ISSN: 2710-0723

Analysis of Motor Vehicle Exhaust Emission Characteristics based on PEMS in Mountain Cities

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Abstract

Taking a gasoline vehicle in Chongqing as the research object, PEMS testing technology was used to study the exhaust emission characteristics of motor vehicles during driving on roads in the central urban area of Chongqing. The focus was on analyzing the data situation and emission rates of different mountain scenes, and analyzing the carbon emission characteristics of road traffic in Chongqing. Through the analysis and comparison of data, it is shown that in terms of the carbon emissions characteristics of road traffic in Chongqing, through long-term measurement data analysis of comprehensive road conditions in the central urban area of Chongqing, it is found that compared with the general emissions of common small vehicles (100-150 kg/km), the comprehensive carbon emissions of road traffic in Chongqing are significantly higher. This also indicates to some extent that the carbon emissions of road conditions in mountainous cities are higher than those in plain cities.

Keywords

Mountain City; Road Traffic Carbon Emissions; PEMS; Motor Vehicle.

1. Introduction

In September 2020, at the 75th United Nations General Assembly, China committed to peaking carbon dioxide emissions by 2030 and striving to achieve carbon neutrality by 2060. In October 2021, the "Opinions on Fully and Accurately Implementing the New Development Concept and Doing a Good Job in Carbon Peaking and Carbon Neutrality" and the "Action Plan for Carbon Peaking before 2030" improved the top-level design of carbon peaking and carbon neutrality. In June 2022, the implementation opinions of the relevant departments of transportation, including the "Opinions of the Central Committee of the Communist Party of China and the State Council on Completely, Accurately, and Comprehensively Implementing the New Development Concept and Doing a Good Job of Carbon Peak and Carbon Neutrality", were issued. In January 2022, multiple ministries and commissions in Chongqing jointly issued the "Suggestions on Promoting Carbon Peak and Carbon Neutrality Work" and planned the "1+2+6+N" policy system framework.For the actual background.The road traffic environment in mountainous cities is complex: Chongqing has unique geographical conditions and relatively large longitudinal slopes of roads. If the longitudinal slope of more than 20% of the roads in the main urban area reaches or exceeds the limit slope (8%), the energy consumption level of vehicles is relatively higher than the national level. The high rate of motorized travel has caused severe road traffic congestion: According to authoritative reports, Chongqing has become the most congested city in China with a peak commuting congestion index of 1.936. Traffic congestion leads to low-speed driving of motor vehicles, resulting in an average increase of at least 30% in additional energy consumption and carbon emissions. The high summer temperatures in Chongqing result in high energy consumption for vehicles: The long and hot summer in Chongqing leads to a significant increase in additional energy consumption for car air

ISSN: 2710-0723

conditioning and body cooling systems. The meteorological conditions of calm wind and high inversion frequency near the ground are also unfavorable for the diffusion of atmospheric pollutants.

In recent years, both domestically and internationally, PEMS detection technology has been used to detect the rear end of motor vehicles Extensive research has been conducted on gas emissions. Song Guohua et al Dazhou Kei car's The exhaust emissions were collected and compared. Zhang Xiao et al.[2]used PEMS to collect Real time exhaust emission data at intersections and road sections were discussed The emission characteristics of motor vehicle exhaust at the fork. Chen Yantao [1,3] adopts PEMS technology The study investigated the CO, HC, and NOx emissions of motor vehicles such as heavy-duty buses Road emission analysis. Cheng Ying et al. [4] used PEMS to study a heavy-duty vehicle CO, HC, and NOx emissions from diesel vehicles, and compare the measured results with The COPERT and MOBILE models were compared. Wang [5], Liu et al. [6] PEMS was used to detect the actual road pollutant emissions of Beijing buses Emissions and fuel consumption characteristics, specifically including CO2, CO, HC, NOx, PM All or part of the pollutants. At the same time, both domestically and internationally, there is a growing demand for garbage collection vehicles [7] Buses [8], taxis [9], hybrid vehicles [10-11], diesel vehicles [12-16], off road Extensive research has been conducted on the exhaust pollution emission characteristics of vehicles [17].

2. Carbon Emission Vehicle Exhaust Emission Experiment

2.1. Experimental Method and Progress

2.1.1. Preliminary Preparation Work for the Experiment

Strict selection of experimental vehicle models is required to ensure ease of on-road experimentation.

Attempt to power the vehicle, but encounter voltage instability, overheating of the connecting wires, and ultimately purchase a lithium-ion battery for power supply.

Gas calibration requires strict selection of corresponding concentration gas cylinders to ensure the preparation of experimental data.

Operating steps of on-board exhaust gas analyzer.

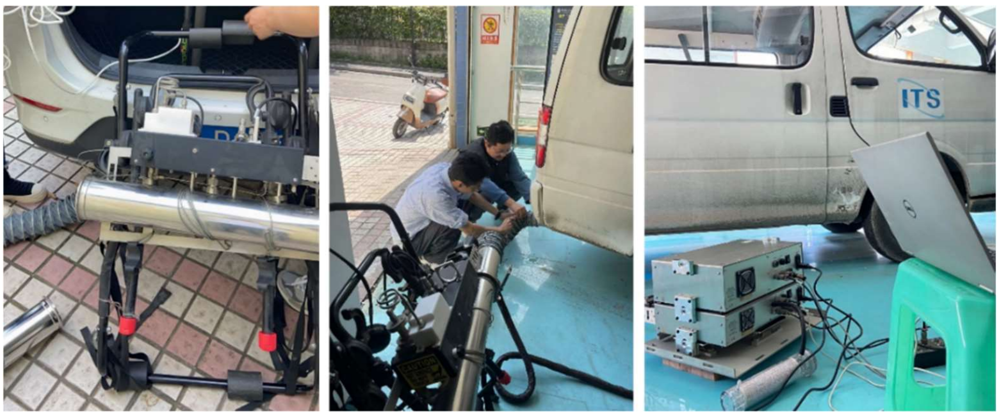

Figure 1. Preliminary Preparation for the Experiment

2.1.2. Trial and Calibration of Handheld Gas Detectors

Location for road testing monitoring: Select a location downwind of the road, about 5 meters ahead of the stop line at the intersection, about 5-10 meters away from the curb, and hold a height of about 1.5 meters for monitoring.

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Figure 2. Trial and Calibration of Handheld Gas Detectors

2.1.3. On Campus Road Testing

The exhaust pipe and equipment connecting pipe fell during the experiment, and finally, they were fixed by wrapping a thin steel wire around the connection between the fuel tank and the pipe.

Figure 3. On campus road testing

2.1.4. Road Test Experiment

Connect the FEM module to the sampling tube using a communication cable Stable connection of exhaust gas connecting pipe Turn off the equipment and remove the Flux tube after cooling GPS placed on the roof (better signal).

Figure 4. Road Test Experiment

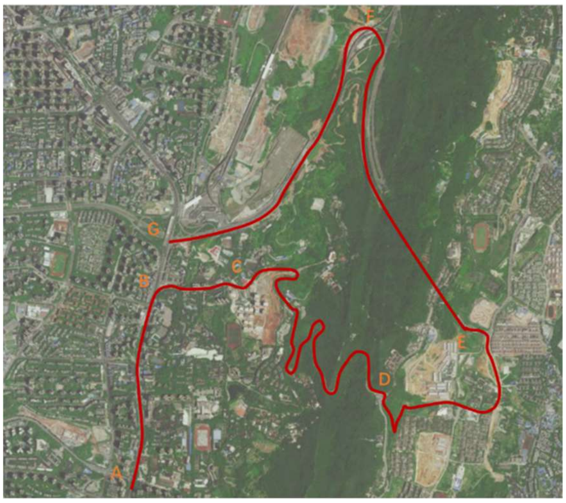

Figure 5. Road Testing Experiment Route 1

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A to B six to four kilometer interchanges; B to C Xuefu Avenue - the main road with ups and downs; Steep curved slopes from C to D; D to E steep bend slope Guangqian Road; E to F Yellow Tunnel Long Tunnel; F to G Jiangnan Interchange - Four kilometer Interchange; Channel Road - Expressway.

Figure 6. Road Testing Experiment Route 2

A to B four kilometer interchange - Huanggepo interchange: Nanping Tunnel; B to C Chongqing Yangtze River Bridge; C to D on steep slopes in the South Park; D to E Zengjiayan Tunnel (detected using a handheld gas detector); E to F Zengjiayan Jialing River Bridge; F to G Liujiatai Tunnel; G to H Xingsheng Avenue Xinjian Avenue Yuli Avenue Wuhong Road: main road; H to I Chaotianmen Bridge; J to K Panlong Interchange - Jiangnan Interchange: Expressway.

2.2. Experimental Equipment Information

The equipment information is shown in Table 1.

Table 1. Test Vehicle Information

Vehicle model	Chevrolet SGM7100JBA2	Engine model	202390488
Fuel type	92 gasoline	displacement	1.0
Total mass	1550kg approved	To carry	5 passengers
Service life	3 years	mileage	70193
Overall size	4474*1730*1471mm	Curb weight	1120kg

2.3. Summary of this Chapter

This chapter mainly introduces the experimental plan, steps, and equipment for carbon emission vehicle exhaust emission experiments. Motor vehicle carbon emission monitoring includes traffic characteristic data, road parameters, motor vehicle driving characteristic data, and carbon emission data collection; The experimental route selection includes typical scenarios such as slopes, bends, and tunnels. From the preparation work in the early stage of the experiment, trial calibration of instruments and equipment, on-campus road testing, road testing experiments, to data post-processing and analysis, a total of 7 experimental personnel conducted more than 40 days. The experimental area includes 5 central urban areas such as Nan'an and Yuzhong, collecting more than 20 data items such as speed, elevation, exhaust pipe temperature, and CO2 emission intensity, and obtaining more than 4000 effective gas emission data. The SEMTECH-ECOSTAR in vehicle exhaust analysis system, one of the few systems in China, was introduced in the experiment to ensure the accuracy of data in motor vehicle pollutant emissions experiments. The obtained traffic carbon emission data will provide strong data support for subsequent research on the influencing factors and prediction of road traffic carbon emissions.

3. Characteristics and Trends of Carbon Emissions

3.1. Carbon Emission Characteristics of Road Traffic in Chongqing

3.1.1. Analysis of Carbon Emission Characteristics in Chongqing City

(1) Time series characteristics of carbon emissions in Chongqing

Based on the data from the National Bureau of Statistics [18] and the China Carbon Accounting Database [19], this study compares the carbon dioxide emission data, per capita carbon dioxide emission intensity, and per unit GDP carbon dioxide emission intensity of Chongqing, Beijing, Shanghai, Tianjin, and Chengdu from 1997 to 2019, and analyzes the carbon emission characteristics of Chongqing from a time series perspective.

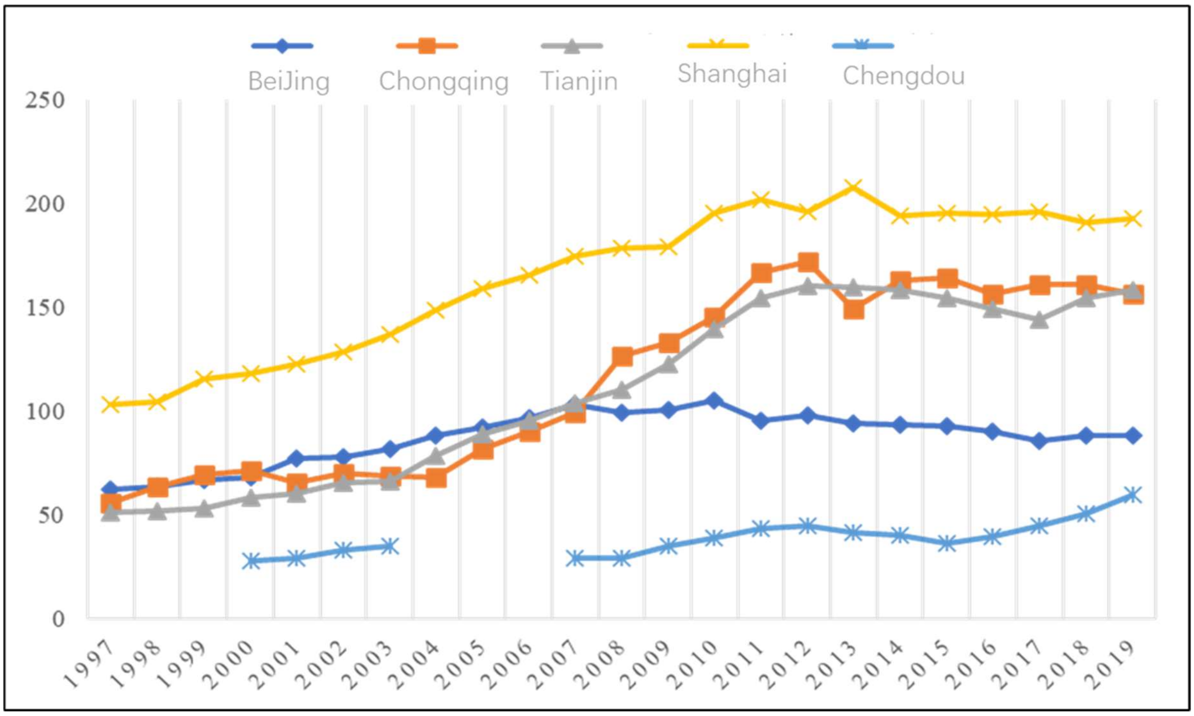

Figure 7. Carbon dioxide emissions from five cities from 1997 to 2019 (in millions of tons) (Data source: China Carbon Accounting Database (CEADs))

The Secondary sector of the economy of Shanghai, Chongqing and Tianjin is relatively developed and plays an important role in economic development. According to Figure 7, the CO2 emissions of these three cities are relatively high. The total carbon emissions of Chongqing are equal to that of Tianjin, and tend to be stable.

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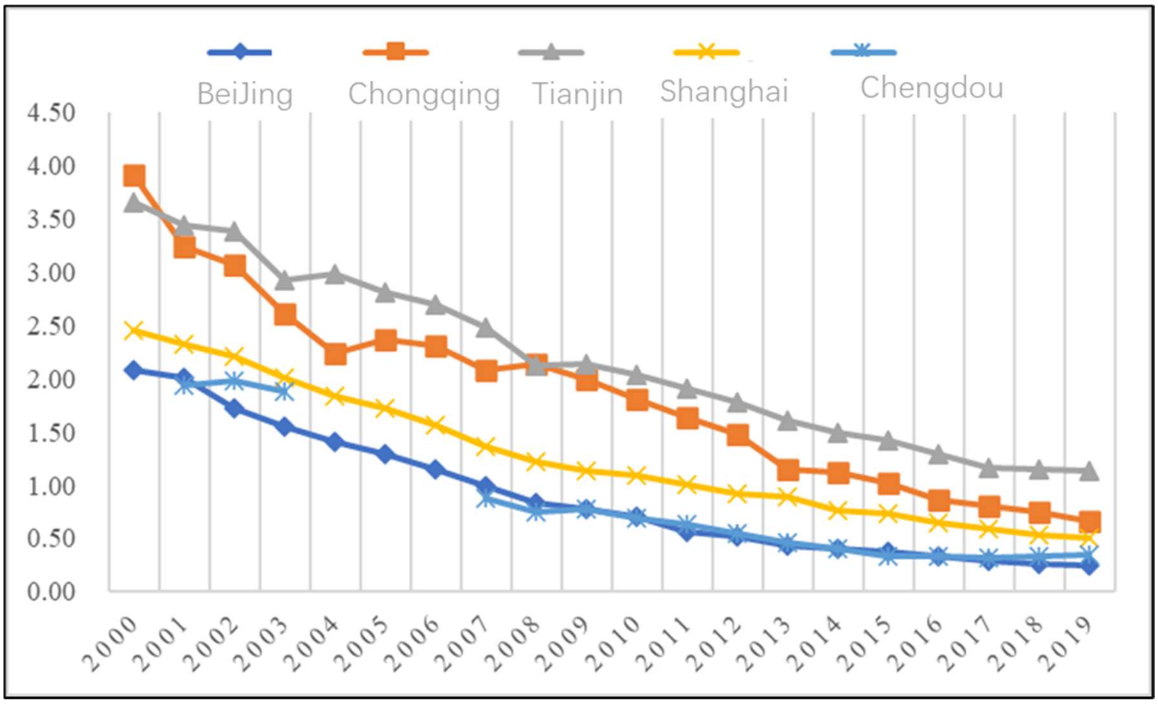

Figure 8. Carbon dioxide emissions per unit of GDP in five cities from 2000 to 2019 (unit: 10000 tons/billion yuan)

(Data source: China Carbon Accounting Database (CEADs), National Bureau of Statistics)

As shown in Figure 8, the carbon emission intensity per unit of GDP in Chongqing is at a relatively high level among the four municipalities directly under the central government, indicating that the industrial energy consumption in Chongqing is relatively high and the economic output is relatively low. However, in recent years, the carbon emission intensity per unit of GDP has gradually decreased compared to developed cities. The proportion of Secondary sector of the economy in Chengdu is smaller than that in Chongqing, and the carbon emission intensity is at a low level among the five cities.

According to the concept of environmental Kuznets curve, it is assumed that the emergence of carbon peak is in line with the law of economic development, and one of the cities will generally go through the process of Deindustrialization after industrialization. Highly industrialized cities with complete infrastructure and post industrialized cities with service-oriented economic structure (such as Beijing and Shanghai) have basically reached the peak of CO2 emissions and achieved decoupling between economic growth and emissions [20] Since the Olympic Games, the city has started "Deindustrialization" development, and its total carbon emissions have steadily declined year by year. As an important industrial city located in the western region, Chongqing has a gap in infrastructure compared to developed cities. Although Chongqing has a complete range of industries, some industries are still in the process of upgrading. The total carbon emissions in 2019 were 1.8 times that of Beijing, and have not yet reached their peak.

(2) Characteristics of carbon emission spatial pattern in Chongqing

Based on the land use changes in Chongqing from 2000 to 2018, this study investigates the spatial pattern of carbon emissions in Chongqing. The only districts and counties in Chongqing with carbon emissions exceeding 1.4 million tons in 2000 were Dadukou District, where Chongqing Iron and Steel Plant was located. However, in 2010, 2015 and 2018, the carbon emissions in the central urban area exceeded 1.4 million tons, and the carbon emissions increased significantly.With the development of cities and the gradual relocation of high energy consumption, high pollution, and extensive enterprises such as the steel industry from the central urban area, the carbon emissions of various districts and counties within the urban area

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have significantly increased. However, the relocation of highly polluting enterprises has not significantly reduced carbon emissions in the central urban area, and the carbon emissions in urban areas, especially in the central urban area, are relatively high.

3.1.2. Carbon Emission Characteristics in the Transportation Sector of Chongqing

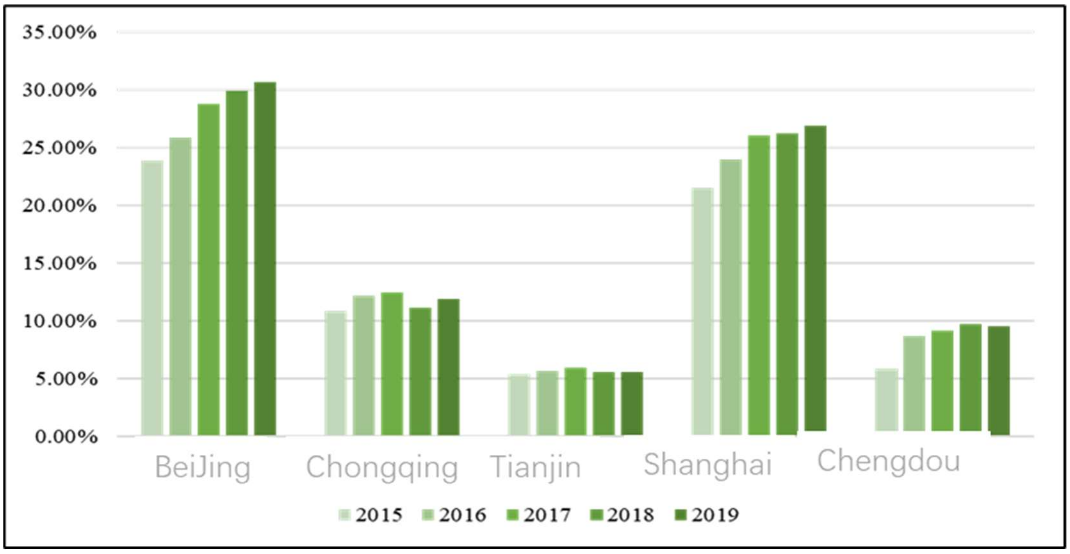

Figure 9. Proportion of CO2 emissions from the transportation industry in the total amount of the five Provinces of China

(Data source: China Carbon Accounting Database (CEADs))

According to Figure 9, in terms of the proportion of urban transportation carbon emissions to the total amount, Tianjin has the lowest proportion and has gradually decreased. Beijing has the highest proportion and gradually increased to 30%, while Shanghai has gradually increased to over 25%. It can be seen that the transportation carbon emission reduction work of service-oriented socio-economic cities has a significant impact on the overall emission reduction goals of the city. The economic proportion of Secondary sector of the economy in Chongqing is relatively high, and the proportion of traffic carbon emissions in the total amount hovers between 10% and 15%, with an insignificant growth trend.Beijing and Shanghai have developed Tertiary sector of the economy and become service-oriented socio-economic cities. The proportion of the three industries in Sichuan Province and Chongqing City is basically the same, and there is also overlap in the industrial segmentation of the two provinces and cities. The pillar industries in Sichuan Province mainly include electronic information industry, equipment manufacturing industry, food and beverage industry, etc; The main pillar industries in Chongqing include automobile manufacturing, electronic information industry, equipment manufacturing, etc. This indicates that the two provinces and cities have similar socio-economic development and are more comparable in terms of transportation carbon emissions. The proportion of transportation carbon emissions in Chongqing is higher than that in Sichuan Province, which may be related to factors other than economic factors such as urban transportation environment characteristics and residents' travel structure.

(2) Carbon Emission Characteristics of Road Traffic in Chongqing

According to the overall requirements of China's transportation carbon peak, the accounting of road traffic carbon emissions should cover all dimensions, including road operating equipment, passenger cars, non operating trucks, and other transportation methods, including transportation vehicles and mobile sources. The "carbon emissions" calculated refer to the direct generation of fossil fuels (diesel, gasoline, natural gas), excluding the indirect generation of carbon dioxide emissions from electricity use.

3.1.3. Road Traffic Characteristics of Chongqing City

(1) Analysis of Road Traffic Characteristics

Chongqing is located in the transition zone from the Sichuan Basin to the mountains around the basin. The overall terrain is high in the east and low in the west, gradually lowering from the north and south ends to the Yangtze River valley. The central urban area is mainly composed of parallel valleys arranged at intervals between low mountains and hills.

Special terrain conditions create unique urban characteristics. Taking the central urban area as an example, cities are distributed between the "four mountains and three troughs", with a multi cluster and multi center urban structure. The urban road network structure is free form, and urban roads are built based on the terrain and terrain, mainly connecting various clusters through bridges and tunnels crossing mountains and rivers.

In summary, the carbon emission characteristics of road traffic in Chongqing are summarized.

Feature 1: Complex road alignment conditions increase vehicle energy consumption.

Within Chongqing, there are high mountains and deep valleys, with crisscrossing gullies. The mountainous area accounts for 76%, hills account for 22%, and river valleys and flat dams only account for 2%. The most prominent road feature in mountainous cities compared to plain cities is the numerous sloping and curved sections. Different road slopes correspond to different slope resistance, which in turn changes the force balance of the vehicle, leading to changes in the traction of the vehicle's engine and corresponding emissions changes. Research has found that without considering the impact of slope, the pollutant emissions are only 33% - 55% of the true value.

In addition to the slope, the road curvature in mountainous cities can also change the driving behavior of drivers, thereby affecting acceleration resistance. The acceleration, average speed, and maximum speed of a driving vehicle at different average speeds will experience significant speed fluctuations at road bends. Road curvature causes regular changes in vehicle operating speed, frequent braking and acceleration, resulting in incomplete combustion of gasoline and an increase in vehicle fuel consumption.

Chongqing has unique geographical conditions, with relatively large road slopes and curves. If the longitudinal slope of the main urban roads reaches or exceeds the limit slope, the energy consumption level of vehicles is relatively higher than the national level.

Feature 2: The problem of road congestion is prominent, resulting in energy waste.

The free road network leads to unreasonable distribution of some road grades and unclear road functions. For example, Xuefu Avenue in Nan'an District is classified as an expressway, but there are many openings on both sides of the road, which does not meet the requirements of expressway standards. Except for expressways and main roads, other urban roads have more sloping and curved sections, and fewer straight and flat sections. The special urban structure and road network structure lead to concentrated urban traffic flow, significant tidal phenomena, and overload of traffic flow on main roads, which are the characteristics of road congestion in central urban areas.

The 2021 Annual Report on Traffic Operation in the Central Urban Area of Chongqing shows that the demand for travel within the Inner Ring Road is stabilizing. After the implementation of bridge and tunnel staggered traffic, the number of vehicles on the network during peak hours has decreased, and congestion has significantly alleviated. The demand for travel beyond the Inner Ring Road and through the two mountains has grown rapidly, and the scope of congestion has expanded. Traffic congestion leads to low-speed driving of motor vehicles, resulting in additional unnecessary energy consumption.

Feature 3: High motorized travel rate among residents and low proportion of green travel.

ISSN: 2710-0723

In terms of residents' travel characteristics, due to the large terrain fluctuations in mountainous cities, the use of low-carbon transportation methods such as walking and non motorized vehicles is relatively difficult, and the rate of motorized travel is relatively high. According to data released by authoritative media in various regions, in 2021, Chongqing (60.8%) had a lower proportion of green travel compared to cities such as Beijing (74.7%), Shanghai (72.1%), and Chengdu (67%). Compared with cities such as Beijing (57.4%), Shanghai (58%), and Shenzhen (60%), Chongqing (36.2%) has a lower share of rail transit in public transportation. The proportion of green and low-carbon travel for residents has a significant room for improvement, which has a significant impact on traffic carbon reduction.

(2) Typical Scenarios of Road Traffic in Chongqing

Classify the typical road traffic scenes in Chongqing that are different from other cities, and summarize the following four types of typical road scenes in mountainous cities.

Slope bend section: The curve corresponds to the linear design of the road plane, distinguished by curvature division (straight line, circular curve, transition curve). The design of the longitudinal section of the road corresponding to the ramp should consider three aspects: longitudinal slope, slope length, and composite slope.

River crossing bridges and mountain crossing tunnels: The urban roads in the central urban area of Chongqing include numerous bridges and tunnels, including 34 river crossing road bridges and 21 mountain crossing road tunnels.

Complex interchanges: Classified by planar geometric shapes, common interchanges have three Y-shaped, three T-shaped, trumpet shaped, cotyledon shaped, diamond shaped, cloverleaf shaped, turbine shaped, and circular shapes. There are many other combined interchanges in the central urban area of Chongqing, all of which belong to complex interchanges.

Irregular intersections: In addition to common intersections such as intersections, the central urban area of Chongqing has Y-shaped, X-shaped, and oblique T-shaped intersections. The intersection forms are diverse and the longitudinal slope is large, and some intersecting roads are curved sections.

3.1.4. Summary

In terms of carbon dioxide emissions, Chongqing has a large area of jurisdiction, a large population, a high proportion of the Secondary sector of the economy, and the industry is biased towards heavy industry. The overall carbon emissions are high, and they have declined steadily since 2012. The per capita emissions and per unit GDP emission intensity are basically at the same level as those of developed cities in China; From the perspective of carbon emission space, the carbon emissions in the main urban areas are generally higher than those in other districts and counties; In terms of carbon emissions from road transportation, the proportion of carbon dioxide emissions from Chongqing's transportation industry to the total emissions has been maintained at around 12% in recent years. Road transportation carbon emissions account for 83% of the carbon emissions under the concept of "big transportation", with road freight and passenger car emissions accounting for a relatively high proportion; From the perspective of road traffic environment, the poor linear conditions of roads, prominent congestion issues, high proportion of motorized travel among residents, and low sharing rate of rail transit all contribute to an increase in road traffic energy consumption and carbon dioxide emissions.

3.2. Carbon Emission Factors and Calculation Methods of Commonly Used Fossil Fuels

3.2.1. Carbon Emission Factors of Commonly Used Fossil Fuels

Emission factors are greenhouse gas emission coefficients that represent the amount of production or consumption per unit, such as the carbon dioxide generated per unit of fossil fuel combustion.

ISSN: 2710-0723

According to the "Guidelines for Calculating and Reporting Greenhouse Gas Emissions from Land Transport Enterprises (Trial)" released by the National Development and Reform Commission in 2015, the following factors should be considered when obtaining greenhouse gas emission factors: clear sources, credibility, adaptability, and timeliness. Use the data provided in relevant guidelines and text. However, the state encourages the measurement or calculation of emission factors through direct measurement, energy balance, or material balance methods within industrial enterprises. The measured values of emission factors have a higher priority than the default reference values of emission factors.

When selecting commonly used fossil fuel emission factors in China, the China Carbon Accounting Database combines the default emission factors for fossil fuels specified in the IPCC 2006 document and the "Guidelines for the Preparation of Provincial Greenhouse Gas Inventories (Trial)" released by the National Development and Reform Commission in 2011. According to the measurement research on 100 coal samples from 602 largest coal mining areas in China, the emission coefficients recommended by the IPCC and the National Development and Reform Commission are often higher than the actual emission coefficients.

3.2.2. Carbon Emission Calculation Method

China lacks official statistical data on CO2 emissions, and a large amount of research focuses on the calculation of carbon emissions. Due to inconsistencies in modeling principles and indicator systems, there are significant differences in the carbon emissions calculated using different methods, making it difficult to provide relatively accurate estimates.

Compared with fixed source emissions from industry and construction, the complexity of transportation systems and the characteristics of mobile carbon sources increase the difficulty of calculating carbon emissions. By combining strategies and utilizing multiple methods for measuring transportation carbon emissions, the overall error can be reduced. The international methods for estimating carbon emissions in the transportation sector are mainly based on the IPCC mobile emission source measurement algorithm. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the IPCC Guidelines) issued by the Intergovernmental Panel on Climate Change of the United Nations provides detailed operational methods and rules for countries and regions to carry out current carbon emission calculations. According to the IPCC Guidelines, the carbon emission coefficient method, also known as the IPCC mobile emission source measurement algorithm, is mainly used for calculating carbon emissions in the transportation industry.

There are two main types of calculation methods for carbon emissions from current road traffic activities, which are used to calculate total emissions under different research objectives or emissions under different modes of transportation: one is the "top-down" method, which calculates traffic carbon emissions through the carbon emission coefficients of various energy sources used by transportation vehicles and the total consumption data of each energy source, The accuracy of calculating carbon emissions from urban road traffic depends on the level of detailed data obtained; Another type of "bottom-up" method calculates transportation carbon emissions through data such as the number of vehicles in use, mileage, unit energy consumption, and energy consumption structure, combined with carbon emission coefficients of various energy sources.

The analysis of carbon emissions status, intensity, and structure in the previous text reflects that the characteristics of transportation carbon emissions in Chongqing are mainly based on the "top-down" method. The analysis data of China's carbon accounting database mainly calculates the total carbon emissions of each region through the fuel consumption of the transportation industry, low fuel calorific value, and carbon emission factors.

In order to cooperate with the acquisition of survey data in the "bottom-up" method and more accurately monitor the emissions of motor vehicles, foreign researchers and researchers have developed the RDE (Real Drive Emission) test method. RDE refers to the pollutant emissions of vehicles when driving on the actual road. Compared with traditional laboratory testing, RDE testing is closer to the actual environment and can more accurately evaluate the emissions of motor vehicles. The RDE test is based on the Portable Emission Measurement System (PEMS), which can actually measure the emissions and operating conditions of the vehicle during actual driving by the driver. Based on the RDE test, scholars at home and abroad have used a variety of model methods to quantify the emission characteristics of motor vehicle pollutants, and have achieved great research results.

3.2.3. Selection of Calculation Methods

The calculation method in this article is mainly based on the "bottom-up" method. Firstly, conduct RED testing experiments to accurately obtain individual vehicle carbon emissions under different road scenarios using vehicle in vehicle emission testing technology. Then, analyze emission factors and total emissions, and use them as the basic data for subsequent carbon emission prediction models. Finally, based on the idea of combining the carbon emissions of individual motor vehicles in different scenarios with the number of kilometers traveled, and considering the carbon emission factors in different scenarios to calculate the carbon emissions of motor vehicles, a model is constructed to predict the total regional carbon emissions.

4. Analysis of Factors Affecting Carbon Emissions

4.1. Overview of Experimental Data

In order to explore the characteristics of carbon emissions from road traffic in Chongqing and summarize the development path serving the carbon reduction of road traffic in Chongqing, this experiment quantitatively analyzed the carbon emissions from road traffic in different scenarios in Chongqing. The following figure shows a visual display of the overall experimental data. The color of the marked points in the figure changes from green to red as the instantaneous displacement of CO2 increases.

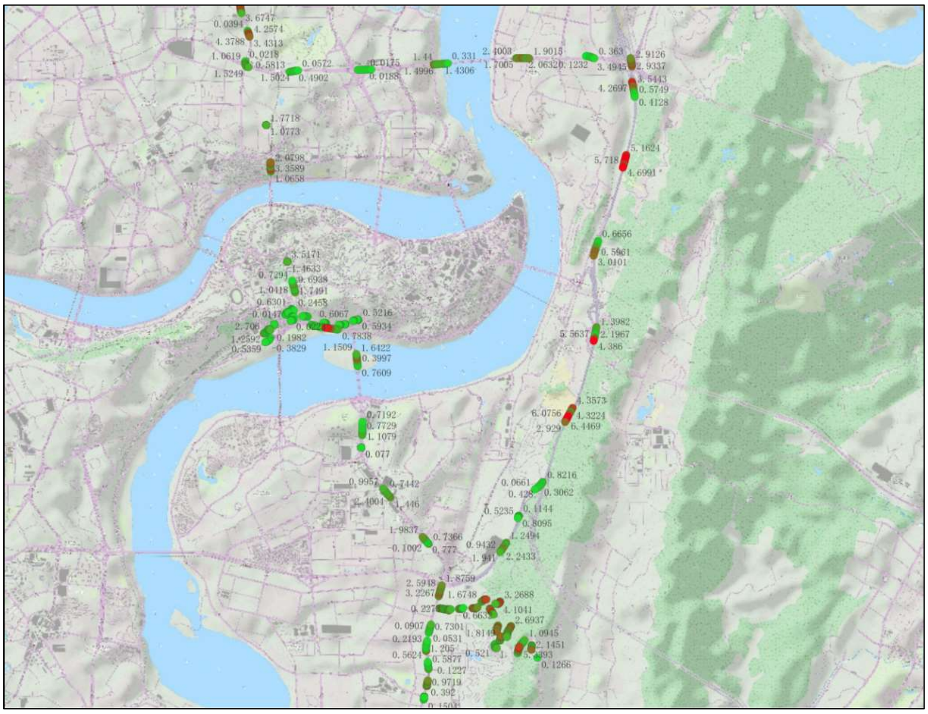

Figure 10. Overview of Carbon Emission Experimental Data

This experiment divides carbon emission scenarios into straight sections, uphill sections, downhill sections, curved sections, slope curved sections, cross river bridge sections, and complex interchange sections. The data will be analyzed and displayed below.

4.2. Straight Road Sections

The survey section is located on Yunan Avenue, which is relatively straight. In this experiment, one section was selected for analysis, with a direction from south to north. The analysis of carbon emission data in the straight section is shown in Figures 11. it can be seen that the CO2 emission rate in this straight section is relatively low, at 70.455g/km.

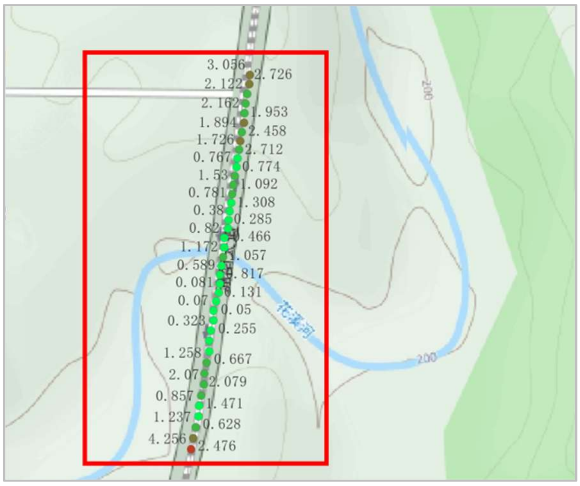

Figure 11. Carbon Emission Data Chart for Straight Sections

4.3. Uphill Section

The survey section is located on the Inner Ring Expressway, with obvious uphill phenomena. This experiment selected one section for analysis, which runs from north to south. The analysis of carbon emission data in the uphill section is shown in Figure 12. the CO2 emission rate in this uphill section is relatively high, at 305.48g/km.

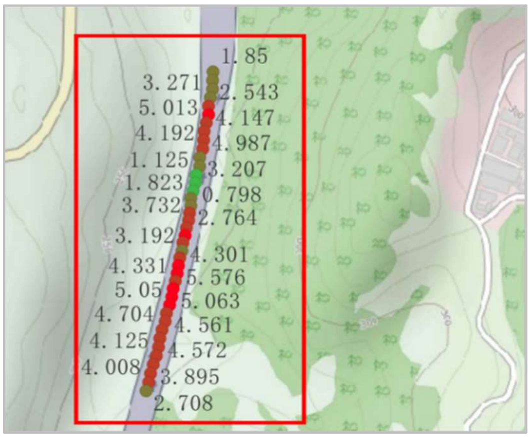

Figure 12. Carbon Emission Data for Uphill Sections

4.4. Downhill Section

The survey section is located on Yunan Avenue, with obvious downhill phenomena. This experiment selected one section for analysis, which runs from south to north. The analysis of carbon emission data in the downhill section is shown in Figure 13. the CO2 emission rate in this downhill section is relatively low, at 53.904g/km.

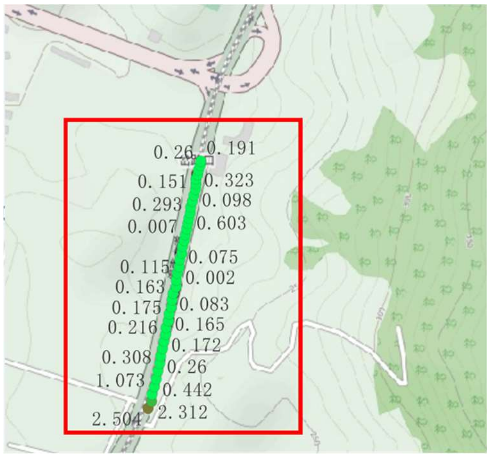

Figure 13. Carbon Emission Data for Downhill Sections

4.5. Curved Road Sections

The survey section is located on the Golden Highway, with obvious bends. This experiment selected one section for analysis, which runs from north to southwest. The analysis of carbon emission data in the curve section is shown in Figure 14. the CO2 emission rate in this bend section is slightly higher, at 126.334g/km.

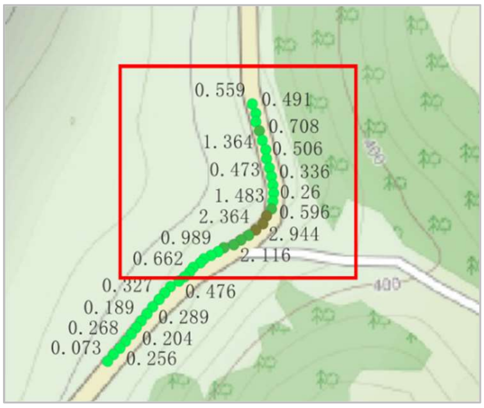

Figure 14. Carbon Emission Data for Curve Sections

4.6. Summary of Experimental Data

The carbon emission rate of carbon dioxide per kilometer from motor vehicles generally varies based on factors such as vehicle type, engine technology level, and fuel type. According to international practice, the carbon emission rate of motor vehicle carbon dioxide per kilometer is generally expressed in grams per kilometer (g/km). Specifically, for some common vehicle types, the carbon dioxide emission rate per kilometer is generally:

Small cars: 100-150 grams/kilometer.

Medium size vehicles: 150-200 grams/kilometer.

Large SUV: 200-300 g/km.

Light commercial vehicle: 150-250 grams/kilometer.

Heavy commercial vehicle: 250-500 grams/kilometer.

The above data is only a reference value, and the actual carbon dioxide emission rate per kilometer of motor vehicles may vary depending on factors such as vehicle type, engine technology level, and fuel type. It can be seen that the emission rates of slope bends, uphill, and complex interchange scenes are higher than the reference values; The emission rate of straight, tunnel, cross river bridge, and downhill scenarios is lower than the reference value; The emission rate of curve scenes is between the reference values.

ISSN: 2710-0723

5. Conclusion

First, in terms of overall carbon dioxide emissions, Chongqing's total carbon emissions are at a high level compared with similar cities due to its large population and high proportion of the Secondary sector of the economy. However, since 2012, while maintaining the steady growth of population and GDP, Chongqing's overall carbon emissions have basically remained stable, and from the overall trend, it has basically reached its peak.

Secondly, in terms of carbon dioxide emission intensity characteristics, the per capita carbon dioxide emissions of Chongqing are relatively low compared to other municipalities directly under the central government, and have shown a stable and decreasing trend since 2012. The carbon emissions per unit of GDP in Chongqing have shown a rapid and obvious downward trend since the high point in 2000, and as of 2019, they are basically at the same level as Shanghai, Beijing, and Chengdu.

Thirdly, in terms of carbon emissions from road transportation, the proportion of carbon dioxide emissions from Chongqing's transportation industry to the total emissions has been maintained at around 12% in recent years. Through comparative analysis with similar cities, it has been found that the transportation carbon emissions of super large cities like transportation hubs are relatively high. Therefore, Chongqing still has room for development in its position as a transportation hub.

Fourthly, in terms of the influencing factors of road traffic carbon emissions, the indicators mainly include engine characteristics, driving characteristics, road environment, traffic flow characteristics, etc. According to typical road scenarios in mountainous cities in Chongqing, the three main factors that affect vehicle carbon emissions characteristics are road elements (plane, vertical section, cross-section), as well as vehicle flow speed characteristics (average speed, speed variation).

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