Coupling Process and System for VSP Traffic Circulation Data and Vehicular Emission Data Analysis

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Abstract
This research focuses on establishing a coupling process and system that integrates VSP traffic circulation data and vehicular emission data. By analysing the features of traffic circulation data and vehicular emission data, this study aims to identify and analyse the dynamic mapping relationship between various vehicular emission parameters, such as traffic circulation parameters and emission indices. The research also explores the impact of factors like traffic flow magnitude, average speed, and motor-driven vehicle operating modes on emission factors. The proposed system simplifies the understanding of automotive emissions and enhances the efficiency and accuracy of traffic emission quantitative evaluation.

Keywords: coupling process, system, VSP traffic circulation data, vehicular emission data, traffic circulation parameters, emission indices, emission factors, traffic flow, average speed, motor-driven vehicle operating modes, quantitative evaluation.

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Introduction

In recent years, the issue of vehicular emissions and their impact on air quality and public health has garnered significant attention. The increasing number of vehicles on the roads, coupled with the growing concern for environmental sustainability, necessitates a comprehensive understanding of the relationship between traffic circulation and vehicular emissions.[1]

To address this, researchers have been exploring methods to integrate VSP (Vehicle Specific Power) traffic circulation data and vehicular emission data, aiming to establish a dynamic mapping relationship between various traffic parameters and emission factors. The coupling of VSP traffic circulation data and vehicular emission data holds great potential for enhancing the efficiency and accuracy of traffic emission evaluation. By leveraging the features inherent in both datasets, researchers can delve deeper into the underlying dynamics of vehicular emissions and their relationship with traffic conditions. The integration of these data sets allows for a more holistic analysis, enabling a comprehensive assessment of the environmental impact of vehicular activities.[2]

The objective of this research is to develop a coupling process and system that effectively integrates VSP traffic circulation data and vehicular emission data. By excavating and analyzing the features of these data sets, this study aims to establish a dynamic mapping relationship between various vehicular emission parameters, including traffic circulation parameters, emission indices, and emission factors. The key variables to be considered include the magnitude of traffic flow, average speed, and motor-driven vehicle operating modes. By understanding the intricate connections between these variables and their impact on emission factors, the research seeks to simplify the physical significance of automotive emissions and enhance the efficiency and accuracy of traffic emission quantitative evaluation.[3]

The proposed coupling process and system present a novel approach to address the complexities associated with vehicular emissions analysis. By leveraging VSP traffic circulation data, which provides detailed information about vehicle movements, and combining it with vehicular emission data, researchers can gain valuable insights into the relationship between traffic patterns and emission levels.[6] This integrated approach offers a comprehensive understanding of the factors influencing vehicular emissions, facilitating informed decision-making in emission reduction strategies and urban planning.

Moreover, this research contributes to the advancement of environmental sustainability efforts in transportation systems. By improving the understanding of vehicular emissions, it becomes possible to identify key areas for intervention and develop effective strategies to mitigate the adverse impacts on air quality and public health.[8] The findings of this study will assist policymakers, urban planners, and transportation authorities in making informed decisions to reduce emissions and create more sustainable transportation systems.

In conclusion, the coupling process and system proposed in this research aim to integrate VSP traffic circulation data and vehicular emission data to establish a dynamic mapping relationship between various traffic parameters and emission factors. By simplifying the understanding of automotive emissions and enhancing the efficiency and accuracy of traffic emission quantitative evaluation, this research contributes to the development of sustainable transportation systems. The subsequent sections of this paper will delve into the methodology, data analysis, and results, providing a comprehensive overview of the research findings and their implications.

Related Work

Over the years, the traffic department and environmental administration have made significant progress in data acquisition and analysis systems, accumulating a vast amount of data. To study regional traffic circulation, it is crucial to conduct a comprehensive traffic analysis to understand the characteristics and development trends of the area. Quantitative analysis of traffic circulation data helps capture specific parameters and provides a theoretical foundation for traffic planning, linear design, and traffic management. Various methods, such as point measurement, section measurement, floating car measurement, and short section measurement, have been employed in traffic studies.[1]

The advancements in detection techniques, such as induction coil detection, ultrasound examination, infrared detection, and mobile message acquisition, have greatly enhanced traffic control and information services.[4] Microwave detection, video image detection, and light beacon detection techniques were developed in the late 1980s and applied in the 1990s. In the early 21st century, GPS detection techniques emerged to detect traffic flow parameters. These technological advancements have significantly improved the accuracy and efficiency of data collection.[2]In the context of reducing automotive emissions and formulating transportation strategies, exhaust emissions inspections are conducted using laboratory facilities to collect actual data on oil consumption and emissions from motor vehicles.[4] These data serve as the basis for studying motor vehicle fuel consumption and emissions, as well as establishing models to evaluate transportation strategies. Currently, there are four main methods for fuel consumption and exhaust emissions inspections, namely engine bench test, tunnel test, remote sensing detection, and on-road emission testing.[4] **However,** the differences in data acquisition methods and application purposes have limited the exploration of the correlated characteristics between these two types of data.[1] The full potential of combining traffic circulation data and vehicular emission data has not been fully realized, hindering accurate and efficient associations between them.[5]

Therefore, this research aims to bridge this gap by developing a comprehensive coupling process and system that integrates VSP traffic circulation data with vehicular emission data. By analyzing the unique features of these datasets, the study seeks to establish a dynamic mapping relationship between various traffic parameters and emission factors, such as the magnitude of traffic flow, average speed, and motor-driven vehicle operating modes.[3] This integration will simplify the understanding of automotive emissions and significantly enhance the efficiency and accuracy of traffic emission quantitative evaluation. The proposed coupling process and system offer a promising approach to address the complexities associated with analysing vehicular emissions.[7]By comparing the scenarios of smooth traffic flow and severe congestion, it was observed that the average speed of the route decreased by around 50%, and the number of stops per kilometre increased by a factor of 1.5. Additionally, the CO2 and NOx emissions from buses increased by approximately 50% and 85% respectively. While the diesel bus exhibited less sensitivity to congestion variations at the route level, the CNG buses consistently displayed lower NOx emissions across all traffic scenarios. These findings, derived from a comprehensive analysis of real-world data, can be utilized in the development of detailed vehicle emissions inventories. Free flow and the severe congestion scenarios shown in Figure 1.

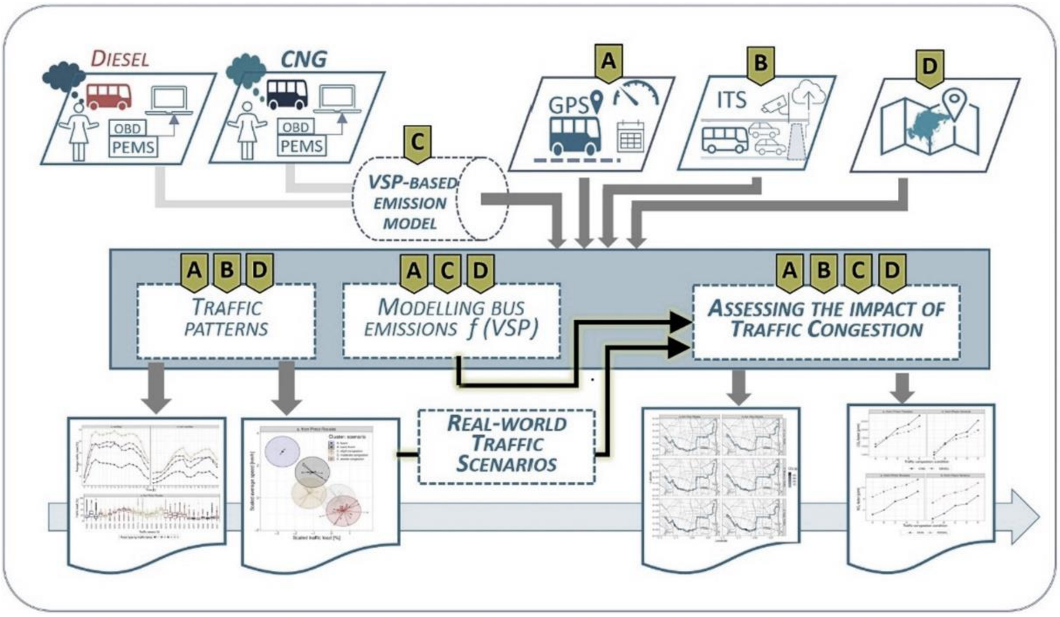

Figure 1. Free Flow Scenarios

By leveraging the synergies between traffic circulation data and vehicular emission data, researchers can gain valuable insights into the relationship between traffic patterns and emission levels. This holistic approach will contribute to informed decision-making in emission reduction strategies, urban planning, and the development of sustainable transportation systems.[6]A subset of driving condition data (depicted in Figure 2) was randomly chosen from the validation database, which constituted 20% of the original on-board test data. This selected subset was fed into the vehicle emission model to determine the emission factor for this specific driving condition segment. Subsequently, the computed results were compared to the measured emission data associated with the driving conditions of this segment, serving as a means to validate the simulation outcomes of the model.[7]

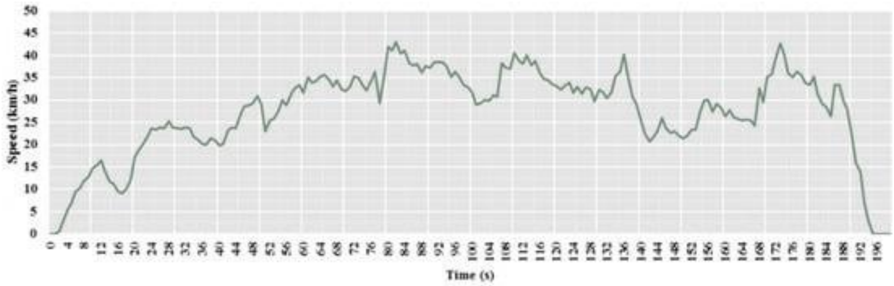

Figure 2. A randomly chosen subset of driving condition data extracted from the validation database

In conclusion, this research aims to develop a comprehensive coupling process and system that integrates VSP traffic circulation data with vehicular emission data. By leveraging the unique features of these datasets, the study seeks to establish a dynamic mapping relationship between various traffic parameters and emission factors. This integration will enhance the efficiency and accuracy of traffic emission quantitative evaluation, leading to more effective transportation strategies and environmental sustainability efforts. The subsequent sections of this paper will provide a detailed methodology, data analysis, and results, shedding light on the research findings and their implications.

Research Objective

The main objective of this research is to develop a coupling process and system that integrates VSP traffic circulation data and vehicular emission data. The research aims to establish a dynamic mapping relationship between traffic circulation parameters and emission indices, as well as to analyse the impact of factors such as traffic flow magnitude, average speed, and motor-driven vehicle operating modes on emission factors. The ultimate goal is to simplify the understanding of automotive emissions and enhance the efficiency and accuracy of quantitative evaluation of traffic emissions.

Coupling Process and System for VSP Traffic Circulation Data

Researchers have developed a method that combines traffic circulation data and emissions data to study their relationship. This method involves several steps:

1. Handling Traffic Circulation Data:
    - Gathering data on vehicle movement using GPS devices installed in vehicles. This data includes information like date, time, location, speed, and elevation. The data is organized and stored in a standardized format to create a database of vehicle movement.
    - Classifying vehicles based on their weight, such as small cars, regular cars, medium-sized cars, and large cars.
    - Matching the data with specific road types based on their locations.
    - Dividing the data into short sections of 180 seconds each to calculate average speeds for further analysis.
    - Clustering the short sections based on their average speeds to create speed intervals.

2. Handling Motor Vehicle Emissions Data:
    - Collecting data on vehicle emissions, including date, time, speed, and emissions such as CO2, NOX, HC, and CO, using vehicle-mounted tail gas test equipment.
    - Dividing vehicles into different fuel types, such as gasoline, diesel, liquefied petroleum gas, etc.
    - Classifying vehicles based on their emission standards and the year of production.

- Dividing the data based on the distance travelled by similar vehicles.
- Calculating the average emission rate for each combination of vehicle type, fuel type, emission standard, and distance travelled.

3. Coupling Traffic Circulation Data and Emissions Data:
    - Establishing a connection between the traffic circulation data and emissions data by matching their speed intervals and VSP (Vehicle Specific Power) distributions.
    - Creating a database that links the VSP bins with their corresponding emissions rates.

4. Estimating Section Emissions:
    - Calculating the emission amount for each road section by multiplying the emission factors with the volume of traffic and road section length.

This method allows researchers to analyse the relationship between traffic circulation and emissions by considering various parameters such as vehicle types, road types, speed intervals, and emission factors. It provides a systematic approach to understanding and estimating emissions in specific regions based on their traffic characteristics.

Detailed explanation into each step of the research method

Step 1: Handling Traffic Circulation Data

- Data Gathering: The researchers collect data on vehicle movement using GPS devices installed in vehicles. This data includes information such as the date, time, location (longitude and latitude), speed, deflection (change in direction), and elevation. They ensure the data is in a standardized format and perform quality control by removing any undesirable records. This data forms a database of vehicle movement.
- Car Model Classification: Vehicles are classified based on their weight, such as minicars, light-duty vehicles, in-between cars, and larger cars. This classification helps in analysing the emissions data according to different vehicle types.
- Road Type Matching: The road network is categorized into different types, such as through streets, trunk roads, secondary distributor roads, and branch roads. By analysing the GPS data and matching it with road network information, each data point is assigned to its corresponding road type.
- Short Stroke Division: To facilitate further analysis, the researchers divide the data into short sections of 180 seconds each. These short sections allow for calculating the average speed of vehicles within each section, which helps in clustering vehicles based on their speed patterns.
- Average Speed Cluster: The short sections obtained in the previous step are clustered based on their average speeds. This clustering groups together sections with similar average speeds, allowing for more accurate analysis.
- VSP (Vehicle Specific Power) Clusters: VSP values are calculated based on the instantaneous velocity and acceleration of vehicles. VSP represents the power demand of a vehicle at a specific moment. The researchers calculate VSP values using a specific formula and divide them into intervals of 1 kW/t. This creates VSP bins and helps in analysing the relationship between VSP distributions and average speeds.

- VSP Distribution Database: The researchers create a database that organizes the VSP distributions based on the collected driving cycle data. They cluster all vehicles, road types, and speed intervals with identical VSP values. The database provides information on the percentage of vehicles within each speed interval that corresponds to specific VSP values.

Step 2: Handling Motor Vehicle Emissions Data

- 2.1 Emission Test Data Gathering: Using PEMS (Portable Emissions Measurement System) equipment, the researchers collect data on motor vehicle fuel consumption and exhaust emissions. This data includes information such as date, time, speed, and emissions like CO2, NOX, HC, and CO. The data is collected in real-time, allowing for detailed analysis.
- 2.2 Fuel Type Division: Vehicles are categorized into different fuel types, including gasoline, diesel oil, liquefied petroleum gas, liquefied natural gas, compressed natural gas, hybrid power, and dual fuel vehicles. This categorization helps in analysing emissions data based on different fuel types.
- 2.3 Discharge Standard Division: Vehicles are classified according to the emission standards they adhere to. The classification takes into account the vehicle's production year and determines its corresponding emission standard type.
- 2.4 Distance Travelled Division: The researchers divide the data based on the distance travelled by similar vehicles. This division helps in analysing emissions based on different travel distances.
- 2.5 Average Emission Rate Calculation: For each combination of vehicle type, fuel type, emission standard, and distance travelled, the researchers calculate the average emission rate. This involves calculating the average emission rate for each VSP bin based on the collected data. The resulting emission rates provide insights into the emissions characteristics of different vehicle types and conditions.
- 2.6 Discharge Rate Database: The calculated emission rates for different vehicle types, emission standards, and travel distances are organized and classified. This information is used to build

Step 3: Emission Inventory Construction

- 3.1 Vehicle Population Distribution: The researchers analyse the registered vehicle population data, which includes information on the number and types of vehicles in the area under study. They categorize the vehicles based on vehicle type, fuel type, and emission standard. This distribution provides an understanding of the composition of the vehicle fleet in terms of emissions characteristics.
- 3.2 Emission Factor Calculation: Using the data obtained from Steps 1 and 2, the researchers calculate the emission factors for each vehicle type, fuel type, and emission standard. The emission factors represent the amount of pollutants emitted per unit of activity (e.g., distance travelled or vehicle specific power). These factors are calculated by combining the average emission rates obtained in Step 2 with the vehicle population distribution obtained in Step 3.1.
- 3.3 Emission Inventory Compilation: Based on the emission factors calculated in Step 3.2 and the vehicle population distribution, the researchers compile an emission inventory. The inventory provides a comprehensive overview of the emissions from different vehicle types, fuel types, and emission standards in the study area. It includes information on pollutant types (CO2, NOX, HC, CO), emission sources, and their corresponding quantities.

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Step 4: Emission Control Policy Analysis

- Policy Assessment: The researchers evaluate existing emission control policies and regulations in the study area. This includes examining emission standards, vehicle inspection and maintenance programs, and other relevant policies aimed at reducing emissions. They assess the effectiveness of these policies in achieving emission reduction goals.
- Scenario Analysis: The researchers develop different emission reduction scenarios based on potential policy interventions. These scenarios involve implementing measures such as stricter emission standards, promoting low-emission vehicles, improving vehicle inspection and maintenance programs, and incentivizing public transportation or carpooling. They analyze the potential impact of each scenario on emissions reduction.
- Model Simulation: Using specialized simulation models, the researchers simulate the effects of the different emission reduction scenarios on traffic emissions. These models take into account factors such as vehicle population, travel demand, road infrastructure, and policy interventions. By running the simulation models with different scenarios, they can quantify the expected emission reductions associated with each policy intervention.
- Policy Recommendations: Based on the analysis of existing policies and the simulation results from different scenarios, the researchers provide recommendations for effective emission control strategies. These recommendations consider the feasibility, cost-effectiveness, and potential impact of each policy intervention. They aim to guide policymakers in formulating and implementing strategies that can effectively reduce traffic-related emissions in the study area.

By following these steps, researchers can gain a comprehensive understanding of traffic-related emissions, develop emission inventories, and analyse the effectiveness of various emission control policies. This knowledge can inform decision-making processes aimed at mitigating the environmental impact of transportation and promoting sustainable mobility.

Conclusion

The proposed coupling process and system provide a comprehensive approach to analyze and understand the relationship between VSP traffic circulation data and vehicular emission data. By identifying the dynamic mapping relationship between traffic circulation parameters and emission indices, and considering factors like traffic flow magnitude, average speed, and motor-driven vehicle operating modes, this research simplifies the understanding of automotive emissions. The developed system enhances the efficiency and accuracy of traffic emission quantitative evaluation, enabling better decision-making in emission reduction strategies and urban planning. The findings of this research contribute to advancing our understanding of vehicular emissions and provide valuable insights for creating more sustainable transportation systems.

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