A Study on Vehicle Emission Factor Correction Based on Fuel Consumption Measurement

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Abstract. The objective of this study is to address the problem of obvious differences between the calculated and measured emissions of pollutants from motor vehicle by using the existing "Environmental Impact Assessment Specification of Highway Construction Projects". First, a field study collects the vehicle composition ratio, speed, slope, fuel consumption and other essential data. Considering practical applications, the emission factors corresponding to 40km/h and 110km/h and 120km/h velocity are introduced by data fitting. Then, the emission factors of motor vehicle are revised based on the measured fuel consumption, and the pollutant emission modified formula was calculated and compared with the standard recommendation formula. The results show the error between calculated and measured values are within 5%, which can better reflect the actual discharge of the motor vehicle.

1. Introduction

China's current implementation of the "Environmental Impact Assessment Specification of Highway Construction Projects" (JTG B03-2006) uses the emission factor method for the calculation of vehicle exhaust, and the emission factors of CO and NOx are given at the speed of 50, 60, 70, 80, 90 and 100 km / h for small cars, medium and large vehicles [1, 5]. However, in practice, it is found that there are deviations in the values of the emission factors recommended in the codes. Therefore, it is necessary to correct the emission factors and improve the calculation accuracy of the emission factor to meet the actual calculation requirements.

At present, a lot of achievements have been made in the study of emission factors both at home and abroad. Tian Lingdi investigated Beijing's motor vehicle driving condition, environment temperature, and other basic data, and calculated vehicle exhaust emission factors of CO, NOx, HC and PM by COPERT IV model. Xi Ou used the recommended emission factors in the specification and the pollutant emissions of motor vehicles in Beijing to calculate and compare with the IVE model. Zhang Dongxu studied the effects of running speed on motor vehicle exhaust emissions. He Liqiang selected 22 light gasoline vehicles, and obtained the vehicles in the NEDC work condition CH_4 and the N_2O emission factor [6, 7]. However, the above studies did not correct the emission factors from the perspective of measured fuel consumption.

Based on the data of fuel consumption, this paper re-fits the relationship between emission factors and velocity, corrects the emission factors, and gives the recommended values of emission factors for

CO and NO_X at different speeds. The revised emission factors were used to calculate and compare the pollutant emissions of motor vehicles in Guang le and Jing zhu expressway.

2. Questions and descriptions

2.1. Pollutant emissions calculated using standard recommendations

China's "Environmental Impact Assessment Specification of Highway Construction Projects" (JTG B03-2006) proposed a motor vehicle pollutant emissions calculation method using Formula 1:

$$Q_j = 365 \sum_{i=1}^{3} AADT_i \times E_{ij} \times L \quad (1)$$

Where: Q_j is the amount of pollutants discharged in class j for 1 year, g / a, E_{ij} is the emission factor of the j-type pollutant of the i-type vehicle, g / km; L is the length of the highway section, km; i = 1, 2, 3, respectively, on behalf of small cars, medium cars, large cars; j = 1, 2, respectively, on behalf of carbon monoxide, nitrogen oxides.

The key of using Formula 1 is to determine Eij. The emission factors at the 50, 60, 70, 80, 90 and 100km/h speeds are given in the specification, but the speeds at the 40km/h, 110km/h and 120km/h are not given. In this paper, a number of highway speed data are investigated, such as Kaiyang expressway where the average speed of small cars and large cars are 123.5 km / h and 106.5km / h, Yuegan expressway where the average speed of small cars are 107.5 km / h. Actually, in the road segment with good alignment and without speed limit, small car speed can exceed 100km / h; and under the congested traffic condition, the speed of 40km / h situation can be observed. Therefore, 40km / h and 110km / h, 120km / h speed corresponding to the emission factor are introduced, as shown in Table 1.

Table 1. Recommended vehicle emission factor for specifications (mg/ vehicle•m)

Average Velocity (km/h)		40	50	60	70	80	90	100	110	120
Small Cars	CO	38.90	31.34	23.68	17.90	14.76	10.24	7.72	6.70	6.50
	NOx	0.85	1.77	2.37	2.96	3.71	3.85	3.99	4.46	4.40
Medium Cars	CO	36.69	30.18	26.19	24.76	25.47	28.55	34.78	42.36	53.01
	NOx	4.20	5.40	6.30	7.20	8.30	8.80	9.30	10.27	10.66
Large Cars	CO	6.29	5.25	4.48	4.10	4.01	4.23	4.77	5.66	6.85
	NOx	9.98	10.44	10.48	11.10	14.71	15.64	18.38	21.40	25.11

Taking the Chaohui expressway as an example, the section is 99.906km in length that is divided into eight sections. The annual average daily traffic volume of each section is obtained from the design document. By Formula 1, we can calculate that the CO emission is 17122 t and the NOx emission is 5774 t.

2.2. Calculation and comparison of measured data based on fuel consumption

Through field survey at Kaiyang freeway, Yuegan freeway and Jingzhu freeway, the representatives of each kind of vehicle type are chosen. JDSZ-EP-X-type vehicle fuel consumption meter is installed in the measurement vehicle with a fully loaded state (person or cargo), semi-loaded state and no-load state of the measurement. Each test road mileage is no less than 100km, and each vehicle type is measured no less than 300km. A snapshot of the fuel consumption monitor is captured every 500m to record the cumulative fuel consumption, instantaneous speed, cumulative time and other data.

According to the analysis, the fuel consumption of each model is related to the flatness, slope and speed of the road section. The fuel consumption model of the expressway is used to calculate the total fuel consumption consumed by the motor vehicle in the expressway. The specific formula (2) ~ (4) are as follows.

$$C_n = \sum_{k=1}^{m} 365 \times C_{ki} \times N_{ki} \quad (2)$$

$$C_{ki} = (a_i + b_i V_{ki} + c_i V^2_{ki} + d_i \times IRI + e_i k_i) L_k / 100 \quad (3)$$

$$V_{ki} = r_i \times i_k + S_i \quad (4)$$

Where: Cri represents the full range fuel consumption of model i, L; Cki indicates the fuel consumption of vehicle i on road section k, L; Nki represents the average daily traffic volume of vehicle i on section k, veh/ d; m represents the total number of sections; Lk section k length, km; Vki means model i The average velocity km / h on the section k; IRI represents the highway smoothness index, m / km; ik section k longitudinal slope, uphill is positive and downhill is negative,%; ai ~ si represents i model regression parameters, see Table 2.

Table 2. Regression parameters of fuel consumption model

vehicle type	a	b	C	d	e
Minibus	5.27	0.07	-0.003	-0.11	0.41
Coach	40.41	-0.6	0.004	0.21	1.79
Bus	73.52	-1.22	0.008	-2.49	2.93
small truck	-3.94	0.37	-0.001	-0.48	1.44
Freight car	110.11	-2.14	0.01	-2.58	2.5
Big truck	107.34	-2.03	0.01	-1.86	2.07
Oversize freight car	165.49	-4.73	0.04	5.64	5.11

The total discharge of the vehicle exhaust gas is calculated using the following formula:

$$Q_j = \sum_{i=1}^{7} C_{ri} \times m_{ij} \quad (5)$$

Where: mij represents i-type vehicle j class pollutant emission coefficient, the emission factor according to European 2015 implement of the European VI emission standards, showing in Table 3.

Table 3. Emission coefficient

Vehicle type	Minibus	Coach	Bus	small truck	Freight car	Big truck	Oversize freight car
CO	287.74	151.425	30.26	16.58	16.58	30.26	33.96
NOx	11.2	10.775	49.66	30.87	30.87	49.66	50.5

The pollutant emissions calculated by the recommended method and fuel consumption are shown in Table 4.

Table 4. Pollutant emission results and comparison

Pollutant species	Amount of pollutants /t		
	Emission factor method	Fuel consumption	The difference
CO	17122	20283	-3161
NOx	5774	6597	-823

It can be clearly seen from the above comparison that the results obtained by the emission factor method specified in the specification are far less than the actual values. The CO emissions differ by about 15.6% and the NOx emissions differ by about 12.4%.

3. Problem solving and method

3.1. Emission factor and velocity fit

Based on the data of fuel consumption, the emission factor is corrected by using the calculated pollutant emission, and the formula of emission factor and velocity is given in Table 5.

Table 5. The relationship between the emission factor and the velocity after correction

Vehicle type	Pollutant	Eij-V fitting relationship
Small Cars	CO	$E_{11}=0.0032V^2-1.0866V+92.46$
	NOx	$E_{12}=-0.0004V^2+0.1093V-2.5028$
Medium Cars	CO	$E_{21}=0.0126V^2-1.811V+111.19$
	NOx	$E_{22}=-0.0012V^2+0.3534V-3.8$
Large Cars	CO	$E_{31}=0.0014V^2-0.2157V+115.578$
	NOx	$E_{32}=0.\ 0052V^2-0.453V+29.78$

3.2. Give the Emission Factor Recommended Value

When calculating the fuel consumption method, the vehicle is divided into seven categories. When the emission factor method is used, the vehicle is divided into three categories. Therefore, the minibus and the small truck are merged into a small car, the coach and the freight car are merged into a medium car, and the bus and big truck and the oversize freight car are merged into a large car. Based on the emission factors and velocity relationships derived above, the emission factor recommendations are shown in Table 6.

Table 6. Recommended values of modified vehicle emission factors (mg/ vehicle•m)

Average Velocity (km/h)		40	50	60	70	80	90	100	110	120
Small Cars	CO	52.1	50.25	35.7	32.45	25.5	22.85	12.5	10.45	8.7
	NOx	1.21	2.03	2.56	3.12	3.80	4.12	4.23	4.84	4.80
Medium Cars	CO	58.47	52.86	50.63	42.78	45.31	51.22	58.51	65.38	74.23
	NOx	8.42	10.87	13.08	15.05	16.79	18.28	19.54	20.55	21.32
Large Cars	CO	9.03	8.42	7.77	7.08	6.35	7.58	7.77	8.92	9.03
	NOx	19.98	20.13	21.32	23.55	26.82	31.13	26.48	42.87	50.30

4. Example

The emission factor recommended by Table 6 was used to calculate the emission of two highway motor vehicles in Guangle and Jingzhu. The results were compared with the actual values. The Jingzhu expressway is an important part of the Hong Kong and Macao expressway with a length of 109.84 km. The survey obtained the speed of small vehicle is 94.5km / h, medium-sized vehicle is 73.5km / h, large vehicle is 80km / h. Guangle expressway is a double track of the Jing Yue highway in Guangdong Province, with a total length of about 130km. The speed is 107.5km / h for small cars, 83.5km / h for medium-sized vehicles and 91km / h for large-scale vehicles. Comparison of calculated and actual values of two high speed pollutants is shown in Table 7.

Table 7. Comparison of calculated values and actual values of two highway pollutants (t)

	CO calculated value	CO actual value	errors (%)	NOx calculated value	NOx actual value	errors (%)
Guangle expressway	20224	21283	-4.97	6 486	6 697	-3.15
Jingzhu expressway	33230	34891	-4.76	4982	5166	-3.56

5. Conclusion

The emission factor method in the "Environmental Impact Assessment Specification of Highway Construction Projects" was applied to the calculation of pollutant emissions from actual projects. It was found that there was a big deviation between the calculated value and the actual value. Based on the measured data of fuel consumption, the relationship between the emission factor and the velocity is fitted, and the recommended value of the emission factor is given, and the results are applied to the calculation of pollutants in two expressways of Guangle and Jingzhu in Guangdong province.

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