicator selection and data sources

2.1 Indicator selection

This paper uses China's civilian airports (not including airports in the Hong Kong, Macau, and Taiwan regions) in the years 2006 and 2015 as its research sample, and carries out the study on the scale of provincial-level units. The main reason that cities were not chosen as the study's regional unit is that overlapping airport usage exists between neighboring cities due to factors like the convenience of transportation and the price of airplane tickets. Furthermore, there is the potential problem of one city using two inter-city airports. It is not realistically possible to establish a clear corresponding relationship between cities and airports, and it is therefore inappropriate to carry out analytical research on this basis.

This paper amends and improves upon the measures of scale generally employed in existing studies on the correlations between regional air transportation development, airport distribution, and socio-economic development through its use of airport passenger and cargo throughput per capita and per unit of GDP to express regional air transportation utilization and study regional demands for and contributions to air transportation, as well as its consideration of throughput both per capita and per GDP in the relationship between airport passenger and cargo throughput and regional socio-economic development. It carries out analysis of the correlation between the regional air transportation utilization indicators and regional per capita GDP (economic development factor), urbanization rate (social development factor), and population density (population factor).

2.2 Data sources

The data used in this paper comes from two sources. First, data regarding airport throughput in provincial-level units was put together by combining the throughput data for all of their airports (specifically: Beijing airports = Beijing Capital International Airport + Nanyuan Airport) (Brunsdon *et al*., 1999; Chu *et al*., 2016), and was sourced from the annual airport bulletin posted on the official website of the Civil Aviation Administration of China (http://caac.gob.cn/XXGK/XXGK/TJSJ/index_1216.html). Second, data regarding the per capita GDP, urbanization rate, and population density of different regions was sourced from the *China Statistical Yearbook*.

3 Analyzing temporal and spatial patterns in China’s air transportation utilization

As China’s economy has grown, its air transportation industry has rapidly developed. Airport passenger and cargo throughput has been on the rise overall, while airport throughput and regional socio-economic development are closely linked. In some regions, although airport passenger and cargo throughput is relatively high, throughput per capita and per unit of GDP are relatively low, which means the real level of air transport utilization is also relatively low. The opposite is the case in other regions where airport throughput is relatively low but throughput per capita and per unit of GDP are relatively high. From this it is apparent that the demand on air transportation in different regions cannot be measured simply by looking at the size of airport passenger and cargo throughput. In light of this, the present study uses cross-sectional data of airport and regional development in the years 2006 and 2015, and uses the dual indicators of airport passenger and cargo throughput per capita and per unit of GDP to measure the level of air transportation utilization in different regions. These two indicators are obtained using the following method: first, a widely recognized passenger and cargo conversion formula is used (1 passenger = 0.09t of cargo (Wang, 2006)) to calculate the region’s airport throughput (unit = standard person), which is equivalent to passenger throughput + cargo throughput / 0.09. Then, the region’s airport throughput is divided by its total population (unit = person) or GDP (unit = one million y uan) to produce a ratio. A comparison of the maximum and minimum values of airport passenger and cargo throughput and the regional air transportation utilization indicators in the years 2006 and 2015 can be found in Table 1. In 2006, Shanghai had the highest airport throughput, while Beijing had the highest throughput per capita and Hainan had the highest throughput per unit of GDP. Meanwhile, Hebei scored lowest in all the three categories of total throughput, throughput per capita, and throughput per unit of GDP. In 2015, Shanghai had the highest airport throughput and throughput per capita, while Hainan had the highest throughput per unit of GDP. In that same year, Tibet had the lowest airport throughput, and Hebei had the lowest throughput both per capita and per unit of GDP. From this it can be seen that high airport passenger and cargo throughput by no means implies that a region has a high level of air transportation utilization.

Table 1 Comparison of the highest, lowest, and average values of airport passenger and cargo throughput and regional air transportation utilization in 2006 and 2015

Year	Value	Airport throughput (Million standard persons)	Airport throughput per capita	Airport throughput per unit of GDP
2006	Highest	Shanghai 742.55	Beijing 3.9	Hainan 110.38
	Lowest	Hebei 7.77	Hebei 0.01	Hebei 0.68
2015	Highest	Shanghai 1403.98	Shanghai 5.81	Haian 94.03
	Lowest	Tibet 39.248	Hebei 0.10	Hebei 2.47

Using ArcGIS software, visualizations were made of airport passenger and cargo throughput, throughput per capita, and throughput per unit of GDP. These are divided into four ranked categories according to natural breaks classification.

By comparing the diagrams showing airport passenger and cargo throughput, throughput per capita, and throughput per unit of GDP in 2006 and 2015 (Figures 1 and 2), an overall trend of growth can be seen for both airport throughput and airport throughput per capita. This is because airport throughput has increased while changes in population size have been relatively small, so throughput per capita has also been increasing. Hebei showed the fastest growth, with per capita throughput increasing by 780% between 2006 and 2015, while Beijing had the slowest growth with an increase of 38% in the same period. Meanwhile, airport throughput per unit of GDP displayed growth in regions with relatively slow economic development, while negative growth was observed in regions with rapid economic development. Throughput per unit of GDP grew fastest in Hebei, with an increase of 265% between 2006 and 2015, while the most rapid negative growth was in Hunan, where throughput per unit of GDP dropped by 34%. This is mainly a result of the fact that as airport passenger and cargo throughput has increased, GDP growth in regions with slower economic development has been relatively low, leading to growth in airport throughput per unit of GDP, while GDP growth in regions with faster economic development has been relatively large, leading to reduction in airport throughput per unit of GDP. From changes to airport passenger and cargo throughput, it can be seen that throughput in Heilongjiang, Shandong, Henan, Jiangsu, and Guizhou grew quite quickly, causing their ranks in this regard to increase. In terms of airport throughput per capita, relatively rapid growth occurred in western regions and eastern coastal regions, causing all of their ranks in this regard to increase. Meanwhile, Qinghai and Gansu increased in rank with regard to airport throughput per unit of GDP. Looking at the spatial distribution of airport passenger and cargo throughput, apart from Beijing, Shanghai, and Guangdong where throughput was relatively high, in general eastern coastal regions and southwestern regions (other than Tibet) are ranked relatively high, while Tibet, northeastern regions, and most northern and northwestern regions are ranked relatively low. Looking at the spatial distribution of airport passenger and cargo throughput per capita, apart from Beijing, Shanghai, and Hainan, which are ranked fairly high, in general western regions and southeastern coastal regions are ranked relatively high, showing that the level of residents' air transportation utilization in these regions is also quite high. Meanwhile, northern and central regions are ranked relatively low in terms of throughput per capita, primarily due to the comparatively small ratio of airport throughput to population size and residents' low use of air transportation in these regions. Looking at the spatial distribution of airport passenger and cargo throughput per unit of GDP, apart from the highly ranked areas of Beijing, Shanghai, and Hainan, in general southwestern regions are ranked quite high, which means that the proportion of GDP accounted for by air transportation is quite high in these regions. Meanwhile, central, northern, and northeastern regions are ranked relatively low, mainly due to comparatively rapid economic growth in these regions. This means that although their air transportation industries have developed quite quickly, the proportion of their GDP accounted for by air transportation remains comparatively small.

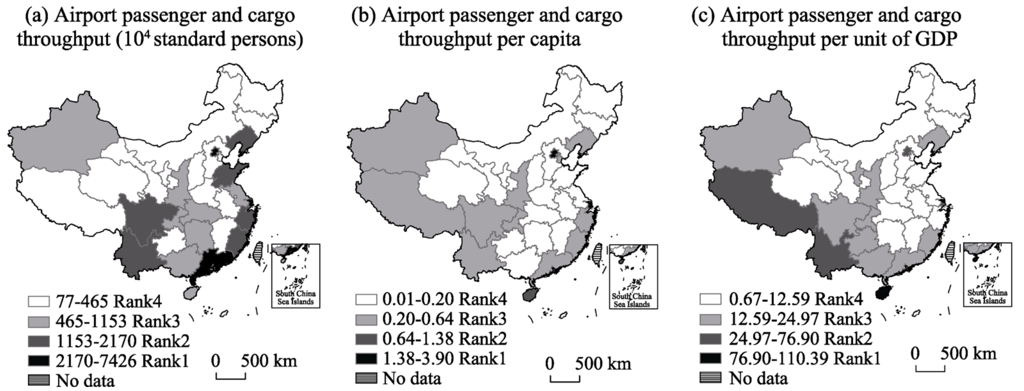

Figure 1 Comparison of airport passenger and cargo throughput and regional air transportation utilization in 2006

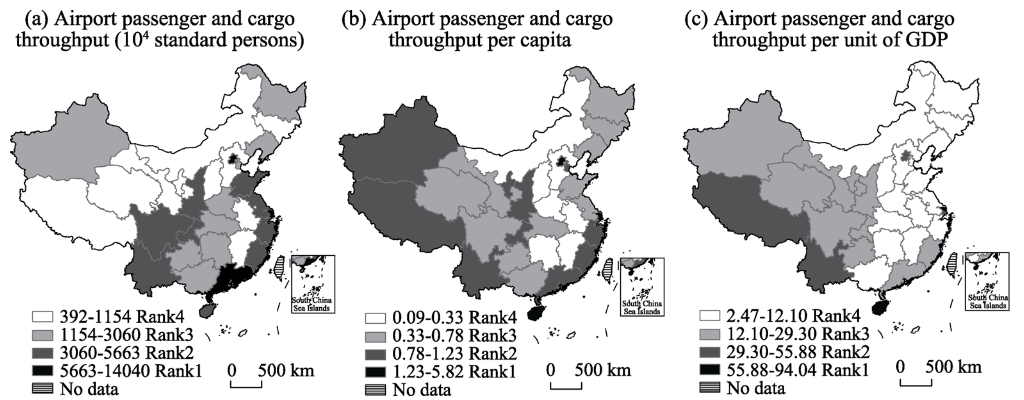

Figure 2 Comparison of airport passenger and cargo throughput and regional air transportation utilization in 2015

By comparing these diagrams, it is apparent that there are quite large differences between distribution according to airport passenger and cargo throughput rank and distribution according to regional air transportation utilization indicator rank. Some regions have a relatively low level of air transportation utilization even though their airport throughput is comparatively high, while the opposite is the case in other regions. Looking at the comparative diagrams for the year 2015, the discrepancy between airport throughput and air transportation utilization level is evident in Shandong, Jiangsu, Hainan, Xinjiang, and Tibet (see Table 2). Although Shandong and Jiangsu both have relatively high airport throughput that puts them in the second rank, their regional air transportation utilization levels sit in the third and fourth

Table 2 Comparison of airport passenger and cargo throughput and regional air transportation utilization rank between China's provinces

Province	Airport passenger and cargo throughput rank	Airport throughput per capita rank	Airport throughput per unit of GDP rank
Shandong	2	3	4
Jiangsu	2	3	4
Hainan	2	1	1
Xinjiang	3	2	3
Tibet	4	2	2

ranks. This indicates that while the number of residents travelling by air is increasing, relative to high population and GDP base figures, the level of air transportation utilization in these regions is comparatively low. Meanwhile, even though Hainan's airport throughput is in the second rank, its level of air transportation utilization is in the first rank. This is mainly because Hainan's advantageous geographical position and climate have driven the development of its tourism industry and allowed it to attract large quantities of domestic and international tourists, which has in turn accelerated development of the air transportation industry in Hainan. Therefore, while the province's population and GDP base figures are both quite low, it has large numbers of people travelling by air, which means its level of air transportation utilization is comparatively high. Xinjiang and Tibet both have low airport throughput that sits in the third and fourth ranks, but their levels of air transportation utilization are relatively high in the second and third ranks. This indicates that these regions' low population and GDP figures are having greater and greater influence as air transportation achieves deeper penetration through the program to develop western China.

4 Analyzing the correlation between regional air transportation utilization and socio-economic development in China

The development of air transportation in a region is primarily determined by the region's level of economic and social development. Socio-economic development mainly influences airport construction through the creation of demand for air transportation and the provision of economic support. In studying the factors correlated with regional air transportation utilization, this paper gives principal consideration to factors of economic development, social development, and population. Furthermore, referring to related papers and according to the real circumstances of airport development and the availability of data, this study uses per capita GDP to represent the economic development factor, urbanization rate to represent the social development factor, and population density to represent the population factor, and gives overall consideration to trends of change in the air transportation utilization indicators and other indicators for each province in the years 2006 and 2015.

There are similar trends of transformation for levels of regional air transportation utilization compared to GDP per capita, urbanization rate, and population density in China (Figures 3 and 4). Provinces with a high GDP, urbanization rate, and population density have a correspondingly high level of air transportation utilization. Taking a step further to analyze the correlation between these three indicators and air transportation utilization, the following figures were obtained: the correlation coefficient for GDP per capita and airport throughput per capita was 0.755 in 2006 and 0.543 in 2015; for urbanization rate and airport throughput per capita it was 0.707 in 2006 and 0.571 in 2015; for population density and airport throughput per capita it was 0.738 in 2006 and 0.711 in 2015; for GDP per capita and airport throughput per unit of GDP it was 0.306 in 2006 and 0.224 in 2015; for urbanization rate and airport throughput per unit of GDP it was 0.297 in 2006 and 0.224 in 2015; and for population density and airport throughput per GDP it was 0.342 in 2006 and 0.285 in 2015. From these figures it is apparent that correlation exists between the regional air transportation utilization indicators and GDP per capita, urbanization rate, and population density.

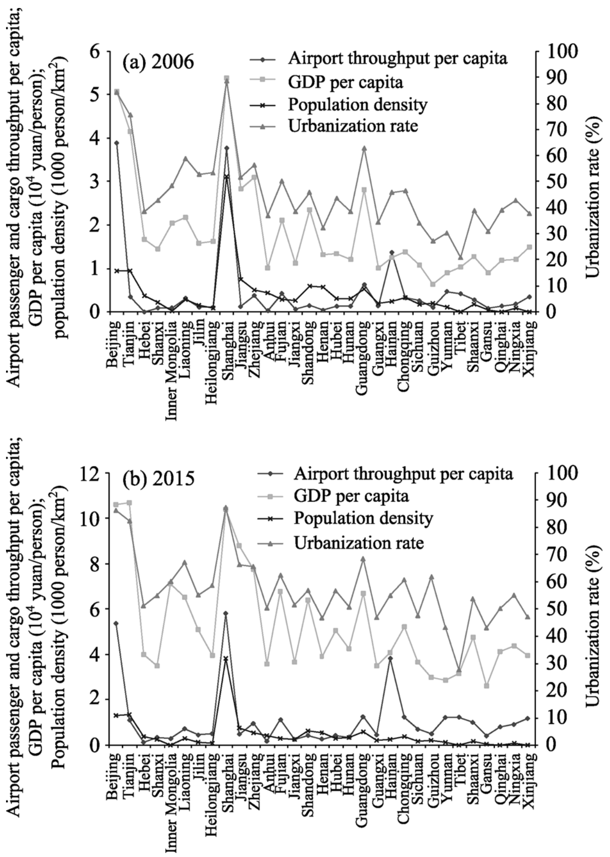

Figure 3 Graphs of airport passenger and cargo throughput per capita and per capita GDP, urbanization rate, and population density in 2006 and 2015

In order to explore whether the conclusions reached through the cross-sectional analysis above are specifically applicable in each province, the present study further examines the correlation between the air transportation utilization indicators and GDP per capita, urbanization rate, and population density in each province between 2006 and 2015 using longitudinal analysis (Table 3).

From the above research, it is already known that as a result of limited changes in population size, airport throughput per capita has grown in all regions, while airport throughput per unit of GDP has increased in some regions and decreased in others due to differences in economic development. As demonstrated by the data in Table 3, positive correlation exists between GDP per capita, urbanization rate, and airport throughput per capita in every province, with values all above the 0.01 or 0.05 levels (apart from Shanghai, which does not have positive correlation between urbanization rate and airport throughput per capita). This indicates that as airport throughput per capita grows in each province, increases in GDP per capita and urbanization rate push residents to choose air travel, which in turn raises the level of regional air transportation utilization. The lack of a positive correlation between urbanization rate and per capita airport throughput in Shanghai mainly stems from the fact that Shanghai's urbanization rate is comparatively high and has not changed significantly between 2006 and 2015, so the role of urbanization in pushing residents toward air travel is not as evident. There is positive correlation between population density and airport throughput per capita in the majority of regions, other than in Heilongjiang, Anhui, Guangxi, Sichuan, and Guizhou where there is negative correlation. Negative correlation shows that increases in population density did not push residents to choose air transportation as their preferred method of travel.

Data in Table 3 also shows that positive and negative correlation exists between airport throughput per unit of GDP and GDP per capita, urbanization rate, and population density in different provinces. In provinces where airport throughput per unit of GDP increased there is positive correlation, which indicates that as GDP per capita, urbanization rate, and population density increase in these provinces, the proportion of their total GDP accounted for by airport throughput also increases, and the utilization of regional GDP in regional aviation grows. In provinces where airport throughput per unit of GDP falls there is negative correlation, which indicates that as GDP per capita, urbanization rate, and population density increase in these regions, the proportion of their total GDP accounted for by airport throughput shrinks, and the utilization of regional GDP in regional aviation falls. The primary reason that negative correlation exists in some regions is that there are large gaps between changes in their airport throughput per unit of GDP and changes in their GDP per capita, urbanization rate, and population density, so correlation is relatively weak.

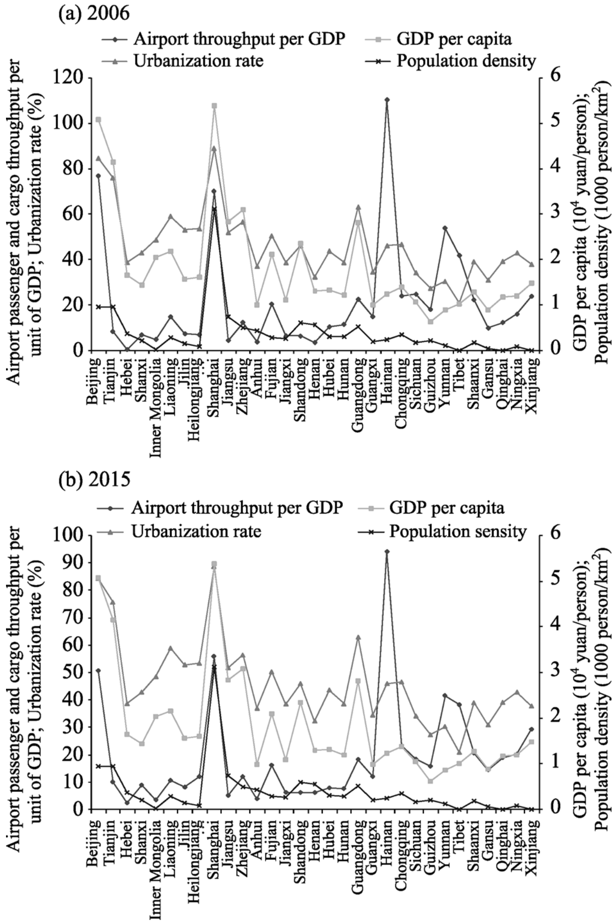

Figure 4 Graphs of airport passenger and cargo throughput per unit of GDP and per capita GDP, urbanization rate, and population density in 2006 and 2015

Through the comparison of data carried out above by means of cross-sectional and longitudinal analysis, two conclusions can be directly reached. First, from the perspective of cross-sectional analysis, regional air transportation utilization and socio-economic development follow the same trend. Second, from the perspective of longitudinal analysis, GDP per capita, urbanization rate, and population density are closely related to increases and decreases in regional air transportation utilization, and are strongly correlated with airport throughput per capita. This means that GDP per capita, urbanization rate, and population density are important influencing factors on regional air transportation utilization (airport throughput per capita).

Table 3 Correlation analysis of regional air transportation utilization and per capita GDP, urbanization rate, and population density in each province

Province	Airport passenger and cargo throughput per capita			Airport passenger and cargo throughput per unit of GDP		
	GDP per capita	Urbaniza-tion rate	Population density	GDP per capita	Urbanization rate	Population density
Beijing	0.964**	0.972**	0.986**	–0.982**	–0.905**	–0.948***
Tianjin	0.952**	0.939**	0.967**	–0.202	–0.219	–0.151
Hebei	0.988**	0.961**	0.989**	0.983**	0.948**	0.992**
Shanxi	0.970**	0.994**	0.946**	0.542	0.690	0.531
Inner Mongolia	0.7220*	0.694*	0.690**	0.144	0.118	0.114
Liaoning	0.998**	0.989**	0.939**	–0.975**	–0.952**	–0.961**
Jilin	0.974**	0.945**	0.903**	0.015	0.408	–0.067
Heilongjiang	0.952**	0.972**	–0.021	0.757*	0.850**	–0.256
Shanghai	0.961**	0.039	0.897**	–0.857**	–0.141	–0.862**
Jiangsu	0.992**	0.969**	0.954**	0.122	0.078	0.125
Zhejiang	0.981**	0.961**	0.907**	–0.496	–0.514	–0.576
Anhui	0.996**	0.989**	–0.243	0.009	–0.011	0.169
Fujian	0.998**	0.989**	0.994**	–0.871**	–0.888**	–0.881**
Jiangxi	0.998**	0.993**	0.980**	–0.115	–0.110	–0.165
Shandong	0.991**	0.992**	0.993**	–0.542	–0.468	–0.495
Henan	0.978**	0.980**	0.459	0.937**	0.945**	0.510
Hubei	0.976**	0.948**	0.975**	–0.886**	–0.928**	–0.824**
Hunan	0.984**	0.978**	0.977**	–0.921**	–0.911**	–0.894**
Guangdong	0.995**	0.965**	0.952**	–0.897**	–0.847**	–0.901**
Guangxi	0.992**	0.987**	–0.148	–0.850**	–0.840**	0.255
Hainan	0.983**	0.996**	0.988**	–0.843**	–0.771**	–0.808**
Chongqing	0.996**	0.990**	0.995**	–0.525	–0.538	–0.532
Sichuan	0.983**	0.985**	–0.010	–0.832**	–0.834**	0.301
Guizhou	0.994**	0.867**	–0.566	–0.209	–0.105	0.610
Yunnan	0.916**	0.962**	0.950**	–0.724*	–0.722*	–0.755**
Tibet	0.969**	0.920**	0.958**	0.073	0.130	0.045
Shaanxi	0.988**	0.992**	0.994**	–0.644*	–0.620	–0.544
Gansu	0.945**	0.972**	0.988**	0.542	0.625	0.696*
Qinghai	0.983**	0.987**	0.994**	0.906**	0.916**	0.934**
Ningxia	0.991**	0.996**	0.995**	0.722*	0.758*	0.976**
Xinjiang	0.982**	0.968**	0.960**	0.680*	0.705*	0.670*

Note: ** represents notable correlation above 0.01, * represents notable correlation above 0.5

5 Predicting the future passenger and cargo throughput of China's airports

Predicting future airport throughput is of major significance for airport construction and management, and airport throughput over the next number of years is an important reference indicator for formulating airport development plans. This paper predicts future throughput by calculating future regional air transportation utilization. This method takes into account the real circumstances of how air transportation is used in different regions, and better accords with the practical demands placed on air transportation by regional development.

Therefore, it represents an upgrade over previous predictive studies, produces more accurate results, and can help make policy decisions regarding civil airport construction projects in China more scientific in nature.

It is evident from the above research that per capita GDP, urbanization rate, and population density are important factors influencing regional air transportation utilization (airport throughput per capita). On this basis and according to historical data, we attempted to use these three main influencing factors and the regional air transportation utilization indicators to establish simple and multiple linear regression forecasting models. It was found that the multiple factor model has a higher R-squared value and the least amount of errors in analytical outcomes compared to real outcomes, so this method was chosen to predict future levels of regional air transportation utilization. On the basis of historical data and control values found in the overall plan for aviation industry development and the 13th Five-Year Plan, trend analysis was used to obtain the values of each province's per capita GDP, urbanization rate, population density, and total population in 2025. The 2025 estimates for per capita GDP, urbanization rate, and population density were used as a foundation for predicting regional air transportation utilization levels, and were inputted into the multiple linear regression model to obtain these levels for each province in the year 2025. Population estimates for 2025 were then used to calculate the airport throughput of every province. Table 4 shows predictions for each province's airport throughput in 2025, as well as rates of throughput growth between 2015 and 2025.

Table 4 Predictions of each province's airport passenger and cargo throughput in 2025

Province	2025 airport passenger and cargo throughput (10^6 standard persons)	2015–2025 growth rate	Province	2025 airport passenger and cargo throughput (10^6 standard persons)	2015–2025 growth rate
Guangdong	237.05	0.7759	Hubei	38.90	0.6539
Shanghai	232.82	0.6583	Tianjin	36.82	1.2010
Beijing	207.13	0.7763	Guangxi	35.06	0.7239
Yunnan	91.66	0.6186	Heilongjiang	31.78	0.7483
Zhejiang	90.42	0.7479	Guizhou	27.92	0.6788
Sichuan	89.68	0.6247	Shanxi	22.45	0.9607
Fujian	77.79	0.8441	Inner Mongolia	20.70	2.2121
Chongqing	70.24	0.9155	Jiangxi	20.36	0.9311
Shandong	69.37	0.7510	Jilin	20.18	0.7494
Shaanxi	67.16	0.8059	Hebei	18.80	1.5541
Jiangsu	64.89	0.7830	Gansu	17.04	0.7272
Hainan	61.75	0.7734	Anhui	15.69	0.7914
Xinjiang	55.28	1.0230	Ningxia	12.28	1.0781
Liaoning	53.89	0.7612	Qinghai	9.78	1.1271
Henan	42.49	0.8399	Tibet	7.4	0.8963
Hunan	39.42	0.7729			

According to forecast data, the conclusion can be reached that all provinces will show an overall trend of airport throughput growth to 2025, while by that year China's total throughput will have increased by 178% over 2015 levels. The province with the highest throughput will reach throughput of 237 million standard persons, while the province with the lowest throughput will attain throughput of 74.4 million standard persons. More specifically, regions including Guangdong, Shanghai, Beijing, Yunnan, Zhejiang, and Sichuan will have relatively high throughput, while regions including Tibet, Qinghai, Ningxia, Anhui, and Gansu will have relatively low throughput. Each province may combine forecasted throughput values and growth rates with its own specific conditions to carry out airport planning and construction. While high future throughput can only illustrate that the scale of air transportation development will be large, throughput growth rate can better reflect the speed of development and how demand will grow in the future. Below is a visualization created through the aid of ArcGIS software in order to paint a clearer picture of the spatial distribution of each province's annual airport throughput growth rate in 2025.

As can be seen in Figure 5, between 2015 and 2025, airport throughput will increase by more than 200% in the fastest growing regions, and will increase by more than 60% in the slowest growing regions. The throughput growth rate will exceed 80% in 13 provinces and 100% in six provinces, which shows that growth of airport throughput will accelerate in the future. In terms of spatial distribution, between 2015 and 2025, the throughput of Inner Mongolia and Hebei will grow at a rapid rate, increasing by 221% and 155% over 2015 levels and reaching 207 million and 188 million standard persons, respectively. While this reflects the fact that airport throughput will grow from a small foundation in these provinces, it also shows that their future development will impose a high rate of demand on airport throughput. Furthermore, with huge growth potential for use of air transportation by residents, it might not be possible for current infrastructure to keep up with demand. Therefore, these provinces should take steps like expanding airports and building new ones, and increasing the frequency of flights on existing air routes or adding new routes to meet constantly growing demands on air transportation. At the same time, the government should intensify policy support for airport construction and development in western regions. The rate of throughput growth in Yunnan, Sichuan, and Hubei is relatively low; between 2015 and 2025, throughput will increase by 62% to 917 million standard persons in Yunnan, by 63% to 897 million standard persons in Sichuan, and by 65% to 389 million standard persons in Hubei. This shows that the residents of these regions already use air transportation to a relatively high degree, that demand for air transportation is already satisfied, and that airport development can be advanced by improving quality of service. Hubei's relatively low rate of airport throughput growth can mainly be attributed to high-speed rail transportation in the region as

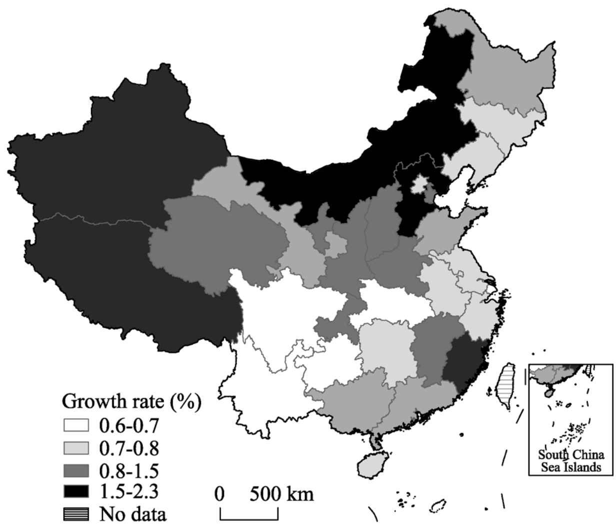

Figure 5 Spatial distribution of airport passenger and cargo throughput growth rates between 2015 and 2025

well as the diversion and competition created by the developed air transportation of neighboring regions. Therefore, in the future all provinces should conduct integration of airport resources in line with practical circumstances to ensure that airports receive traffic suited to their handling capacity.

6 Conclusions and discussion

6.1 Conclusions

Airport throughput is closely related to regional population and GDP. This study is the first to use indicators representing the coupled relationship between aviation development and regional socio-economic development, namely the regional air transportation utilization indicators, to analyze the degree of air transportation utilization in China. The results indicate that airport throughput (measured in standard persons) in 2006 was highest in Shanghai at 74.25 million, and lowest in Hebei at 0.78 million, with an average of 13.42 million. In 2015, Shanghai had highest airport throughput at 140 million, Tibet had the lowest at 3.92 million, and there was an average of 34.2 million. In 2006, of all of China's provincial-level divisions, the regional air transportation utilization indicator set according to airport throughput per capita was highest in Beijing at 3.90, lowest in Hebei at 0.01, and averaged at 0.49, while in 2015 it was highest in Shanghai at 5.81, lowest in Hebei at 0.10, and averaged at 1.07. Meanwhile, the regional air transportation utilization indicator set according to airport throughput per unit of GDP was highest in Hainan at 110.38, lowest in Hebei at 0.68, and averaged at 21.84 in 2006, while in 2015 it was highest in Hainan at 94.03, lowest in Hebei at 2.47, and averaged at 19.36. It is thus apparent that regions with high airport throughput do not necessarily have the highest levels of air transportation utilization, so this study carried out the following research on the regional air transportation utilization indicators:

(1) It analyzed the spatial layout of regional air transportation utilization levels in China between 2006 and 2015. The results indicated a trend of year on year growth of airport throughput per capita in every province, with Hebei showing the fastest growth at 780% over 2006 levels and Beijing showing the slowest growth at 38% over 2006 levels. In terms of spatial distribution, southeastern coastal regions were ranked relatively high due to their developed air transportation industries, and western regions were ranked relatively high due to their small population sizes. Meanwhile, northern and central regions were ranked relatively low due to the comparatively slow development of their air transportation industries, as well as competition from other methods of transportation, relatively low airport throughput, and relatively low airport throughput per capita. As a result of different regions having different GDP sizes, over time airport throughput per unit of GDP showed growth in regions with relatively slow economic development, and negative growth in regions with relatively rapid economic development. Hebei had the fastest growth in airport throughput per unit of GDP between 2006 and 2015 with a rise of 265%, while Hunan had the fastest negative growth with a decrease of 44%. In spatial terms, southwestern regions were ranked relatively high, primarily due to low GDP size, while central, northern, and northeastern regions were ranked relatively low as a result of large GDP size.

(2) Through correlation analysis, this study found that the regional air transportation utilization indicators and socio-economic development follow the same trend. Fluctuations in the regional air transportation utilization indicators and per capita GDP, urbanization rate,

and population density are closely connected. This is specifically reflected by the strong correlation between airport throughput per capita and per capita GDP, urbanization rate, and population density. Most regions had correlation coefficients above the 0.01 level, which reflects notable correlation. All presented positive correlation for airport throughput per capita with per capita GDP and urbanization rate, while most regions presented positive correlation with population density. On the other hand, correlation between airport throughput per unit of GDP and per capita GDP, urbanization rate, and population density was relatively weak, with positive correlation in some regions and negative correlation in others.

(3) Based on predicted values for the per capita GDP, urbanization rate, population density, and total population of different regions in 2025, this study calculated what each province's airport throughput will be in that year, as well as airport throughput growth rates. The results showed that every province will experience growth in their airport throughput between 2015 and 2025. Throughput in Inner Mongolia and Hebei will grow quickly, with respective increases of 221% and 155% over 2015 levels, and the demand on air transportation in these regions will grow rapidly. Meanwhile, airport throughput in Yunnan, Sichuan, and Hubei will increase more slowly, rising 62%, 63%, and 65% over 2015 levels, respectively, which means that the demand on air transportation in these regions will also grow more slowly. Each province may use this forecast data to ensure that work related to the allottment, planning, and construction of airports is prepared in advance. This type of forecasting method can enhance the precision of airport throughput predictions, and provide such predictions with a fresh approach.

6.2 Discussion

This study conducted research using provinces as its unit of analysis, but due to the fact that the airports of some provinces draw traffic from across administrative boundaries, an overlapping relationship exists with inter-provincial airport utilization. The influence of this type of overlapping may be more pronounced in neighboring provinces that are interlocked with irregularly shaped boundaries. This issue was not given consideration in this study due to data limitations, but it could interfere with the accuracy of indicator values and results in related research. However, we believe that from the national perspective, the results of this research can effectively reflect real and objective conditions overall. Selecting multiple linear regression forecasting as the method for predicting each province's airport demand on the whole possesses a relatively high degree of reliability with regard to predetermining and understanding the overall demand on air transportation in every province throughout the country. Despite this, use of a single forecasting method may lead to the existence of some errors in certain provincial units, and therefore it is necessary to further optimize methods for predictive research to delve deeper into air transportation demand in specific provinces.

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