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Research Article

Study on Gasoline Vehicle Emission Inventory Considering Regional Differences in China

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Rapid growth of China's urban road vehicles, in particular, the increase in the number of gasoline vehicles, leads to an increase in the traffic congestion and problems pertaining to air pollution. The establishment of the emission inventory of gasoline vehicles is influenced by several factors, like environmental characteristics, vehicle conditions, road conditions, and so on. In order to obtain gasoline vehicle emission inventory in accordance with the actual situation in different regions, this study proposed a method of establishing a list of gasoline vehicles with regional differences. Comprehensive consideration and evaluation of various factors that affect the vehicle emissions were carried out and the corresponding correction factors were obtained. According to the formula of comprehensive emission factor for Zibo city, the emission inventory of gasoline vehicle was established. This method can be effectively utilized to obtain the emission inventory of gasoline vehicles in different cities more accurately and provide theoretical support for control strategies of gasoline vehicle emissions.

1. Introduction

With the development of urban economy in China, pollution due to vehicle's emission has become a significant environmental problem. By the end of 2015, the gasoline vehicle population in China reached 172 million, for which the quantity of emission accounted for 65.5% of the total emission of vehicles [1]. Therefore, a strengthened control on gasoline vehicle's exhaust emission is a significant measure to improve the urban air quality. To determine more targeted energy saving and emission reduction strategies, the approach to determine a reasonable and accurate emission inventory of gasoline vehicles becomes one of the most important and challenging tasks.

A series of related studies about vehicle emission inventory is available at home and abroad. Sun et al. [2] took into account the dynamic changes of emission standards and fuel quality, and considering the differences of driving conditions for each vehicle type in urban road, suburban road, and highway, they established a high-resolution vehicle emission inventory based on COPERT model and GIS technology. Li et al. [3] selected Chang-Zhu-Tan urban agglomeration as the research region and established the vehicle emission inventory in this region. Further, they analyzed the space-time distribution characteristics and contribution rate of regional vehicle emissions. Yao et al. [4] selected 12 typical cities in China to establish the vehicle emission inventory from 1990 to 2009 and analyzed the historical evolution trend of vehicle emission in various cities. They finally identified the gasoline vehicle as the main source of the city's carbon monoxide (CO) and volatile organic compounds (VOCs) emissions and provided the results of the contribution rate of different gasoline models to specific pollutants. A high-resolution inventory of greenhouse gas (GHG) emission distribution of the road transport sector in Argentina was established based on GIS map by Puliafito et al. [5] after obtaining regional spatial distribution by DMSP satellite.

Commonly, the studies of vehicle emission inventory do not take into account the comprehensive consideration of the influence of environmental factors, vehicle situations, and road conditions in different regions. Based on relevant studies of low-carbon urban planning in Beijing, Wang et al. [6] put forward methods for low-carbon urban planning, including preparation of current and proposed carbon emission inventories, analysis of proposed carbon emission scenarios, city low-carbon development madmap, selection of strategies, and formulation of policies for low-carbon development. Guo et al. [7] evaluated the International Vehicle Emissions (IVE) model by utilizing a dataset available from the remote sensing measurements on a large number of vehicles at five different sites in Hangzhou, China, in 2004 and 2005. They contrasted the remote sensing data of three pollutants and proposed the adjustment of the basic emission factors from the local study to improve the model. Li et al. [8] investigated the emission profile of exhaust $PM_{2.5}$ of 12 light gasoline vehicles by using vehicle test bench and particle dilution sampling system and analyzed the $PM_{2.5}$ emission characteristics of light gasoline vehicle exhaust. Ni et al. [9] tested gasoline vehicle emissions and fuel consumption at different altitudes. They further studied the mechanism of gasoline vehicle emissions and fuel consumption at different altitudes through emission characteristics of CO, total hydrocarbon (THC), and nitrogen oxides (NOx) and also through changes in fuel consumption. Zhou et al. [10] explored the real-world emission status of light gasoline vehicles by using roadside remote sensing measurement and calculated the emission factors based on fuel and distance by mass balance method. Guo et al. [11–13] analyzed the relationship between light duty electronic fuel injection (EFI) gasoline vehicles emissions and useful life using the vehicle emissions test data from motor vehicle exhaust monitoring center.

In this study, the gasoline vehicle was selected as the research object and the environmental parameters, the average vehicle speed, the load coefficient, and the deterioration coefficient were adopted for correction. Furthermore, the comprehensive emission factor suitable for the regional characteristics was obtained. Finally, the gasoline vehicle's emission inventory was computed and analyzed based on the established model.

2. Calculation Framework

2.1. Basic Emission Factors. Since 1999, China has begun to adopt the European emission standard (National Phase-I emission standard corresponding to the emission standard of Euro I), and by 2015 it has implemented the five national standards. In light of the investigation results released by the National Bureau of statistics (China Statistical Yearbook 2015), China's vehicles that have been implementing different emission standards from National Standard I to National Standard V accounted for 2, 4, 12, 54, and 28%, respectively. Based on the national average environmental condition, vehicle condition, and road condition, and related industry standards, the basic emission factors of gasoline vehicle were obtained. Table 1 lists the basic emission factor data of various types of gasoline vehicles under different emission standards.

2.2. Model. First, the regional vehicle population and the annual average distance of various types of gasoline vehicles were obtained pursuant to the ***Yearbook of National Bureau of Statistics and Local Bureau of Statistics***. Second, the basic emission factors of gasoline vehicle were established based on the displacement of various gasoline vehicles and related industry standards. Then the emission correction factors model of gasoline vehicle affected by regional differences were established based on the basic emission factors with a comprehensive consideration of such factual factors affecting gasoline vehicle emission as environmental conditions, vehicle type, engine running status, fuel properties, and vehicle load. Finally, emission inventory of regional gasoline vehicles was acquired by combination of emission factors, local motor vehicle population, and driving mileage of various types of vehicles. The model calculation framework is shown in Figure 1.

Vulcanization correction factors were used to reduce or eliminate the effect of sulfur content in gasoline on other polluting gases.

3. Analysis of Influencing Factors

Environmental condition and vehicle situation are the two standing out factors influencing the gasoline vehicle exhaust. On the one hand, significant regional differences are observed in temperature, humidity, and altitude, which directly affect the engine operating conditions [14]. On the other hand, running velocity, deterioration factor, fuel quality, and vehicle load coefficient also have an immediate implication on its exhaust. For these reasons, the emission correction factors of gasoline vehicle considering regional differences are conducive not only to a more accurate and real local vehicles emission condition, but also to a more realistic emission inventory.

3.1. Environmental Parameter Correction Factors. China is a country with a vast territory of around 9.6 million square kilometers. The far-flung land area and diverse geomorphological characteristics shape a huge environmental difference in different regionals of China, making the hot and humid southern area in contrast with the cold and dry northern area. Based on the information released in ***China Climate Bulletin in 2015***, the representative higher and lower values of altitude, temperature, and humidity are listed in Table 2.

Differences in environmental conditions exert direct impacts on engine operating conditions. In the high altitude and frigid region with thin air, engine excess air coefficient φ_a becomes larger beset by less oxygen, lower atmospheric pressure, and larger intake resistance. Moreover, CO and HC exhaust, on the premise of oxygen deficit and incomplete combustion, increases significantly, which is also aggravated due to low environmental temperature, poor gasoline atomization effect, and insufficient burning of combustible gas mixture in hot and humid environment. In contrast, the engine becomes inefficient, troubled by high environmental temperature, slow engine cooling and heat dissipation, and high operating temperature of combustion chamber,

Table 1: Emission factors for different types of gasoline vehicles.

Vehicle type	Emissions factor (g km^{-1})				
	CO	HC	NOx	$PM_{2.5}$	PM_{10}
Minivan					
GI	6.71	0.663	0.409	0.026	0.029
GII	2.52	0.314	0.324	0.011	0.012
GIII	1.18	0.191	0.100	0.007	0.008
GIV	0.68	0.075	0.032	0.003	0.003
GV	0.46	0.056	0.017	0.003	0.003
Middle-sized Coach					
GI	21.43	2.567	1.781	0.060	0.067
GII	15.37	1.443	1.461	0.018	0.020
GIII	4.33	0.373	0.474	0.011	0.012
GIV	1.98	0.107	0.196	0.006	0.007
GV	1.98	0.107	0.147	0.006	0.007
Light Duty Truck					
GI	26.16	3.324	2.006	0.060	0.067
GII	21.54	2.210	1.656	0.018	0.020
GIII	5.61	0.61	0.534	0.011	0.012
GIV	2.37	0.169	0.229	0.006	0.007
GV	2.37	0.169	0.172	0.006	0.007
Other Gasoline Vehicles					
GI	16.12	1.368	1.89	0.066	0.064
GII	8.25	0.869	1.52	0.044	0.049
GIII	5.456	0.613	1.089	0.026	0.016
GIV	3.77	0.418	0.775	0.015	0.009
GV	3.77	0.418	0.582	0.005	0.006

GI, GII, GIII, GIV, and GV, respectively, represent the national emission standards of Phase-I, Phase-II, Phase-III, Phase-IV, and Phase-V.

Table 2: Extreme statistics of environmental parameters in China.

	Higher value	Representative	Lower value	Representative	D-value
Altitude (M)	4025	Shigatse	33	Tianjin	3992
Temperature (°C)	46	Chongqing	−52.3	Mohe	98.3
Humidity (%)	92	Guiyang	32	Yinchuan	60

Data from China Climate Bulletin in 2015.

ultimately leading to aggravation in pollutant emission with increasing fuel consumption. In high relative humidity environment, water molecules present in the air enter into combustion chamber through the engine intake system. This results in incomplete combustion of combustible gas mixture and carbon deposition. This easily leads to surface ignition under high temperature, inducing preignition deflagration and some other tough operating conditions of engine, and thereby dramatically increasing the emission amount of NO_x and $PM_{2.5/10}$.

According to ***Technical Guidelines for Preparation of Air Pollutants Emission Inventory of Road Vehicles*** [15], based on influencing factors such as temperature, humidity, sulfur content, and altitude, the correction factors with similar environmental conditions were integrated based on actual situations, and the environmental parameter correction factors in high state and low state are listed in Table 3.

Definitions of the low state and high state of various environmental factors are summarized in Table 4.

3.2. Average Velocity Correction Factors. Vehicle operating conditions in different provinces and cities in China vary significantly owing to the different landforms, population densities, and road conditions of various regions. According to the data released in the ***Investigation Report for National Urban Automobiles Driving Conditions in 2015*** by National Bureau of Statistics, vehicle operating conditions of six representative cities are listed in Table 5.

Average velocity exerts direct influences on engine operating condition and emissions. When the vehicle runs in idle low load states and low velocity, less amount of mixed gas would get into the engine through its narrower throttle opening, leading to the serious dilution of the mixed gas by residual gas. Besides, slow engine velocity leads to slow inlet

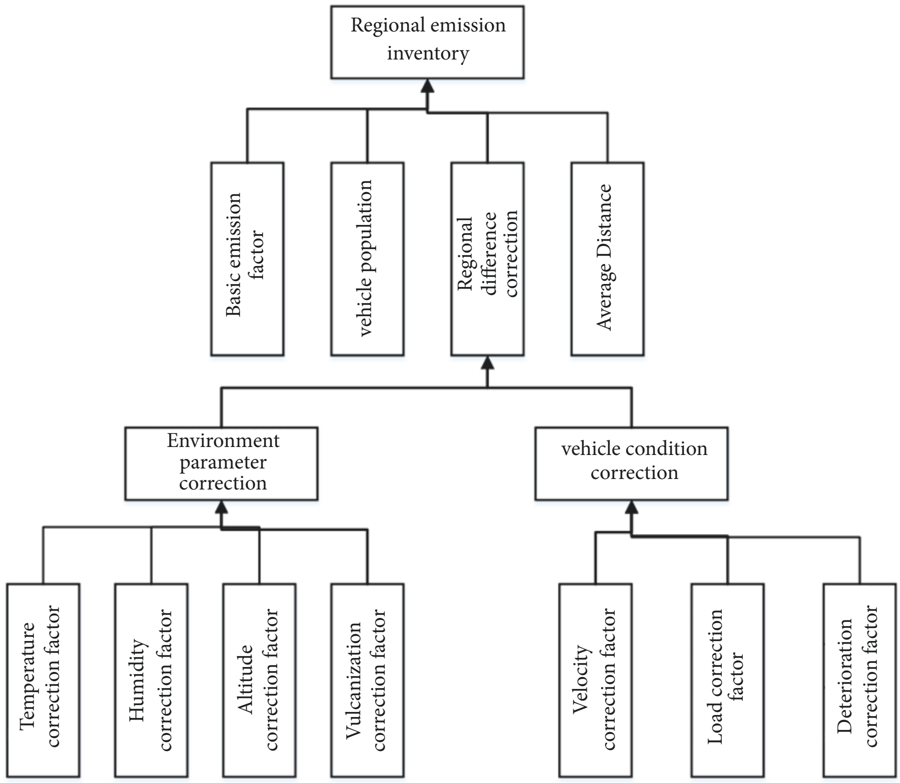

Figure 1: Model calculation flowchart.

Table 3: Gasoline vehicle environmental parameter correction factor.

Classification of Pollutants	CO		HC		NOx		$PM_{2.5}$ /PM_{10}	
	Low state	High state	Low state	High state	Low state	High state	Low state	High state
Temperature Correction Factor	1.36	1.23	1.47	1.08	1.15	1.31	1.45	0.67
Humidity Correction Factor	0.97	1.04	0.99	1.01	1.13	0.87	1.00	1.00
sulfur Content Correction Factor	0.90	1.80	0.96	1.41	0.95	2.08	0.56	1.21
Altitude Correction Factor								
Light/Small-sized	1.00	1.58	1.00	2.46	1.00	3.15	1.00	1.00
Middle-/Large-sized	1.00	3.95	1.00	2.26	1.00	0.88	1.00	1.00

Data from Technical Guidelines for Preparation of Air Pollutants Emission Inventory of Road Vehicles.

Table 4: The boundary between the high and low states.

	Temperature	Humidity	Sulfur content	Altitude
Low state	<10°C	<50%	<10ppm	<1500m
High state	>+25°C	>50%	>500ppm	>1500m

velocity, poor gasoline atomization and evaporation effect, and uneven mixed gas. Thus, in this case, the rich mixture is required. However, an overrich mixture in turn arouses incomplete combustion, thus exacerbating exhaust emission.

According to the guide, the gasoline vehicle velocity involved in the correction method has been divided into the following five intervals: 0–20, 20–30, 30–40, 40–80, and 80 km h^{-1}. Moreover, the average vehicle velocity correction factors of the gasoline vehicle were worked out and listed in Table 6.

3.3. Load Correction Factors. Owing to a sound growth momentum, the transportation industry in China confronts a noticeable problem of spatial development imbalance. For

Table 5: Typical urban vehicle operating conditions in China.

Unit	maximum velocity (km h^{-1})	Average velocity ($km\ h^{-1}$)	Idling Time Proportion (%)
Beijing	70.5	27.7	20.5
Shanghai	52.3	21.6	30.2
Guangzhou	55.4	25.6	17.3
Dalian	76.3	40.5	8.6
Wuhan	80.5	36.4	15.3
Lasa	105.4	60.7	5

instance, China's eastern coastal area, which boasts prosperous commodity economy, perfect transportation infrastructure, and advanced road network structure, possesses high transport efficiency with an average load coefficient around 65%. China's midwestern areas, in contrast, being limited by such factors of policy, economy, and landform, have relatively low transport efficiency with an average load coefficient of around 45%.

Engine operating condition is directly influenced by vehicle load. With the increase in the loading weight, the vehicle suffers more running resistance and ramp resistance in the course of moving. In order to maintain the average velocity and reserve power, the richer mixed gas should be provided to the engine, which will generate a smaller excess air coefficient of chamber. Under the circumstances, the mixed gas, in which gasoline accounts for a large proportion, burns rapidly with less heat loss, contributing to a higher effective power of engine. However, still its combustion remains incomplete due to the insufficient inlet, thus producing large amounts of CO and HC and leading to carbon deposition. In this case, the probability of ignition and detonation of engine surface gets significantly increased, as also the exhaust amount of $PM_{2.5}/_{10}$.

With reference to the index of load correction factors of gasoline vehicle in the guide, the load correction factors were obtained and listed in Table 7.

3.4. Degradation Correction Factors. Exposure of the running vehicle to the external environment such as sunshine, air, wind, sand, rain, and snow is inevitable. Moreover, the interaction of internal parts of vehicle also leads to the heating, wear, and corrosion. Vehicle degradation is usually divided into tangible wear, invisible wear, and general wear. Similar to other mechanical equipment, the vehicle also degrades under the technical conditions and its performance also reduces after a period of use. This is well represented by the reduction of mechanical transmission efficiency and the increase of fuel consumption, as well as poor exhaust ternary catalytic effect. These degradation results lead to direct increase in exhaust pollutant emission.

The selection of service life as a deterioration correction parameter can facilitate the calculation and analysis of emission inventories. Therefore, referring to the data information in the guide, the correction parameters of gasoline vehicle deterioration were obtained as summarized in Table 8.

4. The Vehicle Emission Inventory

4.1. The Combined Emission Factors. The combined emission factors are the most important parameters for establishing the gasoline vehicle emission inventory. The combined correction emission factors of gasoline vehicle were calculated in accordance with the actual situation by correcting the basic emission factors in different regions, like environmental characteristics, vehicle conditions, and so on. These factors were calculated by using formula (1) as follows:

$$EF_{m,i,j} = \sum_{k=3}^{5} \left(BEF_{m,i,j} \times \varphi_j \times \psi_j \times \lambda_j \times \alpha_i \times \zeta_i \times \eta_i \times \chi_j \times \frac{n_{i,j,k}}{n_{i,j}} \right) \quad (1)$$

The meaning of each symbol in the formula is summarized in Table 9.

$EF_{m,i,j}$ indicates the m type emission factor of i vehicle in the j region; $BEF_{m,i,j}$ denotes the m type basic emission factor of i vehicle in the j region; $n_{i,j}$ represents the i type vehicle population in the j region; and $n_{i,j,k}$ indicates the i type vehicle pollution in the j region that conforms to the k emission standard.

The calculation method of gasoline vehicle emission inventory is represented as follows:

$$Q_{m,i,j} = EF_{m,i,j} \times VKT_{i,j} \times N_{i,j} \times 10^{-6} \quad (2)$$

where $Q_{m,i,j}$ indicates the m type emission of i vehicle in the j region; $EF_{m,i,j}$ represents the m type emission factor of i vehicle in the j region; $VKT_{i,j}$ denotes the annual average driving distance of i vehicle in the j region; and $N_{i,j}$ indicates the i type vehicle emission in the j region.

4.2. Application Analysis

4.2.1. Regional Parameters of Zibo. According to ***2015 Statistical Yearbook of Zibo Statistical Bureau*** [16], Zibo's vehicle population was 719,000 in 2015. The huge emission from vehicles resulted in great pressure to the atmospheric environment in Zibo. Pursuant to statistical data of atmospheric environmental quality released by Zibo Environmental Protection Bureau in 2015, there were only 41 days with good air quality. Therefore, establishment of the gasoline vehicle emission inventory, which is in accordance with the actual situation of Zibo city, was expected to lay the foundation for formulation of a targeted emission control strategy.

The basic environmental parameters and average vehicle running state of Zibo city were obtained by referring to the relevant data released by the Zibo Environmental Protection Bureau and the Zibo Traffic Administration Bureau. The annual average temperature in Zibo is 13.2°C, the annual relative humidity is 57%, and the average altitude is 34.7 m. The average running velocity of gasoline vehicle is 43 $km\ h^{-1}$, the average service life of gasoline vehicle is 3–5 years, the average load factor is 50%, and the sulfur content of gasoline

Table 6: Gasoline vehicle average speed correction factor.

Vehicle emission	Velocity Range (km h^{-1})				
	<20	20–30	30–40	40–80	>80
CO	1.69	1.26	0.79	0.39	0.62
HC	1.68	1.25	0.78	0.32	0.59
NO_x	1.38	1.13	0.90	0.86	0.96
$PM_{2.5}/PM_{10}$	1.68	1.25	0.78	0.32	0.59

Data from Chinese Research Academy of Environmental Sciences—Technical Guidelines for Preparation of Air Pollutants Emission Inventory of Road Vehicles [15].

Table 7: Gasoline vehicle load correction factor.

Load Coefficient	CO	HC	NO_x	$PM_{2.5}/PM_{10}$
0	0.87	1.00	0.83	0.90
50%	1.00	1.00	1.00	1.00
60%	1.07	1.00	1.09	1.05
75%	1.16	1.00	1.21	1.13
100%	1.33	1.00	1.43	1.26

Data from Chinese Research Academy of Environmental Sciences—Technical Guidelines for Preparation of Air Pollutants Emission Inventory of Road Vehicles [15].

Table 8: Gasoline vehicle deterioration correction factor.

Pollutant	1–4 years	4–7 years	7–10 years	Above 10 years
CO	1.02	1.14	1.27	1.48
HC	1.01	1.09	1.19	1.34
NOx	1.00	1.12	1.34	1.47
$PM_{2.5}/PM_{10}$	1.01	1.15	1.26	1.45

Data from Chinese Research Academy of Environmental Sciences—Technical Guidelines for Preparation of Air Pollutants Emission Inventory of Road Vehicles [15]

is less than 50 ppm. The regional emission correction factors of Zibo, as listed in Table 10, were obtained according to Tables 3–8.

4.2.2. Regional Vehicle Characteristics. The annual average driving distance and local vehicle population are important indicators for measuring the degree of transportation development in a region, as well as the important basis for establishing regional emission inventory. Through consulting ***2015 Statistical Yearbook of Zibo Transportation Administration Bureau***, the annual average driving distance and population of different types of gasoline vehicles in Zibo were obtained. The specific data is presented in Table 11, where the numbers 1 to 4 represent minivan, middle-sized coach, light duty truck, and other gasoline vehicles, respectively.

4.2.3. The Regional Emission Inventory. The regional combined emission factors can be obtained by combining basic emission factors with correction factors in Zibo. Then the gasoline vehicle emission inventory can be obtained by combining regional vehicle characteristics. The results are listed in Table 12.

Figure 2 reveals the following conclusions:

(1) For minivan and light duty truck, the emission amount of CO and HC, respectively, accounts for 94 and 96% of the total emission amount, more than 90% of the total emissions of these two pollutants.

(2) The number of small-sized trucks is only 10% of small passenger vehicles; however, its NOx emissions account for about 40% of total NOx emissions.

(3) Large number of small passenger vehicles account for 70% of the total $PM_{2.5}/PM_{10}$ emissions and are the key models for $PM_{2.5}/PM_{10}$ emission control.

In order to compare emission estimation using average emission factors versus emission correction factors in Zibo, we calculated a new emission inventory by using average emission factors. The results are listed in Table 13.

Table 13 summarizes that the estimated total emission from gasoline vehicles in Zibo city is 140.3% higher than the actual value calculated from the average emission factor in the standard. This huge error is attributed to the different traffic conditions in different regions, which results in different revision coefficients of emission factors. For Zibo city, the average velocity is the main factor leading to the error. Thus, the total emission from gasoline vehicles in Zibo cannot be estimated by means of the average emission factors, and the corresponding correction factors should be obtained by combining the actual local traffic conditions.

4.3. Uncertainty Analysis. The uncertain factors that affect the emission inventory of traditional gasoline vehicles include the establishment of local statistical data and emission factors. In this paper, Monte Carlo uncertainty analysis method is applied to quantify the potential uncertainty of gasoline vehicle emission inventory. Simultaneity, the uncertainty range of the emission inventory (95% confidence interval) is obtained by repeated sampling method, as shown in Table 14.

By the careful consideration of various factors that may affect the establishment of emission factors, the overall uncertainty of pollutant emissions does not exceed 35%. Among them, $PM_{2.5}/PM_{10}$ has the highest uncertainty, and the relative error of total emissions is ±34.13%; furthermore, there is a significant difference in different vehicle types. This may be due to the fact that there are some differences between the national emission factors and the actual situation in Zibo. When using self-expanding simulation, the uncertainty of

Table 9: The meaning of each symbol in the formula.

Symbol	Meaning	Symbol	Meaning
BEF	Basic emission factor	λ	Altitude correction
i	Vehicle type	α	Velocity correction
j	Regional number	ζ	Deterioration correction
m	Pollutants type	η	Sulfide correction
k	Emission standard	χ	Load correction
φ	Temperature correction	n	Vehicle population
ψ	Humidity correction		

Table 10: Regional emission correction factor of Zibo City.

Correction type	φ	ψ	η	λ	α	χ	ζ
CO	1.00	1.04	0.90	1.00	0.39	1.00	1.14
HC	1.00	1.01	0.96	1.00	0.32	1.00	1.09
NO_X	1.00	0.87	0.95	1.00	0.86	1.00	1.12
$PM_{2.5}/PM_{10}$	1.00	1.00	0.56	1.00	0.32	1.00	1.15

Data from Tables 3–8.

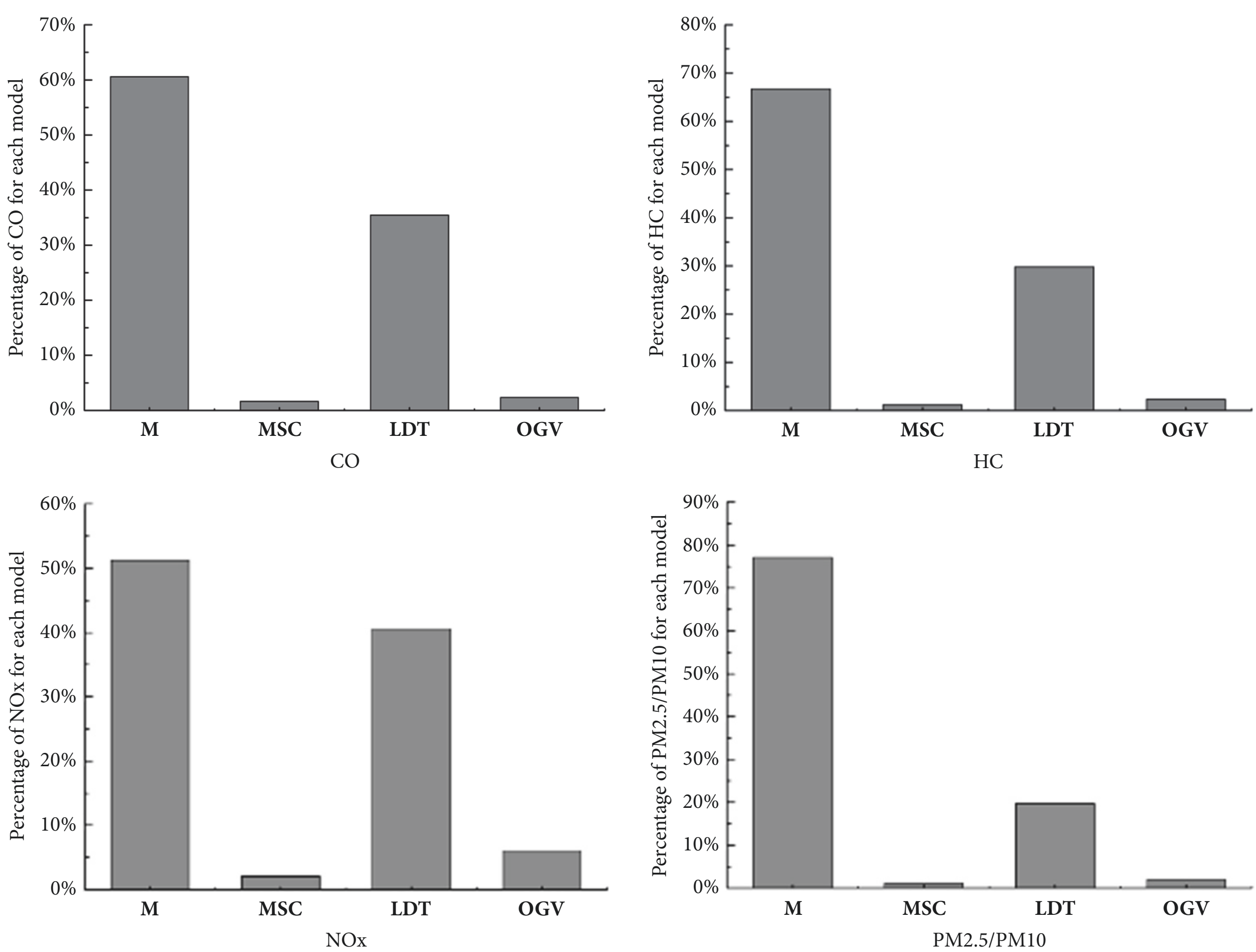

Figure 2: Emission sharing rate of each pollutant. Notes: M: minivan; MSC: middle-sized Coach; LDT: light duty truck; MDT: medium duty truck; and OGV: other gasoline vehicles.

Table 11: Annual average driving distance and population.

	1	2	3	4
Vehicle population/veh	622782	2716	46930	11446
Driving distance/km	18000	31320	31000	8000

Data from 2015 Statistical Yearbook of Zibo Transportation Administration Bureau [16].

emission factors is increased, and thus the uncertainty range of the inventory is enlarged. Compared with $PM_{2.5}/PM_{10}$, the uncertainty of other pollutants is lower, which may be due to the relatively close emission factors obtained through different ways, which leads to underestimation of its uncertainty of quantitative analysis.

According to the result of uncertainty analysis, the minivan is the most influential for the uncertainty of HC and $PM_{2.5}/PM_{10}$ emissions, and the uncertainty of CO and NOx emissions is mainly determined by light duty trucks.

4.4. Comparison Analysis. The emissions inventory established in this study was compared with the inventory developed by other scholars. We used a similar approach to vehicle types selection and calculation of emissions inventories. The results are shown in Table 15. These data include the results of gasoline vehicle emissions of Chengdu [17] (Chen et al. 2015), Zhengzhou [18] (Gong et al. 2017), Foshan [19] (Zeng et al. 2013), and Tianjin [20] (Zhang et al. 2017).

According to the comparison of the data in Table 15, there are some differences in the pollutant emissions between Zibo and other cities in China. We analyze the reasons for these differences mainly in the following three aspects. Firstly, the based year: China's emission standards have been formulated since 2000 and then updated every 3-4 years; each update brings about a reduction of about 30% of the emission factor. Secondly, the vehicle population: due to differences in urban scale and economic development level among cities, there is a big difference in vehicle population, and there is a positive correlation between vehicle population and emissions. The third is the differences between the emission factors and the correction factors. For example, the basic emission factors used by Zeng et al. are derived from the experimental data of foreign vehicles, and there is a big difference between the emission factors obtained by the Chinese road tests used in this study. Moreover, the correction factors used in the relevant research have some difference, such as Chen et al.'s study, which increased the impact of factors such as slope on vehicle emissions.

4.5. Impact in Air Quality. In this study, there is no total statistics of all atmospheric environmental pollutants; thus, it is impossible to analyze the degree of environmental impact of vehicle emissions. Referring to the conclusions of other similar cities, gasoline vehicles account for total CO, HC, NOx, and PM2.5/PM10 by 20%, 30%, 25%, and 12%, respectively. According to the comparison of the research results, the pollutant emission factors obtained in this study are approximately 41% of the average emission factors.

We are currently conducting larger vehicle road trials to update and obtain more detailed emission factors and develop relevant emissions inventory software to accommodate international research needs, including China.

5. Summary and Outlook

Considering that gasoline vehicle emission conditions differ significantly in different areas, the study determining basic emission factors with reference to the relevant guidelines, correcting factors based on regional differences, combined with driving distance and vehicle population, and other information of local gasoline vehicles finally figures out the method of establishing gasoline vehicle emission inventory, including the following.

(1) The gasoline vehicles are classified into four types based on their usage, and basic emission factors are determined according to the relevant guidelines. Notably, the emission estimation from the revised emission factor and the average emission factor are significantly different. This difference is attributed to the fact that the average velocity of gasoline vehicle in Zibo city is $43\,\text{km h}^{-1}$ and the corresponding velocity correction coefficient is 0.39; thus the velocity correction factor is far less than the standard. Therefore, it is important to identify local emission factors in conjunction with local factors when emissions from an area are estimated. Moreover, velocity is an important factor affecting emissions.

(2) After the analysis of the differences in environmental parameters in different regions, average velocity, load coefficients, and deterioration factors, the corrections factors were confirmed. Moreover, their influences on the gasoline vehicle emission were systematically investigated. Comparative analysis of the emission estimations from other provinces or regions in China indicates that the difference in emission factors in different regions is due to different major factors. For example, the major emission factor of Chongqing Province is slope and Zibo city terrain is dominated by plain; therefore, the determination of Zibo city emission factor does not need to consider the slope factor.

(3) The computing method of gasoline vehicle emission inventory for different cities was established, considering Zibo city as an applied research example. Emission share rates of different vehicle types were analyzed, and finally the focus of governance was determined.

This study can extend theoretical support to quantitative evaluation on gasoline vehicle emission conditions in different areas and lay foundation for providing well-targeted regulation measures. In developing countries, medium-sized cities such as Zibo are very common, so this study has practical significance for the international urban emission estimation similar to Zibo urban cluster.

Table 12: Pollutant emission inventory of gasoline vehicle in Zibo City.

Vehicle type	Total emission volume (t/a)			
	CO	HC	NO_X	$PM_{2.5}/PM_{10}$
Minivan	4138.54	497.61	261.71	41.45
Middle-sized Coach	112.80	8.55	10.55	0.62
Light Duty Truck	2422.53	221.98	207.21	10.58
Other Gasoline Vehicles	160.67	17.42	30.89	1.08
Total	6834.55	745.57	510.36	53.73

Table 13: Pollutant emission inventory of gasoline vehicle in Zibo City referring to average emission factors.

Vehicle type	Total emission volume (t/a)			
	CO	HC	NO_X	$PM_{2.5}/PM_{10}$
Minivan	9944.94	1195.76	628.88	99.61
Middle-sized Coach	271.07	20.55	25.34	1.49
Light Duty Truck	5821.36	533.43	497.93	25.43
Other Gasoline Vehicles	386.10	41.86	74.24	2.59
Total	16423.47	1791.60	1226.39	129.11

Table 14: Uncertainly analysis of the emission inventory of gasoline vehicles.

Pollutants	Vehicle type	Estimated value/t	Simulated average/t	95% confidence interval/t	Relative error
CO	Minivan	4138.54	7838.56	[6214.76,9462.36]	±20.72%
	Middle-sized Coach	112.80	185.30	[130.63,239.98]	±29.50%
	Light Duty Truck	2422.53	3198.93	[2128.35,4269.51]	±33.47%
	Other Gasoline Vehicles	160.67	260.80	[178.43,343.17]	±31.58%
	Total	**6834.55**	**11483.59**	**[8652.17,14315.02]**	**±24.66%**
HC	Minivan	497.61	911.55	[581.55,1241.56]	±36.20%
	Middle-sized Coach	8.55	18.26	[13.69,22.83]	±25.03%
	Light Duty Truck	221.98	423.32	[355.85,490.80]	±15.94%
	Other Gasoline Vehicles	17.42	27.45	[19.87,35.02]	±27.61%
	Total	**745.57**	**1380.58**	**[970.96,1790.21]**	**±29.67%**
NO_x	Minivan	261.71	546.78	[431.45,662.11]	±21.09%
	Middle-sized Coach	10.55	20.77	[16.10,25.44]	±22.48%
	Light Duty Truck	207.21	293.43	[190.33,396.52]	±35.14%
	Other Gasoline Vehicles	30.89	67.25	[50.39,84.12]	±25.07%
	Total	**510.36**	**928.23**	**[688.27,1168.19]**	**±25.85%**
$PM_{2.5}/PM_{10}$	Minivan	41.45	80.76	[51.81,109.71]	±35.85%
	Middle-sized Coach	0.62	0.97	[0.77,1.16]	±20.62%
	Light Duty Truck	10.58	16.19	[11.71,20.68]	±27.67%
	Other Gasoline Vehicles	1.08	1.73	[1.35,2.11]	±21.97%
	Total	**53.73**	**99.65**	**[65.64,133.66]**	**±34.13%**

Table 15: Comparison of emission inventory between Zibo and other regions.

Region	Based year	Vehicle population (veh)	Emissions ($\times 10^4$ t)				Sources
			CO	HC	NO_x	$PM_{2.5}/PM_{10}$	
Zibo	2015	68.4×10^4	0.68	0.08	0.05	0.0053	This study
Chengdu	2012	144.3×10^4	2.59	-	0.21	0.0153	Chen et al. 2015
Zhengzhou	2013	123.3×10^4	2.34	0.23	0.19	0.0121	Gong et al.2017
Foshan	2010	70.2×10^4	1.13	-	0.06	0.0069	Zeng et al. 2013
Tianjin	2013	155.6×10^4	1.82	0.20	0.14	0.0143	Zhang et al.2017

Note: "-" indicates no data.

Data Availability

We have generated links to all the data for others to get and a web page is added as follows: Data.htm. Besides, our original data comes from the following URL: https://wenku.baidu.com/view/586194e3b307e87101f696e3.html?qq-pf-to=pcqq.c2c.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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