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The Comparison on for Traffic Accident Forecasting in Long and Short Period Based on Multi-layer Recursive Forecasting Method

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Abstract: The multi-layer recursive forecasting method is used on road traffic accident forecasting in this study. We suggested the factors as density of population, GDP per capita, highway passenger transport, highway freight volume, highway mileage, density of road network, amount of vehicle, amount of cars per capita and environmental factors is selected by MATLAB in forecasting model. The model including autoregression item and the model including autoregression item and environmental factors is proposed. By changing the forecasting period, the forecasting results in years and months are acquired and analyzed. We conclude that the forecasting accuracy in short period is higher than in long period by comparing with results of long and short period.

Keywords: Auto regression, environmental factors, forecasting, long period, multi-layer recursive, road traffic accident, short period

INTRODUCTION

As the development of society, the forecasting is focused increasingly. So it is caused for many researchers to discuss the forecasting methods. Because of wide application on computer, the researches are developed on quantitative forecasting and analyzing. But the adaptability of every method is limited. When forecasting is carried out by different method, the results have distinct difference (Zhang and Han, 2002; Wen-Lin, 2005; Jian-Xi and De-Yan, 2011). At the same time, as the change of many factors such as parameter, forecasting period, the change of result is caused. The cause is that parameters of many forecasting models are no-time varying but forecasting object is varied continuously. By those models, time varying parameter system is considered as no-time varying parameter system. So when no-time varying model is applied to forecast time varying parameter system, forecasting accuracy is impacted. Forecasting period impacts the forecasting accuracy also. Road traffic accident forecasting is analyzing and predicting the future tendency of road traffic accident. It is a describing process to the future state of road traffic accident based on researching systematically past and current state and analyzing systematically the change of related factors. The used methods include qualltative and quantitative methods. It are better for the quantitative methods to describe the future tendency of road traffic accident ,so is used widely, such as fuzzy mathematics, statistics and gray theory, Xiang-Yong *et al*. (2003), El-Basyouny and Sayed (2009), Ma *et al*. (2008), Mountain *et al*. (1996), Sayed (2000), Shan *et al*. (2008) and SooBeom *et al*. (2005).

Zhi-Gang (2001) gang opposed the multi-layer recursive forecasting method based on modern control theory. After that, many researchers applied this forecasting method to many systems, such as construction, traffic etc and good forecasting results were obtained (Yan-Na *et al*., 2008; Guo *et al*., 2000; Guo and Shi, 2009; Bing *et al*., 2005; Xiang-Yong *et al*., 2006; Ren-de *et al*., 2008a; Shuang-Zhong *et al*., 2004). As a new mathematical statistics method, multilevel recursive method regards forecasting objects as stochastic dynamical time-variant system and abandons constant parameter model in usual statistical forecast methods. The method divides the prediction of system state into two steps. The first is to predict time-varying parameter and the second is to forecast system state on the basis of the first step. Thus the method has superiority dealing with strongly fluctuated questions and non-linear questions. The key of the method is the prediction of time-varying parameter. In view of the dynamic and time-varying characteristic of a traffic system, a multi-level recursive forecasting method was proposed and a multi-level recursive forecasting model for forecasting road traffic accidents was established in road traffic accidents forecasting (Tian-Tang and Zhen-Bo, 2003).

Beginning from the external features of traffic system, this study look road traffic accident as a time series to found input-output model based on the characteristic of multi-level recursive forecasting method. The model I ncluding autoregression item and

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the model including autoregression item and environmental factors is proposed respectively. By changing the forecasting period, the forecasting results in years and months are acquired and analyzed. We conclude that the forecasting accuracy in short period is higher than in long period by comparing with results of long and short period.

MATERIALS AND METHODS

Establishing forecasting model is the key step on forecasting. After established control model for control system design is mended, this model can be applied to forecasting. The multilevel recursive forecasting method which regards forecasting objects as stochastic dynamical time-variant system differs from fixed parameters method. Its basic idea is breaking the state forecasting of time-variant system into forecasting of time-variant parameters and forecasting of system state to reduce forecasting error highly (Hecht-Nielsen, 1989; Wang and Jian-She, 2008; Xiaokun and Kara, 2007; Ren-de *et al*., 2008b).

Road traffic accident is affected by many factors and does great harm to road traffic security. Applying deterministic models needs many parameters that can't be met usually. Therefore using multilevel recursive non-stationary time series model to forecast road traffic accident has superiority. Road traffic accident is stochastic, so it is necessary to regard road traffic system as nonlinear time – variant parameters system. For forecasting road traffic accident in the future, nonlinear recursive forecasting model must be established. According to the separable theorem of output, many multi-output system models may be divided into some single output system models, so nonlinear system may be replaced by a set of linear system. When forecasting on dynamic traffic system is carried, single output system is considered only. For advancing adaptability of forecasting model, a great of past data which accords with past changing rule of system is necessary in multilevel analysis on time series.

The road traffic accident changing rule on time is essential bases on taking road traffic safety management measures. So, for preventing traffic accident, it is important to analyze and know traffic accident rule. However, because traffic accident changing rule has great difference in different period, the forecasting result is different always by same forecasting method.

The multi-level recursive forecasting model of on traffic accident is established as formula (1) (Xiang-Yong *et al*., 2006):

$$
\begin{aligned}
y(k) &= \alpha_1(k)y(k-1)+\alpha_2(k)y(k-2)+\cdots \\
&+\alpha_n(k)y(k-n)+\beta_1(k)u_1(k) \\
&+\beta_2(k)u_2(k)+\cdots+\beta_n(k)u_m(k)+e(k) \\
&=\sum_{i=1}^{n}\alpha_i(k)y(k-i)+\sum_{j=1}^{m}\beta_j(k)u_j(k)+e(k)
\end{aligned} \tag{1}
$$

where,

$y(k)$ = One-dimensional outputs, i.e., road accidents prediction value in future time k

$u_1(k), u_2(k), \cdots, u_m(k)$ = m one-dimensional inputs, i.e., road accidents impact measures

$\alpha_1(k), \alpha_2(k), \cdots \alpha_n(k),$ $\beta_1(k), \beta_2(k), \cdots \beta_m(k)$ = n+m forecasting time varying parameters

$e(k)$ = One-dimensional white noise

k = Time

n = Auto regression rank of model

The first item in the right of this equation is called auto regression item which reflects historical development rule of road traffic itself; the second is called environmental factor which reflects the impact of exterior environment to the road accidents. When building the road accidents prediction model in detailed, if the evolvement rule of road traffic is obvious, the accident itself reflects the impacts of several factors to it and has self-rule. Road traffic accidents multi-level auto-recursive forecast model only with auto regression item can be set up. Let:

$$
\begin{aligned}
&\varphi(k)=[y(k-1),y(k-2),\cdots,\\
&y(k-n),u_1(k),u_2(k),\cdots u_m(k)]^T\\
&\theta(k)=[\alpha_1(k),\alpha_2(k),\cdots\alpha_n(k),\\
&\beta_1(k),\beta_2(k),\cdots\beta_n(k)]^T
\end{aligned}
$$

then the formula (1) can be written as:

$$y(k)=\varphi(k)^T\theta(k)+e(k) \tag{2}$$

when y(k), φ(k), $\hat{\theta}$(k-1) is given, the recursive track formula of time varying parameter $\hat{\theta}$(k) can be obtained:

$$
\begin{aligned}
&\hat{\theta}(k)=\hat{\theta}(k-1)+\frac{1}{\|\varphi(k)\|^2}\\
&\varphi(k)\{y(k)-\varphi(k)^T\hat{\theta}(k-1)\}\beta
\end{aligned} \tag{3}
$$

It satisfies the constraint condition y(k) = $\varphi(k)^T\theta(k)$ and minimizes index parameter j = $\|\hat{\theta}(k)-\theta(k-1)\|^2$. According to different characteristic of parameter prediction series $\{\theta_i(k)\}$, by choosing different parameter forecasting method, each time varying parameter`s next step prediction value $\hat{\theta}^*$(N+1) can be obtained. In the basis of parameter forecasting, using next step prediction formula of y(k):

Table 1: 1998-2009 road traffic accident death

Year	1998	1999	2000	2001	2002	2003
Accident death toll (ten thousand men)	0.643	0.867	0.981	0.944	0.917	0.891
Year	2004	2005	2006	2007	2008	2009
Accident death toll ten thousand men)	0.780	0.705	0.631	0.576	0.503	0.452

Table 2: 1998-2009 population and density of population

Year	1998	1999	2000	2001	2002	2003
Population (thousand men)	88380	88830	89970	90410	90820	91250
Density of population (thousand men/square kilometer)	0.578	0.581	0.588	0.591	0.594	0.596
Year	2004	2005	2006	2007	2008	2009
Population (thousand men)	91800	92480	93090	93670	94170	94700
Density of population (thousand men/square kilometer)	0.600	0.604	0.608	0.612	0.615	0.619

Table 3: 1998-2009 highway mileage and density of highway network

Year	1998	1999	2000	2001	2002	2003
Highway mileage(kilometer)	64145	67847	70686	71128	74029	76266
Density of highway network(kilometer/ square kilometer)	0.419	0.443	0.462	0.465	0.484	0.498
Year	2004	2005	2006	2007	2008	2009
Highway mileage(kilometer)	77768	80132	204911	212236	220687	226693
Density of highway network(kilometer/ square kilometer)	0.508	0.524	1.339	1.387	1.442	1.482

$$\hat{y}(N+1/N) = \varphi(N+1)^T \hat{\theta}^*(N+1) \tag{4}$$

there, $\hat{y}$(N+1/N) is next step prediction value of y(N).

RESULTS AND DISCUSSION

This study selects road traffic accident statistical data as basic data for road traffic accident recursive forecasting in M province in china. The multi-level recursive forecasting model including autoregression item only and including autoregression item and environmental factors is established respectively.

Long period accident forecasting: The road traffic accident multi-recursive forecasting model is established based on 1998-2007 accident death statistical data in M province in china. 2008-2009 data is used to test the validity of model. Data shows as Table 1. Related factors show as Table 2 to 6.

Road traffic accident forecasting results show in Table 7 based on multi-level recursive forecasting method including auto regression item only. Table 8 shows the forecasting results based on multi-level recursive forecasting method including auto regression item and environmental factors.

Table 4: 1998-2009 per capita GDP

Year	1998	1999	2000	2001	2002	2003
GDP per-capita (ten thousand yuan)	0.8128	0.8673	0.9555	1.0465	1.1645	1.3661
Year	2004	2005	2006	2007	2008	2009
GDP per-capita (ten thousand yuan)	1.6874	2.0096	2.3794	2.7807	3.3083	3.5894

Table 5: 1998-2009 amount of motor vehicle

Year	1998	1999	2000	2001	2002	2003
Amount of motor vehicle (ten thousand vehicles)	572.17	688.16	784.29	822.28	916.53	1105.17
Amount of automobile(ten thousand vehicles)	90.04	98.14	112.30	133.50	150.569	175.74
Amount of automobile per capita(vehicles)	0.0102	0.0011	0.0125	0.0148	0.0166	0.0193
Year	2004	2005	2006	2007	2008	2009
Amount of motor vehicle(ten thousand vehicles)	1154.35	1331.15	1498.68	1527.45	1578.01	1899.76
Amount of automobile(ten thousand vehicles)	344.06	420.73	515.82	540.28	597.26	709.70
Amount of automobile per capita(vehicles)	0.0375	0.0455	0.0554	0.0577	0.0634	0.0754

Table 6: 1998-2009 highway passenger transport and highway freight volume

Year	Highway passenger transport (billion peoples)	Highway freight volume (billion tons)
1998	4.65	6.47
1999	5.48	6.77
2000	6.15	7.68
2001	6.58	8.16
2002	6.99	8.97
2003	7.11	9.59
2004	8.43	10.69
2005	9.32	12.05
2006	10.33	13.68
2007	11.73	16.40
2008	20.59	20.66
2009	22.62	25.17

Table 7: Road traffic accident forecasting result and error (autoregression)

Year	Real deaths (ten thousand men)	Forecasting result (ten thousand men)	Relative error (%)
2008	0.503	0.539	7.16
2009	0.452	0.485	7.30
Average relati ve error (%)	7.23		

Table 8: Road traffic accident forecasting result and error (environmental factors)

Year	Real deaths(ten thousand men)	Forecasting result (ten thousand men)	Relative error (%)
2008	0.503	0.473	-6.03
2009	0.452	0.417	-7.79
Average relative error (%)	6.91%		

Table 9: 2008 road traffic accident deaths monthly

Month	1	2	3	4	5	6
Accident death toll (thousand men)	0.392	0.381	0.358	0.389	0.367	0.341
Month	7	8	9	10	11	12
Accident death toll (thousand men)	0.314	0.374	0.391	0.403	0.598	0.718

Table 10: 2009 road traffic accident deaths monthly

Month	1	2	3	4	5	6
Accident death toll (thousand men)	0.288	0.310	0.316	0.324	0.308	0.311
Month	7	8	9	10	11	12
Accident death toll (thousand men)	0.343	0.391	0.371	0.425	0.520	0.549
Accident death toll (thousand men)	0.343	0.391	0.371	0.425	0.520	0.549

Table 11: 2008 highway passenger transport and highway freight volume monthly

Month	1	2	3	4	5	6
Highway passenger transport (billion peoples)	1.49	1.49	1.40	1.49	1.77	1.58
Highway freight volume(billion tons)	1.44	1.44	1.61	1.52	1.52	1.69
Month	7	8	9	10	11	12
Highway passenger transport (billion peoples)	1.68	1.68	1.86	1.96	1.77	2.42
Highway freight volume(billion tons)	1.52	1.86	1.78	2.03	1.78	2.47

Table 12: 2009 highway passenger transport and highway freight volume monthly

Month	1	2	3	4	5	6
Highway passenger transport (billion peoples)	1.87	1.87	1.87	1.87	1.68	1.78
Highway freight volume(billion tons)	1.88	1.88	1.97	2.06	2.06	1.97
Month	7	8	9	10	11	12
Highway passenger transport (billion peoples)	1.87	1.87	1.96	2.06	1.96	1.96
Highway freight volume(billion tons)	2.15	2.33	2.24	2.33	2.06	2.24

Table 13: Road traffic accident forecasting result and error (autoregression)

Month(2009)	Real death (thousand men)	Forecasting result (thousand men)	Relative error (%)
10	0.425	0.404	-4.94
11	0.520	0.493	-5.19
12	0.549	0.524	-4.55
Average relative error(%)		4.89	

Table 14: Road traffic accident forecasting result and error (environmental factors)

Month (2009)	Real death (thousand men)	Forecasting result (thousand men)	Relative error (%)
10	0.425	0.400	-5.88
11	0.520	0.488	-6.15
12	0.549	0.519	-5.46
Average relative error(%)		5.83	

Short period accident forecasting: The road traffic accident multi-level recursive forecasting model is established based on 12 months in 2008 and initial 9 months in 2009 accident statistical data in M province in china. Other 3 months in 2009 data is used to test the validity of model. Data shows as Table 9 and 10.

Many factors impact traffic accident, but determining their correlativity is difficult. At the same time, the change of related factors monthly is less than yearly, so we select highway passenger transport and highway freight volume as environmental factors, such as Table 11 and 12. Forecasting results is showed in Table 13 and 14.

CONCLUSION

Because traffic forecasting is complex and difficult, it is important to use suitable forecasting method. It is necessary not only to analyze and know the characteristic of road traffic accident but also to analyze and study forecasting methods.

Beginning from the external features of traffic system, this study look road traffic accident as a time series to establish input-output model based on the characteristic of multi-level recursive forecasting method. By changing the forecasting period, the forecasting results in years and months are acquired and analyzed. By comparing forecasting results of long period with short period in Table 15 and 16, we conclude:

- Whether auto regression multi-level recursive forecasting model or including multi-level recursive forecasting model environmental factors, the road traffic accident forecasting accuracy in short period is higher than in long period.
- From Table 15 and 16, the conclusion is obtained that in short period road traffic accident forecasting, forecasting accuracy on the auto regression multi-level recursive forecasting model is more high than on forecasting model including environmental factors, but in long period road traffic accident forecasting, forecasting accuracy on the multi-level recursive forecasting model including environmental factors is more high than on the auto regression multi-level recursive forecasting model. This indicates is must be analized and researched whether multi-level recursive forecasting model including environmental factors is established or not in road traffic accident forecasting.
- In road traffic accident forecasting that this study carried, the adaptability of multi-level recursive forecasting model in short period is stronger than in long period.

Table 15: Road traffic accident forecasting result comparison first

		Multi-level recursive (environmental factors)		Multi-level recursive (autoregression)	
Year	Real death (thousand men)	Forecasting result(thousand men)	Relative error (%)	Forecasting result (thousand men)	Relative error (%)
2008	0.503	0.473	-6.03	0.539	7.16
2009	0.452	0.417	-7.79	0.48	7.30
Average relative error (%)	6.91		7.23		

Table 16: Road traffic accident forecasting result comparison second

		Multi-level recursive (autoregression)		Multi-level recursive (environmental factors)	
Month	Real death (thousand men)	Forecasting result(thousand men)	Relative error (%)	Forecasting result(thousand men)	Relative error (%)
10	0.425	0.404	-4.94	0.400	-5.88
11	0.520	0.493	-5.19	0.488	-6.15
12	0.549	0.524	-4.55	0.519	-5.46
Average relative error (%)	4.89	5.83			

- Forecasting accuracy on the multi-level recursive forecasting method is related to many factors such as model orders, initial value, environmental factors, characteristic of basic data used, etc.

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