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Research on Market Share Prediction of Highway Passenger Transport Based on Exponential Smoothing Method

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Abstract: Highway transportation is an important part of our country traffic transportation system, taking on most of the capacity demand in passenger transport markets. But with the rapid development of domestic rail transportation technology, people's travel mode has gradually changed from highway transportation to rail transportation. This makes the highway passenger transport management department must consider the impact of the change of people's travel mode on the highway passenger transport market demand when making production plans. The market share of highway passenger transport is an important index to measure the development level of highway passenger transport, which can directly reflect the supply-demand relationship between highway passenger transport and passenger transport market. Therefore, this paper selects the market share of highway passenger transport as the prediction evaluation index, and predicts and analyzes the market share data of highway passenger transport in Henan Province from 2010 to 2021 based on the exponential smoothing method. It mainly calculates the single exponential smoothing results under several different smoothing coefficients by using the smoothing analysis tool in EXCEL, and determines the optimal smoothing coefficient by taking the minimum root mean square error (RMSE) as the criterion. Then, it solves the lag defect of the single exponential smoothing prediction results by using the quadratic exponential smoothing. Finally, the trend prediction model of highway passenger transport market share in Henan Province is obtained. The prediction results of this model can guide the rational allocation of highway transportation resources and the formulation of passenger transport production plan in Henan Province.

Keywords: Highway Passenger Transport, Market Share, Exponential Smoothing Method, Forecast

1. Introduction

Highway transportation plays an important role in national economic and social development, and occupies most market shares in domestic passenger traffic market. However, with the rapid development of our country's rail transportation technology and the policy adjustment of transportation structure, people's travel mode has gradually changed from highway travel to railway travel. This makes it necessary for highway passenger transport management department to focus on the impact of the change in travel mode of travelers on the market demand for highway passenger transport when formulating production plans, so as to reasonably allocate highway transport resources and avoid economic losses caused by redundant transport capacity [1]. Therefore, it is of great practical value to predict and master the development and change law of highway passenger transport market scientifically and accurately for the allocation of highway transport resources and the formulation of passenger transport production plan.

At present, related scholars have done a lot of research on highway passenger volume forecast. Tongsong Pei proposed a highway passenger volume prediction model based on the BP neural network modified by Markov [2]. Qiuming Gan proposed a highway passenger volume prediction model based on genetic optimization support vector machine [3]. Yugang Liu proposed a highway passenger volume forecasting method based on grey relational elasticity model [4]. Yizhi Wang proposed a highway passenger volume forecasting method based on grey Markov model [5]. Litao

Tang proposed a highway passenger volume forecasting method based on BP neural network and multiple regression [6]. Sen Xu proposed a highway passenger volume prediction model based on Softplus function with dual-hidden layer BP neural network [7]. Ya Lu proposed a highway passenger volume forecasting method based on multiple regression model [8]. Dong Wang proposed a highway passenger volume prediction method based on grey correlation analysis and BP neural network [9]. Lijuan Cheng proposed a highway passenger volume forecasting method based on LSSVM and Markov chain model [10]. Xincang Cai proposed a highway passenger volume prediction method based on principal component analysis and particle swarm optimization support vector machine [11]. Yiping Tan proposed a highway passenger volume forecasting method based on the basic theory and model of principal component analysis [12].

It can be seen that at present, researchers mainly choose highway passenger volume as the prediction and evaluation index, and have done a lot of prediction research based on various prediction models and methods. However, the evaluation index of highway passenger volume forecast for the market demand of highway passenger transport is relatively single, and cannot fully reflect the supply and demand relationship between highway passenger transport and passenger transport market, and most of the forecasting models and methods are more complex, with a large amount of calculation. As an important index to measure the development level of highway passenger transport, the market share of highway passenger transport can directly reflect the supply-demand relationship between highway passenger transport and passenger transport market. The exponential smoothing method has the advantages of easy to use and simple operation, and can better show the change trend of time series data. Therefore, this paper selects the market share of highway passenger transport as the prediction evaluation index, and uses the exponential smoothing method to forecast the market share data of highway passenger transport in Henan Province from 2010 to 2021.

2. Exponential Smoothing Method

Exponential smoothing method eliminates the influence of random factors by smoothing the historical time series layer by layer, identifies the basic change trend of phenomena, and predicts the future value based on it [13]. The exponential smoothing method does not discard the past observation values, but gives a gradually weakening influence degree, that is, the farther the distance from the observation period, gives a weight that gradually converges to zero and shows an exponential decline. Exponential smoothing method is a special form of weighted average, and its basic formula is as follows:

$$S_t = aY_t + (1-a)S_{t-1} \qquad (1)$$

In the above formula, S_t is the smoothness value of the t period, Y_t is the actual observed value of the t period, S_{t-1}

is the smoothness value of the $t-1$ period, a is the smoothness coefficient, and $a \in (0,1)$, where the smoothness value of the $t-1$ period is the predicted value of the t period. S_t is the weighted average of Y_t and S_{t-1}. The value of a determines the degree of correction of previous prediction errors, that is, determines the degree of influence of Y_t and S_{t-1} on S_t. The predicted value S_t can be traced back to S_1, including all the previous observed values.

The smoothness coefficient a determines the level of smoothness and the speed of response to the difference between the predicted and actual values. Generally speaking, when the time series is relatively stable, small a can be selected. When the time series fluctuates greatly, larger a should be selected to avoid ignoring the influence of the long term. In fact, the prediction results of multiple smoothing coefficient a values can be compared by trial calculation, and then the a value with the smallest root mean square error (RMSE) can be found for prediction, so as to improve the prediction accuracy [14].

3. Highway Passenger Transport Market Share Forecast

By referring to the 2022 statistical yearbook of Henan Provincial bureau of statistics [15], the market share data of highway passenger transport in Henan Province from 2010 to 2021 are obtained, as shown in Table 1. Through statistical analysis of the sample data and observation of the overall distribution characteristics of the data, it can be seen that the highway passenger transport market share of Henan Province from 2010 to 2021 shows a linear decline trend. Therefore, the quadratic exponential smoothing prediction model is chosen as the research method, as shown in Figure 1.

Table 1. *Market share of highway passenger transport in Henan Province over the years.*

Years	2010	2011	2012	2013	2014	2015
Highway passenger transport share (%)	94.53	95.01	95.05	91.19	90.48	88.74
Years	2016	2017	2018	2019	2020	2021
Highway passenger transport share (%)	86.98	84.71	83.21	81.90	78.68	72.92
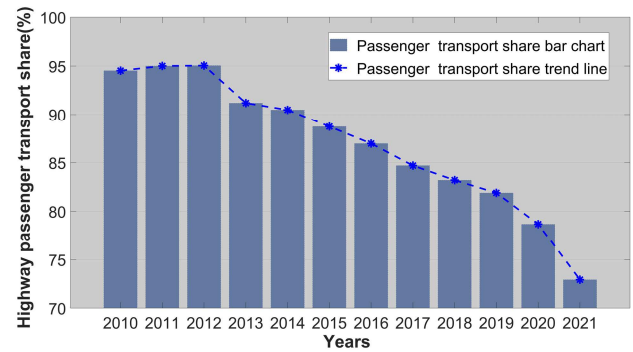
Figure 1. *Statistical chart of highway passenger transport market share in Henan Province over the years.*

3.1. Single Exponential Smoothing Prediction Model

$$S_t = aY_t + (1-a)S_{t-1} \qquad (2)$$

In the above formula, S_t is the exponential smoothing value of the t period, S_{t-1} is the exponential smoothing value of the $t-1$ phase, Y_t is the actual observed value of the t period, a is the smoothing coefficient, and $a \in (0,1)$.

3.2. Quadratic Exponential Smoothing Prediction Model

Because the single exponential smoothing method only considers the weighted average of historical data and does not consider the change trend of historical data, when the change of time series shows a linear trend, the single exponential smoothing method will have obvious lag deviation, and the degree of deviation decreases with the increase of smoothing coefficient a. So we set up a quadratic exponential smoothing model based on the single exponential smoothing.

Set $S_t^{(1)}$ is the single exponential smoothing value, $S_t^{(2)}$ is the quadratic exponential smoothing value, the quadratic exponential smoothing calculation formula is:

$$S_t^{(2)} = aS_t^{(1)} + (1-a)S_{t-1}^{(2)} \qquad (3)$$

The established prediction mathematical model is as follows:

$$\acute{y}_{t+T} = a_t + b_t T \ (T=1,\ 2,\ 3\dots) \qquad (4)$$

In the above formula, t is the current period number, T is the number of periods from the current period t to the forecast period $t+T$, $\acute{y}_{t+T}$ is the predicted value of $t+T$ period. a_t is the intercept, b_t is the slope, and its formula is:

$$a_t = 2S_t^{(1)} - S_t^{(2)} \qquad (5)$$

$$b_t = (\frac{a}{1-a})(S_t^{(1)} - S_t^{(2)})) \qquad (6)$$

3.3. Exponential Smoothing Prediction

The prediction is made using the exponential smoothing analysis tool provided in the EXCEL tool kit. Due to the small sample size of the original data, the average value of the previous three periods was selected as the smoothing initial value S_1, that is, $S_1 = \frac{Y_1 + Y_2 + Y_3}{3}$. Since sequence data has an obvious linear decline trend, smoothness coefficient $a \in [0.6, 0.9]$ is selected based on experience. The trial algorithm was adopted, and different smoothing coefficients a were selected for trial calculation, and the trial calculation results were shown in Tables 2-5 and Figures 2-5.

Table 2. *The single exponential smoothing of forecast data table when $a=0.6$.*

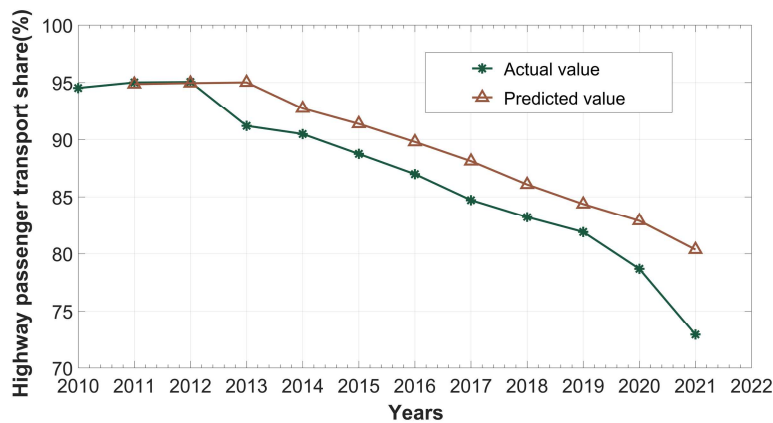| Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Highway passenger transport share (%)	94.53	95.01	95.05	91.19	90.48	88.74	86.98	84.71	83.21	81.90	78.68	72.92
Predicted value (%)	—	94.86	94.95	95.01	92.72	91.37	89.79	88.11	86.07	84.36	82.88	80.36
Relative error	—	0.16%	0.10%	4.19%	2.48%	2.97%	3.23%	4.01%	3.43%	3.00%	5.34%	10.21%

Figure 2. *The single exponential smoothing forecast result graph when $a=0.6$.*

Table 3. *The single exponential smoothing of forecast data table when $a=0.7$.*

Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Highway passenger transport share (%)	94.53	95.01	95.05	91.19	90.48	88.74	86.98	84.71	83.21	81.90	78.68	72.92
Predicted value (%)	—	94.86	94.97	95.02	92.34	91.04	89.43	87.72	85.61	83.93	82.51	79.83
Relative error	—	0.16%	0.08%	4.20%	2.06%	2.59%	2.81%	3.55%	2.89%	2.49%	4.86%	9.48%

Table 4. *The single exponential smoothing of forecast data table when $a=0.8$.*

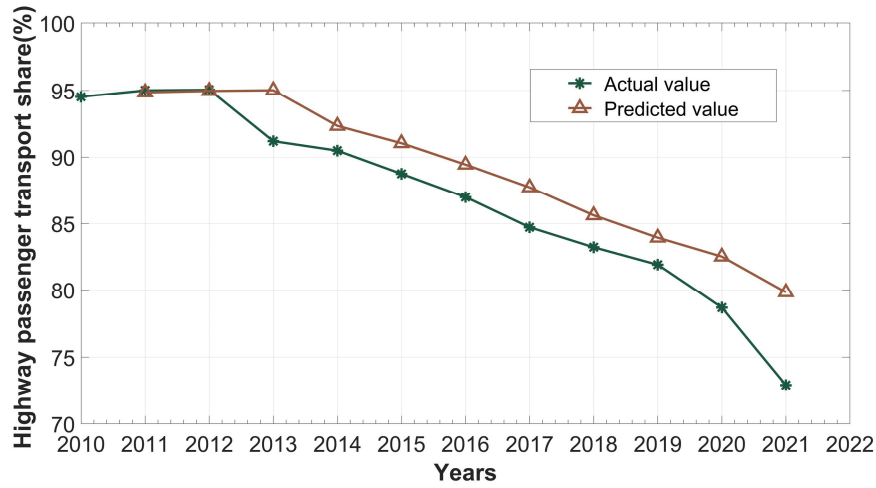| Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Highway passenger transport share (%)	94.53	95.01	95.05	91.19	90.48	88.74	86.98	84.71	83.21	81.90	78.68	72.92
Predicted value (%)	—	94.86	94.98	95.03	91.96	90.77	89.15	87.41	85.25	83.62	82.24	79.39
Relative error	—	0.16%	0.07%	4.22%	1.64%	2.29%	2.49%	3.19%	2.45%	2.10%	4.53%	8.88%

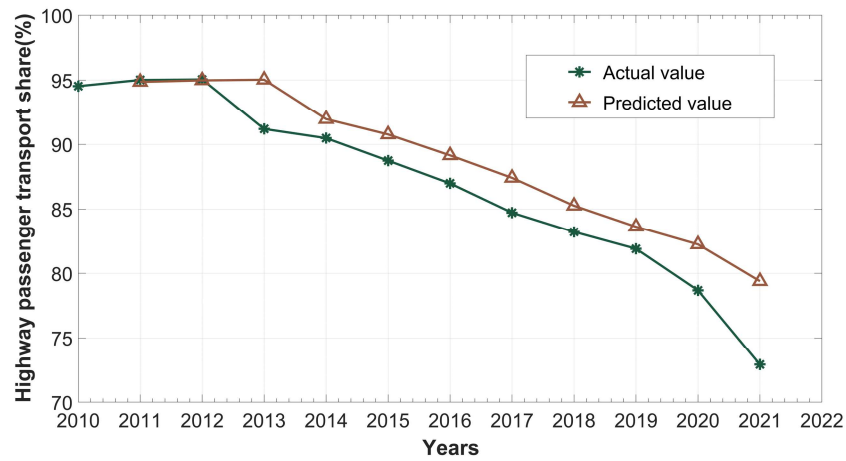*Figure 3. The single exponential smoothing forecast result graph when a=0.7.*

Figure 4. The single exponential smoothing forecast result graph when a=0.8.

Table 5. The single exponential smoothing of forecast data table when a=0.9.

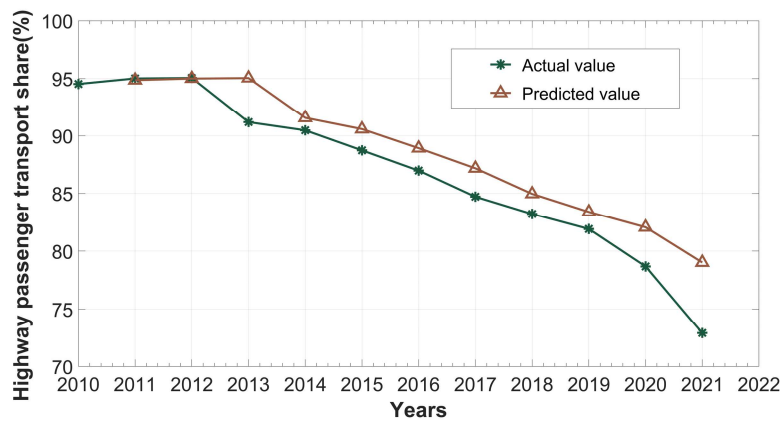| Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Highway passenger transport share (%)	94.53	95.01	95.05	91.19	90.48	88.74	86.98	84.71	83.21	81.90	78.68	72.92
Predicted value (%)	—	94.86	95.00	95.04	91.57	90.59	88.93	87.18	84.96	83.39	82.05	79.02
Relative error	—	0.16%	0.05%	4.22%	1.21%	2.08%	2.24%	2.91%	2.10%	1.82%	4.28%	8.36%

Figure 5. The single exponential smoothing forecast result graph when a=0.9.

It can be seen from the smoothing curves under different smoothing coefficients a that there is a certain lag deviation in the predicted data. Taking the minimum root mean square error (RMSE) as the criterion, the optimal value of smoothing

coefficient a was determined by comparing the root mean square error (RMSE) values under different smoothing coefficients a. The calculation formula of root mean square error (RMSE) is:

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(S_t - Y_t)^2}{n}} \qquad (7)$$

In the above formula, S_t is the predicted value of period t, Y_t is the actual observed value of period t, and n is the predicted total number of periods. After calculation, the root mean square error (RMSE) under different smoothing coefficients a is shown in Table 6.

Table 6. *RMSE under different smoothing coefficients a.*

Smoothing coefficient a	a=0.6	a=0.7	a=0.8	a=0.9
RMSE	3.48	3.17	2.94	2.75

As can be seen from Table 6, when a=0.9, the root mean square error (RMSE) is the smallest, so a=0.9 is selected for quadratic exponential smoothing, and its prediction results are shown in Table 7 and Figure 6. It can be found that the predicted value of quadratic exponential smoothing is closer to the actual value, and the root mean square error (RMSE) is 1.76 after calculation, which further improves the prediction accuracy of the model.

Table 7. *The quadratic exponential smoothing of forecast data table when a=0.9.*

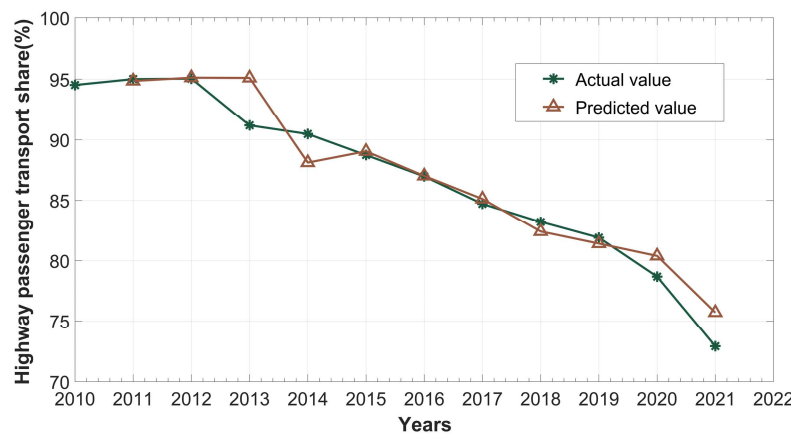| Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Highway passenger transport share (%)	94.53	95.01	95.05	91.19	90.48	88.74	86.98	84.71	83.21	81.90	78.68	72.92
Predicted value (%)	—	94.86	95.13	95.10	88.11	89.25	87.13	85.25	82.55	81.58	80.52	75.84
Relative error	—	0.16%	0.09%	4.29%	2.61%	0.58%	0.17%	0.63%	0.80%	0.39%	2.34%	4.00%

Figure 6. *The quadratic exponential smoothing forecast result graph when a=0.9.*

Using the intercept and slope calculation formulas introduced above, we can obtain:

$$a_t = 2S_t^{(1)} - S_t^{(2)} = 72.95$$

$$b_t = (\frac{a}{1-a})(S_t^{(1)} - S_t^{(2)}) = -5.23$$

Therefore, the prediction model of highway passenger transport market share in Henan Province is as follows:

$$\acute{y}_{t+T} = a_t + b_t T = 72.95 - 5.23T$$

For example, the market share of highway passenger transport in Henan Province in 2022 is:

$$\acute{y}_{2022} = 72.95 - 5.23 \times 1 = 67.72 \ (\%)$$

The market share of highway passenger transport in Henan Province in 2023 is as follows:

$$\acute{y}_{2023} = 72.95 - 5.23 \times 2 = 62.49 \ (\%)$$

4. Conclusion

Based on the analysis of highway passenger volume data in Henan Province, this paper obtains the market share data of highway passenger transport in Henan Province from 2010 to 2021. The exponential smoothing analysis tool in EXCEL tool kit was used, and the trial algorithm was adopted to conduct the predictive calculation of exponential smoothing under the conditions of smoothing coefficient a=0.6, 0.7, 0.8 and 0.9, and the root mean square error (RMSE) under different smoothing coefficients a was calculated. The minimum root mean square error (RMSE) was taken as the criterion for discrimination. The optimal smoothing coefficient a is determined to be 0.9, and then through quadratic exponential smoothing, the prediction mathematical model of highway passenger transport market share in Henan Province is obtained. Through this model, we can know the forecast trend data of highway passenger transport market share in Henan Province in the future period, and the forecast data has certain reference value for the formulation of highway passenger transport production plan in Henan Province.

Acknowledgements

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