Journal of Computers Vol. 28, No. 5, 2017, pp. 147-154
doi:10.3966/199115992017102805013

Research on Weighted Travel Time Value Based on Passenger Flow Share Rate

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Received 6 July, 2016; Revised 7 February, 2017; Accepted 8 February, 2017

Abstract. The rapid development of high-speed railway has an important and meaningful influence on the Chinese economic development. The existing studies mainly set the eastern developed area as the research background, and using the actual passenger flow and the unit time value demonstrates the impact of railway on regional economy. In this paper, setting the western region as the background, using a number of Logit model calculates the passenger flow, and introducing the weighted travel time value quantitatively calculates and analyzes the impact of railway and regional economy. At the same time, the Baoji-Lanzhou transport corridor, which is the main railway of the west high railway network, is going to be put into operation, by investigating regional economy along the corridor, and using the grey prediction method and Matlab toolbox predicts the GDP and passenger flow, and analyzes the sensitivity. The results obtained in this paper can provide a decision basis for the subdivision of railway passenger transport market and the optimization of passenger transport products.

Keywords: grey prediction, high speed railway, share rate, travel time value

1 Introduction

As the savings of the value is the most directly form to improve the resources utilization efficiency, and also promotes the basic power to develop the transportation continuously, on the contrary, ignoring the value of the time savings would cause economic losses [1]. The research abroad on the influence of high speed railway on the regional economic development has been studied for a long time, and domestic scholars have also achieved some valuable results. Among them, Wang, Zhou and Wang built a simplified minimum cost and maximum utility time value model to calculate and analyze the passenger time value along Gansu- Shaanxi transport corridor [2]. Fu and Li used the economics theory to analyze the airline passenger travel time value, and found out that the multi fares can bring more revenue for the airline [3]. Bu Chao and Lin used the improved Logit model to analyse travel time value to make the results more accurate [4], but the shortage is the introduction of SP and RP for data processing with certain subjectivity, while this paper introduces the multinomial Logit model and grey predict to make the passenger flow simulation and prediction more reasonable. Hu used the gravity model to predict the flow [5], obtaining the travel time value along Beijing-Shanghai high speed railway, but has not made the sensitivity analysis, while this paper makes the sensitivity analysis and compares the passenger dedicated line data with the existing line data by the special guest to make the conclusion more reliable.

On this basis, with the railway passenger flow share rate based on multinomial Logit model and setting the Baoji-Lanzhou railway corridor as background, using grey predict model makes the predict for the main city economic data and passenger flow of the various modes. introducing weighted travel time replaces the traditional simple travel time to find out the passenger average saving time after the Baoji-Lanzhou high speed railway on operation. The most important innovation in this paper is that introducing a number of Logit model and grey prediction simulates and predicts the Baoji-Lanzhou high speed railway passenger data firstly, and then, introducing the weighted average travel time calculates passengers saving time by different traffic modes more reasonable, and finally, using the sensitivity analysis and comparing the data make the conclusion more reliable.

2 Travel Time Value

Travel time is the necessary time consumers paid, so saving travel time is the most direct form to save time resources, and travel time savings is one of main point of the continuous development of transportation industry [6]. For travelers, choosing different transport modes will cause their different time costs. operating speed will give the operator a different . At home, according to the relevant data, the main factor of evaluating a feasible road project is whether the time saving benefits account for 30% to 50% [7].

A passenger on a business trip may not produce value. That saving travel time can increase the time of production activities and create the value is only can be considered as travel time value [3]. As shown in Equation 1.

$$R_{(t)} = Q_{(t)} \times R \times W_{O,D} \times P_{(t)} \quad \textbf{(1)}$$

Where $R_{(t)}$ is the value of travel time, $Q_{(t)}$ is the number of passengers changing the mode of transportation, R is the effective utilization coefficient of passenger travel; $W_{(O,D)}$ is the time savings when the passengers change the travel mode from the origin to the destination; $P_{(t)}$ is the unit time value.

The unit time is affected by the gross domestic product and the total number of people in the region, and the specific formula as equation (2).

$$P_{(t)} = \frac{G}{T * M} \quad \textbf{(2)}$$

Where, G is the region's GDP; T is the annual working hours; M refers to the resident population in the region.

By assigning weights to all kinds of transport modes by share rates, it clearly finds out that the introduction of a new type of transportation may change passenger travel time. The following is a formula for calculating the weighted average travel time, as shown in Fig. 3.

$$W_{A,B} = \sum_{j=1}^{n} X_j P_n(j) \quad \textbf{(3)}$$

Where $W_{A,B}$ is the weighted average travel time between the city A to the city B. X_j is the total travel time of the transport mode J, $P_n(j)$ is passenger sharing rate of the transport mode J.

Under random utility, travelers always choose the travel mode with the largest travel utility. Defining the set of options for walker n as A_n, the utility of the travel plan *J* is $57._{27.}$, and the conditions for the traveler select the program *I* from A_n:

$$U_i > U_j \quad ,i \neq j, j \in A_n \quad \textbf{(4)}$$

The utility theory holds that the utility value is a random variable, which is composed of the utility items composed of observable factors and the utility random items composed of non observable factors. Assuming that they are linear relationship with each other, and the utility of the walker n selecting the program I is U_{in} :

$$U_{in} = V_{in} + \varepsilon_{in} \tag{5}$$

Where, V_{in} is the definite term that the traveler n selecting transport mode i, and ε_{in} is a random item. When it obeys the Gamble distribution and is independent on each other, the probability that the traveler n selecting transport mode is:

$$P_n(i) = expU_{in} \Big/ \sum_j expU_{jn} \tag{6}$$

It will cause exponential growth and the result differences will expand on seriously, namely indexation will lead to larger differences between utility values processing results and actual utility values. This paper improves the Logit model by averaging utility value of the different transport modes, and improved model is:

$$P_n(i) = exp\frac{U_i}{\sum_{i=1}^{n} U_i} \Bigg/ \sum_{i=1}^{n} exp\frac{U_i}{\sum_{i=1}^{n} U_i} \tag{7}$$

Where: $P_n(i)$ refers to the share rate of passenger flow by transport mode i, U_i refers to the utility value of transport mode i.

3 Grey Prediction Model

The grey system theory is the method added the original data directly, and moving average weight, making the formation of the series be certain regularity. Using the typical curve approximates the corresponding curve, and setting the approximated curve as the model predicts the system [8].

Building Grey prediction model

The generated sequence of the original sequence accumulated once is

$$x^{(1)} = \left\{ x_i^{(1)} \mid x_i^{(1)} = \sum_{j=1}^{i} x_j^{(0)} \right\} \tag{8}$$

Set $X^{(1)}$ fits the first order differential equation, as shown in Equation 9.

$$\frac{d_{x^{(1)}}}{d_t} + ax^{(1)} = u \tag{9}$$

The first order differential Equation 10 can be obtained by solving Equation 5.

$$x_{k+1}^{(1)} = \left[x_1^{(1)} - \frac{u}{a} \right] e^{-ak} + \frac{u}{a} \tag{10}$$

Then the least squares estimation can be used to find out the coefficient u and a , and plugging the coefficient into the original equation can get the response equation, and then the sequence value can be obtained after the subtraction operation.

4 Example Analysis

This paper sets the Baoji-Lanzhou corridor of northwest region as an example, and studies the impact of time value from the opening Baoji-Lanzhou dedicated railway and the Baoji-Lanzhou section of the existing Longhai railway.

4.1 The Travel Time Value Baoji-Lanzhou Dedicated Railway

According to the data of 875 samples of Baoji-Lanzhou corridor [9], it can get the share rate of the main cities: Baoji, Tianshui, Dingxi, Lanzhou and other places after the completion of the Baoji-Lanzhou high-speed railway. The share rate of the main transport modes of the corridors are shown in Table 1.

Table 1. The passenger market share rate of each transport modes in Baoji-Lanzhou corridor without high speed railway

sections	Existing railway	High speed way	Common speed way	Civil aviation
Baoji--Tainshui	0.66	0.22	0.12	-
Baoji--Dingxi	0.36	0.14	0.50	-
Baoji--Lanzhou	0.27	0.22	0.18	0.33
Tainshui--Dingxi	0.27	0.31	0.42	-
Tainshui--Lanzhou	0.13	0.26	0.61	-
Dingxi--Lanzhou	0.53	0.36	0.11	-

Assuming that the Baoji-Lanzhou high-speed rail runs at the design speed of 250km/h, speculating the time required to each site. Travel time between the origin and the destination by the various transport modes can be obtained by investigation. Plugging the data into the type 2 can calculate weighted average travel time between the main site having high speed railway or not. Combining the formula 11, it draws the average time savings after the completion of Baoji-Lanzhou high speed railway [10]. Specific results are shown in Table 2.

$$\Delta W_{O,D} = W_{A,B(n)} - W_{A,B(y)} \quad \textbf{(11)}$$

Table 2. The weighted average travel time

Sections	Weighted average travel time		Average saving time(h)
	Having high speed railway (h)	No high speed railway(h)	
Baoji--Tainshui	1.5	1.7	0.26
Baoji--Dingxi	4.1	5.6	1.49
Baoji--Lanzhou	3.7	4.2	0.49
Tainshui--Dingxi	2.2	2.6	0.45
Tainshui--Lanzhou	3.5	4.2	0.62
Dingxi--Lanzhou	1.3	1.5	0.15

According to the market investigation, this paper chooses the grey prediction method to establish GM (1,1) model, and the following results can be obtained by Matlab programming.

$$\hat{U} = \begin{bmatrix} a \\ u \end{bmatrix} = \begin{bmatrix} -0.07712 \\ 751509 \end{bmatrix}$$

To calculate the fitting value $\hat{X}$, and reduction can obtain the calculated value $\hat{X}_K^{(0)}$, then analyzing the error, and the results is shown in Table 3.

Table 3. The simulation results of passengers flow grey prediction

Years	2012	2013	2014	2015
Actual value	843150	855000	906850	995900
Simulated value	843150	848843	916898	990406
residual	0	6157	-10048	5494
Relative error	-	0.72%	-1.108%	0.552%

Combined with the data of Table 4, making the fitting curve of actual value and the grey prediction value of the passenger flow from Baoji to Tianshui, as shown in Fig. 1.

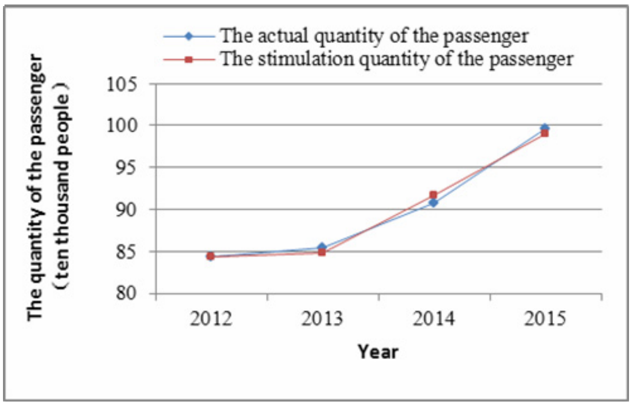

Fig. 1. The result of grey prediction and the actual value

According to Fig. 1 and Table 4, it finds out that the passenger flow total forecast value fits well with the actual value, so building model in this way is more reliable.
By using the same method to predict the passenger flow of the main site section in Baoji-Lanzhou corridor by 2017, using formula 8-9, it can get each section posterior error rate and small error probability, as shown on Table 4.

Table 4. The model accuracy

index	baoji--tianshui	baoji--dingxi	baoji--lanzhou	tianshui--dingxi	tianshui--lanzhou	dingxi--lanzhou
C	0.108	0.019	0.037	0.134	0.016	0.113
P	1	1	1	1	1	1
Predicted accuracy	good	good	good	good	good	good

According to the simulation accuracy in Table 5, the passenger volume prediction of each sections meets with the requirements of the grey prediction theory. Therefore, the GM can be used to forecast the passenger flow in 2017, as shown in Table 5.

Table 5. The passenger volume forecasting in 2017

sections	Baoji--Tianshui	Baoji--Dingxi	Baoji--Lanzhou	Tianshui--Dingxi	Tianshui--Lanzhou	Dingxi--Lanzhou
2017	115 · 56	5.38	23.01	47 · 59	21 · 20	222.27

The grey prediction model is used to get the GDP of the main city and the forecast value of the resident population. The working time of the whole year is calculated by 2000 hours. Plugging them into the formula 2 can calculate the unit time value of each city, as shown in Table 6.

Table 6. The major economic data in Baoji-Lanzhou corridor in 2017

index	Lanzhou	Dingxi	Tianshui	Baoji
resident population (ten thousand people)	371.58	277.75	332.78	377.93
GDP (billion Yuan)	2466.97	366.39	648.13	2067.00
Unit time value(Yuan)	33.2	6.6	9.7	27.3

R indicates the effective utilization coefficient of passenger travel, and generally takes as 50%. From Formula 1, it can know the travel time value of the main city in Baoji-Lanzhou corridor, as shown in Table 7.

Table 7. The travel time value of major cities in Baoji-Lanzhou corridor

Sections	Travel time value (ten thousand Yuan)
Baoji-Tianshui	411
Baoji-Dingxi	26
Baoji-Lanzhou	186
Tianshui-Dingxi	72
Tianshui-Lanzhou	216
Dingxi-Lanzhou	566
Total	1478

As can be seen from Formula 1, the effective utilization coefficient of passenger travel is an important factor of the travel time. Therefore, this paper analyzes the change of the sharing rate from the different passengers effective utilization coefficient. In the above, the effective utilization coefficient of passenger travel is based on 50%, so setting 50% as the basis and 2% as the step, and floating up and down10% calculate the travel time value. the specific results are shown in Fig. 2.

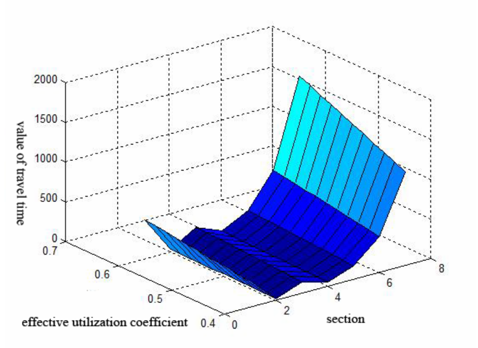

Fig. 2. Travel time value for each region under the different effective utilization coefficient

As can be seen from Fig. 2, with the increase of the travel effective utilization coefficient, the time value of passengers also shows an increasing trend. At present, China's high-speed rail network continues to improve, high-speed rail bringing the visual effect is that the time distance between cities is shorter. Therefore, the proportion of passengers travel on official business will continue to rise, so the time value of high-speed rail will grow linearly.

4.2 The Long-hai Line Travel Time Value

Through the inspecting Gansu province and Baoji Yearbook, it can obtain the economic data of each sites of Baoji-Lanzhou section of the Long-hai line from 2012 to 2015, as seen in Table 8.

Table 8. The GDP and population of each cities of Baoji-Lanzhou section along the Longhai line

Cities	index							
	GDP (billion Yuan)				Population (ten thousand people)			
	2015	2014	2013	2012	2015	2014	2013	2012
Lanzhou	2095.9	1913.5	1776.8	1564.4	367.1	366.5	364.2	363.1
Dingxi	304.92	267.94	252.2	224.1	277.4	277.2	277.1	276.9
Longxi	57.4	52.37	49.4	48.3	51.9	51.1	50.6	50.1
Wushan	51.2	49.4	46.3	41.1	49.2	48.9	48.1	47.6
Gangu	59.8	55.6	50.3	49.2	62.3	62.1	61.2	60.4
Tianshui	560.1	496.9	480.0	413.9	331.0	330.3	329.3	328.2
Baoji	1788.6	1658.0	1545.9	1409.9	376.0	375.2	374.2	373.7

According to the calculated results in Table 9, combined with the formula 2, it can get the unit time value of Baoji-Lanzhou section of the Longhai line from 2012 to 2015, and the specific value is shown in Table 9.

Table 9. The unit time value of Baoji-Lanzhou section of the Longhai line (unit: Yuan)

Sections	2015	2014	2013	2012
Lanzhou	28.5	26.1	24.4	21.5
Dingxi	5.5	4.8	4.6	4
Longxi	5.5	5.1	4.9	4.8
Wushan	5.2	5	4.8	4.3
Gangu	4.8	4.4	4.1	4
Tianshui	8.5	7.5	7.3	6.3
Baoji	23.8	22.1	20.7	18.9

On the basis of Table 10, using the grey prediction method, it can predict the unit time value Baoji-Lanzhou section of the Longhai line by 2017, and the specific value is shown in Table 10.

Table 10. The unit time value Baoji-Lanzhou section of the Longhai line by 2017 (unit: Yuan)

Years	Lanzhou	Dingxi	Tianshui	Baoji
2017	33.2	6.6	9.7	27.3

According to the data in Table 11, and formula 1,it can predict travel time value of Baoji-Lanzhou section of the Longhai line by 2017, and the specific value is shown in Table 11.

Table 11. Travel time value of Baoji-Lanzhou section of the Longhai line

Sections	Travel Time Value (million Yuan)
Baoji—Tianshui	417.9
Baoji—Dingxi	4.6
Baoji—Lanzhou	402.5
Tianshui—Dingxi	4.1
Tianshui—Lanzhou	154.4
Dingxi—Lanzhou	93.5
Total	1077

4.3 Data Analysis

Comparing the Table 8 and Table 11, the Baoji-Lanzhou high speed railway will assume a large part of the traffic flow after it opening and is an important transport mode of Baoji-Lanzhou corridor. In this paper, using the grey prediction model makes the prediction for the passenger flow, GDP and resident population by 2017. Thus travel time value of the corridor will be calculated. From above, it shows that only time value can generate about $14 million 780 thousand in revenue after it opening. While the time value Baoji-Lanzhou section of the existing Longhai line is 10 million 770 thousand Yuan. The quantification of the benefits brought by the passenger travel time savings provides a theoretical basis for the economic evaluation of transportation projects and the forecast of passenger volume [11]. Through comparison of the simulation results and prediction results of Baoji-Lanzhou section of the Longhai line, the operation of Baoji-Lanzhou high speed railway will greatly reduce the shortage of transport capacity in Northwest china.

5 Conclusions

Western region Railway construction gradually becomes the main component of regional economic development and productivity layout, which has a profound impact on the economic and social development of the region along the line, and enhances the strategic position on the large regions. Travel time value is an important index to analyze the economic benefit in transportation project [10]. Therefore studying it provides an important references for economic construction of Western region. By studying the travel time value from macroscopic and microcosmic aspects, it is meaningful for economic construction of Western region.

From the macroscopic aspect, the railway construction department has a preliminary judgment on the feasibility of railway construction. Under the background of economic globalization and market integration, the development of transportation projects has become a necessary means for the rapid development of China's economy. The transportation project investment needs to invest a large amount of social resources, so the construction of a transport corridor needs a lot of economic investigation. The travel time value accounts for 70% of all profits [12], which is the most important of all the economic evaluation items. From the above analysis on time value, it can be seen that only the time value created by existing Baoji-Lanzhou railway and Baoji-Lanzhou high speed railway can create 250 million income, and this is not just a number, but the high speed railway can change our lives. However, the role of railway transport is not only a small part of the time value, and effect this region. From the perspective of spatial spillover effect, economic activities (production factors, labor, advanced technology etc.) along the corridor will spread and gather along the railway network, and thus it effects economic construction of the corridor greatly.

From the microscopic aspect, by considering the travel time value, passengers can make a better travel choice and maximize their own interests. It also provides an important reference for tariff. When choosing the travel mode, travelers will take into account the economic burden caused by different transport modes, that is, willingness to pay. The railway sector should consider the passenger's willingness to pay for the different travel modes when the fare is made. If the fare is higher than the passenger's willingness to pay, the passengers flow will reduce. Therefore, the research on the travel time value provides a theoretical basis for the fare formulation.

Acknowledgements

This work is supported in part by The Research Planning Funds of Humanities and social sciences for the Ministry of Education (14YJA790023, 15XJAZH002).

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