Hindawi
Mobile Information Systems
Volume 2022, Article ID 3156759, 8 pages
https://doi.org/10.1155/2022/3156759

Research Article

Effects of Carbon Emission on the Environment of High-Speed Vehicles on Highways for Intelligent Transportation Systems

Yuanyuan Liu,[1] Jingwei Liu ,[2] and Huili Dou[1]

[1]*Institute of Urban Rail Transit, Zhejiang Institute of Communications, Hangzhou, Zhejiang 311112, China*
[2]*Zhejiang Jiaoke Transportation Technology Co. Ltd, Zhejiang Scientific Research Institute of Transport, Hangzhou, Zhejiang 310000, China*

Correspondence should be addressed to Jingwei Liu; 1317420137@st.usst.edu.cn

Received 20 July 2022; Revised 2 September 2022; Accepted 13 September 2022; Published 26 September 2022

Academic Editor: Santosh Tirunagari

The emergence of intelligent applications of the Internet of things (IoT) is facilitating human beings up to a great extent. However, numerous applications of the IoT have an adverse impact on our society and environment as well that needs to be dealt with properly to provide smart services to the end-users. For instance, the carbon emissions of vehicles from intelligent transportation systems (ITS) driving on highways are high due to low-carbon traffic management. Therefore, this paper studies the impact of high-speed vehicles on the road causing carbon emissions. For this purpose, Ford, Volkswagen, and Toyota models were used as test subjects to count relevant parameters during May and October 2020. Carbon emissions and vehicle speed on highways were calculated. The relationship between vehicle speed and fuel consumption on the expressway was also analyzed. The results confirm that the fuel consumption of Ford, Volkswagen, and Toyota is the lowest when the vehicle speed is 70 km/h, 80 km/h, and 90 km/h, respectively. The relationship between vehicle speed and carbon emissions in sunny and rainy weather is also analyzed based on the proposed model. It was concluded that the carbon emissions of Ford, Volkswagen, and Toyota are 6.24 mg/1000 km, 6.52 mg/1000 km, and 9.29 mg/1000 km, respectively, under sunny weather conditions. In contrast, the emissions continue to increase when the car accelerates. The driving speed range corresponding to the minimum carbon emissions per hundred kilometres of the three vehicles is 60–120 km/h. However, the carbon emissions of the three vehicles change in rainy weather. The minimum carbon emission of Ford is 6.07 mg/1000 km when the driving speed is within the range of 80–100 km/h. In comparison, Volkswagen and Toyota have the lowest carbon emissions of 6.23 mg/1000 km and 9.15 mg/1000 km, respectively, when the vehicle speed is in the range of 80–120 km/h. The results obtained in this paper establish a unique relationship between vehicle speed, type of vehicle, weather, and highway conditions for any application of the ITS.

1. Introduction

The Internet of things (IoTs) has found its presence in almost every application, e.g., smart farming, healthcare, smart surveillance systems, and intelligent transportation systems (ITS). Among these applications, the vehicles of ITS emit too much carbon into the environment, which has an adverse impact on health and wellbeing of the individuals. Various artificial intelligence techniques will have a pivotal role in this context [1]. In the future, delivering totally driverless vehicles and seamlessly integrated urban transportation will depend heavily on the application of these artificial intelligence techniques. However, we do not have to wait until tomorrow to profit from fourth-generation technology like artificial intelligence and machine learning. They are already in use in a variety of transportation-related applications, reducing CO_2 emissions. Currently, vehicle emissions are frequently evaluated using mobile emission factor models, which are prone to model mistakes. Furthermore, the spatial and temporal accuracy required for the evaluation procedure is lacking in these emission factor models. To address these shortcomings, relevant agencies are looking towards these artificial intelligence and machine learning techniques.

At present times, the global industrial economy has developed rapidly. The population continues to grow. The rate of car usage is increasing. The amount of greenhouse gases emitted into the atmosphere by daily human life activities and industrial production is also rising, leading to increased global warming [2]. For this condition, the transportation and air quality managers are responsible for creating and assessing transportation control measures and various transportation improvement projects. Individual signalized junctions, traffic control devices, highway facility upgrades (e.g., ramps and roundabouts), improved incident response and management, and other tactics are some of the benefits of such models at the microlevel. It is critical to detect hot spots along routes to assess the air quality advantages of such initiatives. Therefore, countries worldwide have begun to pay attention to "low-carbon." They want people to minimize greenhouse gas emissions in production and life [3]. Transportation is the field that emits an enormous amount of greenhouse gases. According to relevant data, the energy consumed by transportation in 2020 was 1916.9 billion tons of oil equivalent. It accounts for 25% of global energy consumption. Similarly, the transportation industry accounts for 14% of the worldwide greenhouse gas emissions, and its conversion into carbon dioxide equivalent reaches 5.8×109 tons. Most of these gases contain carbon dioxide [4]. To resolve the problem of excessive carbon dioxide emission from highways, we maximize energy conservation and emission reduction and minimize the adverse impact on the ecological environment caused by inappropriate highway policy management; it is necessary to revise the policy of speed restriction of vehicles to lower the carbon emission.

The innovations of this paper are as follows: first, it analyzes the main factors affecting vehicle carbon emissions. It collects the average speed and fuel consumption data of different vehicles (cars and trucks) at different speeds (80–120 km/h for cars and 60–100 km/h for trucks). Secondly, the initially collected fuel consumption data are converted into carbon dioxide emissions through the traditional international carbon emission accounting method. The relationship model between the two parameters is established by using the regression analysis method. It also removes irrelevant variables' influence in the research process and controls the main objective facets. It will help clarify the influence law of different speed limit conditions on vehicle carbon emissions, take the carbon emission rate as an important reference index for the setting of the speed limit value, and provide a reference for the speed management strategy in the process of highway operation. It will also provide data support and a theoretical basis for the construction of green transportation.

The remaining paper is organized as follows: Section 2 explains the related work linked to this study. Section 3 gives us an insightful analysis of the influence of speed limit on fuel consumption. The construction of the carbon emission model affected by vehicle speed on expressway and results and analysis are presented in Sections 4 and 5. Finally, the concluding remarks are added in Section 6.

2. Related Work

The change of the speed limit value usually affects motor vehicle speed and traffic flow density in various ITS applications of the IoT. It can further affect fuel consumption and exhaust emissions. Therefore, this section will analyze the factors affecting the carbon emission of motor vehicles based on the influence of different factors on speed and fuel consumption [5, 6]. Britain was the first country to count the energy consumption of its residents, such as natural gas and oil. It quantitatively converted energy consumption into CO_2 emissions. Based on these data, it intuitively reflected British residents' daily life and future carbon emissions. Britain had to start with residents' lifestyles and production modes to carry out low-carbon and formulate low-carbon standards for family life [7]. Japanese scholars focus on studying the carbon emissions of the domestic transportation industry and residents' lives. It developed corresponding emission reduction schemes according to each industry's energy technology and industrial distribution [8]. Chinese experts use the leap model to predict Shanghai's carbon emissions and energy consumption. It analyzed the impact of low-carbon measures on the environment and energy. According to the results, the comprehensive development of low-carbon transportation can effectively alleviate the energy supply problem. If the amount of carbon dioxide and air pollutants emitted is reduced, it can improve the air quality and the greenhouse effect to a certain extent [9, 10]. Environmental protection has become the development goal of all countries worldwide. The transportation sector needs to formulate a green policy to achieve the purpose of low-carbon [11]. Highway carbon emissions account for the most significant proportion of the transportation industry. China has built large-scale highways. They have become the core of transportation [12]. Therefore, there is an urgent need to study highway carbon emissions. This paper analyzes highway carbon emissions from a vehicle's driving speed. It establishes the highway vehicle speed and the carbon emission model, examines the impact of vehicle fuel consumption on carbon emissions, and determines the driving speed with the lowest carbon emissions of different models. It has become essential for relevant departments to formulate highway management measures.

3. Analysis of the Influence of the Speed Limit on Fuel Consumption

In this section of the study paper, we will study the effects of the speed limit on drivers and the influence of the speed limit on V_{85} and V_{50}. It will help us analyze the speed limit's impact on the fuel consumption of vehicles. The details are as follows.

3.1. Effect of the Speed Limit on Drivers. It is necessary to conduct a preliminary analysis in order to provide technical routes and method guidance for follow-up research. It will also help study the impact of speed restriction on fuel consumption.

According to the highway management policy, speed limit signs have a certain restraining and warning effect on drivers [13]. Due to drivers' physiological and psychological complexity, scholars at home and abroad mainly study drivers' behavior under speed limit signs using simulation and questionnaires. Relevant research shows that when the driver passes the speed limit sign, he quickly processes the sign information. The brain will produce three decisions: the actual driving speed is lower, equal to, or higher than the speed limit value. Finally, the driver will perform operations according to the vehicle's initial speed and driving habits [14]. According to the existing literature investigation, if other factors and the interference of the actual road conditions are not considered, drivers will behave differently in the decision-making process. In the road section without speed limit signs, drivers often drive at a higher speed to pursue travel efficiency.

In contrast, while passing a speed limit sign on a road segment with speed limit signs, drivers frequently drop their driving speed abruptly to avoid the punishment and poor record produced by speeding. They will, however, accelerate rapidly after reaching the speed limit road stretch [15]. Based on the above analysis, drivers' frequent deceleration and acceleration before and after the speed limit sign will lead to a sharp increase in fuel consumption and carbon emissions.

3.2. Influence of the Speed Limit on V_{85} and V_{50}. According to the existing research, the vehicle running speed is closely related to the speed limit. The influence of the speed restriction on vehicle speed cannot be ignored, according to highway management policy [15]. Speed restrictions have an impact on vehicle functioning and driver behavior. In general, the driver travels at a fast speed in open regions with a higher defined speed value. In contrast, when the speed limit value is low, drivers tend to reduce their speed during driving. Therefore, we can predict that the higher speed limit and vehicle speed increase fuel consumption and carbon emissions and vice versa [16]. To further verify this assumption and show the relationship between the limited speed and the driving speed of motor vehicles, researchers continuously collect the traffic flow speed data at the speed values of 80–120 km/h through field tests. They also study the impact of the speed limit on V_{85} and V_{50}. The research shows that in the free flow state when $v/c \leq 0.55$, the traffic flow successively passes through the sections with different speed limit schemes. The increasing running speed conforms to the law of the rise of the speed limit scheme [17]. When drivers drive freely on the highway, they are greatly affected by the limited speed value. The majority of drivers will go strictly according to the speed limit.

4. Construction of the Carbon Emission Model Affected by Vehicle Speed on Expressway

This section of the paper explains the establishment model of vehicle speed and carbon emission on expressway, data selection for model construction, and the carbon emission calculation method. Together, they will highlight the structure of the carbon emission model affected by the speed of vehicles on highways. The details are as follows.

4.1. Establishing the Vehicle Speed Model and Carbon Emission on the Expressway. This paper takes Ford, Volkswagen, and Toyota vehicles as the research object. It analyzes the relationship between their driving speed and carbon emissions on the highway. It establishes a model of vehicle speed on roads and carbon emissions with a slope value of 0%. The following formula is used to calculate the carbon emissions generated by fuel consumption:

$$C_i = T_{iz} \cdot Q_{i,\text{fuel}}. \tag{1}$$

In the abovementioned formula, T_{iz} represents the carbon emission coefficient of vehicle type i (kg/L); C_i refers to the carbon emission of model I (kg/100 km); $Q_{i,\text{fuel}}$ means the fuel consumption per 100 km of the model i (L/100 km).

We can calculate the carbon emissions of vehicle types i at various speeds in the abovementioned formula. It sets a relationship between the driving speed and carbon emissions of the three vehicle types through software R. The calculation formula is as follows:

$$C_{i,v} = T_{iz}\left(a + bV + cV^2\right), \tag{2}$$

where $C_{i,v}$ refers to the carbon emission generated by the i model driving at various speeds (kg/100 km) and V relates to vehicle running speed (km/h).

It can be inferred that there is a direct correlation between different vehicle speeds and the fuel required for combustion. Therefore, to select a higher simulation accuracy and more suitable quadratic function as the fitting function, the following highway vehicle speed carbon emission model can be obtained:

$$E_3\text{CO}_2 = 0.0103X^2 - 0.7762X + 41.275. \tag{3}$$

In the abovementioned formula, $E_3\text{CO}_2$ represents the carbon emissions (kg/100 km) at different driving speeds on the expressway and X represents the limited speed of the expressway section [60100].

4.2. Data Selection for Model Construction. In this paper, the number of vehicles driving on the highway is statistically analyzed. For this purpose, Ford, Volkswagen, and Toyota are selected as study subjects. The carbon dioxide emissions of three types of vehicles at the instantaneous speed on the highway were recorded. During the study, the three cars were filled with the same gasoline model from the gas station. The time of statistical data is from May to October 2020. This period can reduce the impact of large traffic volume on data accuracy. The vehicle is tested with the help of a survey method. The vehicle exhaust tester detects the amount of carbon dioxide emitted. Table 1 shows the basic parameters of vehicles selected for this study.

4.3. The Carbon Emission Calculation Method. This subsection will help us calculate the carbon emission and vehicle speed. Also, it will show the relation of these parameters. The details are as follows.

Table 1: Basic parameters of vehicle.

Vehicle brand	Model	Driving years	Displacement	Power
Ford	Carnival	4	1.5	76.9
Public	Langyi	3	2.0	89.5
Toyota	Prado	3.5	4.0	180

4.3.1. Calculating Carbon Emissions. The carbon emission factor refers to the carbon emissions generated per unit of energy during the combustion or use of energy. It is usually obtained using energy consumption and carbon emissions [18]. When it comes to environmental pollution, China has yet to develop an autonomous system that is in keeping with its national circumstances. As a result, research into energy emission factors is still in its infancy. Therefore, the emission factors that represent global climate change issued by the United Nations IPCC committee are used as China's road energy emission factors. They are shown in Table 2.

The International Energy Agency analyzes global climate change and puts forward the net calorific value. It is statistically selected by combining the characteristics of energy combustion. The default static calorific value of energy during vehicle driving is listed in Table 3.

In this paper, the carbon emission during fuel combustion is calculated based on the default emission factor of fuel, the net calorific value, and the fuel characteristic factor. The following is the calculation formula:

$$E = \sum_{i=1}^{n} m \times \rho \times N \times Fi \times Ii. \quad (4)$$

In the above formula, E represents the carbon emission (mg); ρ indicates the density of gasoline or diesel (kg/l); m refers to gasoline or diesel consumption (L); N refers to the default net calorific value of gasoline or diesel (MJ/kg); L_i represents the distinguishing factor; and F_i means the net calorific value emission factor (mg/MJ).

4.3.2. Calculating Vehicle Speed and Carbon Emissions. The relation between vehicle speed and energy consumption is represented by a quadratic parabola. The relationship between carbon emissions and vehicle speed is constructed based on the calculation method of carbon emissions from energy combustion [19]. It is expressed in the following formula:

$$E = \sum_{i=1}^{n} (0.0025v2 - 0.2554v + 31.75) \times \rho \times N \times Fi \times Ii. \quad (5)$$

In the above equation, E shows a quadratic parabola relation between the carbon emission of 100 km [mg/100 km] and the vehicle speed. When the vehicle is driven at average speed, the energy consumption and carbon emission are low. Based on this phenomenon, the carbon emissions of 100 kilometres in 20–80 km/h are calculated.

5. Results and Analysis

In this part of the paper, we will study the development results of the expressway in China and analyze the results of vehicle speed, fuel consumption, and carbon emission on the expressway. It will help us analyze and understand the results extracted from this study's proposed methodology. The details are as follows.

Table 2: Thedefault emission factor of vehicle driving energy (mg/MJ).

Fuel type	Emission factor		
	CO_2	CH_4	N_2O
Gasoline/diesel	74200	3.2	0.7

Table 3: Thedefault net calorific value and confidence interval limit of energy (MJ/kg).

Fuel type	Net calorific value	Net calorific value limit	
		Upper limit	Lower limit
Gasoline/diesel	43.2	43.4	41.5

5.1. Development Results of the Expressway in China. China has vigorously built expressways since the late 1980s. The driving section starts from Shanghai to Jiading, with a total length of 18.5 kilometres. Until 1997, China's expressway building distance was 4771 kilometres. China reached a milestone in expressway development in 2002, with expressway traffic exceeding 25000 kilometres. China's highway development speed has overtaken that of industrialized countries for the first time in more than 40 years in only a few years. Highway length rose by 1.1648 million kilometres between 2005 and 2010, compared to the preceding five years. The mileage of highways has also increased from 41000 kilometres to 74000 kilometres in 2005. The mileage of highways in China ranks second in the world. The total mileage of highways built in 11 provinces is more than 3000 kilometres. Table 4 lists China's highway mileage statistics from 2015 to 2020. Figure 1 shows the energy consumption of various transportation modes in the transportation industry in 2020.

5.2. Analyzing the Results of Vehicle Speed and Fuel Consumption on Expressway. The vehicle's fuel consumption is directly related to its weight and change in the driving speed. When measuring the fuel consumption of vehicles, a road section similar to the highway, with a distance of 1000 meters, is selected. Ford, Volkswagen, and Toyota will drive back and forth constantly. The fuel consumption of the three vehicles during driving will be calculated. The measured vehicle speed range is 40 to 120 km/h. This measurement is carried out at an interval of 10 km/h. These three models involve most of the vehicles running on the highway. To ensure the measurement data's accuracy and avoid human factors' impact on the data's accuracy, two groups of analysts complete this measurement, respectively, after which the average value of the measurement data will be taken. Through this measurement, we can find the relationship and fundamental law between vehicle speed and fuel

Table 4: Statistical table of highway mileage in China from 2015 to 2020.

Particular year	2015	2016	2017	2018	2019	2020
Highway mileage (10000 km)	12.36	13.2	13.64	14.26	14.96	15.23
Mileage of class highway (10000 km)	404.65	422.66	433.87	446.60	469.88	485.37
Highway mileage/class highway mileage	3.05%	3.12%	3.14%	3.19%	3.18%	3.14%

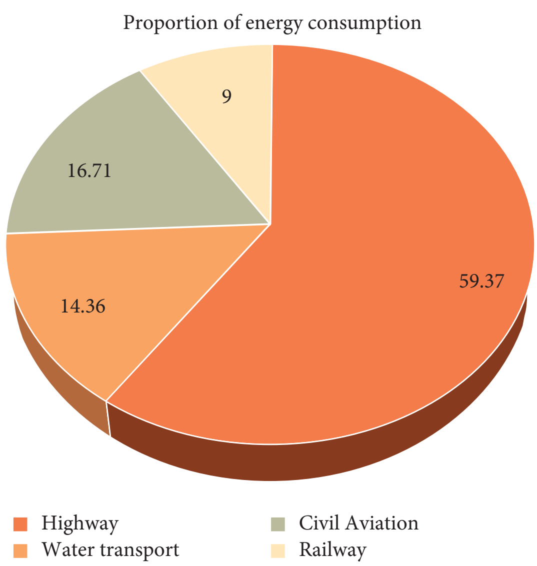

Figure 1: Proportion of energy consumption of different transportation modes in the transportation industry in 2020.

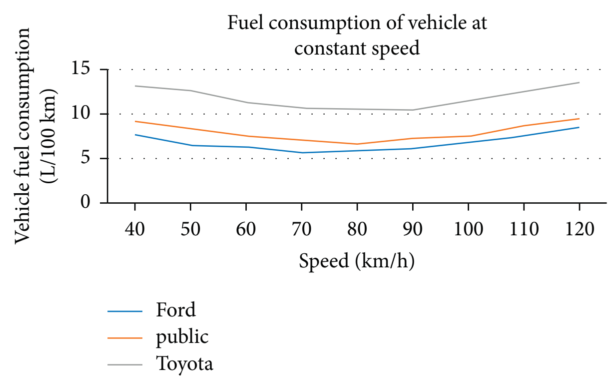

Figure 2: Constant fuel consumption and speed of three brands of vehicles.

consumption. The speed and fuel consumption of the three brands of vehicles are shown in Figure 2.

According to the graph of three brands of vehicles in Figure 2, there is a direct relationship between the constant speed of vehicles and the fuel consumption per 100 kilometres. The lowest fuel consumption of Toyota cars per 100 kilometres is with a speed of 90 km/h. The fuel consumption per 100 kilometres continues to rise after the vehicle is given acceleration. The displacement of Toyota cars selected in this paper is 4.0 t; therefore, the fuel consumption per 100 kilometres is higher. The lowest fuel consumption of Volkswagen is 6.6 l/100 km, and the corresponding driving speed is 80 km/h. After that, the fuel consumption per 100 kilometres increases slightly. The minimum fuel consumption of Ford Motor is 5.7 l/100 km. When the fuel consumption is the lowest, the vehicle's driving speed is 70 km/h. When the vehicle's going speed increases to 120 km/h, the fuel consumption per 100 kilometres is the highest in this speed range, with a value of 8.5 l/100 km. From this, it can be seen that the vehicle's driving speed directly affects the fuel consumption of the vehicle per 100 kilometres. Through the analysis combined with the carbon emission, the vehicle's carbon emission when driving at a faster speed is low. However, fuel consumption increases when reduced to the lowest value. Therefore, from the perspective of environmental protection, when analyzing the impact of highway vehicle speed on carbon emissions, it can be seen that there is no direct relation between vehicle speed and carbon emissions.

5.3. Analysis of Vehicle Speed and Carbon Emission on Expressway. There is a direct relationship between fuel consumption and road traffic conditions during vehicle driving. Generally, changing traffic conditions and road environment will also shift vehicle driving fuel consumption accordingly. The main research section of this paper is the expressway. It features smooth roads, rapid vehicle speeds, and no challenging spots and uses little gasoline. There is a direct link between the vehicle carbon emission coefficient, fuel consumption per 100 kilometres, and carbon emissions, according to formula (3) mentioned above. According to the vehicle carbon emission coefficient and fuel consumption per 100 kilometres, the carbon emissions of highway vehicles at different driving speeds can be calculated. The carbon emission factors of various vehicles are listed in Table 5.

5.3.1. Relation between Vehicle Speed and Carbon Emissions on Sunny Highways. In this paper, by consulting the carbon emission coefficients of three types of vehicles, namely, Ford, Volkswagen, and Toyota, the fuel consumption per 100 kilometres of the three types of vehicles at different speeds on the highway is counted. The instantaneous speed of the data sample is 0–120 km/h, divided according to different vehicle speed ranges. The intervals are (0–20), (20–40), (40–60), (60–80), (80–100), and (100–120), respectively. The fuel consumption per 100 kilometres corresponding to the instantaneous speed in each interval is selected, the data of three vehicles are counted, and to calculate the carbon emissions, it is substituted into formula (4). Due to many reasons for the studied models and vehicle speeds, formula (4) is more accurate. The calculated carbon emission results of three vehicles in different speed ranges on sunny days are drawn as a broken line diagram. It is shown in Figure 2.

According to the abovementioned Figure 3, the carbon emissions of three vehicles, namely, Ford, Volkswagen, and

Table 5: TheCarbon emission coefficient of different models.

Vehicle type	Displacement	Carbon emission coefficient (kg CO_2 e/km)
Large gasoline vehicle	>2.0 L	0.298
Medium-sized gasoline vehicle	1.4–2.0 L	0.208
Small gasoline vehicle	≤1.4 L	0.166

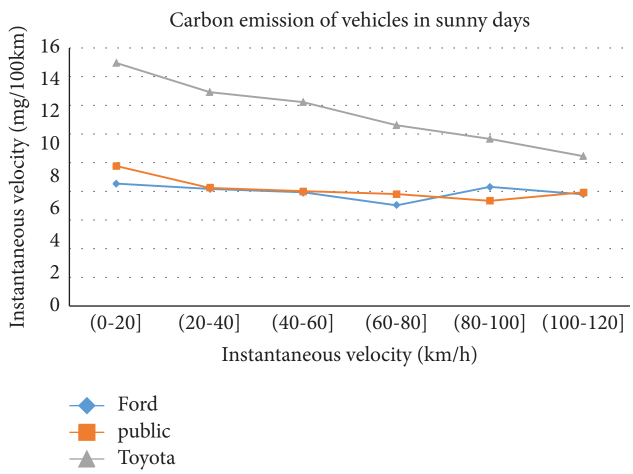

Figure 3: Carbon emissions of three vehicles in different speed ranges on sunny days.

Toyota, are different at different speeds. The broken line shows that the highest speed range of carbon emissions is 0–20 km/h, and the carbon emissions of Ford, Volkswagen, and Toyota are 7.59 mg/1000 km, 8.68 mg/1000 km, and 15.07 mg/1000 km, respectively. With the increase of the vehicle instantaneous speed, the carbon emissions per 100 kilometres of the three vehicles continue to decline. Among them, Ford has the lowest carbon emission in the speed range of 60–80 km/h. It is 6.24 mg/1000 km. The carbon output increases somewhat as the vehicle's instantaneous speed increases, while the instantaneous speed reduces significantly in the range of 100–120 km/h. The carbon emission of Volkswagen is the lowest in the immediate speed range, which is 6.52 mg/1000 km, and the carbon emission of the vehicle grows after 100–120 km/h. After Toyota continues accelerating the vehicle's instantaneous speed, the carbon emission per 100 kilometres continues to decline. When the carbon emission per 100 kilometres is the lowest, the instantaneous speed of the vehicle is 100–120 km/h. Its carbon emission is 9.29 mg/1000 km. Through the above data analysis, it is concluded that the fuel consumption per 100 kilometres and the vehicle carbon emission coefficient directly determine the vehicle carbon emission. Toyota has the highest carbon emission coefficient per 100 kilometres among the three vehicles selected in this paper.

5.3.2. Relation between Vehicle Speed and Carbon Emission of Expressway on Rainy Days. Under the premise of a certain vehicle speed, the weather will also directly affect the carbon

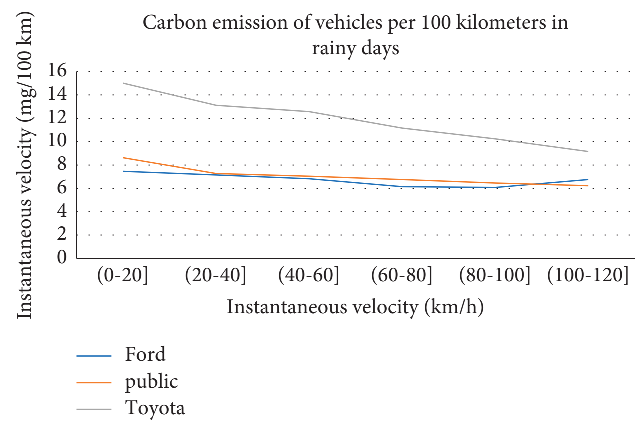

Figure 4: Carbon emissions of three vehicles in different speed ranges on rainy days.

emission during vehicle driving. On rainy days, the road surface is wet and slippery. The driving resistance between the vehicle and the road surface is reduced, and the carbon emission is lower than that on sunny days. At the same time, there is a significant difference between the vehicle driving speed and the speed range with the lowest carbon emission. Here, six vehicle speed ranges 0–20 km/h, 20–40 km/h, 40–60 km/h, 60–80 km/h, 80–100 km/h, and100–120 km/h are selected. The fuel consumption and carbon emission coefficients of three automobiles per 100 kilometres are replaced to compute the associated carbon emissions using the highway vehicle speed and the carbon emission model developed in this research. Figure 4 depicts the carbon emissions of three automobiles travelling 100 kilometres at various speeds on wet days.

Figure 4 shows the carbon emissions of three vehicles at different meteorite speeds on rainy days. According to the broken line chart, the lowest value of carbon emissions per 100 kilometres of Ford, Volkswagen, and Toyota vehicles on rainy days changes the vehicle speed range. The carbon emissions are lower than those on sunny days. Among them, the lowest carbon emission of Ford is 6.07 mg/1000 km when the instantaneous speed of the vehicle is within the range of 80–100 km/h. The carbon emission will increase after the vehicle accelerates. When the carbon emission is the lowest, the instantaneous speed ranges of Volkswagen and Toyota are the same, that is, 00–120 km/h. The corresponding carbon emissions are 6.23 mg/1000 km and 9.15 mg/1000 km, respectively, and the two curves continue to decline. It shows that the speed and weather of highway vehicles directly impact carbon emissions. The most acceptable vehicle speed is also different for different models. Therefore, the highway should integrate various vehicles to set the best speed to reduce carbon emissions and realize low-carbon transportation.

6. Conclusion

This study successfully produced an empirical method for detecting hot spots along roads for gasoline-powered light-duty vehicles of intelligent transportation systems (ITS). To show insights generated from recorded tailpipe emissions data, the approach was used to sample case studies involving various automobiles and study corridors. The geographical distribution of emissions example research indicated that emissions from a single signalized junction contributed considerably to overall emissions for a certain corridor. Furthermore, emissions during idling were significantly lower than in other driving modes. An empirical approach was utilized in this effort to measure microscale occurrences. Three automobiles that drive mostly on the highway were chosen for testing purposes in order to investigate their influence. These three vehicles involve three kinds of daily vehicle displacement, namely, Ford, Volkswagen, and Toyota. In this paper, the carbon emissions during fuel combustion are calculated based on the default emission factor, the net calorific value of fuel, and the fuel characteristic factor. At the same time, the relationship between vehicle speed and energy consumption is a quadratic parabola. Based on the carbon emissions of energy combustion, the vehicle speed and carbon emissions are calculated. The highway vehicle speed and carbon emissions model are also established. The carbon emission coefficients of Ford, Volkswagen, and Toyota are examined using the highway vehicle speed and the carbon emission model. The fuel consumption per 100 kilometres of various vehicles is computed. The results show that the driving speed of vehicles directly affects the fuel consumption of vehicles. The minimum fuel consumptions per 100 kilometres for Ford, Volkswagen, and Toyota are 5.710.5 l/100 km, 6.610.5 l/100 km, and 10.5 l/100 km, respectively, with the corresponding vehicle driving speeds of 70 km/h, 80 km/h, and 90 km/h, respectively. After continuously accelerating the driving speed, the fuel consumption per 100 kilometres is increased as it is directly proportional to the driving speed of vehicles. The findings of the vehicle fuel consumption per 100 kilometres, the highway vehicle speed, and the carbon emission model are used to examine the highway vehicle speed and carbon emission. The carbon emission coefficients for several emission models are provided.

The data are substituted into the carbon emission model for calculation. The minimum carbon emissions of Ford, Volkswagen, and Toyota in a sunny environment are 6.24 mg/1000 km, 6.52 mg/1000 km, and 9.29 mg/1000 km, respectively. The corresponding speed ranges are 60–80 km/h, 80–120 km/h, and 100–120 km/h. On rainy days, the minimum carbon emissions of Ford, Volkswagen, and Toyota are 6.07 mg/1000 km, 6.23 mg/1000 km, and 9.15 mg/1000 km, respectively. The speed range of Ford was 80–100 km/h, while the speed range of both Volkswagen and Toyota was 100–120 km/h.

Data Availability

Data are available on reasonable request from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] L. Liu, H. Zong, E. Zhao, C. Chen, and J. Wang, "Can China realize its carbon emission reduction goal in 2020: from the perspective of thermal power development," *Applied Energy*, vol. 124, pp. 199–212, 2014.

[2] K. R. Salk, P. H. Ostrom, B. A. Biddanda, A. D. Weinke, S. T. Kendall, and N. E. Ostrom, "Ecosystem metabolism and greenhouse gas production in a mesotrophic northern temperate lake experiencing seasonal hypoxia," *Biogeochemistry*, vol. 131, no. 3, pp. 303–319, 2016.

[3] A. La Notte, S. Tonin, and G. Lucaroni, "Assessing direct and indirect emissions of greenhouse gases in road transportation, taking into account the role of uncertainty in the emissions inventory," *Environmental Impact Assessment Review*, vol. 69, pp. 82–93, 2018.

[4] J. Koiwanit, "A comparative assessment of life-cycle greenhouse gas emissions from hypothetical electric airport transportation services in Thailand IOP conference series: earth and environmental science," *IOP Conference Series: Earth and Environmental Science*, vol. 150, no. 1, Article ID 012031, 2018.

[5] J. Mandal, A. Goswami, J. Wang, and M. K. Tiwari, "Optimization of vehicle speed for batches to minimize supply chain cost under uncertain demand," *Information Sciences*, vol. 515, pp. 26–43, 2020.

[6] M. U. Karaoğlan, N. S. Kuralay, and C. O. Colpan, "The effect of gear ratıos on the exhaust emıssıons and fuel consumptıon of a parallel hybrid vehicle powertrain," *Journal of Cleaner Production*, vol. 210, pp. 1033–1041, 2019.

[7] P. J. Mago and R. Luck, "Potential reduction of carbon dioxide emissions from the use of electric energy storage on a power generation unit/organic Rankine system," *Energy Conversion and Management*, vol. 133, pp. 67–75, 2017.

[8] S. I. Rais, A. Mansoor, N. Ahmed, S. T. H. Shah, and B. Sultana, "Relationship between emissions of carbon dioxide from the cement industry, health expenditures and economic growth in Pakistan," *iRASD Journal of Economics*, vol. 3, no. 2, pp. 133–142, 2021.

[9] Y. Wang, Q. Song, J. He, and Y. Qi, "Developing low-carbon cities through pilots," *Climate Policy*, vol. 15, no. 1, pp. S81–S103, 2015.

[10] L. I. Wenxia, Z. H. A. N. G. Chunmin, and M. A. Changxi, "An. Optimization model and solution algorithm of multiobjective vehicle path under low carbon conditions," *Journal of Transport Information and Safety*, vol. 38, no. 1, pp. 118–126, 2020.

[11] H. Li and L. Su, "Multimodal transport path optimization model and algorithm considering carbon emission multitask," *The Journal of Supercomputing*, vol. 76, no. 12, pp. 9355–9373, 2020.

[12] Y. U. Jie, D. A. Ya-bin, and O. U. Y. A. N. G. Bin, "Analysis of carbon emission changes in China's transportation industry based on LMDI decomposition method," *China Journal of Highway and Transport*, vol. 28, no. 10, 112 pages, 2015.

[13] F. Vrbanić, M. Miletić, L. Tišljarić, and E. Ivanjko, "Influence of variable speed limit control on fuel and electric energy consumption, and exhaust gas emissions in mixed traffic flows," *Sustainability*, vol. 14, no. 2, 932 pages, 2022.

[14] M. Lashgari, A. A. Akbari, and S. Nasersarraf, "A new model for simultaneously optimizing ship route, sailing speed, and fuel consumption in a shipping problem under different price scenarios," *Applied Ocean Research*, vol. 113, Article ID 102725, 2021.

[15] V. V. Gerasidi and A. V. Lisachenko, "Analysis of fuel consumption of modern electronically controlled high-speed marine engines," *Journal of Physics: Conference Series*, vol. 2061, Article ID 012057, October.

[16] Y. Yang, M. Li, J. Yu, and F. He, "Expressway bottleneck pattern identification using traffic big data—the case of ring roads in Beijing, China," *Journal of Intelligent Transportation Systems*, vol. 24, no. 1, pp. 54–67, 2020.

[17] Q. Wu and J. J. Wang, "Exploration on speed-limit signs of traffic accident section on freeways," in *Applied Mechanics and Materials*, vol. 361, pp. 2349–2352, Trans Tech Publications Ltd, 2013.

[18] Z. L. Wu, D. Wang, and Y. T. Su, "Study on spatial-temporal variation and influencing factors of urban carbon emissions in Guangdong province based on EDGAR data," *Areal Res. Dev*, vol. 39, pp. 127–132, 2020.

[19] A. Giallanza and G. L. Puma, "Fuzzy green vehicle routing problem for designing a three echelons supply chain," *Journal of Cleaner Production*, vol. 259, Article ID 120774, 2020.