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Passenger and cargo throughput forecast of China's three major airports

Shengkang Chen[a], Xiaojin Li[b]

Civil Aviation University of China, Tianjin, China
[a]sk664623662@163.com, [b]xiaojinli@vip.sina.com

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***Abstract*:** China is a large civil aviation country in the world. With the continuous development of China's economy, the demand for air cargo transportation and passenger transportation is constantly rising in many cities. In this paper, the grey-forecast model GM (1,1) is adopted to forecast the passenger and cargo throughput of Beijing Capital(PEK), Shanghai Pudong(PVG) and Guangzhou Baiyun (CAN) Airport in the next few years. Based on the predicted data, we analyzed the future traffic development trend, and found out the advantages and disadvantages of the three airports. Finally, we put forward corresponding suggestions for the future development of the three airports in order to promote the sustainable development of the airports.

1. Introduction

Since China has put forward the strategy of "being a powerful country in civil aviation", China is now planning the stride forward from large aviation industry to power one. Further more, airport service level is an important indicator of civil aviation power. With the increase of air transport demand in China, many large airports have experienced high load operation, which is not conducive to the sustainable development of airports. Therefore, airport companies need to predict air transport demand to avoid that situation. The purpose of prediction is to reveal the development law of things, better grasp the future dynamics of things, and to provide necessary information for decision-making. passenger and cargo throughput forecast is the basis of airport development decision and airport construction, and is the grand of determining the short-term construction planning scale and long-term reservation control of the airport[1].

Tailin Chen[2]applied the grey theory to the prediction of airport aviation business volume. He pointed out that this method has advanced theory, reliable prediction results and certain application value. Xiaoping Lin[3] established the prediction model of cargo throughput of Chengdu Shuangliu Airport by using the grey theory. He compared the actual data with the prediction results and proved that the grey model is feasible and accurate in predicting the cargo throughput of Shuangliu Airport. Yubao Chen [4] took the capital airport as an example and used the combined forecasting method to predict the passenger throughput. Xinwo Yang[5] used the combined forecasting method to forecast

the passenger throughput and cargo throughput in the Pearl River Delta. Yuanchang Deng[6] predicted the passenger transport demand of Guangzhou Baiyun International Airport. Zhanwei Wang [8]predicted the future passenger and cargo throughput of the top 10 hub airports in Asia, and made a comparative analysis among them. Yunfang Wang[9]used the the grey-forecast model to predict the cargo throughput of Beijing Capital Airport.

From the above references, it can be seen that most people have predicted the passenger and cargo throughput of the airport, which proved that the grey-forecast model has a good prediction effect. Based on the above references, this paper forecasted the passenger and cargo throughput of three large airports in China through the grey-forecast model, compared and analyzed the development trend of different airports.

2. Data selection

According to the 2019 China Airport throughput data released on the official website of Civil Aviation Administration of China. In 2019, the passenger throughput of china has exceeded 1.3 billion, and the top ten airports has all exceeded 40 million. Among them, Beijing Capital Airport(PEK)ranked first, Shanghai Pudong (PVG)and Guangzhou Baiyun(CAN) ranked second and third respectively.[10]

COVID-19 in 2020 had a great impact on the flow of people and the transportation of goods. Therefore, the comparison of airport data in 2020 is meaningful only when compared with other airports in this year, which is not significant compared with historical data. Therefore, this paper takes the PEK,PVG,CAN, which ranked the top 3 in China's airport capacity in 2019, as the sample airport. From the annual reports of the above three airports, the passenger and cargo throughput of PEK, PVG ,CAN from 2012 to 2019 are selected to predict the changes of passenger and cargo throughput in the next 10 years through the grey-forecast model.

3. Introduction of the gray prediction model

The grey prediction model theory is put forward by Professor Ju long Deng[11] of Hua zhong University of science and technology. At present, many prediction methods (such as linear regression) need more information, while the grey-forecast model does not need a large number of samples, it establishes a grey differential prediction model through a small amount of incomplete information. It can make a fuzzy long-term description of the development law of things, and is well used in the fields of traffic demand prediction.

The modeling process of GM(1,1)is as follows :

First, we should weaken the volatility and randomness of the original data, Record the original data as: .$X^{(0)}$

$$X^{(0)} = (x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)),$$

using the Accumulating Generation Operation (AGO),$X^{(1)}$ will be produced.

$$X^{(1)} = (x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n))$$

among them$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i)\, k = 1,2,\cdots,n$

Make a sequence for the generated mean $Z^{(1)}X^{(1)}$

$$Z^{(1)} = (z^{(1)}(2), z^{(1)}(3), \cdots, z^{(1)}(n))$$

among them$z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1)$

Then, according to GM(1,1), the grey differential equation is:

$$x^{(0)}(k) + az^{(1)}(k) = u \tag{1}$$

"a"and"u" are parameters to be estimated, and"$\hat{\alpha}$"are parameter vectors to be estimated. using the least square method:

$$\hat{\alpha} = (a,u)^T \hat{\alpha} = (B^T B)^{-1} B^T Y_n$$

In above formula

$$B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix}, Y_n = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix}$$

The whitening equation of grey differential equation (1) is:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u \tag{2}$$

The solution of equation (1 .2) is:

$$\hat{x}^{(1)}(t) = \left(x^{(1)}(0) - \frac{u}{a}\right) e^{-at} + \frac{u}{a} \tag{3}$$

Finally, the formula of accumulated predicted value obtained from above is:

$$\hat{x}^{(1)}(k+1) = \left(x^{(1)}1 - \frac{u}{a}\right) e^{-ak} + \frac{u}{a}. \tag{4}$$

using the Inverse Accumulating Generation Operation (IAGO) as follows:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) \tag{5}$$

4. Calculation and test of data

4.1 Data Calculation

By bringing the data of PEK,PVG,CAN into the forecasting model, the predicted value can be obtained. The following Table 1 and Table 2 show the data of CAN of the three airports calculated by the model:

Table 1. Comparison the Passenger Predicted Value and Actual Value of CAN

Year	Actual value (Thousand_person)	predicted value	forecast error
2012	48309.41	48309.41	0
2013	52450.26	50936.77	0.0289
2014	54780.35	54123.56	0.0120
2015	55201.92	57509.73	0.0418
2016	59732.15	61107.75	0.0230
2017	65887.47	64930.88	0.0145
2018	69720.40	68993.20	0.0104
2019	73378.48	73309.67	0.0009

Table 2. Comparison the Cargo Predicted Value and Actual Value of CAN

Year	Actual value (Kiloton)	Predicted value	Forecast error
2012	1248.76	1248.76	0
2013	1309.75	1354.17	0.0339
2014	1454.04	1442.27	0.0081
2015	1537.76	1536.10	0.0011
2016	1652.21	1636.04	0.0098
2017	1780.42	1742.47	0.0213
2018	1890.56	1855.83	0.0184
2019	1919.93	1976.57	0.0295

4.2 Date Test

Then the residual error detection and stage ratio deviation inspection are carried out for the prediction results. The inspection method is as follows:

(1)Residual error detection

Absolute error:

$$\varepsilon(k) = x^{(0)}(k) - \hat{x}^{(0)}(k), \text{ k=2,3…,n} \tag{6}$$

Relative error:

$$\varepsilon_r(k) = \frac{|x^{(0)}(k) - \hat{x}^{(0)}(k)|}{x^{(0)}(k)} \times 100\%, \tag{7}$$

k=2,3,…,n

Average relative residual:

$$\bar{\varepsilon_r} = \frac{1}{n-1}\sum_{k=2}^{n} |\varepsilon_r(k)| \tag{8}$$

When the average relative residual is less than 0.2, it is considered that the fitting degree between the model and the original data is acceptable. When the average relative residual is less than 0.1, it is considered that the fitting degree between the model and the original data is high.

(2) Stage ratio deviation inspection:

Firstly, the stage ratio of the original data is calculated $\sigma(k)$:

$$\sigma(k) = \text{n}\frac{x^{(0)}(k)}{x^{(0)}(k-1)}, \text{ k=2,3,…,n} \tag{9}$$

According to the predicted development coefficient (-a), the corresponding stage ratio deviation and average stage ratio deviation are calculated:

$$\eta(k) = |1 - \frac{1-0.5a}{1+0.5a} \times \frac{1}{\sigma(k)}|, \tag{10}$$

$$\bar{\eta} = \sum_{k=2}^{n} \eta(k) / (n-1) \tag{11}$$

When the average stage ratio deviation is less than 0.2, it is considered that the fitting degree between the model and the original data is acceptable. When the average stage ratio deviation is less than 0.1, it is considered that the fitting degree between the model and the original data is high

The test results calculated by Matlab are as show in Table 3:

Table 3. Test results

Airport name	Transport volume index	Residual test value	Level deviation check value
PEK	Cargo throughput	1.10%	0.017
	Passenger throughput	3.65%	0.028
PVG	Cargo throughput	1.88%	0.023
	Passenger throughput	1.74%	0.018
CAN	Cargo throughput	3.67%	0.031
	Passenger throughput	2.86%	0.043

As can be seen from the above table, the residual error detection and stage ratio deviation inspection of the prediction models of the three airports are all qualified. The average relative residuals are less than 1 0%, The Average stage ratio deviation are all less than 0 .1. Therefore, the model has a high degree of fitting to the original data, and the prediction accuracy is ideal. so, the author thinks that using the grey-forecast model to forecast the passenger and cargo throughput of PEK,PVG,CAN in the next ten years can achieve satisfactory forecasting results.

5. Prediction results and analysis

The forecast results of passenger throughput and cargo throughput of PEK, PVG and CAN in the next 10 years are as show in Table 4 and Table 5:

Table 4. The forecast value of Passenger

Year	PEK (Thousand_person)	PVG (Thousand_person)	CAN (Thousand_person)
2021	109,008.51	92,557.46	82,769.67
2022	112,576.40	100,005.37	87,948.05
2023	116,261.07	108,052.59	93,450.40
2024	120,066.34	116,747.35	99,297.00
2025	123,996.16	126,141.76	105,509.39
2026	128,054.60	136,292.12	112,110.45
2027	132,245.87	147,259.25	119,124.50
2028	136,574.33	159,108.89	126,577.37
2029	141,044.46	171,912.05	134,496.52
2030	145,660.90	185,745.44	142,911.12

Table 5. The forecast value of Cargo

Year	PEK (Kiloton)	PVG (Kiloton)	CAN(Kiloton)
2021	1,918.13	4,162.10	2,242.11
2022	1,919.52	4,327.35	2,387.97
2023	1,920.91	4,499.15	2,543.33
2024	1,922.31	4,677.78	2,708.79
2025	1,923.70	4,863.50	2,885.02
2026	1,925.09	5,056.59	3,072.71
2027	1,926.49	5,257.34	3,272.61
2028	1,927.89	5,466.07	3,485.51
2029	1,929.29	5,683.08	3,712.27
2030	1,930.68	5,908.71	3,953.78

In order to show its development trend more intuitively, we made a line chart as show in Fig1 and Fig2:

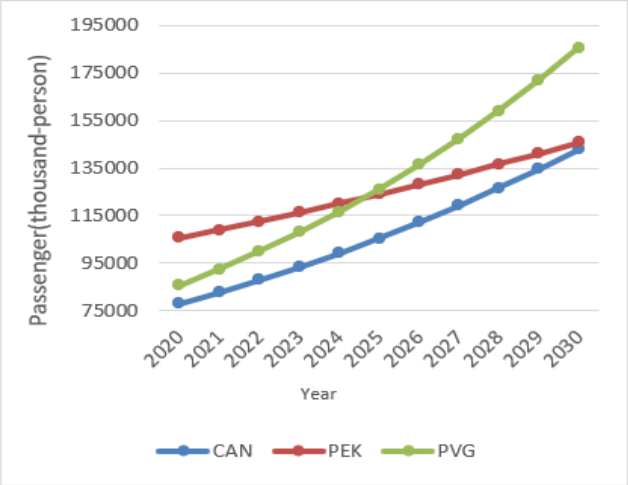

Fig. 1. The line chart of passenger

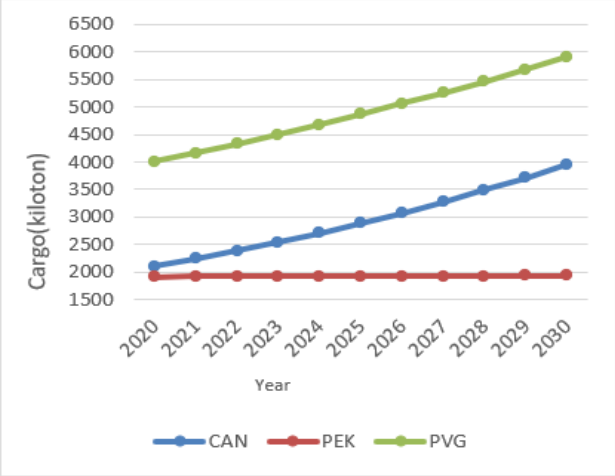

Fig. 2. The line chart of cargo

As it can be seen from the table above, the passenger and cargo throughput of the three airports will show a steady growth trend in the next decade. And the growth rate of PVG is the most outstanding of the three, its airport passenger throughput is expected to reach 126.1418 million in 2025, exceeding that of PEK. CAN follow behind. Although the passenger throughput of PEK is high and on the rise, it still grows slowly compared with the other two airports. In the future, the trend of cargo throughput is also the highest in PVG. In 2025, the cargo throughput will achieve a breakthrough of 4,863,500 tons, followed by GAN, which will reach 2,885,023 tons, while the cargo throughput growth trend of PEK is almost a straight horizontal line.

6. Development proposal

Based on the above model analysis and research, we have a comprehensive understanding of the future development trend about the three major airports, and according to the data analysis, we have put forward the following suggestions to improve and perfect the future situation.

For PEK, one of the reasons is responsible for the slow growth of its passenger and cargo

throughput is that its financial industry, information transmission, computer services and software industries account for a relatively high proportion, and the demand for cargo throughput is not high compared with the other two airport. Therefore, PEK can be organically connected with the city's logistics industry to stimulate the demand for air cargo; At the same time, the city's developed emerging technologies such as big data, artificial intelligence and block-chain can also be used to improve the airport's air capacity.

For PVG and CAN the ever-increasing passenger and cargo throughput bring the increasing pressure on this two airports at the same time. They should further strengthen the construction of airport infrastructure such as cargo stands and freight stations, and increase the flight team. In the process of continuous business development, they are supposed to formulate corresponding air transportation capacity improvement plans, set up research centers, and use cutting-edge technologies to better meet the travel needs of the people and the demand for cargo transportation.

7. Conclusion

From the prediction results of the three airports, the future development prospects of them are very brilliant. On the whole, the transportation demand of this three airports will rise steadily in the next 10 years. The passenger transport demand of PVG and CAN will grow rapidly in the next 10 years. This two airport should improve its passenger service capacity to meet the future passenger traffic demand. As for PEK, the demand for cargo throughput is growing slowly. Therefore, stimulating the demand for cargo transport is the main task for its future development.

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