Application of evaluation of aircraft material demand forecasting method and mining of association rules

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Abstract - **The support probability of aviation materials is a crucial part in the process of normal operation of airlines. But the higher support probability will inevitably lead to the increase of inventory cost of aviation materials, and restrict airlines to improve their efficiency. Hence it is of great significance for airlines reducing the material cost on the premise of normal operation to predict the material requirements accurately based on reasonable models. This paper summarizes a series of prediction models of aviation material requirements, and applies the grey comprehensive correlation degree to evaluate the models. On this basis, the method of association rules is used to discover the association relationships between the types of aviation materials and the prediction models.**

Keywords - **Association rule, aviation material prediction, grey comprehensive correlation degree, model recommendation**

I. INTRODUCTION

With the rapid development of China's economy, the aviation industry of China also has made great progress. However, with the rapid development, airlines are also facing with a series of questions. Especially, supply chain and security of aviation materials have been the focus of attention of each airline. The cost of aviation materials is an important part of aircraft operating costs of aviation transport enterprises, which ranks only second to the cost of purchase of aircraft and aviation fuel. Thus, to reduce aviation materials inventory cost of airlines effectively, it is crucial to predict the quantity demanded of aviation materials scientifically and reasonably.

At present, the study of methods of aviation materials demand forecasting has been paid highly attention by academia and application fields. Regattieri et al. applied the AW/M model to predict the fluctuant demands of spare parts of aviation materials [1]. Johnston et al. evaluated the optimal prediction parameters through analyzing the cycle length from 2 to 12, and built moving average model (MA(i)) to achieve prediction [2]. Aslam et al. put forward the prediction model based on exponentially weighted moving average [3]. Croston raised a method called Croston-CR, which overcame the shortage of exponential smoothing method, respectively evaluated the quantity demanded and the frequency of demand and prevented the shortage of inventory by adjusting the safety stock [4]. On the basis of Croston, Segerstedt computed the quantity of orders and order lead time [5]. Willemain et al. applied Croston's method to predict the intermittent demand for spare parts, which can bring tangible benefits for enterprises [6]. Godfrey carried out medicine research with linear regression model [7]. Isobe et al. applied linear regression model to research in astronomy [8]. Liu et al. used linear regression model to analyze near infrared spectrum [9]. And Figura applied it to predict underground water temperature [10]. Ramos et al. used ARIMA model to forecast consumer retail sales [11]. Li & Wang developed an automatic auto regressive integrated moving average modeling based data aggregation scheme in wireless sensor networks [12]. Chang et al. predicted the Internet users and the industry revenue of online games by using grey theory [13]. Ou applied GM(1,1) model to forecast the agricultural output [14]. Zhou et al. utilized GM(1,1) to predict the output of the fuel [15]. Yang & Shieh used SVR to predict consumers' affective responses [16].

The previous related research made outstanding contributions to improve the efficiency of demand forecasting. But in the practical application, the prediction methods suited to the different materials differ from one another. This paper put forward the prediction methods based on multi model and use grey comprehensive correlation degree to evaluate the predictive effect. And we mine the association pattern between material types and prediction models, so that the applicable prediction models can be given based on the association rules after airlines accumulating a certain amount of prediction record.

The paper is organized as follows: The second section mainly introduces the process of prediction and recommendation. In the section III, we make a case analysis. Finally, we present our conclusions in Section IV.

II. THE ANALYSIS AND RECOMMENDATION OF ALTERNATIVE PREDICTION MODELS

The statistical characteristics of different types of demand data of aviation materials are not the same. Because there are a great variety of aviation materials, it is difficult for each aviation material requirement to build and verify mathematical model respectively. To solve the above problems, eight prediction models are introduced to predict the aviation material requirements, which are Poisson distribution model, linear regression model, auto regression (AR) model, integrated autoregressive moving average (ARIMA) model, automatic arima model, holt-winters model, grey prediction model GM(1,1) and support vector machine regression (SVR) model. The TABLE I shows the description of the alternative prediction models.

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In this paper, the prediction and recommendation of material demand is divided into five steps:

(1) The preprocessing of data, including the outbound quantity, flight hours and flight frequency of aviation material;

(2) Multi model prediction. We apply eight kinds of prediction models to predict the demand of aviation material.

(3) Calculate the grey comprehensive correlation degree. Grey comprehensive correlation degree are used to evaluate the effect of prediction models.

(4) Mine the association rules. We apply apriori algorithm to mine the association pattern between material types and prediction models.

(5) Model recommendation. The optimal models are given based on the association rules mined by step (4) according to different aviation material.

III. RESULTS FOR CASE STUDY

In order to verify the multi prediction models and the model recommendation methods, this paper selected the monthly data of the material A of an airline company

TABLE I
THE ALTERNATIVE PREDICTION MODELS

Name	**Model description**
Poisson distribution model	$$p_k(t)=\frac{(\lambda_t)^k}{k!}e^{-\lambda_t},k\in Z^+,t>0 \quad (1)$$ $p_k(t)$ is the probability that the quantity demand of the aviation material is k within the time (0, t).
Linear regression model	Y_i is used to reflect the outbound quantity of aviation material, and X_i is the flight frequency or flight hours of aviation material. $$Y_i=a+bX_i+\varepsilon_i \quad (2)$$
Auto regression(AR) model	It is built according to the outbound quantity Y of aviation material. $$Y(t)=\varepsilon(t)+\sum_i^p\varphi_iY(t-i) \quad (3)$$
ARIMA(p,d,q)	$$X(t)=\beta_0+\sum_{i=1}^q\beta_iX(t-i)-\varepsilon(t)-\sum_{j=1}^p\alpha_j\varepsilon(t-j) \quad (4)$$
Automatic arima model	There are tens of thousands of aviation materials in aviation enterprises. It is impossible for every time series data to arrange the staff to build model. Thus, it is necessary to introduce the automatic arima model, which can automatically identify the pattern of time series and estimate the parameters of models.
Holt-winters model	$$a_i=\alpha(y_i-c_{i-p})+(1-\alpha)(a_{i-1}+b_{i-1}) \quad (5)$$ $$b_i=\beta(a_i-a_{i-1})+(1-\beta)b_{i-1} \quad (6)$$ $$c_i=\gamma(y_i-a_{i-1}-b_{i-1})+(1-\gamma)c_{i-p} \quad (7)$$
Grey prediction model GM(1,1)	$$\frac{dx^{(1)}}{dt}+ax^{(1)}=u \quad (8)$$ $x^{(1)}$ is the cumulative sequence in term of the historical outbound quantity of aviation material. t is the time. a,u are development grey number and Internal control grey number.
Support vector regression (SVR) model.	$$f(x)=w^t\phi(x)+b,\ w\in R^n,b\in R \quad (9)$$ The $f(x)$ reflects the historical outbound quantity of aviation material. x is flight hours or flight frequency. $\phi(x)$ is the nonlinear function.

from January 2000 to July 2014, including the consumption quantity of the material A, the number of flight hours and the landing times. The detailed calculation and analysis results will be presented in the next part of this paper.

A. The results of the prediction models

The paper selected the monthly data of the material A of an airline company from January 2000 to July 2014. Because the parameters of the model need a certain amount of data, the first 12 months of the data are only used to estimate of the model parameters, not to forecast the demand. Fig. 1 to Fig. 9 show the actual monthly outbound quantity of material A and eight kinds of prediction models from January 2001 to July 2014.

From the comparison of the actual demand with the forecasted results, among the eight models, the effect of grey prediction model GM(1,1) is the worst. Based on the analysis of the application of GM(1,1) in the grey forecasting model, it is generally believed that the necessary condition for obtaining high precision with GM(1, 1) model is that the equal time interval, the non negative and the monotonicity. Although the demand of A is satisfied with the equal time interval and the non negative, it is not satisfied with the monotone. So the prediction accuracy of the grey model GM(1,1) is poor. In contrast, the time series methods and the support vector machine regression model have better prediction effect.

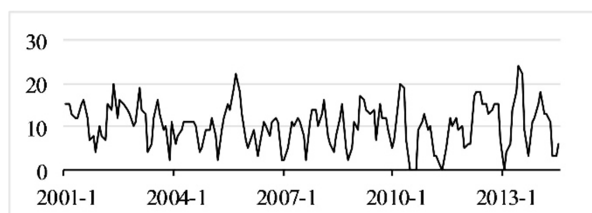

Fig. 1. Actual demand.

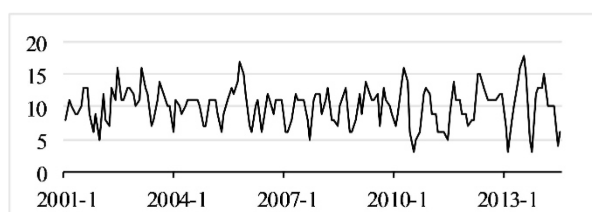

Fig. 2. Result of AR model.

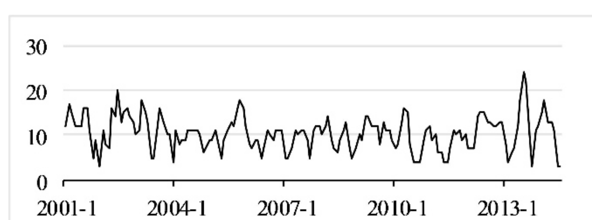

Fig. 3. Result of ARIMA model.

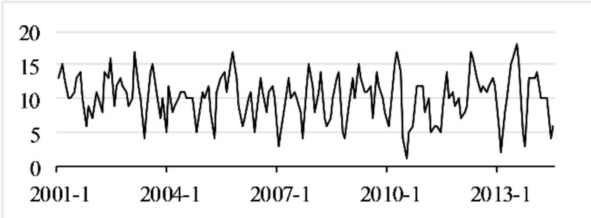

Fig. 4. Result of Automatic arima model.

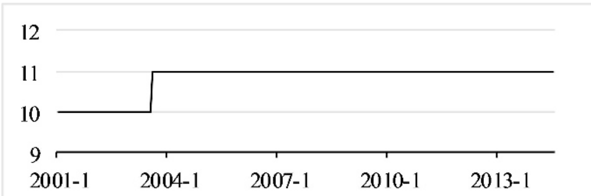

Fig. 5. Result of GM(1,1) model.

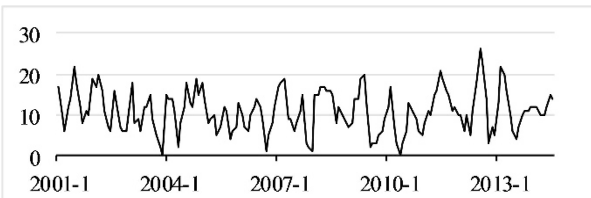

Fig. 6. Result of holt-winters model.

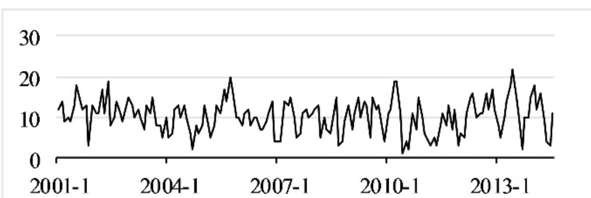

Fig. 7. Result of linear regression model.

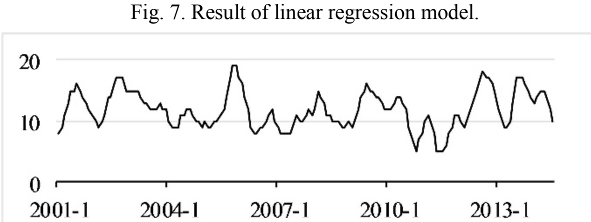

Fig. 8. Result of Poisson model.

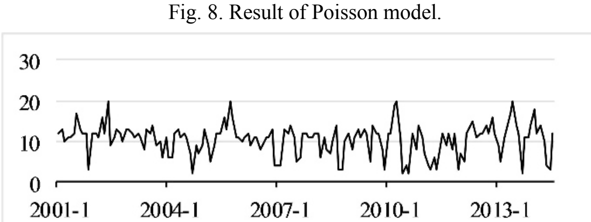

Fig. 9. Result of SVR model.

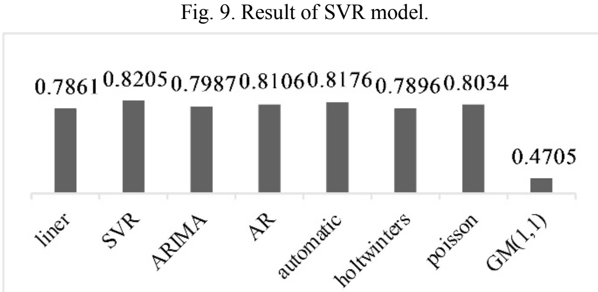

Fig. 10. Grey comprehensive correlation degree-December, 2011

B. Evaluation results of grey comprehensive correlation degree

In this paper, the grey comprehensive correlation degree is used to evaluate the prediction models. Taking the calculation process of the grey comprehensive correlation degree in December 2011 for example, the specific analysis process is as follows.

(1) Select the actual demand of the material *A* and the results of eight prediction models.

(2) Set the weight of grey absolute correlation degree and grey relative correlation degree to 0.5.

(3) Get the grey comprehensive correlation degree, as shown in the Fig.10.

According to the order of the grey comprehensive correlation degree from large to small, it shows that the prediction effect of the support vector machine regression model outperform other forecasting models in December 2011. The predictive effect of Automatic ARIMA model is worse than support vector machine regression model, but it is better than other models. The effect of grey forecasting model GM(1,1) is the most unsatisfactory, which is consistent with the conclusion of the last section.

(4) Obtain the forecast record according to the threshold of the grey correlation degree

According to the characteristics of aircraft demand and the requirement of aircraft management, set the threshold value of the grey comprehensive correlation degree to 0.8. Set the prediction model as an alternative model, whose grey comprehensive correlation degree is more than 0.8. The forecast record in December 2011 is as follows:

$$\{A, SVR, AR, Automatic-ARIMA, Poisson\} \tag{10}$$

C. The association rules between the aircraft material types and prediction models

According to the relationship between material types and alternative prediction models, the confidence level is set to 0.8, and the support level is set to 0.5. The following association rules can be obtained by mining the forecast records from February 2001 to July 2014 which contains 162 monthly forecast records.

According to the association rules obtained from the TABLE II, it can be known that the applicability of Automatic ARIMA model is higher than other forecast models for material A, and the second is the support vector machine regression model. The enterprise will be able to directly select the Automatic ARIMA model to predict the future demand of material A, which can greatly improve the efficiency of the demand prediction.

IV. CONCLUSION

In this paper, we analyzed the problems of aircraft material demand forecasting, and summarized the 8 kinds

TABLE II
ASSOCIATION RULES

NO	Association rules	Support	Confidence
1	{A} => { Automatic ARIMA}	0.74	0.92
2	{A} => { SVR}	0.55	0.85

of demand forecasting models. Then, the grey comprehensive correlation degree between the predicted results of each model and the actual consumption is calculated. According to the threshold value of the grey comprehensive correlation degree, the forecast model was selected, and the forecast record was obtained. Finally, the apriori algorithm is introduced in the paper, and the association rules between the aviation material type and the prediction models were obtained by mining the forecast records. In the future, the optimal forecasting model can be directly given according to the association rules and the type of aviation material, which greatly improves the efficiency of the demand forecasting.

In this paper, the grey comprehensive correlation degree is used to evaluate the eight prediction models. Although it makes up for some deficiencies of absolute degree of grey incidence and the relative degree of incidence, there is not a reliable basis about how to determine the weight between the grey absolute correlation and the relative, which is mainly adjusted according to the experience and historical data. In future studies, we will focus on the weight, so that it can be determined more scientific standards.

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