

Manpower Management Benefits Predictor Method for Aircraft Two Level Maintenance Concept

Yuanda Wang (Corresponding author)

College of Aeronautics, Northwestern Polytechnical University

PO box 120, 127 Youyi xi road, Xi'an 710072, China

E-mail: ilabus807@126.com

Bifeng Song

College of Aeronautics, Northwestern Polytechnical University

PO box 120, 127 Youyi xi road, Xi'an 710072, China

Abstract

In maintenance management process of aircraft, how to use the lesser maintenance manpower to get in return the higher maintenance Benefits, it is a problem that the management specialists pay more attention to, so, manpower management and cost estimate are the important compose parts of aircraft Life Cycle Costs (LCC) management. Via improve the maintenance level of aircraft, predigesting maintenance system from three level to two level maintenance (TLM) could save manpower, improve readiness, achieve the goal of bring favorable maintenance management Benefits. We imported gray system Verhulst model theory, established the manpower management forecast model for transforming maintenance system, and predicted according to the actual save manpower data of the United State Air Force. It is proved that the creditability of the prediction model is higher, has certain practical value.

Keywords: Aircraft, Gray Verhulst model, Two level maintenance concept, Manpower management Benefits, Predictor Method

1. Introduction

Military aircraft perform three level maintenance system for a long time. With the increasingly complex in airborne system and great advance in technologies, aircraft's Life Cycle Costs (LCC) especially servicing support costs went on improving, logistical supply line is too long, manpower costs and maintenance costs are too high, there has a biggest conflict between increasing aircraft readiness and reducing LCC, we could buy but cannot afford. So the aircraft maintenance management specialists were trying to find an efficient path of costs saving. With the fast development of avionics and engine technologies and foundation of maintenance system engineering conception, it provides a necessary condition of predigesting maintenance level. In October 1993, the United States Air Force implied two Level maintenance (TLM) concept, transformed Organizational level, Intermediate level and Depot level to Organizational level and Depot level. By the verification of several local wars, TLM have gained magnificent martial and economic Benefits.

Maintenance systems include maintenance production system and maintenance management system. In the maintenance management process, maintenance manpower Benefits estimate is the research emphases. There are some models described calculating procedure, but we have no model, which can calculate TLM manpower costs. USAAF AFH 21-130 gave the total saving manpower costs estimate formula:

$$\text{Total estimated savings} = (\text{base manpower savings}) - (\text{increased depot manpower costs}) - (\text{increased transportation costs}) + \text{or} - \text{change in inventory requirement} + \text{or} - \text{change in RSP cost.}$$

From the upper formula we can see, if we want to calculate manpower Benefits accurately, many practice running data are needed, it is impossible achieved in the beginning of researching maintenance system transform period. So we must find the useful models for reference and practice calculate.

Base on the coming into being manpower Benefits of USAAF implied TLM, we import gray prediction theory, get a prediction model, and solve the above problem preferably.

2. Basic conception of gray prediction theory

The existing system statistical analysis usually use the mathematics statistics method, and the sample are the more and the better, distribution rule is known, thus this method isn't fit the condition of unknown distribution rule. Partial information is known and partial information is unknown, we called such system as gray system. This system regards the random variable as the gray variable which is varying in a certain range, regards the random process as the gray process which is varying in a certain range and a certain time period, use the original data to accumulating generator operator (AGO), and attenuate it's random factors, then establish the whitenization form differential equation for the making sequence of numbers, find out the equation's solution sequence of numbers, finally through the inverse accumulating generator operator (IAGO), we find out the predicted value.

The characteristics of grey prediction theory are as follow:

(1) Though the grey prediction, we can establish the differential equation. This equation is a differential equation type model, which established by the viewpoints and methods of relational degree convergence theory, generator number, and grey differential equation, it has a wide range of use.

(2) By the method of data processing, it can put the disorderly and unsystematic original data in order, and become a rule generator sequence of numbers.

(3) Though the residual test, posterior error test, and relational degree test, we can test the precision.

(4) According to the predict precision, we also topology predict model, establish the all data GM model, new information GM model, residual model and adjust predict model (include GM model), so as to increase predict precision.

(5) Because grey prediction establishes model is a generator data model, the results calculate value by the GM model must be dealt with inverse generator to revert prediction value.

3. Verhulst model

3.1 Verhulst model introduction

For non-monotonous swing sequence or saturated S shape sequence, GM (2,1), DGM and Verhulst model can be established.

We use grey prediction to establish GM (1,1) power model for generator sequence of numbers, and use accumulating generator operator processing procedure to deal with the original sequence of numbers.

Suppose there is an original sequence of numbers $X^{(0)}$:

$$X^{(0)} = [x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)] \quad (1)$$

Make 1 time accumulating generator operator (1-AGO) for $X^{(0)}$, we can gain the generator sequence of numbers $X^{(1)}$.

In here,

$$x^{(1)}(k) = \sum_{m=1}^k x^{(0)}(m) \quad (2)$$

$Z^{(1)}$ is $X^{(1)}$ proximate mean generator sequence, we call $Z^{(1)}$

$$x^{(0)}(k) + az^{(1)}(k) = b(z^{(1)}(k))^\alpha \quad (3)$$

as GM (1,1) power model.

Establish whitenization differential equation for $X^{(1)}$,

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b(x^{(1)})^\alpha \quad (4)$$

in equation, when $\alpha=2$, this model is called grey Verhulst model.

Verhulst model mainly used to describe the process, which has saturation state, which is S shape process. This model usually used to population projection, biology growth, breeding prediction and product economy life prediction, etc.

Suppose parameter column vector $\hat{a} = \begin{bmatrix} a \\ b \end{bmatrix}$

From relation formula $Y = B\hat{a}$, we can get parameter calculate formula:

$$\hat{a} = (B^T B)^{-1} B^T Y \quad (5)$$

Among this formula:

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

Solve for this whitenization differential equation, we get the time response formula of Verhulst model:

$$\hat{x}^{(1)}(k+1) = \frac{ax^{(1)}(0)}{bx^{(1)}(0) + (a - bx^{(1)}(0))e^{ak}} \quad (6)$$

Make 1 time inverse generator operator (1-IAGO), and revert it, we get prediction-estimated value:

$$\hat{x}^{(0)}(k) = \hat{x}^{(1)}(k) - \hat{x}^{(1)}(k-1) \quad (7)$$

3.2 Model precision test

The precision degree test methods for prediction value commonly have 3 types:

(1) Residual magnitude test.

It is a count test through model precision point.

(2) Posterior error test.

It is a statistical test through probability distribution of residual.

(3) Relating degree test.

It is a geometric test through model curve behavior data curve.

According to the result of different test, we can judge whether the model is fit, or correct the model. In this article, we use the conventional residual magnitude test method.

Residual is $\varepsilon(k) = x^{(0)}(k) - \hat{x}^{(0)}(k)$,

and relative error is $\Delta_k = \frac{|\varepsilon(k)|}{x^{(0)}(k)}$.

4. Calculation of USAAF TLM manpower Benefits

Table 1 gives the saving maintenance manpower data of USAAF maintenance system from three level to two level.

Apply table 1 data, we establish Verhulst model. Because the 1994 and 1995 year are the maintenance system adjustment initial period, these two year's data were insufficient to reflect the matter of question, so we omit it, and calculate from 1996 year.

Because the original data curve is approximate to S shape, we choose

$$x^{(1)} = (5820, 5680, 5962, 5888),$$

it's 1-IAGO sequence is

$$x^{(0)} = \{x^{(0)}(k)\}_1^4 = (5820, -140, 282, -74),$$

it's proximate mean generator sequence is

$$z^{(1)} = \{z^{(1)}(k)\}_2^4 = (5750, 5686, 5790).$$

According to (5), (6) formulas, we get $a=0.067369$, $b=0.000012$.

The predictive model of manpower Benefits is

$$\hat{x}^{(1)}(k+1) = \frac{392.0876}{0.0698 - 0.0024e^{0.067369k}}$$

Thereout, we can simulate and predict the saving manpower after the USAAF implied TLM concept:

$$\hat{x}^{(1)}(1) = 5820, \quad \hat{x}^{(1)}(2) = 5842.588, \quad \hat{x}^{(1)}(3) = 5866.882, \quad \hat{x}^{(1)}(4) = 5893.127, \\ \hat{x}^{(1)}(5) = 5921.462942.$$

In here, $\hat{x}^{(1)}(5)$ is the saving manpower predicted value of USAAF in 2000, and that actual data of 2000 year $x^{(1)}(5) = 5925$.

Residual is

$$\varepsilon(k) = x^{(1)}(5) - \hat{x}^{(1)}(5) = 3.537058,$$

Relative error is

$$\Delta_5 = \frac{|\varepsilon(5)|}{x^{(1)}(5)} = 0.6\%,$$

Predictive precision is 99.4%, so we consider that the simulate effect is better.

5. Conclusions

By establishing and applying Verhulst model, we get the predictive value. Residual test shows that the predictive value is close to the actual value. It proved this model is very suitable to describe the saving manpower Benefits after maintenance system predigested from three level to two level. It provides a means of maintenance manpower management Benefits for some countries air force, we can use this model in the field of demonstration and conversion for two level maintenance concept.

But we must notice that the model can only be predicted the former 8~10 years condition after predigested maintenance system, because once TLM ran normally, it is no meaning to compare TLM with three level maintenance.

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Table 1. a USA AF unit saved manpower after changing maintenance

Year	1994	1995	1996	1997	1998	1999
Data	996	2048	5820	5680	5962	5888