Summer 6-1-2014

Research on Motor Vehicle Ownership of Jinan Based on the Traffic Environmental Bearing Capacity Motor

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Abstract：In this paper, the author quantified the city traffic environment carrying capacity on the basis of the relationships among traffic environment carrying capacity、the bearing capacity of the urban traffic and urban environmental capacity. And based on the actual vehicle maintain models of Jinan city, the author adjusted the formula of motor vehicle exhaust emission source ,then fixed the OPSM street valley diffusion model of China's big cities in combination with the practical situation of Jinan, and established a new $TECC$ calculation formula based on the traffic environmental bearing capacity of single factor contaminant, finally calculated Jinan's threshold and predicted years of threshold, which would provide reference for the government and related departments to formulate the traffic development and management measures, and also would offer a thought for the research of urban motor vehicle development scale.

Keywords：The traffic environmental bearing capacity correction model，Motor vehicle ownership thresholds，Jinan

1. INTRODUCTION

With the rapid development of urban economy, the urbanization level and urban motorization level are also constantly raised; The growth of the urban vehicle ownership has become the inevitable result of the city's economic development. Motor vehicle meets the demand of urban residents simultaneously, however which also has profound impact on the urban ecological resources environment. According to the domestic and foreign related research data that 60% of air pollution comes from the city of motor vehicle emissions. So studies about motor vehicle ownership threshold under the requirements of urban transportation environmental bearing capacity are getting more and more attention of relevant scholars.

The influence of traffic environment carrying capacity of vehicle ownership lies in affects of urban traffic bearing capacity and urban environmental capacity. The affect of urban traffic capacity of motor vehicle ownership mainly lies in affects of urban traffic bearing capacity and urban environmental capacity. The influence of urban traffic capacity of motor vehicle ownership mainly lies in the motorization development scale the city as a whole can inherit with the existing city space scope,the city transportation condition and the service level of urban traffic, which is a kind of resource constraint; And the influence of urban environmental capacity of vehicle ownership reflects on the city’s tolerance of urban atmosphere and noise pollution brought by the city motor vehicle, which is a kind of ecological environmental constraint. In this paper, the urban environmental capacity research mainly focuses on the motor vehicle emission pollution.

2. THE BASIC THEORY OF TRAFFIC ENVIRONMENT CARRYING CAPACITY

The concept of Traffic Environmental bearing Capacity (TECC)[1] is put forward on the basis of the bearing capacity of the urban traffic and urban traffic environment capacity, which refers to the biggest developing scale of transportation system the city's traffic environment can withstand in the condition of that the function and structure of the urban traffic environment system is in the direction of malignant transformation under the specific time, area and traffic structure. Relationships between the three type as shown in the following:

$$TECC = \min(TC, TEC) \quad (1)$$

Type: $TECC$ - city traffic environment carrying capacity;
TC - urban traffic capacity;
TEC - city traffic environment capacity

3. MODELS TO QUANTIFY

3.1 Quantitative model of the urban traffic capacity (TC).

The bearing capacity of the urban traffic is influenced by the rate of urban road area, motor vehicle travel share rate, road network density, and the share rate of motor vehicle travel time. The calculation model is as follows:

$$TC = \frac{MEd}{BR} \cdot t \cdot r \quad (2)$$

Type: M – refers to cities built roads area (m^2);
E - refers to roadway network area ratio;
d -refers to motor vehicle roadway share;
B - refers to motor bike area ratio of roadway;
R - refers to city motor vehicle average car rate;
t -refers to single motor vehicle average travel time (h);
r -refers to traffic control reduction factor.

3.2 Quantitative model of urban traffic environment capacity (TEC)

Urban traffic environmental capacity includes urban air environmental capacity and the urban traffic noise environment capacity. This paper mainly discusses urban atmospheric environment capacity of transportation, namely traffic environment capacity of air pollution, which means the maximum number of city motor vehicle that the urban ecological environment CO、NO_X、SO_2 allowed . Therefore, the city's concentrations ΔC_j of j atmospheric pollutant can be said by type:

$$\Delta C_j = \sum_{i=1}^{n} \beta_{ij} \cdot C_j \quad (3)$$

$$\beta_{ij} = \frac{L \cdot e_{ij} \cdot P_i \cdot N}{S \cdot H_t \cdot c_j} \times 100\% \quad (4)$$

Type: C_j – refers to the concentration of j kind air pollutant of city atmosphere;
β_{ij} – refers to the contribution rates of the i type motor vehicle exhaust emission for the j kind of atmospheric pollutant concentration;
L – refers to the total length of urban roads (km);
e_{ij} – refers to the j kind of atmospheric pollutant comprehensive pollutant emission factor of the i type motor vehicle (g/Km);
P_i – refers to the urban vehicle ownership proportion of the type motor vehicle;
N –refers to the total motor vehicle ownership in the city (a);
S – refers to city road area (m2);
H_t – refers to city gas height (m);

According to the motor vehicle exhaust OSPM diffusion model [2-7] of different cities, ΔC_j can be shown in the following type:

$$\Delta C_j = k \cdot Q_j \cdot f(u, x, z, w) \quad (5)$$

$$Q_j = \mathrm{N} \cdot \mathrm{R} \cdot \sum_{i=1}^{n} P_i \cdot e_{ij} \cdot \frac{1}{3600} \ (\mathrm{mg/m \cdot s\text{-}1}) \qquad (6)$$

Type: k – refers to a factor depending on the street valley dimension;

Q_j - refers to the average source of the j kind of motor vehicle emission that the urban environment can tolerate;

R –refers to the city's motor vehicle operational rate per year;

In view of the specific traffic situation of Jinan, introducing an adjustment coefficient η to revise Chinese big cities streets motor vehicle exhaust OPSM diffusion model $k \cdot f(u, x, z, w)^{[1]} = 0.24 / [w(u \cdot \sin\theta + 0.5)]_r^{0.68}$, concluding the follow formula :

$$k \cdot f(u, x, z, w)^{[1]} = \eta \cdot 0.24 / [w(u \cdot \sin\theta + 0.5)]_r^{0.68} \qquad (7)$$

Arranging the above formulas and introducing parameter C_{tj} could discern TEC computation formula is as follows:

$$TEC = \frac{\sum_{i=1}^{n} \beta_{ij} \cdot C_{tj}}{R \cdot \sum_{i=1}^{n} P_i \cdot e_{ij}} \cdot \frac{1}{\eta \cdot 0.24 / [w(u \cdot \sin\theta + 0.5)]_r^{0.68}} \cdot 3600 \qquad (8)$$

Type: C_{tj} - refers to the urban environment limit concentration of the j kind atmospheric pollutant (mg/m3);

η -refers to adjusted factor;

w –refers to OPSM correction model street valley width (m);

$$TECC = \min(TC, TEC)$$

$$= \begin{cases} \dfrac{MEd}{BR} \cdot t \cdot r & TC \le TEC \\ \dfrac{\sum_{i=1}^{n} \beta_{ij} \cdot C_{tj}}{R \cdot \sum_{i=1}^{n} \Phi_i \cdot e_{ij}} \cdot \dfrac{1}{\eta \cdot 0.24 / [w(u \cdot \sin\theta + 0.5)]_r^{0.68}} \cdot 3600 & TEC \le TC \end{cases} \qquad (9)$$

4. CALCULATION OF JINAN

4.1 Calculation of Jinan traffic capacity(TC)

According to the Jinan statistical yearbook 2012, related parameters selection are shown as follows ：

(1) By the end of 2012, Jinan built road area is 83.37 million square meters;

(2) Motor vehicle roadway taking-up form of Jinan city road structure is double motor vehicle driveways, non-motor vehicle driveways and hybrid motor vehicles, so the roadway taking-up proportion here is 0.75;

(3) The Jinan road structure arrangement belongs to our country general arrangement form of city road, and roadway taking-up area ratio of the motor vehicle also conform to the basic road conditions, therefore here this paper takes 0.6;

(4) The roadway taking-up area of single motor vehicle: According to the DMV statistics show that in 2012,

vehicle average speed is 27.4 Km/h in off-peak hours in Jinan. In addition the related studies have shown that [1] when the speed of a motor vehicle is around 30 km/h, the vehicle's lateral minimum safe distance is 0.5-0.5 m, the lateral distance between motor vehicle and the pavement is 0.6 m and the minimum lateral safe distance overtaking is 1.2-1.2 m, finally the roadway taking-up area of single motor vehicle can be calculated as $B = 20 \times (2.5 + 1.5) = 80\ m^2$,according to that the minimum distance is 1.5 m and the daily road length of motor vehicle calculated by 20 m；

(5) The rate of the working car: according to the Jinan daily in 2012[8], the average rate of the working car in Jinan is 82%;

(6) Traffic control reduction factor: taking experience value of 0.5;

(7) Driving time of a single motor vehicle: according to the weighted average calculation of a benchmark model to calculate and determine t (here by taxi as a benchmark models):

$$t = t' \times k' + t'' \times k'' \qquad (10)$$

Type： t' - Taxi average operation time;

k' - City taxi traffic volume proportion of motor vehicle traffic;

t'' - Average operation time of other cars;

k'' - Other models of motor vehicle traffic city motor vehicle transport volume percentage;

Selecting 2012 taxis in Jinan as the calculating indexes, so

$$k' = \frac{14636.5}{107766} \times 100\% = 13.58\%$$

$$k'' = \frac{93129.5}{10766} \times 100\% = 86.42\%$$

According to the research, taxi average operation time is about 10 hours, other models are about 3 hours in Jinan, and the calculation of single motor vehicle driving time in 2012 is as the following formula:

$$t = 10 \times 13.58\% + 3 \times 86.42\% = 3.9506(h)$$

Table1. The related data of TC model

Project	M (m2)	E	d	B	R	T	r
The parameter value	8.337×10^7	0.75	0.6	80	0.82	3.9506	0.5

Putting the above data in Table1 into the formula, this paper obtains Jinan city traffic capacity TC

$$TC = \frac{MEd}{BR} \cdot t \cdot r = \frac{8337 \times 0.75 \times 0.82 \times 10^4}{80 \times 0.64} \times 3.9506 \times 0.5$$
$$= 2.6194 million$$

4.2 Calculation of Jinan city traffic environment capacity（TEC）

(1) Jinan vehicle models classification and comprehensive pollution discharge factor:

According to the present the situation of retain Jinan automobile, motor vehicle can be divided into heavy vehicles, light vehicle, taxi, car and motorcycle five types, specific car ownership situation are shown in table 2 below:

Table 2. Jinan's vehicle ownership situation in 2012

	Heavy duty vehicle	Light vehicle	The car	The taxi	The motorcycle	total
Ownership $N_{i(car)}$	56531	548668	444837	9020	329476	1388532
Ownership ratio $P_{i(\%)}$	4.07	39.51	32.04	0.65	23.73	100

From table 1, it can be concluded that Jinan models of motor vehicles weight parameter P:

$$P = (P_1, P_2, P_3, P_4, P_5) = (0.0407, 0.3951, 0.3204, 0.0065, 0.2373)$$

According to relevant research materials [9] the Jinan various models of motor vehicle emission factors are shown in table 3 below:

Table 3. Jinan comprehensive pollution of different types of motor vehicle emission factor (g/Km)

	CO	CH	NO_X	PM
Heavy duty vehicle	69.581	3.893	12.180	1.685
Light vehicle	21.592	3.612	2.438	0.036
The car	37.448	5.026	2.182	—
The taxi	16.856	2.168	0.843	—
The motorcycle	9.126	4.248	0.261	—

(2) The determination of single factor pollution emission factor

Motor vehicle exhaust are mainly CO, CH, NO_X and particulate matter , the research idea of this article is to select a exhaust pollutants as the single factor pollution environmental capacity constraints. Selecting the single factor of pollutants from the following two aspects :on the one hand, we consider that only NO_X and particulate matter are listed as one of environmental evaluation factors in the national environmental bulletin among the four major pollutants CO, CH, NO_X and particles in the motor vehicle exhaust emissions; On the other hand, using the statistical software SPSS to analysis the correlation of Jinan's growth rate of car ownership and annual average concentration of three kinds of pollutants NO_X、SO_2、particulate matter), and using Matlab software to get the linear fitting curve (figure 1) of Jinan's growth rate of car ownership and annual average concentration of three kinds of pollutants(NO_X、SO_2、particulate matter)in 2003-2012. Through correlation analysis and fitting image we can find that the correlation of city's growth rate of car ownership and the concentration variation of NO_X is most obvious, so it has high reliability and accuracy to select NO_X as the single factor contaminant in the quantitative analysis of Jinan traffic environment capacity.

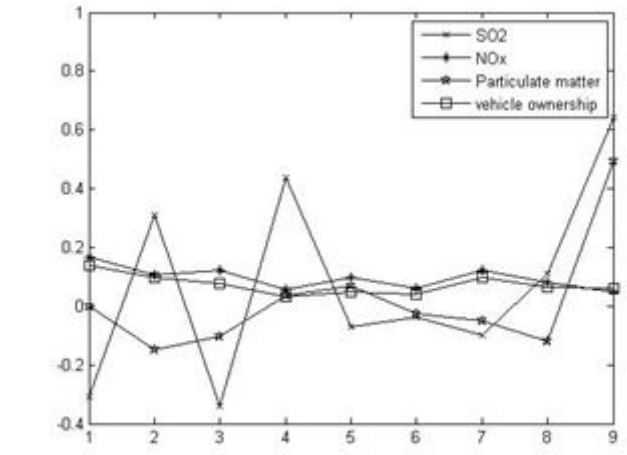

Figure 1. Linear fitting chart of three kinds of pollutants concentration rate and motor vehicle ownership rate

(3) The determination of single factor pollution contribution rate β of motor vehicles

$$\beta = \sum_{i=1}^{n} \beta_i = \frac{Motor\ vehicle\ NO_X\ emissions}{The\ amount\ of\ urban\ atmosphere} \times 100\% = \frac{L \cdot \sum_{i=1}^{n} e_{iNO_X} \cdot P_i \cdot N}{S \times H_t \times C_{NO_X}} \times 100\% \quad (11)$$

In addition, according to the recorded data of statistical yearbook 2012 of Jinan, the parameter L is 5126 Km and C_{NOX} is 0.049$mg/mg/m^3$. Putting the above data into the calculation formula of β, calculating the β = 38.78%.

(4) Urban environmental capacity standards of pollution emission factor NO_X

According to the relevant provisions on NO_X in the national air quality standard (GB 3095-1996), Jinan implements the national secondary standard requirement, so the required annual density of NO_X is 0.05 mg/m^3, and C_{tNOX} is 0.05mg/m^3.

(5) The determination of improved OSPM model parameters

Jinan city belongs to the warm temperate zone continental climate, annual average temperature is 13.5 ℃ ~ 15.5 ℃, the atmospheric stability is neutral, so the correction factor value is 0.8; Unit street valley width W of Jinan city can be calculated according to the type

$$W = \frac{S}{nL} = \frac{8337 \times 10^4}{4 \times 5126 \times 10^3} = 4.07(m)$$

Among them: S – refers to Jinan built road area (m2);
L –refers to the total length of Jinan built roads (km);
n -refers to the average number of lanes of Jinan

Setting model feelings point in the center between roadway, this article selects Jing ten road as the research target, then channel spacing taken 100 m, and the feelings point $x = (2 \times 100) \div 4 = 50$ .In addition, according to the experience value calculation street valley height is 15 m, and the distance z from the feelings point to the ground is 1.5 m. Finally according to the calculation formula of OSPM model parameters:

$$X = \frac{2x}{W} = 5.6m \qquad Z = \frac{2z}{H} = 0.2$$

$$r = X^2 + Z^2 = 31.4 \qquad \theta = 90^\circ$$

Jinan belongs to weak wind area, and according to the meteorological conditions of Jinan 2012 observations, the wind average speed of Jinan is $u = 2.6$ m/s.

(3)To solve the model

According to the aforementioned calculation formula of urban environmental capacity of the motor vehicle exhaust pollutant TEC:

$$TEC = \frac{\sum_{i=1}^{n} \beta_{ij} \cdot C_{tj}}{R \cdot \sum_{i=1}^{n} P_i \cdot e_{ij}} \cdot \frac{1}{k \cdot \eta \cdot f(u, x, z, w)} \cdot 3600$$

$$= \frac{\sum_{i=1}^{n} \beta_{ij} \cdot C_{tj}}{R \cdot \sum_{i=1}^{n} P_i \cdot e_{ij}} \cdot \frac{1}{\eta \cdot 0.24 / [w(u \cdot \sin\theta + 0.5)] r^{0.68}} \cdot 3600$$

$$= \frac{\beta \cdot C_{tNOx}}{R \cdot \sum_{i=1}^{n} P_i \cdot e_{iNOx}} \cdot \frac{1}{\eta \cdot 0.24 / [w(u \cdot \sin\theta + 0.5)] r^{0.68}} \cdot 3600$$

$$= 2.0981(million)$$

In conclusion:

$$TECC = \min(TC, TEC)$$
$$= \min(208.91, 261.94)$$
$$= 2.0891(million)$$

In conclusion, based on the traffic environmental bearing capacity, Jinan motor vehicle's largest forecast is 2.0891 million.

4.3 inan's forecast

This article finally using GM (1, 1) - Markov chain model to forecast motor vehicle ownership in the next six years of Jinan city. Prediction results are shown in table 4 below:

Table 4. Jinan's prediction results in 2013-2018

Year	2013	2014	2015	2016	2017	2018
Prediction value (Thousands)	156.8	169.0	182.1	196.2	211.3	225.7
Prediction correction value (Thousands)	155.232	163.93	178.458	193.257	207.928	219.561

According to statistical yearbook data statistics of Jinan in 2012, as of the end of 2012, Jinan motor vehicle ownership has achieved 1.388 million vehicles, and according to the Jinan traffic environmental carrying capacity threshold of 2.0891 million, there is also certain development space for motor vehicle development scale in Jinan. In addition, if keeping the growth trend of existing motor vehicle ownership, and considering the forecast result based on GM (1, 1)- Markov chain model, Jinan will achieve the traffic environmental carrying capacity threshold in 2018 .

5. CONCLUSIONS

This article is based on the theory of traffic environmental carrying capacity, and adjusts the formula of the motor vehicle exhaust emission source intensity according to the actual situation of Jinan's classifying models, also connecting with the relationship between motor vehicle emission pollutants and motor vehicle ownership to improve OPSM street valley diffusion model, then obtains the calculation formula of the traffic environmental bearing capacity ($TECC$). Finally, this paper calculates the motor vehicle ownership and predicts it's developing scale in the future, also obtains the year when the city motor vehicles have reached the threshold. In addition, providing the reference for transportation development and the management strategies to the government and related departments, and also offering a thought for the research of urban motor vehicle developing scale through the above analysis and calculation.

REFERENCES

[1] Qian Wang. (2009).Urban motor vehicle development scale study Based on the traffic environmental carrying capacity [D].Beijing. Beijing Jiaotong University.

[2] Jixia Cheng. (2004-09). Urban environment traffic capacity model [J]. Journal of Chang an university, (24).

[3] EPA. Description of the MOBILE high way vehicle emission factor model [S]. Washington D. C, US: EPA, 1997.

[4] The state environmental protection administration supervision and management [M]. Beijing: chemical industry press, 2000.

[5] Depaul F. A. Tracer study of dispersion in an urban street canyon [J]. Atmospheric Environment, 1985, 19(2): 555-559.

[6] Sharan M.A mathematical model for the dispersion of air pollution's in low wind conditions [J] .Atmospheric Environment, 1996, 30(8): 1209-1220.

[7] Yamar tino R. Development and evaluation of simple models for the flow. Turbulence and pollutant concentration fields within at urban street canyon [J]. Atmospheric Environment, 1985, 19(12): 2137-2156.

[8] Jinan city taxi service center.

[9] Lizhu Wang, Qiang Sui, Xie qiang, Yongqiang Yu. (2002-04).The determination of motor vehicle emission factors in Jinan [J]. Journal of Environmental Protection in Transportation, (23).

[10] ZhenLin Wei, JinSheng Shen. (2004-04). Based on the amount of urban motor vehicle UTECC control research [J]. Journal of China safety science, (14).

[11] Rong Hu. (2010).Urban traffic environment study based on the atmospheric environmental bearing capacity.[D]. Wuhan.Journal of wuhan university of technology.

[12] Wenjuan Zhao. (2007). Study about Atmosphere environment bearing capacity of urban road traffic [J].Chengdu. Journal of southwest jiaotong university. 2007.6.

[13] Jinan statistical yearbook 2008

[14] Jinan statistical yearbook 2012