PREDICTIVE MODEL OF RAIL CONSUMPTION FOR BEIJING SUBWAY LINE 2

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Abstract: This paper focus on the rare researched project, the consumption of subway steel rail based on quantitative analysis; make a Fuzzy Time Series Prediction Model for the aggregate consumption of the steel rail expended in subway. Set Beijing Subway Line.2 as a case object, make an analysis and give a prediction, conclude the rule of steel rail consumption, the result provides a scientific basis for management of Beijing subway steel rail maintenance.

1 INTRODUCTION

As the development of science and urbanization, the effective rail transportation plays more and more important roles in modem cities nowadays. The transportation development history in western countries shows us that the only way to better the urban traffic fundamentally is to adopt urban track transportation or so called mass transit (made up of subway and light rail). Great traffic volume, fast, safe, punctual, eco-friendly, energy saving, subway release great pressure of urban traffic, accelerating the city development as an essential part of mass transit.

From domestic and international practice, as the improvement of traffic volume and vehicles there exist many problems that is exigent to be solved in urban subway Operation. One of the most important problem is how to manage the consumption of materials in subway scientifically.Subway materials consumption increase year by year, requires a large amount of money on subway line maintenance. In such a realistic condition, metro lines material costs budget is becoming more and more important

2 REVIEWS

As the main bearing parts of urban rail transit, rail bares the reciprocal action of train wheels directly. The statues of the steel rail affect the whole urban transit, and the relations between the two had been studied for a long time. But most of the researches are based on main line railway. Even though there are many similarities between subway and main line railway, there do exist some differences that can't be ignored. The main line railway is fast, low traffic volume, heavy loaded while the subway run high traffic volume, light loaded and mostly concentrated on safety.

The last decade saw the start of studies on urban rail transit; the studies endure a period that is focused on main line railway. Starting with quantitative analysis on steel rail consumption(Cao Minghua, Chen Yonggui, 2008; Matsumoto K, Suda Y, et al., 2006), several scholars are looking into the cause of the consumption(YU Chunhua, 2007).

And some scholars turn to the area of the management steel rail maintenance. It aims to lower the consumption and cost, while the urban transit runs smoothly. This project has been divided into two levels, on one hand is to replace the badly fatigue damaged steel rail, maintain the rail with oil on time (Liu Canlong, 2008; Matsumoto K, Suda Y

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et al., 2008[), one the other hand is to look into the management skills (ZhouYu, XuYude, 2008; Bozyslaw et al., 2003) ,technology and method (YU Chunhua, 2007) adopted in rail maintenance.

We can draw a conclusion that, the current domestic and overseas scholars are mainly focused on two aspects: the causes of the rail consumption and the maintenance of the rails and related management work. Few have been tried to discuss it based on quantitative analysis, which is of great value from the materials management. Realized this we will make a Fuzzy Time Series Prediction Model for the aggregate consumption of the steel rail expended in subway, Set Beijing Subway Line 2 as a case object, make an analysis and give a prediction, conclude the rule of steel rail consumption, and test it in the end.

3 THE FORECAST OF RAIL CONSUMPTION ON BEIJING SUBWAY LINE 2

3.1 Fuzzy Time Series Prediction Model

3.1.1 Source Data into the Fuzzy

Source data of the Steel rail consumption is a real number set, $x_1, x_2, \cdots, x_T$. Use the set defined in A fuzzy set, $SV_1, SV_2, \cdots, SV_T$, to restore the original data's uncertainty.

Preset: $U_t=\max(x_{t-1},x_t,x_{t+1})$, $V_t=\min(x_{t-1},x_t,x_{t+1})$, $t=2,3, \cdots T-1$, $V_1=\min(x_1,x_2)$, $U_1=\max(x_1,x_2)$, $V_T=\min(x_{T-1},x_T)$, $U_T=\max(x_{T-1},x_T)$.

Define $SV_t(x)$ as follow:

If x belongs to $[V_t,U_t]$, then $SV_t(x)=1-|x-a_t|/c_t$; otherwise, $SV_t(x)=0$, And $c_t=(U_t-V_t)/2$, $a_t=(U_t+V_t)/2$, $t=1,2,\cdots,T$.

3.1.2 The Order of the Fuzzy Time Series

According to the figure of the Steel rail consumption scatterplot, it was observed that the curve of these consumption numbers approximate to a linear diagram or a conic diagram. So we could determine that the function of the fuzzy time series is first order or second order.

3.1.3 Fuzzy Coefficient

Define: p_i is Triangular Fuzzy Number and p_i` is p_i's estimated value.

Then we determine $(ß_i,S_i)$ With the fuzziness of the tendency equation as small as possible. The ambiguity S of the tendency equation is $S=\Sigma_i^k w_iS_i$, including w_i is S_i's weight. The ambiguity S can be determined by linear regression method.

We can suppose that the linear regression equation of the original sequence is like this:

$$SV_t`=a_0`+a_1`*t+a_2`*t^2+\cdots+a_k`*t^k \quad (1)$$

And a_i` is real number, for $i=0,1,2,\cdots,k$.

Define: $w_i=|a_i`|/\Sigma|a_i`|$. The closeness between SV_t and SV_t` can be expressed by $h_t$, $h_t=(SV_t, SV_t`)$, $t=1,2,3,\cdots,T$. suppose h_t is not less than a given number h_0. So the question to make the ambiguity S of the tendency equation minimum can be changed into a linear programming problem as follows:

$$\text{Min } S=\Sigma w_iS_i \quad (2)$$

s.t. $h_t \geq h_0$, $t=0, 1, 2, \cdots T$

For $SV_t`=p_0`+p_1`*t+p_2`*t^2+\cdots+p_k`*t^k$, $SV_t$` is the triangular fuzzy number by $(\Sigma ß_it^i, \Sigma S_it^i)$. So h_t can be expressed by:

$$h_t=(SV_t,\ SV_t`)=1-|a_t-\Sigma ß_it^i|/(c_t+\Sigma S_it^i) \quad (3)$$

And if h_t is not less than h_0, the only way it can happen is as follow:

$$\begin{cases} \Sigma ß_it^i-(1-h_0)\Sigma S_it^i \leq a_t+c_t(1-h_0), & t=1,2,3,\cdots T \\ \Sigma ß_it^i-(1-h_0)\Sigma S_it^i \geq a_t-c_t(1-h_0), & t=1,2,3,\cdots T \\ S_i \geq 0, i=0,1,2,\cdots k \end{cases}$$

After these operations, we can get p_i's estimated value p_i`, for $i=0, 1, 2, \cdots, k$, and the tendency equation:

$$SV`(t)=p_0`+p_1`*t+p_2`*t^2+\cdots+p_k`*t^k \quad (4)$$

If t is bigger than T, the value of SV`(t) is a Triangular Fuzzy Number too. When time changes, the Equation graphic of SV`(t) is not only one curve but also curve clusters with border curves $f_1(t)$ and $f_2(t)$ and a central curve $f_0(t)$, for

$$f_1(t)=ß(t)+S(t) \quad (5)$$

$$f_2(t)=ß(t)-S(t) \quad (6)$$

and

$$f_0(t)=ß(t) \quad (7)$$

3.1.4 Error Regulation

Using the tendency equation from above, we can get a Series value x_t` which can compare with the Actual value $x_t$ and calculate the mean error ð by the function: ð= Σ $(x_i-x_i`)$^2/n. based on the central curve $f_0(t)$, it can be regulated to two forecast curves:

$$g_1(t)=ß(t)+ð \quad (8)$$

$$g_2(t)=ß(t)-ð \quad (9)$$

3.2 Forecasting Results

Through the investigation into Beijing Subway Group, we got a Series data of Rail Consumption shown in the table 1.

Table 1: Rail Consumption (Unit: ton).

year	Rail Consumption
2003	0.00
2004	23.44
2005	3.86
2006	7.73
2007	0.00
2008	78.30
2009	62.26

From consumption data curve, it was observed that it presented upswing change tendency but not around centre line fluctuating. For this kind of data, we can use Fuzzy Time Series Prediction Model predict its change.

In This paper, MATLAB has been used to program for the proposed model. Finally got the predicting curves shown as below:

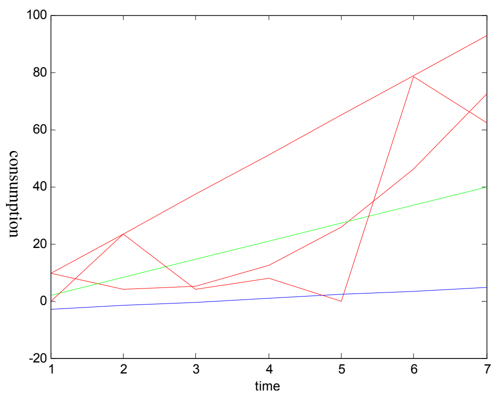

Figure 1: 2003-2009's Rail consumption fitting curve.

Functions of fitting curves are as follow:
The top curve: $f_1(t)$= -4.2087+13.8521*t.
The central curve: $f_0(t)$= -4.2087+6.2847*t.
The under curve: $f_2(t)$= -4.2087+1.2827*t.
The conic function: $f_3(t)=21.6786-15.1486*t+3.2*t^2$.

Shown in the Fig.1, The changing trend of the conic is closer to the real one. So use the conic function forecast rail consumption. as a result we can get a Series value and the mean error ð. through calculation, the value of ð is 15.2325. Based on the central curve $f_3(t)$, it can be regulated to two forecast curves:

The top curve: $g_1(t)=36.9111-15.1486*t+3.2*t^2$;
The central curve: $g_2(t)=f_3(t)=21.6786-15.1486*t+3.2*t^2$;
The under curve: $g_3(t)=6.4461-15.1486*t+3.2*t^2$;

And the value of t takes 2003 as the starting point, namely t was equal to 1 in 2003.

According to the final prediction curve function, we can forecast rail consumption in the next five years as the follow table.2.

Table 2: forecasting rail consumption in (unit: ton).

year	the top curve	the central curve	the under curve
2010	120.5223	105.2898	90.0573
2011	159.7737	144.5412	129.3087
2012	205.4251	190.1926	174.9601
2013	257.4765	242.244	227.0115
2014	315.9279	300.6954	285.4629

According to Beijing Subway Group's operation Management, it needs to make a budget plan of materials consumption for the next year at the end of each year. Therefore, the model in this article is important to the manager.

3.3 Optimize the Model

As all the method we adopt to predict can no escape from relative error, and the sample data is so limited, it is quite important to apply operational change management. Having proved the method is effective, we can dig into a new round of consumption rule by enlarge the sample data volume. To make the prediction more reliable, the Beijing subway group may take measures to collect the specific data along the whole rail line, with which the model will work better.

4 CONCLUSIONS

This paper gives three prediction line based on Fuzzy Time Series Prediction Model, Get an annual interval consumption of rails. On one hand, this interval provides the material manager a way to check whether the rail purchase plan is reasonable. On the other hand, The Purchasing Department can just make ends meet as been more acknowledged of the sum amount rail that is needed, which, cut the cost as a result.

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