Application of Combined Forecast Method in Highway Network Scale Forecast in Moderately Developed Cities

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Abstract: In this paper, based on traditional highway network scale forecast method, the combined forecast model of variance-covariance appropriate for moderately developed cities is proposed and the application verification of the model is conducted in Zhaoqing, indicating the feasibility and maneuverability of the model and method. To sum up, the model and method can provide theoretical and practical foundation for highway network scale forecast of cities as the same type.

1 INTRODUCTION

According to Notice on Adjusting the Standard of Urban Scale Division printed and issued by the State Council in 2014, the total population of Zhaoqing is 4.3373 million in 2014 and the resident population in the urban area is 658,600, thus Zhaoqing belongs to medium-sized city. Meanwhile, GDP of Zhaoqing in 2015 is 197 billion Yuan and the per capita GDP is 48,670 Yuan, indicating developed economy.

The development scale of highway network is an important symbol of the development level of social economy. The size of development scale of highway network determines the convenience of regional traffic and is directly related to the economic development and progress of social civilization. The determination of reasonable scale of highway network is a major step in the planning of highway network as well as the premise and foundation for the optimization of highway network. Up to now, there are several kind of research methods for reasonable scale of highway network at home and abroad and each method owns its theoretical support and corresponding algorithm. However, there are few methods for highway network forecast especially for moderately developed cities. In order to improve such a situation, the combined forecast of variance-covairance based on traditional highway network scale forecast method is proposed in this research so as to provide theoretical and practical guidance for the development of highway network scale of cities of the same type.

2 THEORIES AND METHODS FOR HIGHWAY NETWORK SCALE FORECAST

2.1 Connectivity Method

The connectivity model comprehensively reflects the connectivity and accessibility situations of each node in the highway network, which is related to the development level of regional economy. According to the quantity of highway network nodes in the region, the development scale of highway network is calculated and the calculation model is shown as below:

$$L = C \times \varepsilon \times \sqrt{N \times A} \quad (1)$$

In the formula:

L -the scale of highway network (km);

C -the connectivity degree of highway network;

N -the quantity of nodes inside the region;

A -the area of the region (km^2);

ε -the deformation coefficient of highway network, the ratio of the actual mileage to the linear mileage between each node.

It can be seen from the model above that under the circumstance that the area of the region and the

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quantity of nodes are relatively stable, the variable that determines the reasonable mileage is the deformation coefficient of highway network and the targeted value of connectivity degree of highway network. Generally speaking, the major influencing factor for highway network scale is the targeted value of connectivity degree of highway network while the major influencing factor for the deformation coefficient of highway network is the landscape distribution of route area. If there are more mountainous area in the region, the bending degree of route in the region is relatively larger and the deformation coefficient of highway network of the region is correspondingly larger, vice versa. The connectivity of highway network C refers to the parameter of connection form between nodes. When the value of C equals to 1.0, the highway network is displayed as a tree and each node is connected by two routines. When the value of C equals to 2.0, the highway network is displayed in grid reticulation and each node is mainly connected by multiple routines. When the value of C equals to 3.0, the highway network is displayed in triangle and each node is mainly connected with six routines.

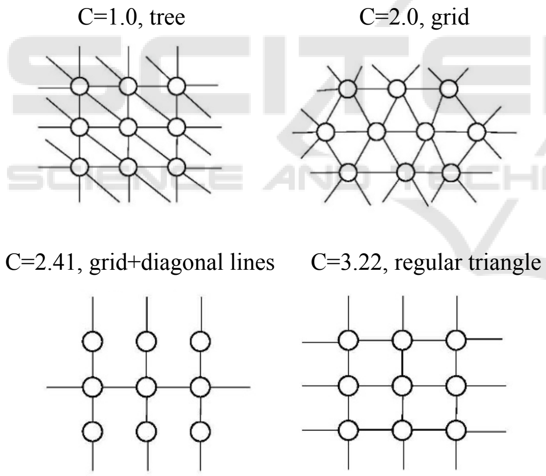

Figure 1: diagram of node connection model

Generally speaking, as for regions with relatively developed economy and larger population density, the value of connectivity degree of highway network reaches 2.0~3.0. As for regions with relatively backward economic development and smaller population density, the value of connectivity degree of highway network is lower, at 1.5~2.0. The value for recent planning is lower while the value for long-term planning is higher.

2.2 Land Coefficient Method First Section

In order to investigate the correlation between the highway network of similar regions and population, economic development level and regional area, the model is established. Furthermore, the highway network scale is deduced according to the population and economic development level of the region under planning. The calculation model for the land coefficient method is as shown below:

$$L = \alpha \times I \times \sqrt{P \times A} \quad (2)$$

In the formula:

L-the highway network scale (km);

α-the land coefficient;

I-per capita economic index (10,000Yuan/person);

A-the area of the region (km^2);

P-the total population (10 thousand).

2.3 Growth Curve Method

Compertz curve and Logist curve are commonly-used growth curves. Compertz curve (S curve) is chosen in this project and the calculation formula is as shown below:

$$L = k \times a^{b^t} \quad (3)$$

In the formula:

L -the total scale of regional highway network (km);

k、a、b-coefficients

t-time (year).

2.4 Combined Forecast of Variance-covariance

Based on the forecast results above, the variance-covariance method is applied to combined forecast of each group of forecast results. The method applied is to achieve the weighted average of the forecast results of various forecast methods according to the value of their variances, through which the final forecast results are obtained. The weight calculation formula of various forecast methods is as follows:

$$\omega_i = \left(\sum_{t=1}^{n} e_{it}^2\right)^{-1} \left[\sum_{i=1}^{k} \left(\sum_{t=1}^{n} e_{jt}^2\right)^{-1}\right]^{-1} \quad (4)$$

In the formula:

e_{it}^2refers to the predicted error of sample tth of ith forecast method, that is $e_{it} = y_t - \hat{y}_{it}$.

3 CASE ANALYSIS

3.1 Analysis on Influencing Factors for Highway Network Development in Zhaoqing

The reasonable scale of highway network is influenced by various factors, among which sociodemographic factor, geographical location factor, the level and structure of economic development, construction capital and national policy occupy the dominant position.

As for population, according to Overall Urban Planning of Zhaoqing (2015-2030) (the draft for comments), the resident population scale of Zhaoqing in 2013 shall be controlled at 4.9 million and the urbanization level of city area shall reach 56%. The improvement of new population and urbanization rate will generate new demands towards highway transportation in Zhaoqing.

In terms of geographical location, the total land area of Zhaoqing is 14,900 km^2, ranking the fifth place in the whole province. The rate of current construction land is 5,85%, showing relatively lower development strength and greater future development space. Meanwhile, Zhaoqing locates on the important passageway that Pearl River Delta connects Southwest China where several major arteries of traffic, including highway, railway and waterway, join. In 2013, Secretary of the provincial CPC, Hu Chunhua, clearly pointed out while visiting Zhaoqing that, “Zhaoqing needs to utilize the advantage of various major traffic arteries to construct to be a hub portal city that Pearl River Delta connects Southwest China”, in which the excellent location advantage of Zhaoqing is mentioned. The larger land are and greater location advantage are the foundation and motivation for the development of highway transportation in Zhaoqing.

In regard to the level and structure of economic development, the regional gross production of Zhaoqing reaches 197.001 billion Yuan in 2015, ranking the eleventh place in the whole province and the per capita regional gross production reaches 48,700 Yuan, ranking the tenth place in the whole province, indicating that the per capita GDP is relatively low, falling short of 1/3 of the average level of the Pearl River Delta region and the national average. The rate of tertiary industrial structure of Zhaoqing in 2015 is 14.7:49.2:36.1. The proportion of increase value of the second industry to the regional GDP is close to 50% while the service industry lags behind. Some manufacturing industries remain in the low-end link of industrial chain and core technology and self-owned brands lack. From the perspective that transportation, especially highway transportation, plays the basic leading role in economic development, there remains much room for the improvement in highway transportation of Zhaoqing.

Regarding the construction capital and national policy, Chinese economy has stepped into new normal with slackened economic growth rate, and stable growth, method transformation and structure adjustment are matters of top priority. It is proposed in Guangdong Province that the building of a moderately prosperous society in all respects shall be accomplished first in 2018 with economic growth at medium and high speed and annual growth of regional GDP of 7%. Nevertheless, the economic foundation of Zhaoqing is relatively weak. During the proposal of the Thirteenth Five-Year Plan, the economy of Zhaoqing keeps increasing at medium and high speed and the annual growth of regional GDP reaches around 9%. The rapid development of economy provides better capital guarantee for the construction of highway system. Meanwhile, there are corresponding financial support policies for the construction of traffic infrastructure in Guangdong Province and even China. With the assistance of investment modes like PPP, the scale of highway traffic system of Zhaoqing in the future will further increase and the structure will be further optimized.

3.2 Connectivity Method

With village committees as nodes, the planning objective of highway that connects natural villages is reflected through the improved connectivity of the whole highway network of each planning period. There are 1329 village committees, 244 community committees, 92 town (national township) governments and 12 street offices, that is, 1677 nodes in total, in Zhaoqing. If 60 tourism sites in Overall Planning of Tourism Development of Zhaoqing are additionally considered, the quantity of nodes in the whole highway network shall be calculated as 1737.

The landscapes within the territory of Zhaoqing are complex. Mountainous regions and hills occupy 81% of the total city area while there are fewer basins and plains. The non-linear coefficient is considered as 1.5. Though the average grade and level of highway network of the next year will be continuously improved as planned, with consideration of the fact that most newly-added highway mileages in the future highway network locate in mountainous regions, the annual non-linear coefficients in the future will not be adjusted as considered.

Till the end of 2015, the total highway mileage of Zhaoqing is 14,128 km with connectivity of 1.85, which is lower than the average provincial level. Thus, improving the connectivity of the whole highway network will be one of the key missions of future highway construction in Zhaoqing. According to analysis on the existing highways in Zhaoqing, with comprehensive consideration of various factors like economic development level, traffic demands, natural conditions and capital raising ability, the development objective of connectivity of highway network of Zhaoqing is 2.10 in 2020, 2.30 in 2025 and 2.40 in 2030. The forecast results are shown in Table 1.

Table 1: Table of Forecast Results of Total Scale of Highway Network in Zhaoqing (connectivity method).

Year	Area (km^2)	Non-linear coefficient	Quantity of nodes	Conne-ctivity	Total mileage (km)
2015	14856	1.5	1737	1.85	14128
2020	14856	1.5	1737	2.10	16015
2025	14856	1.5	1737	2.30	17541
2030	14856	1.5	1737	2.40	18303

3.3 Land Coefficient Method

Table 2: Total Highway Mileage of the Whole Highway Network in Zhaoqing in the Recent 20 Years and Basic Parameters for the Land Coefficient Method.

Year	Total mileage of highway network (km)	The Land coeffi-cient	Per capita GDP (ten thousand Yuan/person)	The total population inside the region (ten thousand people)	Area of the region (km^2)
1996	5464	4.23	0.5739	340.89	14856
1997	5968	4.11	0.6399	346.34	14856
1998	6010	3.89	0.6752	351.61	14856
1999	6498	3.96	0.7138	355.97	14856
2000	7196	4.18	0.7422	361.54	14856
2001	7164	3.91	0.7827	368.34	14856
2002	7342	3.72	0.8401	372.47	14856
2003	7705	3.50	0.9258	381.27	14856
2004	8051	3.10	1.0829	386.6	14856
2005	8291	2.77	1.2315	396.48	14856
2006	10067	3.07	1.3366	404.65	14856
2007	10168	2.60	1.5915	407.71	14856
2008	10218	2.05	2.0133	410.28	15007
2009	10352	1.86	2.2415	413.69	14856
2010	11261	1.64	2.7325	422.41	14891
2011	11457	1.35	3.3614	426.9	14891
2012	12611	1.36	3.6650	427.59	14891
2013	13382	1.28	4.1479	429.82	14891
2014	13633	1.17	4.5795	433.73	14891
2015	14128	1.18	4.8670	405.96	14856

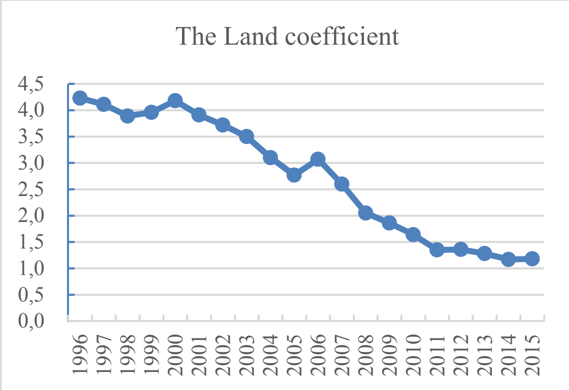

Figure 2: Trend map of the land coefficient of Zhaoqing in the recent 20 years

The development situations of highway network own the closest relationship with the economic development level. It is planned to analyze the changing principles of the land coefficient and determine the land coefficient of future highway development in Zhaoqing through analyzing the development situations of highway network of Zhaoqing in the recent 20 years and the development situations of major social economy indexes of Zhaoqing in the recent 20 years. It can be seen from Tab.2 and Fig.2 that the land coefficient of highway network development of Zhaoqing generally is declining and tends to be stable.

With trend extrapolation applied, it can be deduced that the land coefficients of Zhaoqing in the future will be 0.96 in 2020, 0.75 in 2025 and 0.63 in 2030, with which the total scale of future highway in Zhaoqing can be calculated. According to formulas above, the calculated total scale of future highway in Zhaoqing is as shown in Table 3.

Table 3: Table of Forecast Results of Total Scale of Highway Network of Zhaoqing (land coefficient method).

Year	Area of the region (km^2)	The total population inside the region (ten thousand people)	Per capita GDP (ten thousand Yuan/person)	the land coeffi-cient	The total mileage of highway network (km)
2015	14856	405.96	4.867	1.18	14128
2020	14856	435	7.150	0.96	17449
2025	14856	462.5	9.568	0.75	18810
2030	14856	490	11.364	0.63	19316

3.4 Growth Curve Method

Combined with the data of the total mileage of highway network of Zhaoqing in the recent 20 years, the three parameters, k, a and b, are calibrated through least square method and it is obtained that k=3610612.55, a = 0.001606 and b = 0.991756. The data of the total mileage of highway network of Zhaoqing in 2020, 2025 and 2030 is forecast through Compertz curve is as shown in Table 4.

Table 4: Table of Forecast Results of Total Scale of Highway Network of Zhaoqing(Compertz curve method).

Year	2015	2020	2025	2030
The total mileage of highway network (km)	14128	19302	23863	29250

3.5 Combined Forecast of Variance-covariance

Combined with forecast results of various methods, with reference to the development principle of the total scale of highway network of developed countries and regions (when per capita GDP reaches 5,000 dollars, the total scale of highway network tends to be stable), combined forecast of variance-covariance is applied to finally determine that the total scales of highway network in the whole city in 2020, 2025 and 2030 are 17500 km, 18500 km and 19000 km respectively.

Table 5: Summary Table of Forecast Results of Total Scale of Highway Network in Zhaoqing.

Forecast method\year	2020	2025	2030
The connectivity method	16015	17541	18303
The land coefficient method	17449	18811	19316
The growth curve method	19303	23864	29250
The combined forecast value	17500	18500	19000

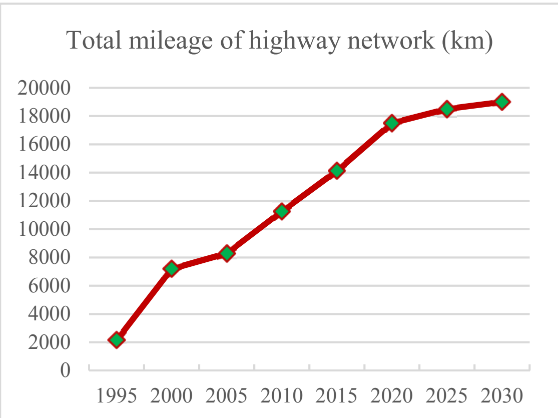

Figure 3: The diagram of changes of total scale of highway network in Zhaoqing from 1995 to 2030.

4 CONCLUSIONS

In this paper, after applying several quantitative methods to forecast the scale of highway network, the variance-covariance method is applied to combine the forecast results, which improves the accuracy of forecast results. The variance-covariance method is also applied to the planning of highway network in Zhaoqing, through which the feasibility and maneuverability of forecast methods are verified. The forecast results obtained provide reference for decision-making of local competent department of transportation, which further demonstrates that the forecast method can be popularized and promoted in the forecast of highway network scale of moderately developed cities.

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