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Xian yan[1], Chen jian[2]

[1,2]Xinjin Flight College of Civil Aviation Flight University of China, Chengdu, Sichuan, 611431, China

xianyan04@163.com

Abstract：In order to accurately predict the aviation fuel consumption of general aviation airport, this article analyzes Xinjin Airport's aviation fuel consumption over the years, using elasticity coefficient method, trend extrapolation method and grey theory prediction GM(1,1) model to forecast Xinjin Airport's fuel consumption in the next five years. To avoid the loss of information in a single model, a combination forecast model is established based on the three models. The weight of each model is determined based on the relative weight of the error of each model. The results show that the combined model can more accurately and effectively predict the airport aviation fuel consumption. It can provide reference and basis for the construction and planning of fuel facilities and equipment for general aviation airports, and the storage and security management of aviation fuel materials, and has certain practical significance for improving aviation fuel safety and security in the navigation industry.

1. Significance and method of airport fuel consumption forecast

In recent years, China's general aviation industry has developed rapidly, and a series of policies and measures issued by the government and the bureau will promote the sustainable and efficient development of the navigation industry. As the aircraft's blood, aviation fuel is the most important part of aircraft replacement [1]. Aviation fuel security is also an important part of flight support. For the general aviation airports, the cost of fuel accounts for about 10-15% of the airport's operating costs.

The fuel consumption of the airport is affected by a combination of factors, including fuel efficiency, facilities and equipment configuration, fuel supply and transportation, staffing and management [2]. Through the prediction of fuel consumption, it can provide data support for airport fuel storage, procurement, supply and safety management. Secondly, it provides reference for the construction and planning of fuel supply facilities. Thirdly, it will improve the efficiency of airport fuel use, control fuel costs, and provide effective guidance for aviation enterprises to make risk decisions in advance.

The statistical analysis of fuel consumption statistics is an irregular, complex nonlinear system. This paper analyzes the long-term development of fuel consumption at Xinjin Airport based on an example, and considers a representative trend extrapolation method and a grey prediction method model [3]. Since the growth of fuel consumption is inextricably linked to economic growth and belongs to the category of regression prediction, this paper also considers the use of the elastic coefficient method for predictive analysis. Because the fuel consumption is the result of multiple factors working together, in order to avoid the loss of information in a single model, it combines the above three prediction models to establish a combined model based on error correction [5] to improve the accuracy.

2. Three predictive models

2.1 Elasticity coefficient method

The elastic coefficient is an important parameter for energy demand forecasting. The elasticity coefficient method is an indirect prediction method which can predict the development of another factor by elasticity coefficient on the basis of the development and change of one factor [4]. The air fuel consumption elasticity coefficient of Xinjin is an indicator reflecting the proportional relationship between the growth rate of fuel consumption in Xinjin and the growth rate of Xinjin County's economy (GDP). By analyzing the relationship between the two, the fuel consumption elasticity coefficient in the next few years and the annual fuel demand can be predicted.

The calculation equations related to the elastic coefficient prediction method are (1-1).

$$e = \frac{V_{fuel}}{V_{GDP}} \qquad Y_\tau = Y_0 \times (1 + e \times \alpha)^{(\tau - \tau_0)} \qquad （1\text{-}1）$$

where: e—Aviation fuel elasticity coefficient of Xinjin; V_{fuel}—Annual growth rate of fuel consumption; V_{GDP}—Average annual growth rate of the economy; Y_τ—Forecast fuel consumption (t) for year; Y_0—Base year fuel consumption (tons);α—Annual average growth rate of the national economy;τ—Forecast year;τ_0—base year.

The historical data of Xinjin GDP and Xinjin Airport fuel consumption are shown in Figure 1 and 2. According to equation (1-1), the elastic coefficient of refined oil in the Sichuan area can be calculated, as shown in Figure 3.
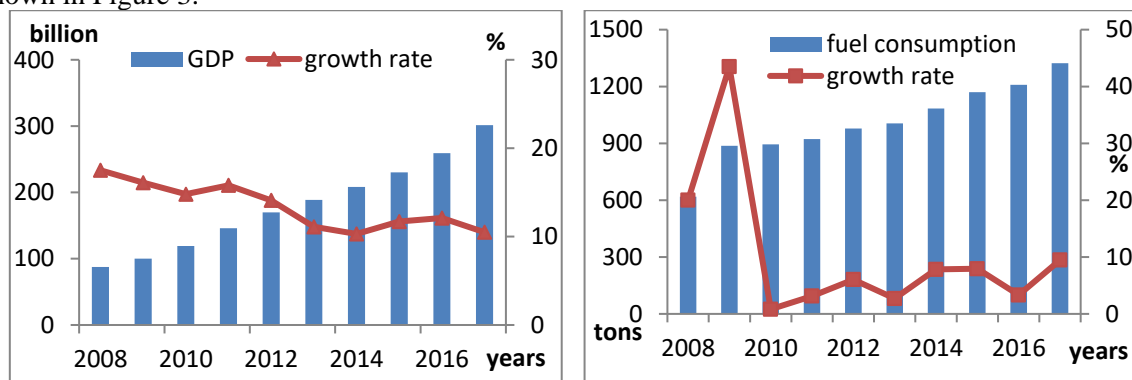

Figure 1. Annual variation of GDP   Figure 2. Annual Change of fuel consumption

Since the elastic fuel consumption coefficient of Xinjin is a stationary process with time series, the linear regression method can be used to calculate the elastic coefficient of the t-year. By fitting, the coefficient of elasticity e of 2018-2023 can be calculated.

Based on the prediction of the elasticity coefficient, the aviation fuel consumption can be predicted according to equation (1-1), as shown in Table 1.
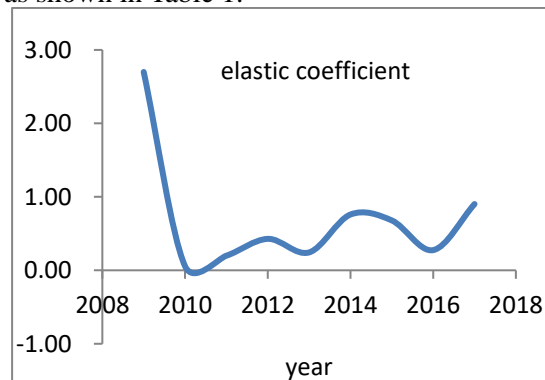

Figure 3. Elastic coefficient

Table 1. Elastic coefficient method predicts fuel consumption of Xinjin Airport in the next 5 years

years	2018	2019	2020	2021	2022	2023
Aviation fuel consumption （tons）	1461.01	1592.21	1713.87	1823.59	1919.57	2000.68

2.2 Trend extrapolation method

According to the trend of Xinjin Airport fuel consumption, Figure 2 shows that the fuel consumption has increased year by year, and there has not been a jump change. The main factors that have determined the fuel consumption in the past or now also determine the future fuel consumption. The influencing factors have not changed much, so the trend extrapolation method is applicable to the prediction of airport fuel consumption[5]. The trend extrapolation method is to select the appropriate curve equation and use the least squares method or the fitting method to determine the parameters and establish a prediction model. Through differential analysis, it can be judged that the fuel consumption prediction is a reasonable secondary prediction model, and the corresponding prediction curve $y=a+bx+cx^2$, so the quadratic curve model is determined.

    a, b and c are determined according to the least square method.

$$\begin{cases} \sum y = a + b\sum x + c\sum x^2 \\ \sum xy = a\sum x + b\sum x^2 + c\sum x^3 \\ \sum x^2 y = a\sum x^2 + b\sum x^3 + c\sum x^4 \end{cases} \quad (2\text{-}1)$$

where: y—Aviation fuel consumption （ton）；x—Corresponding to the year of 2008, for example, in 2018, $x=11$;a、b、c—Undetermined coefficient.

    According to the consumption graph 2, three undetermined coefficients can be solved, and the prediction model is obtained as in equation (2-2).

$$y = -0.668x^2 + 70.820x + 645.438 \quad (2\text{-}2)$$

Table 2. Goodness of fit test

R	Coefficient R^2	Standard error
0.963	0.928	50.952

Table 3. Significance test of the equation (F test)

	Sum of squares	Degree of freedom	F test value	Sig.
return	332602.93	2	44.840	0.00
Residual	25961.32	7		
Total deviation	358564.25	9		

    In Table 2, $R^2=0.928$, which shows that the fitting degree of the quadratic regression equation reaches 92.8%, and the fitting effect is good; Table 3 shows the significance test of the overall linearity of the regression equation, $F=44.840>F_\alpha$, Sig=0<0.05, indicating that the linear relationship of the simulation equation is significant under the condition that the significance level is equal to 0.05, all parameters are Through the significance test, the above model can be used to predict the aviation fuel consumption of Xinjin Airport.

Table 4.Trend extrapolation predicts fuel consumption at Xinjin Airport over the next five years

years	2018	2019	2020	2021	2022	2023
Aviation fuel consumption （ton）	1343.63	1399.086	1453.206	1505.99	1557.438	1607.55

2.3 Grey prediction

Grey prediction is a method for predicting systems with uncertain factors. The method is used to

predict the series, which is widely used in time series prediction. GM(1,1) represents a differential equation-type predictive model for a variable, and it is a linear motion of a single-order sequence[6]. This paper uses the historical data of Xinjin Airport fuel consumption as an observation to establish a model.GM(1,1)The model building process is as follows:

There are series of $X^{(0)}$ with a total of n observations $x^{(0)}(1)$, $x^{(0)}(2)$, …… $x^{(0)}(n)$, Adding $x^{(0)}$ to generate a new series $x^{(1)}$, Its elements:

$$x^1(i) = \sum_{m=1}^{i} x^{(0)}(m) \quad i = 1, 2, \cdots, n \tag{3-1}$$

For the series $x^{(1)}$, a equation for the prediction model can be established: $\dfrac{dx^{(1)}}{dt} + ax = b$

Where: a, b are the parameters to be estimated, the development coefficient and the gray action.

Let $\hat{a}$ be the parameter vector to be estimated, $\hat{a} = \begin{bmatrix} a \\ b \end{bmatrix}$ Solve by least squares method,

$$\hat{a} = (B^T B)^{-1} B^T y_n; \qquad y_n = [x^{(0)}(2) \quad x^{(0)}(3) \quad ... \quad x^{(0)}(n)]^T \tag{3-2}$$

The obtained $\hat{a}$ is substituted into the equation, and the differential equation is solved. The prediction model can be obtained as follows:

$$B = \begin{bmatrix} -\dfrac{1}{2}(x^{(1)}(1) + x^{(1)}(2)) & 1 \\ -\dfrac{1}{2}(x^{(1)}(2) + x^{(1)}(3)) & 1 \\ \cdots\cdots & \cdots\cdots \\ -\dfrac{1}{2}(x^{(1)}(n-1) + x^{(1)}(n)) & 1 \end{bmatrix}$$

$$x^{(i)}(i+1) = \left(x^{(0)}(1) - \dfrac{b}{a} \right) e^{-ai} + \dfrac{b}{a} \qquad (i = 1, 2, \cdots n) \tag{3-3}$$

Based on data from 2008-2017, n=10,

$\hat{x}^{(i)}(i+1) = 15448.4722 e^{0.053106i} - 14830.9442$; $\hat{x}^{(0)}(i) = x^{(1)}(i+1) - x^{(1)}(i)$ (i=0,1,2…22)(3-4)

$\hat{x}^{(0)}(i)$——Aviation fuel consumption（tons）;

i——Relative to the first year of the base year 2008, such as 2010, then i=2.

Table 5. Error analysis of grey prediction model

Test items	Relevance degree ξ	Variance ratio c	Small error probability p
Numerical value	0.61392	0.1240	1

Table 5 shows that the correlation degree of the predicted series $\hat{x}^{(0)}(i)$ to $x^{(0)}$ ξ>0.6, indicating that the prediction result is satisfactory, and the rear difference ratio is c<0.35, and the small error probability p>0.95, indicating that the prediction accuracy level is good.

Table 6. Grey forecasting method predicts fuel consumption of Xinjin Airport in the next 5 years

years	2018	2019	2020	2021	2022	2023
Aviation fuel consumption（tons）	1359.00	1433.12	1511.28	1593.71	1680.64	1772.30

3. Combined forecasting model

The key to the combined model is to determine the weight of each prediction method in the comprehensive prediction. If the weighting coefficients W_j of various prediction methods are well determined, the advantages of each prediction method can be fully utilized to achieve the best effect of the combined prediction[7]. In this paper, error is used as the weight analysis, that is, the error value of

each prediction method is determined to determine its proportion in the combined forecast [10-12]. The weight is determined, and the combined forecast sales calculation formula is shown in equation (4-1).

$$Z_{ij} = \frac{A_{ij} - Y_i}{Y_i} \quad M_i = \sum Z_{ij} \quad S = \sum M_i \quad X_i = \frac{S}{M_i} \quad w_j = \frac{X_i}{\sum X_i} \quad ; \quad Q = \sum Q_j w_j$$

（4-1）

where: Z_{ij}—the error of the i-th method in the j-th year; A_{ij}—the predicted value of the i-th method in the j-th year; Y_j—the consumption of the j-th year；M_i—the average error of the i-th method; S—the total average error; X_i—the reciprocal of proportion of the average error of the i-th method to total error; w_j—the weight of the j-th method in the comprehensive forecast; Q_j—the predicted value of the j-th method; Q—Combine predicted values.

Combined with equation (4-1), it can be concluded that $w_1=0.1883$；$w_2=0.2382$；$w_3=0.5734$。

According to the weight and combined forecasting model, the fuel consumption can be calculated, as shown in Table 7.

Table 7. Combined model predicts fuel consumption of Xinjin Airport in the next 5 years

years	2018	2019	2020	2021	2022	2023
Aviation fuel consumption（tons）	1380.408	1464.611	1548.607	1631.955	1714.358	1795.679

4. Conclusion

(1) The article predicts the fuel consumption of Xinjin Airport in the next 5 years through the elastic coefficient method, trend extrapolation method and grey prediction GM(1,1) model. The results show that the forecast data is valid. In order to improve the accuracy, the error analysis of a single model is carried out by using a combined model based on three models. The results show that the combined model has improved accuracy and accuracy of the predicted values.

(2) The research results of the article can provide theoretical reference for the mid- and long-term layout construction planning and fuel procurement supply of general aviation airports, and have important practical significance for improving the safety of aviation fuel. It is mainly reflected in: the fuel consumption forecast of the airport can optimize the inventory, determine whether the future oil storage capacity is reasonable, whether the oil tank needs to be expanded, whether the oil tank turnover rate is reasonable, and ensure the fuel supply, especially in the case of tight fuel supply. To ensure that the number of oil workers is reasonable, the professional and management personnel are equipped to meet the fuel consumption requirements; to ensure that the existing management system or operational specifications can meet the safety of fuel supply and serve for airport decision-making.

(3) The combined prediction model used in the paper has high precision and is suitable for all kinds of general aviation airports. At the same time, this prediction model is also applicable to the prediction of fuel consumption of civil aviation transportation airports.

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