Study on the Impact of High Speed Rail Construction on Expressways Based on AHP, Logit and Multivariate Statistical Regression Method

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Abstract: In view of whether or not the vehicle traffic pressure has been slowed down after the completion of the high-speed railway, a complete modeling work is carried out based on the theory of AHP analytic hierarchy process and Logit model. First, on the basis of consulting a lot of actual data and data, and considering various factors, we consider the alleviation of the high speed rail's pressure on expressway traffic. On the basis of this, combined with the factors that affect the location and quantity of high-speed railway stations, we use the Logit model to analyze and explain the difference of the impact of the high speed rail on the highway traffic pressure. Combined with the results obtained from the Logit model, taking into account the characteristics of the high speed rail, such as the number of people traveling, the comfort and the speediness, and the traffic congestion determination model of the city, we can find out whether the high speed rail has a slow solution to the traffic pressure of the expressway. By collecting and analyzing the data, we get the factors that influence people's choice of travel mode. Every year, the number of trips used by various means of transportation, combined with the main factors, alleviate the pressure of high-speed rail to the traffic pressure of Expressway vehicles.

1. Restatement of the Problem

1.1. Introduction

With the continuous improvement of people's quality of life, almost every family owns private cars, which is one of the reasons for the congestion of expressways whenever holidays come. However, with the rapid development of high-speed rail in China's modern "four great inventions", it has brought great convenience to people's travel. Therefore, people on the long journey have gradually made high-speed rail the first choice for their own travel. On the one hand, the construction of high-speed rail can relieve the running pressure of ordinary trains, and on the other hand, it also plays a role of decompression for the operation of expressways.

Because the urban road has the characteristics of high density and continuity of traffic flow, driveways occupied and so on. It may also reduce the capacity of all lanes. Even if the time is short, it may cause traffic queues and traffic jams. If not handled properly, there may even be regional congestion.

In 2018, the number of motor vehicles in China reached 325 million. With the sustained and rapid development of China's economy and society, motor vehicle ownership continues to maintain a rapid growth trend. According to statistics from the Ministry of Public Security, up to Traffic Safety Day, the number of motor vehicles in China had reached 325 million, an increase of 15.56 million compared with the end of 2017; the number of motor vehicle drivers reached 407 million, an increase of 22.36 million compared with the end of 2017.At the same time, private cars are growing faster. The number of small and micro passenger cars registered in the name of individuals reached 187 million, and the number of private cars owned by every 100 households had exceeded 40. From the perspective of the city, there are 61 cities in the country with more than one million cars, 26 cities over 2 million, and 8 cities over 3 million. Contrary to the rapid increase in vehicle

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ownership, 520 traffic accidents involving more than three deaths have occurred in China since this year, a decrease of 24.2% over the same period last year; 95 traffic accidents involving more than five deaths, a decrease of 13.6% over the same period last year; and five major accidents involving more than 10 deaths, a decrease of 44.4% over the same period last year.

1.2. Question

In order to better judge whether the high speed rail has a mitigate effect on the traffic pressure of highways and the optimal number of high-speed rail allocation in selected cities, the following questions are raised in this paper.

(1) According to the judgment model of urban road traffic congestion, we can determine whether the high speed rail has a mitigate effect on the highway traffic pressure.

(2) According to the conclusion of question 1, combined with the Logit model, the paper analyzes the specific degree of the stress alleviation effect of high speed rail on expressway traffic.

(3) Considering the factors such as the economic, geographical advantages and population density of selected cities, considering the various factors that affect the allocation of high-speed rail, a mathematical model is constructed based on factor analysis and variable dimension reduction.

2. Problem Analysis

2.1. Question One:

The problem requires to determine whether the high speed rail's pressure on the highway's vehicles has a mitigate effect. First of all, we need to make clear the determination of urban traffic congestion. After making clear the concept, we use AHP analytic hierarchy process (AHP) and annual highway vehicle flow, and analyze the factors that affect the highway traffic, and it is concluded that whether the high speed rail has a mitigate effect on the highway traffic pressure.

2.2. Question Two:

Through the analysis in question 1, we can conclude that the high speed rail has a mitigate effect on the highway traffic pressure. Combined with the advantages of high speed rail, better comfort, punctuality rate and better security, and the disadvantages of frequent highway traffic accidents, low safety and environmental pollution, we decided to use the Logit model to carry out the preliminary exploration of problem two. Based on multivariate Logit modeling, combined with the conclusions drawn from the analysis and description of the high speed rail traffic pressure on the highway to alleviate the significant degree.

2.3. Question Three

Question three requires the construction of a mathematical model. According to the conditions of the GDP level, population base and geographical location of different scale cities, and according to the statistics of the number of motor vehicles in various cities according to the statistics of the traffic departments, we also take into account the various factors that affect the location and quantity of the high-speed rail stations. The optimum quantity of iron is achieved.

3. Basic Assumptions

(1) Choose three main indicators: traffic flow speed, saturation (V/C) and traffic density to judge the congestion of expressway;

(2) The psychological factors of traveling in the course of behavior are not considered, that is, the psychological factors of passengers will not affect their physiological endurance.

(3) The traffic mode is related to the estimated parameters of the function.

(4) Travel choice behavior can be expressed as deterministic utility and stochastic utility.

(5) Passengers will choose the maximum utility function

4. Symbolic Description

Table 1. Symbolic Description.

Symbol	explanation	Symbol	explanation
V_{ij}	Utility Measurable Part A Age	NUMBER	Quantity of high speed rail
ε_{ij}	Economics of Error Terms with Unmeasurable Utility	PC	Passenger traffic volume
X_{ij}	Explanatory Variable Vector of Passenger i Selection Scheme j	A	age A1=under 20 years old A2=20~50years old A3=over 50 years old
β_i	Parameter vectors to be estimated		
W	Travel time		
C	Comfort	Y	Does the location have high-speed rail? Y_1=yes,Y_2=no

5. Establishment and Solution of Model

5.1. Does The High Speed Rail Alleviate The Pressure On The Freeway?

5.1.1. The Solution Process of Multivariate Logit Model Theory

The utility U_{ij} obtained by decision maker i choosing scheme j can be expressed as:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{1}$$

In order to simplify the calculation, the effective function is set as a linear function:

$$U_{ij} = \beta_i X_{ij} + \varepsilon_{ij} \tag{2}$$

If the alternatives are independent, the error terms are independent and obey the same Gumbel distribution. Then the probability of decision maker i choosing scheme j P_{ij} is:

$$P_{ij} = \frac{e^{V_{ij}}}{\sum_{j=1}^{J} e^{V_{ij}}} \tag{3}$$

Maximum likelihood method can be used to estimate the unknown parameters of multivariate logit model. The case in which a variable is defined as a decision maker's choice of alternatives

$$f_{ij} = \begin{cases} 1, & \text{decision maker i chooses scheme j} \\ 0, & \text{else} \end{cases} \tag{4}$$

Thus, the likelihood function of multivariate logit model can be obtained

$$L = \prod_{i=1}^{I} \prod_{j=1}^{J} P_{ij} \tag{5}$$

Convert it into logarithmic function form:

$$\ln L = \sum_{i=1}^{I} \sum_{j=1}^{J} f_{ij} \ln P_{ij} \tag{6}$$

The value of the parameter vector can be obtained by maximizing $\ln L$.

5.1.2. Establishment and Analysis of Model

Passengers travel can choose 2 main modes of transport: high speed rail and high speed. P_1 and P_2 are used to express the probability of high speed rail and high speed.

On the basis of high-speed rail, there are a set of effective equations for the two modes of transportation that passengers can choose:

$$\ln\left(\frac{P_2}{P_1}\right) = \beta_0^1 + \beta_1^1 X_1 + \beta_2^1 X_2 + \cdots + \beta_k^1 X_k \tag{7}$$

All variables in Table 1 are included in the model calculation. The model parameters are estimated and tested by SPSS software. The results of model fitting test are shown in Table 2.

Table 2. Model Fitness Check Results

	Fitting standard likelihood of-2ln	Chi-square	likelihood ratio significant level
intercept	394.016	none	none
A	286.430	14.964	0.017
E	298.030	17.013	0.010
C	355.345	12.154	0.008
Y	292.436	21.556	0.000
W	305.461	34.506	0.000
Final value	276.156	134.157	0.000
Likelihood Ratio Index ρ 2		0.305	

From Table 2, it can be seen that the -2ln -likelihood value of -2 decreased from 394.016 to 276.156, and the likelihood ratio was 134.157. The likelihood ratio was higher than that of chi-square test (significant level was 0.000) $P < 0.01$, indicating that the model had a higher fitting degree. The significant level P of variables included in the model are travel time W, location of high speed rail Y and comfort level C is less than 0.01, indicating that these variables are important parameters for model prediction. The other variables are less than 0.05, which shows that other variables have a high correlation with the model. In addition, the likelihood ratio index is 0.305, which shows that the model has a good explanatory effect.

In order to understand the impact of the establishment of high-speed railway on the expressway, the maximum likelihood method is used to estimate the parameters. The results are shown in Table 3.

Table 3. The Degree of Influence on Expressway.

Mode of transportation	variables	Parameter estimation	Standard error	Wald value	Significant value
High-speed rail	intercept				
	Y	-16.551	0.346	90.651	0.000
	E	-0.022	0.010	5.085	0.024
	C	0.180	0.048	10.533	0.002
	W	0.056	0.043	1.567	0.305

As can be seen from Table 3, the estimated values of comfort and travel time are positive, but the values are low, which indicates that these two factors have less impact on expressways. Negative economy indicates that the higher the cost, the more impact it has on the expressway. The location of high-speed rail is extremely important. It can be concluded from the analysis results that there are certain differences in the influence of various factors on the high speed rail to the expressway.

5.1.3. Come to Conclusion

It can be concluded that the opening of the high speed railway has eased the pressure on the expressway traffic, and is extremely obvious.

5.2. How to Establish and Solve the Optimal Allocation of High-Speed Rail in Beijing

5.2.1. Establishment and Solution of Model

Analysis of optimal number of high-speed rail in developed cities:

In 2008, the Beijing Tianjin inter city railway is open to traffic.

Using data from 2014 to 2016 as research representatives, as shown in Table 4

Table 4. 2014-2016 year high speed railway, Beijing Tianjin inter city railway (data source China traffic Yearbook)

Particular year	Total population (10,000 people)	Passenger traffic (10,000 people)	Beijing GDP (10000)	Quantity of high speed rail (trip / year)
2011	2119	6868	16251.93	73154
2012	2130	7350	17879.4	96532
2013	2146	8476	19800.8	115620
2014	2152	9150	21330.83	137140
2015	2171	9785	22968.6	164315
2016	2173	10753	24899.26	193450
2017	2171	15486	28000.00	Pending solution

For the total population of GDP, the number of high-speed rail and the passenger volume were analyzed by distance correlation. There were correlations between the four:

Considering that the railway passenger volume PC is approximately linearly related to the number of high-speed railways NUMBER, we hypothesize that variable dimension reduction can be carried out here.

Table 5. Relevant Parameters

assembly	Initial eigenvalue			Extracting Square Sum of Load		
	Total	Percentage of variance	Accumulate %	Total	Percentage of variance	Accumulate %
1	1.990	66.331	66.331	1.990	66.331	66.331
2	1.001	33.373	99.704	1.001	33.373	99.704
3	0.009	0.296	100.00			

Fitting the number of high-speed rail NUMBER according to the three-dimensional regression of GDP population, we get Figure 1:

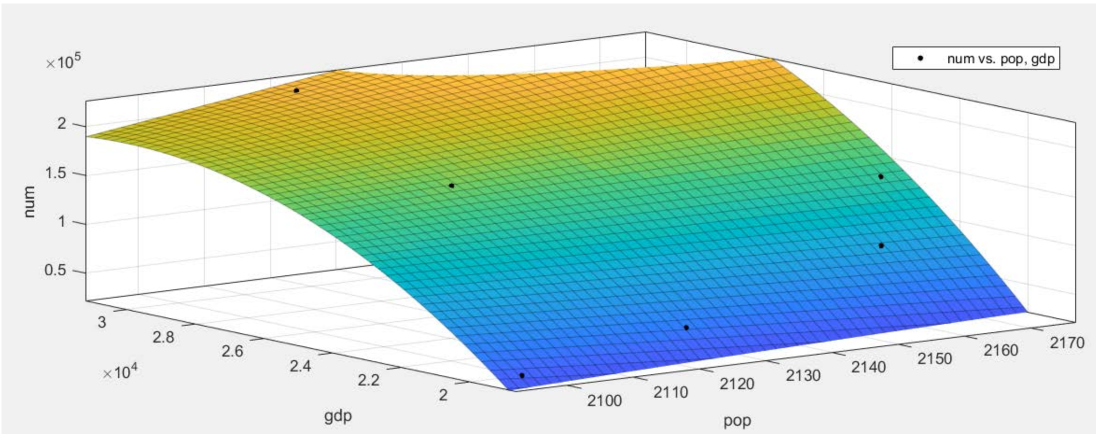

Fig. 1 numerical simulation results of Beijing high speed rail

$$\mathrm{num} = 4.891 \cdot 10^6 - 2829\mathrm{pop} - 171.8\mathrm{gdp} + 0.121\mathrm{pop} \cdot \mathrm{gdp} - 0.001354\mathrm{gdp}^2 \qquad (8)$$

5.2.2. Solution of Multivariate Statistical Regression Model

According to the above three element regression model, the optimal number of high-speed rail allocation in 2017 is 232653 trips per year.

References

[1] Zhao Shougen. Study on the impact of accident location on traffic waves. Journal of Physics, 2009, 58 (11): 7497-05

[2] Hu Huijuan. An Analysis of the Impact of Human Capital Flow on Regional Economic Growth [J]. Popular Investment Guide. 2017 (05)

[3], Jiang Hai. Summary of category optimization based on Logit discrete choice model [J]. Journal of operations research. 2017 (04)

[4] Chen Xianbin, Lin Song, Yin Changming. Asymptotic behavior of two stage Logit generalized estimating equation [J]. Journal of Science (NATURAL SCIENCE). 2018 (05)

[5] Chen Ruiping. Research on the development system of agro ecotourism industry based on AHP: take [J]. as an example, [J]. China's agricultural resources and zoning. 2017 (08)

[6] Gou Chaoyang, Wu Pansheng, Lin Wei, Zhang Yuping. Prediction of low carbon Tourism Based on one regression model [J]. Journal of China. 2015 (02)