Traffic Forecast Model of Highway Network Based on Improved Four Stages Model

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Abstract. Traffic forecast is the basis of traffic planning. And it is an important basis for determining the road traffic network structure layout, capacity and provincial corridor layout. The accuracy level of the model and algorithm directly restricts the reasonable degree and scientific level of traffic network planning. Because of the traditional four stages model has the shortage of single forecast process, this paper considers the travel time under the condition of traffic congestion when forecast traffic distribution. Therefore, this paper puts forward the circular forecast flow method. The direct relationship between traffic distribution and traffic forecast is established, which makes the traffic forecast model closer to the reality.

1 Introduction

Traffic forecast is one of the bases of traffic planning, while traffic forecast model is the means and basis of traffic forecast. The reasonable degree of traffic forecast model determines the accuracy and reliability of the future traffic trend and the traffic planner's decision-making[1,2]. Highway traffic forecast make quantitative and qualitative inferences on highway traffic and passenger and freight transport[3-5] in the coming period based on scientific forecast method and existing experience.This paper improved and calibrated the model and established a direct connection between traffic distribution and forecast.

2 Model

2.1 Traffic Generation Forecast Model

1) The elastic coefficient method. The model is expressed as follows.

$$\begin{aligned} y_t &= y_{t'}(1+i)^t \\ i &= E_s \cdot q = i' \cdot \frac{q}{q'} \end{aligned} \tag{1}$$

Where, y_t is the prediction value of the prediction object y at the time t; $y_{t'}$ is the value of the prediction object y at the current moment; i' (%) is the average growth rate of the forecast object in the past period of time; *i* (%) is the average growth rate of the forecast object in a future period of time. The formula is as follows.

Growth rate of traffic volume = Elastic coefficient × Growth rate of GDP

2) Calibration of model parameters. The calibration process of the model parameters is as follows:

Step 1: Suppose the elastic coefficient is 1.0, passenger transport generation volume in each traffic zone in 2010 is obtained by elastic coefficient method.

Step 2: Compare the actual value of traffic in each zone.

Step 3: Calculate the cumulative error under the above elastic coefficient according to the above cumulative error formula.

Step 4: Adjust the elastic coefficient based on the observation results of the step 2.

Step 5: Repeat the above steps.

Step 6: Repeat the above steps until the cumulative error is minimal.

The elastic coefficient of passenger transport generation in Zhejiang Province from 2004 to 2010 is shown in Table I.

Table I. Results of model calibration by elastic coefficient method

	Passenger transport		Freight transport	
	Generation	Attraction	Generation	Attraction
Elastic coefficient	1.76	1.88	1.04	0.89

2.2 Traffic Distribution Forecast Model. The dual-constrained gravity model is as follows.

$$q_{ij} = a_i O_i b_j D_j f(d_{ij})$$
$$a_i = [\sum_j b_j D_j f(d_{ij})]^{-1}$$
$$b_j = [\sum_i a_i O_i f(d_{ij})]^{-1} \quad (2)$$

Taking the power exponent traffic impedance function $f(d_{ij}) = d_{ij}^{-b}$ as an example, the calculation process is as follows.

① Let k=0, k is the times of calculation.

② The least square method can be used to calculate γ.

③ Let $a_i^k = 1$, calculate the b_j^k.

④ Calculate a_i^{k+1}.

⑤ Judgment the convergence. End the calculation if satisfy the following formula, else let $k+1=k$, return to step 2 recalculate.

$$1-\varepsilon < a_i^{k+1} / a_i^k < 1+\varepsilon, 1-\varepsilon < b_i^{k+1} / b_i^k < 1+\varepsilon \quad (3)$$

The impedance function is composite function (Gamma function), and model parameters *a*=1.0369，*b*=-0.6010，*c*=0.0362.

$$q_{ij} = a_i O_i b_j D_j f(d_{ij}) \quad (4)$$

$$
\begin{aligned}
f(d_{ij}) &= 1.0369 \cdot d_{ij}^{\ 0.6010} \cdot e^{-0.0362 d_{ij}} \\
a_i &= [\sum_j b_j D_j f(d_{ij})]^{-1} \\
b_j &= [\sum_i a_i O_i f(d_{ij})]^{-1}
\end{aligned} \tag{5}
$$

2.3 Traffic Modal Split Model. T In 2004 and 2010, the proportion chart of each type vehicle on highway is shown in Fig.1.

In 2004 and 2010, the number of each type vehicle in Zhejiang Province is shown in Fig. 2.

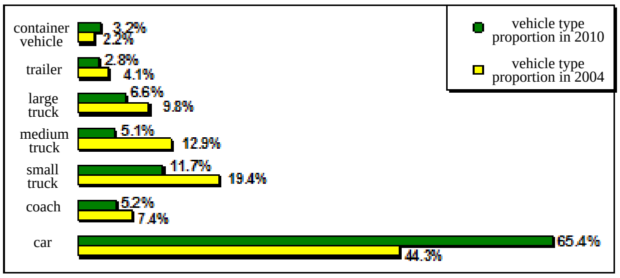


Fig. 1. The proportion chart on highway in 2004 and 2010

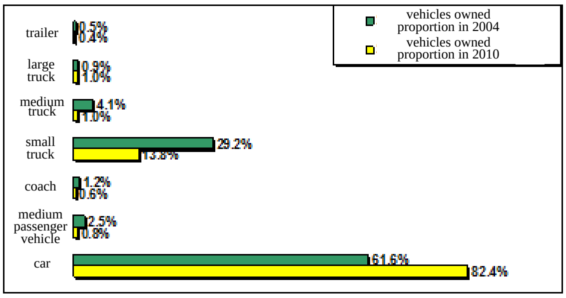


Fig. 2. The proportion chart of each type vehicle

2.4 Traffic Assignment Model. By unilaterally changing the appearance path. The mathematical expression is as follows.

$$
\min Z(x) = \sum_{rs} q_{rs} \times E[\min_{k \in \Psi_{rs}} \{C_k^{rs}\} | C^{rs}(x)] + \sum_a x_a t_a(x_a) - \sum_a \int_0^{x_a} t_a(w) dw \tag{6}
$$

The calculation process is as follows.

Step 1: Initialization. Make random assignment to obtain the traffic assignment volume x_a^1 of each section.

Step 2: Calculate the travel time of each section according to the current traffic assignment volume x_a^n of each section.

Step 3: Calculate the travel time.

Step 4: Use weighted average method to calculate the current traffic volume x_a^n of each section.

$$
x_a^{n+1} = x_a^n + \frac{1}{n}(y_a^n - x_a^n), \forall a \tag{7}
$$

Step 5: Stop the calculation if the difference between x_a^n and x_a^{n+1} is not too large.

The MSA algorithm used to solve the SUE model in TransCAD. Step size formula is as follows.

$$
a_n = k_1 / (k_2 + n) \tag{8}
$$

Where, a_n is step size. n is number of iteration. k_1, k_2 is constant. k_1, k_2 should satisfy the following two conditions.

$$
\sum_{n=1}^{\infty} a_n \to \infty \tag{9}
$$

$$
\sum_{n=1}^{\infty} a_n^2 \to \infty \tag{10}
$$

$$
a_n = 1/n \quad k_1 = 1, k_2 = 0 \tag{11}
$$

3 Case study

the current year is set as 2013, and the predicted characteristic year is 2020, 2025, 2025 and 2035. The base year is 2010.

3.1Traffic Generation Forecast. Determine the coefficient of transportation development in the future year. The results are shown in Table II.

Table II. Traffic volume elastic coefficient of highway passenger and freight in traffic zone

	2010~2015	2016~2020	2021~2025	2026~2030	2031~2035
Hangzhou	0.62	0.49	0.39	0.32	0.25
Huzhou	0.42	0.33	0.27	0.21	0.17
Jiaxing	0.50	0.40	0.32	0.25	0.20
Ningbo	0.55	0.44	0.35	0.28	0.22
Shaoxing	0.51	0.41	0.33	0.26	0.21
Zhoushan	0.53	0.42	0.34	0.27	0.22
Wenzhou	0.55	0.44	0.35	0.28	0.23
Taizhou	0.51	0.41	0.33	0.26	0.21
Jinhua	0.50	0.40	0.32	0.26	0.20
Quzhou	0.49	0.39	0.31	0.25	0.2
Lishui	0.66	0.53	0.42	0.34	0.27
Shanghai	0.63	0.51	0.41	0.32	0.26
Jiangsu	0.52	0.42	0.33	0.27	0.21
Anhui	0.50	0.40	0.32	0.25	0.20
Jiangxi	0.50	0.40	0.32	0.25	0.20
Fujian	0.50	0.40	0.32	0.26	0.21

Calculate the growth rate of passenger and freight transportation. The results are as shown in Table III.

Table III. Forecast result of traffic volume growth rate in each traffic zone in the future (unit: %)

	2010~2015	2016~2020	2021~2025	2026~2030	2031~2035
Hangzhou	7.44%	5.41%	3.96%	2.99%	2.15%
Huzhou	4.65%	3.36%	2.53%	1.81%	1.35%
Jiaxing	4.91%	3.61%	2.66%	1.91%	1.41%
Ningbo	6.14%	4.52%	3.31%	2.44%	1.76%
Shaoxing	4.77%	3.53%	2.61%	1.89%	1.41%
Zhoushan	7.84%	5.71%	4.26%	3.11%	2.33%
Wenzhou	6.18%	4.55%	3.33%	2.45%	1.85%
Taizhou	4.85%	3.58%	2.65%	1.92%	1.43%
Jinhua	5.96%	4.39%	3.23%	2.41%	1.71%
Quzhou	6.02%	4.41%	3.23%	2.39%	1.76%
Lishui	7.83%	5.79%	4.22%	3.14%	2.30%
Shanghai	6.43%	4.79%	3.54%	2.54%	1.90%
Jiangsu	6.55%	4.86%	3.52%	2.65%	1.89%
Anhui	5.89%	4.34%	3.19%	2.29%	1.69%
Jiangxi	6.68%	4.92%	3.62%	2.60%	1.92%
Fujian	6.45%	4.75%	3.49%	2.61%	1.94%

The generation volume and attraction volume in each region in each year is shown as Table IV and Fig. 3.

Table IV. All types vehicles volume in each zone in Zhejiang Province (unit: pcu/d)

Region name	Year	Hangzhou	Huzhou	Jiaxing	Ningbo	Shaoxing	Zhoushan	Wenzhou	Taizhou
Attraction volume	2013	645150	137829	163952	414602	212519	23036	204018	185029
	2015	1188146	218165	253164	713839	333155	27586	380808	347950
	2020	1545801	248498	292147	861022	384168	32899	450560	395676
	2025	1895392	274212	325611	994180	427772	38004	512245	436328
	2030	2213984	295254	353202	1108559	463638	42618	564298	469692
	2035	2489199	311989	375319	1203036	492287	46771	606691	496308
Generation volume	2013	633958	135051	161738	414367	213859	25633	207298	187052
	2015	1200352	221574	256683	715277	330534	23446	375990	344423
	2020	1561188	252530	296344	862864	381054	27426	444622	391514
	2025	1913731	278783	330423	996345	424229	31249	505313	431635
	2030	2234880	300242	358509	1111016	459757	34745	556502	464548
	2035	2512160	317342	381016	1205738	488150	37963	598214	490818
Region name	Year	Jinhua	Quzhou	Lishui	Shanghai	Jiangsu	Anhui	Jiangxi	Fujian
Attraction volume	2013	308032	159782	123530	129062	133038	122562	60506	65315
	2015	575595	273553	236535	179027	181485	161905	69769	71623
	2020	677185	325172	278417	227673	240200	203374	88326	90389
	2025	766923	371014	315500	272033	295697	240918	105303	107374
	2030	842634	409798	346821	310269	344866	273137	119946	121966
	2035	904299	441486	372339	341930	386367	299704	132154	134006
Generation volume	2013	303612	168483	125664	139076	134182	128097	54879	55013
	2015	579515	266023	234103	168305	179852	154838	76846	84544
	2020	682095	315866	275393	214080	237953	194603	97225	106750
	2025	772765	360096	311936	255793	292920	230582	115846	126860
	2030	849250	397564	342801	291796	341623	261438	131885	144126
	2035	911557	428162	367933	321559	382747	286901	145268	158357

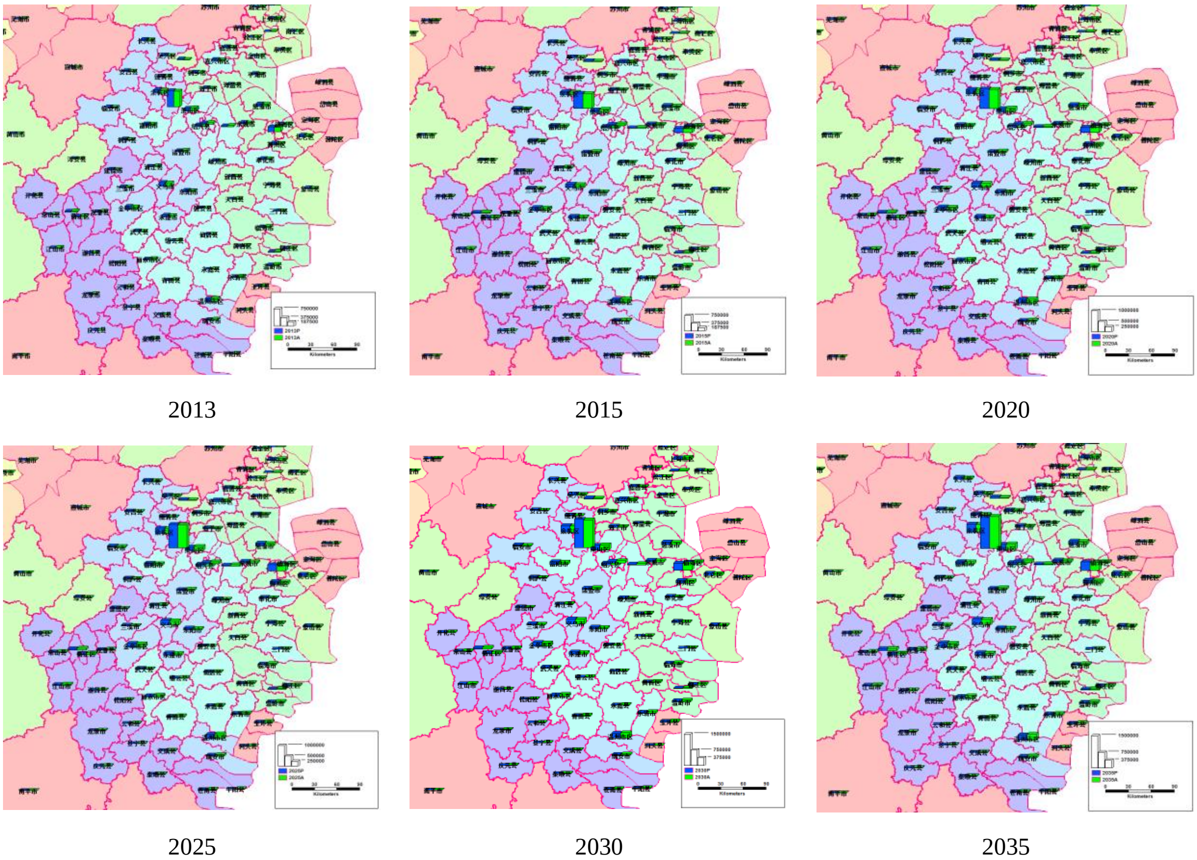


Fig. 3. All types vehicles volume in each zone in Zhejiang Province in the year of 2013, 2015, 2020, 2025, 2030, 2035

3.2 Traffic Distribution Forecast. The current year and the characteristic year of Zhejiang Province traffic zone desire line diagram as shown in Fig. 4.

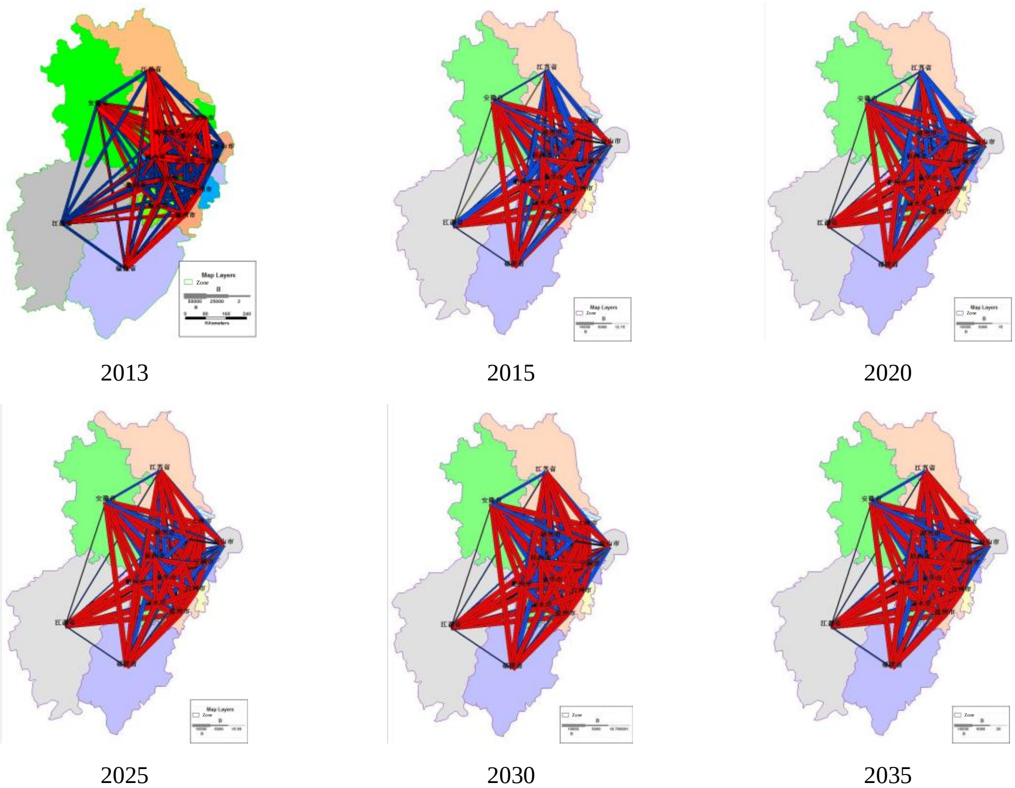
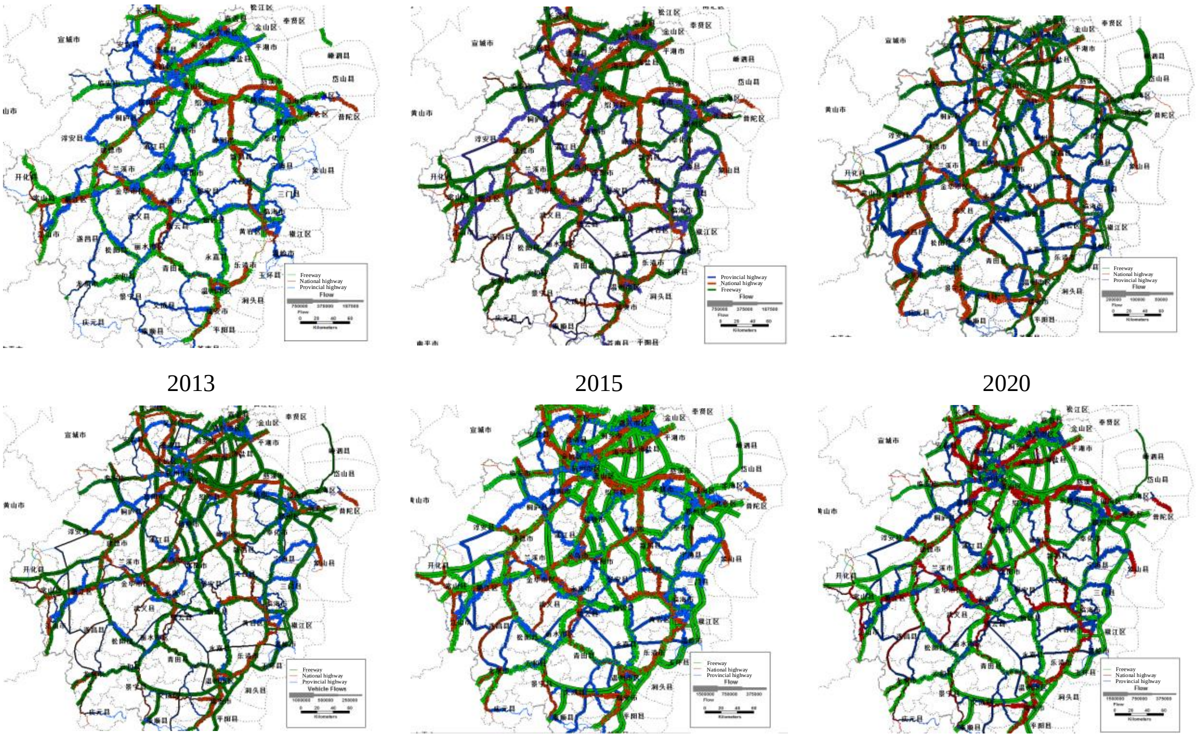


Fig. 4. Diagram of Traffic zone desire line in Zhejiang Province

3.3 Traffic Modal Split And Traffic Assignment Forecast. The results of traffic assignment in Zhejiang Province are shown in Fig. 5.



2013 2015 2020

2025 2030 2035

Fig. 5. Diagram of highway traffic assignment in Zhejiang province

4 Conclusion

The method and model of each stage of traffic forecast is deeply analyzed and improved the traditional four stages model. Thus, the direct relation between traffic distribution and traffic forecast is established. Then calibrated the existing models and determined the road network operation parameters according to the actual traffic characteristics of Zhejiang Province.

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