

Study on Forecast of Passenger Flow Density of the Jiao-Ji Railway Passage Based on Multi-method Integration

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Abstract: Passenger flow forecasting is an important part of railway project planning and design, and is the main basis of train operation plan compilation and line economic benefit calculation. This paper takes the relationship between railway passenger transport and economic and social development as the breakthrough point, adopts the method of combining qualitative analysis with quantitative calculation, and applies data mining technology to analyze the evolution mechanism of passenger transport demand, the main influencing factors and the future development trend of passenger transport demand in the Jiao-Ji railway passage. Taking "feature analysis, mechanism research and trend judgment" as the core, a prediction model based on multi-method integration is established to predict passenger density of the Jiao-Ji railway passage. Finally, some suggestions are put forward for the train operation plan, so as to optimize the transportation capacity of the Jiao-Ji railway passage.

1. Introduction

The Jiao-Ji railway passage is composed of Jiaoji railway and Jiaoji passenger dedicated railway. After the completion of Jinan-Qingdao high-speed railway in 2019, there will be a "six-line Passenger-Freight separation" pattern in which Jiaoji line, Jiaoji passenger dedicated railway and Jinan-Qinghai high-speed railway coexist. At present, on the basis of mainly completing the freight transport function, Jiaoji Railway also operates a small number of ordinary speed passenger trains. In separate restricted sections, the passing capacity is tense and the transportation pressure is high. At present, Jiaoji passenger dedicated railway adopts the mixed running mode of EMU train and general speed train. It mainly undertakes the passenger exchange and transportation task between Jiaodong Peninsula and other areas of the country and Shandong Province. However, due to the development of social economy and the adjustment of industrial structure in Shandong Province, the Jiao-Ji railway passage still can not meet the increasing demand of passenger flow. In order to adapt to the changes of market demand and transport network structure, it is urgent to fully tap the passenger transport capacity of the Jiao-Ji railway passage [1].

2. Analysis and Screening of Impact Indicators of Passenger Transport Demand

2.1 Analysis on Influencing Factors of Passenger Transport Demand.

From the point of view of comprehensive transportation, when analyzing the influencing factors of passenger transport demand in the Jiao-Ji railway passage, it mainly carries out from the external and internal aspects.

(1) External influencing factors: level of economic development and mode of development; industrial structure; income level of residents; population and urbanization.

(2) Internal influencing factors: scale of transportation infrastructure; level of passenger transport service.

2.2 Setting and Screening of Impact Indicators.

In this paper, the grey relational analysis method is used to screen the development indicators of Shandong Province from the external and internal factors, so as to set up evaluation indicators.

(1) Grey relational analysis

Grey relational analysis means that in a system, if the two factors change in the same situation, that is, the degree of synchronous change is higher, the two factors can be considered to have a greater correlation; on the contrary, the degree of correlation between the two factors is smaller. The methods are as follows:

1) Determine the comparative sequence;

2) dimensionless treatment;

3) Finding the Grey Relevance Coefficient of Reference Sequence and Comparison Sequence

$\xi_i(k)$

$$\xi_i(k) = \frac{\min_i |x'_0(k) - x'_i(k)| + \rho \cdot \max_i |x'_0(k) - x'_i(k)|}{|x'_0(k) - x'_i(k)| + \rho \cdot \max_i |x'_0(k) - x'_i(k)|}$$

k=1, ...,m (1)

4) Seeking the Relevance Degree r_i

$$r_i = \frac{1}{m} \sum_{k=1}^m \xi_i(k) \quad (2)$$

The grey correlation analysis method is used to calculate the correlation between the passenger flow density from Jinan to Zibo and the influencing factors in Shandong Province. From the results, 10 indicators with comprehensive correlation degree greater than 0.9 were selected. Considering the collinearity between economic indicators, the same classified indicators were screened. In conclusion, the per capita GDP, tertiary industry output value and household consumption level can reflect passenger transport demand more comprehensively. In order to ensure the accuracy of model fitting and parameter estimation, it is necessary to introduce endogenous variables. Because of the low grey relational degree of endogenous variables, the Person coefficients of related indexes are calculated by regression analysis [2].

Table 1 Person coefficient calculation results

index	Person coefficient
Railway mileage	0.973
Mileage of High Speed Railway	0.986

According to the analysis results, the endogenous variables have a linear relationship with passenger transport density. Therefore, this paper chooses four indicators: per capita GDP (x_1), tertiary industry output value (x_2), resident consumption level (x_3), railway operating mileage (x_4), which can more comprehensively reflect the characteristic indicators of demand generation and then model passenger transport demand generation.

3. Forecast of Passenger Flow Density Demand

3.1 Construction of Demand Forecasting Model

From the perspective of macroeconomic development and social progress, based on the stage characteristics and evolution mechanism of the relationship between transportation and economy, this paper constructs a multi-regression prediction model to forecast the demand of passenger transport, in which the time series method is used to quantitatively predict the control variables.

3.2 Control variable prediction

In this paper, grey forecasting method is used to forecast per capita GDP and tertiary industry output value, and quadratic exponential smoothing method is used to forecast residents' consumption level.

(1) Grey prediction model

At present, the most common system model of grey prediction method is GM (1,1), which is a special expression of GM (1, N) N = 1.

$$X = (X^{(0)}(1), X^{(0)}(2), \dots, X^{(0)}(m)) \quad (3)$$

$$X^{(1)}(t) = \sum_{i=1}^m X^{(0)}(t) \quad (4)$$

$X^{(1)}(t)$ is a cumulative generation, marked as 1-AGO; n times cumulative generation $X^{(n)}(t)$, marked as n-AGO. The cumulative generation has the following relations.

$$X^{(n)}(t) = X^{(n)}(t-1) + X^{(n-1)}(t) \quad (5)$$

So $X^{(1)}$ can establish the following first order differential equation.

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = b \quad (6)$$

$X^{(1)}$ is the background value of demand forecasting; A and B are the parameters of differential equation. This differential equation can be calculated by the least square method, and finally the solution of the first order differential equation, the prediction result, can be obtained [3].

(2) Quadratic exponential smoothing method

Let the time series be X_1, X_2, \dots, X_i ; The exponential smoothing value is denoted by the letter S, that is, the exponential smoothing value in the t and i periods is denoted by $S_t^{(i)}$. Then the formula for calculating the exponential smoothing value is as follows (a is the smoothing coefficient):

$$S_t^{(2)} = aS_t^{(1)} + (1-a)S_{t-1}^{(2)} \quad (7)$$

The mathematical model of the second exponential smoothing method for the index predicted value y_{t+T} whose prediction period is T year and the base year is t year is as follows:

$$y_{t+T} = a_t + b_t T \quad (8)$$

In the formula, a_t and b_t are smoothing coefficients. The calculation formulas are as follows:

$$a_t = 2S_t^{(1)} - S_t^{(2)} \quad (9)$$

$$b_t = \frac{a}{1-a} (S_t^{(1)} - S_t^{(2)}) \quad (10)$$

According to the data of 2012-2016, the original data sequence is formed, and the residual test and precision test of the model are carried out. The prediction results are as follows [4]:

Table 2 Person coefficient calculation results

index	2018	2019	2020	2021	2022
Per capita GDP(yuan)	75154	79062	83173	87498	92048
Tertiary industry output value(billion yuan)	3865	4252	4677	5145	5660
Household consumption level (yuan)	32801	36738	41146	46084	51614

Finally, according to the 13th Five-Year Plan of Jinan Railway Administration, the railway mileage of the year can be predicted, thus realizing the prediction of four control variables.

3.3 Section Density Demand Forecasting Model

According to the results of screening and analysis of the influencing factors, the idea of

multi-factor combination forecasting was adopted to carry out a variety of combinatorial experiments on the indicators, and a multiple linear regression model was constructed. The model is as follows:

$$y = a_0 + a_1x_1 + a_2x_2 + \cdots + a_nx_n + \varepsilon \quad (12)$$

The dependent variable y of the model is the object of prediction; the effect of the influencing factors is reflected in the control variable x_i ; a_i is the regression coefficient; and ε is the random error term.

By using SPSS software, the passenger flow density of each section is analyzed, and the prediction results of each section are as follows:

Table 3 Prediction of Upper Passenger Transport Density (thousand people)

section	2018	2019	2020	2021	2022
Jinan-Zibo	31180	34300	37730	41510	45660
Zibo-Weifang	28370	31210	34330	37760	41540
Weifang-Lancun	24310	26740	29410	32350	35590
Lancun-Qingdao	14760	16240	17860	19650	21620

Table 4 Forecast of Passenger Transport Density (thousand people)

section	2018	2019	2020	2021	2022
Jinan-Zibo	30770	33850	37230	40950	45050
Zibo-Weifang	27680	30440	33490	36840	40520
Weifang-Lancun	23610	25970	28570	31420	34570
Lancun-Qingdao	14580	16040	17640	19410	21350

3.4 Optimizing Train Operation Schemes

According to the prediction results of passenger flow density in each section of the Jiao-Ji railway passage, the operation scheme of the Jiao-Ji railway passage is adjusted. The adjustment results are as follows [5].

Table 5 Adjustment Result of the Jiao-Ji railway passage Operation Plan

Line separation	section	2018		2019		2020		2021		2022	
Jiaoji railway	Jinan-Zibo	11		11		11		11		11	
	Zibo-Weifang	11		11		11		11		11	
	Weifang-Lancun	31		31		31		31		31	
	Lancun-Qingdao	16		16		16		16		16	
Jiaoji passenger dedicated railway (High Speed / General Speed)	Jinan-Zibo	84	20	79	17	83	17	86	17	90	17
	Zibo-Weifang	84	19	75	16	81	16	84	16	88	16
	Weifang-Lancun	82	11	72	8	79	8	83	8	89	8
	Lancun-Qingdao	52	15	47	12	49	12	55	12	59	12

4. Summary

From the point of view of passenger demand forecasting, this paper analyses the important factors affecting passenger traffic volume, and screens the influencing indicators, and obtains the control variables to construct the multiple linear regression model, so as to realize the prediction of the control variables and the passenger flow density of each section based on historical data. The train operation plan of the Jiao-Ji railway passage is worked out by combining theoretical algorithm with practice. When compiling the train operation plan of the Jiaoji Passage, the scientific calculation method and the existing train operation plan of the Jiaoji Passage were adopted. Considering the impact of Jinan-Qingdao high-speed railway opening on passenger flow at the end of 2019, the operation plan of the Jiaoji Passage is adjusted. According to the passenger flow situation in different periods and the adjustment plan of the operation plan, the adjustment plan of the operation plan in different periods is obtained. The final adjustment plan is to increase the running logarithm of

Jinan-Qingdao inter-city trains, reduce the running logarithm of some through trains and transfer some trains with slower running speed from Jiaoji passenger special line to Jiaoji passenger special line, so as to improve the passing capacity of Jiaoji passenger special train.

References

- [1] Ziwen Lu, Junwei Zeng, Yongsheng Qian. Comprehensive Transportation Development Evaluation Based on Entropy Value Method and Grey Relation [J]. Highway Engineering. Vol. 43 (2018) No. 06, p. 73-77.
- [2] Youan Wang, Xumei Chen, Yanhui Han, et al. Forecast of Passenger and Freight Traffic Volume based on Elasticity Coefficient Method and Grey Model[J]. Procedia - Social and Behavioral Sciences. Vol. 96 (2013), p. 136-147.
- [3] Zhicheng Cao, Yisheng Liu, Jiwei Dong. Prediction of Railway Passenger Delivery Volume Based on Triple Exponential Smoothing Method [J]. Railway Transportation and Economy. Vol. 40 (2018) No. 11, p. 49-53.
- [4] Yanping Cui, Xiao Yu. Research on annual passenger volume prediction of Jiaoji passenger dedicated line [J]. Railway transportation and economy. Vol. 36 (2014) No. 05, p. 44-48.
- [5] Luoman Liu. The application of exponential smoothing in time series analysis [J]. Journal of Shenyang Normal University (Natural Science Edition). Vol. 27 (2009) No. 04, p. 416-418.