Research on Consumption Law Prediction of aircraft spares based on Holt-Winters

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ABSTRACT: In view of the trend and seasonal factors affecting the consumption of spare parts for aviation spares, the Holt-Winters exponential smoothing method was used for prediction research. The analysis results are consistent with the actual situation, and the practice proves that the method is feasible.

1. INTRODUCTION
A time series is a sequence formed by arranging the values of a statistical indicator in chronological order, which implies the development trend and direction of the numerical value, by analogy or extension, to predict the situation that may be achieved at a certain time or some time later\cite{1-4}. According to different data analysis methods, time series analysis methods can be divided into moving average method\cite{5}, weighted moving average method\cite{6}, exponential smoothing method\cite{7}, trend prediction method\cite{8} and so on. According to the length of time, the forecast can be divided into short-term forecast, medium-term forecast and long-term forecast.

2. EXPONENTIAL SMOOTHING
In practical applications, the exponential smoothing method is relatively simple because of its relatively simple model, and its short-term prediction ability is better. The basic idea is to consider both the data of this cycle and the previous data when predicting the next time period. In the simple
moving average method, each data is given the same weight, and the exponential smoothing method can assign different weights to the data according to the parameters, thereby obtaining better fitting curves and prediction results. In the exponential smoothing method, the most recent data gives a higher weight, the earlier data gives a relatively lower weight, and the weight is geometrically decremented at a fixed ratio, so that the most recent data plays a greater role in future prediction analysis. In line with objective reality. According to the selected parameters, it can be divided into single parameter exponential smoothing method, two parameter exponential smoothing method and three parameter exponential smoothing method. One-parameter exponential smoothing is suitable for time series data with stationary characteristics, and two-parameter exponential smoothing is suitable for trending characteristics. Time series data, three-parameter exponential smoothing is suitable for time series data with trend characteristics and seasonal characteristics.

In order to facilitate the visualization of the image and realize the visualization effect, it needs to be converted into a time series diagram. Since there are usually random or error components in the timing diagram. In order to identify the laws implied in the data and remove the influence of the fluctuations, a smooth line is drawn by the centered moving average method, and its expression is

$$ s = \left( x_{t-1} + x_{t-2} + \cdots + x_{t-k} \right) / (2q + 1) \quad (1) $$

Where is the smoothed value of time point t, and $k = 2q+1$ is the number of observations averaged each time, which is usually set to an odd number. The larger $k$, the smoother but more distorted the curve is. Accordingly you need to try a number of different values. The three-parameter exponential smoothing and the Holt-Winters exponential smoothing method can be used to fit the time series with horizontal, trend, and seasonal terms. The three-parameter exponential smoothing is essentially the three-dimensional exponential smoothing method. The commonly used cumulative model is

$$ s_i = \alpha (s_{i-1} + p_{i-1}) + (1 - \alpha) (s_{i-1} + t_{i-1}) \quad (2) $$

$$ t_i = \beta (s_{i-1} - s_{i-2}) + (1 - \beta) t_{i-1} \quad (3) $$

$$ p_i = \gamma (s_{i-1} - s_{i-2}) + (1 - \gamma) p_{i-1} \quad (4) $$

$$ x_{i+k} = s_i + h \cdot t_i + p_{i+k} \quad (5) $$

Which is the seasonal effect representing time $t$. The exponential decline of the parameter control level term, the exponential decline of the parameter control slope, except for the parameter and the exponential decrease of the parameter control seasonal term, the value range is also [0, 1], the larger the value, the more The seasonal effect weight of the near observations is greater.

Several accuracy metrics commonly used in practice are the mean error (ME), the square root of the mean residual sum of squares (RMSE), the mean absolute error, the average percentage error, etc. In general, the average error and the average percentage error are not practical. The most commonly used is the square root of the sum of squared residuals. The smaller the value, the more reliable the model is.

3. AVIATION MATERIAL SPARE PARTS CONSUMPTION

From the perspective of the consumption of aviation spares, there are seasonal factors. Time series data with seasonal factors can be decomposed into trend factors, seasonal factors, and random factors. The trend factor can reflect long-term changes, seasonal factors reflect cyclical changes within a year, and random (error) factors can reflect changes that are not explained by trends and seasonal effects.

The spare parts of aviation spares play an important role in ensuring the smooth operation of aviation missions. If the number of storage spare parts is too large, the storage cost is too high and the economy is not good. If the number of storage spare parts is too small, the completion of the task cannot be guaranteed. Therefore, by predicting the model for prediction, the economic precision can be achieved.
4. INSTANCE SIMULATION

The consumption of a certain type of aviation spares in a certain department from 2008 to 2013 is shown in Table 1. [9]

| Year | Qtr1 | Qtr2 | Qtr3 | Qtr4 |
|------|------|------|------|------|
| 2008 | 25   | 32   | 37   | 26   |
| 2009 | 30   | 38   | 42   | 30   |
| 2010 | 29   | 39   | 50   | 35   |
| 2011 | 30   | 39   | 51   | 37   |
| 2012 | 29   | 42   | 55   | 38   |
| 2013 | 31   | 43   | 54   | 41   |

In order to facilitate the visualization of the image and realize the visualization effect, it needs to be converted into a time series diagram, as shown in Figure 1.

![Figure 1. Aviation spare consumption sequence](image1.png)

As can be seen from the above image, as $k$ increases, the image becomes smoother and smoother. As time goes on, the overall trend of spare parts consumption is getting bigger.

![Figure 2. Simple moving average using smooth horizontal 3 processed sequences](image2.png)
Figure 3. Simple moving average using smooth horizontal 5 processed sequences

Figure 4. Simple moving average using smooth horizontal 9 processed sequences

Figure 5. Seasonal decomposing graph
As can be seen from Figure 5, the trend of the sequence is monotonic, and the seasonal effect indicates that there are more spare parts consumed in the second and third quarters. The y-axis dimensions of each graph are different, so we use the gray bars on the right side of the graph to indicate the magnitude, i.e., each strip represents the same magnitude.

In the monthly chart, the year is a sub-sequence. From Figure 5, it can be seen that there is a trend and seasonal effect on the spare parts consumption of the aircraft.

Table 2. Forecast of aviation spare parts consumption for the four quarters of 2014

| Point   | Forecast | Lo80  | Hi80  | Lo95  | Hi95  |
|---------|----------|-------|-------|-------|-------|
| 2014Q1  | 33.345   | 29.602| 37.089| 27.621| 39.070|
| 2014Q2  | 45.371   | 41.628| 49.115| 39.647| 51.096|
| 2014Q3  | 56.430   | 52.687| 60.173| 50.705| 62.155|
| 2014Q4  | 43.314   | 39.570| 47.057| 37.589| 49.038|

Based on this model, the forecast of aviation spare parts consumption is shown in Table 2 for the four quarters of 2014. The 80% and 95% confidence intervals are given in the table.

Table 3. Common accuracy metrics

| Metrics | ME    | RMSE  | MAE   | MPE   | MAPE  | MASE  | ACF1  |
|---------|-------|-------|-------|-------|-------|-------|-------|
| Results | -0.134| 2.385 | 2.026 | -0.694| 5.584 | 0.737 | 0.249 |

Table 3 shows several accuracy metrics commonly used today. Generally, the average error and the average percentage error are not practical, and the most common is the square root of the sum of
squared residuals (RMSE). The average residual square of this example. The square root of the sum is 2.385, and the value is small, indicating that the model is more reliable.

5. CONCLUSION
Forecasting the consumption of spare parts for aviation spares can achieve the purpose of refined protection. The Holt-Winters exponential smoothing method is used to predict the research. The square root of the sum of squared residuals is relatively small, and the calculation is simple and operability. It provides data decision support for the aviation material spare parts raising managers to better realize the navigation and the purpose of fine support.

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REFERENCES
[1] Ronghui Qi, Chuanshuai Dong, Li-Zhi Zhang. Wave-wise falling film in liquid desiccant dehumidification systems: Model development and time-series parameter analysis[J]. International Journal of Heat and Mass Transfer, 2019, 132.
[2] S. Bajocco, C. Ferrara, A. Alivernini, M. Bascietto, C. Ricotta. Remotely-sensed phenology of Italian forests: Going beyond the species[J]. International Journal of Applied Earth Observations and Geoinformation, 2019, 74.
[3] Kieran A. Monaghan, Ana L. Machado, Margarida Corado, Frederick J. Wrona, Amadeu M. V. M. Soares. Seasonal time-series reveal the impact and rapid recovery in richness, abundance and community structure of benthic macroinvertebrates following catchment wildfire[J]. Science of the Total Environment, 2019, 651.
[4] Ortiz A, Bradler K, Garnham J, Slaney C, McLean S, Alda M. Nonlinear dynamics of mood regulation in unaffected first-degree relatives of bipolar disorder patients[J]. Journal of Affective Disorders, 2019, 243.
[5] CAO Huiling, ZHANG Zhuo. Smoothing evaluation research of gas path parameter based on multiple smoothing indices fusion[J]. JOURNAL OF CIVIL AVIATION UNIVERSITY OF CHINA, 2016, 34(03):17-21+32.
[6] YUAN Rui-ping, AI Shuang, LOU Feng. A Study on Performance Evaluation Method of Beijing Municipal Government Website[J]. MATHEMATICS IN PRACTICE AND THEORY, 2018, 48(02):41-48.
[7] LI Shou-jin, CUI Zi-zi, ZHAO Jing. Research and Application on Dynamic Cubic Exponential Smoothing Method Based on Matlab self-adaption — A case study from nationwide road traffic accidents[J]. MATHEMATICS IN PRACTICE AND THEORY, 2018, 48(12):169-177.
[8] Qu Panpan; Xuan Zhengnan; Zhang Yifen; He Zhaorong; Sun Zhiwei. The application and prospect of trend prediction for equipment condition in oil-monitoring [J]. Modern Manufacturing Engineering, 2017(11):157-161.
[9] YANG Yan-ming. Statistics Analysis and Application About Quality Management[M]. Beijing: tsinghua publishing company, 2015