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Impact of Information Feedback Strategy on Vehicle Emissions Reduction on Beltways

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Abstract:

In recent years, the information feedback strategy plays an important role in the Intelligent Transportation System (ITS). It improves the efficiency of the use of existing road facilities and eases the congestion problem. However, there is not do any work that studies the impact of information feedback on the environmental problems brought by the vehicle emissions. In this paper, we consider the aspect of emissions reduction with information feedback strategy. Firstly, we introduce the feedback strategy applied to the beltway scenarios, this information feedback strategy does not take into account the environment. Secondly, the representative emission model, International Vehicle Emissions (IVE), is selected to estimate the fuel consumption and the emissions of vehicles on beltways. Finally, based on the fuel consumption and the emission model, we evaluate the impact of information feedback strategy on vehicle emissions on beltways. The result shows that strategy can alleviate traffic congestion, improve transport efficiency and reduce polluting gas emissions.

Keywords*: Information feedback strategy, Emissions, Beltway scenarios, IVE model.*

I. INTRODUCTION

The comprehensive capacity of transportation system is a key index to measure the prosperity of a country. Not only is it crucial to the national economic development, but it also determines the modernizing progress of a country. Under this background, Intelligent transportation system (ITS) has come into being. The ITS can make full use of existing transport facilities to ease road congestion, reduce environmental pollution and to improve transport efficiency [1-3].

In the ITS field, most studies focus on using the information feedback strategy to help drivers to make a better route selection in order to reduce traffic congestion. However, with the development of economy and rapid growth of urban vehicles, vehicle emissions become a serious problem. Hence, considering the environmental problems, we select a representative emission model from many fuel consumption and emission models, we investigate the impact of information feedback strategy on vehicle emissions reduction.

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1.1 Research on Information Feedback Strategies

As the critical part of ITS, the information feedback strategy has been modified since Wahle et al. first proposed in 2000. Some typical information feedback strategies are mean velocity route guidance strategy [2], congestion coefficient route guidance strategy [3], prediction route guidance strategy, space flux route guidance strategy [9], exponential function route guidance strategy [7] and so on.

However, a excellent information feedback strategy will make the best use of road resources to feedback real-time traffic information rationally and efficiently, provide drivers driving directions and cease urban traffic congestion.

In fact, the information feedback strategy improves the road transport efficiency. Furthermore, it not only improves the average flux and speed, but also reduces average passing time. Nevertheless, the information feedback strategies don't take all the factors into consideration, such as the vehicle emissions. In order to preserve environment sustainable development, the environmental pollution caused by the vehicle emissions cannot be ignored while managing transportation system.

1.2 Research on Fuel Consumption and Emissions

It is considered that fuel consumption and emissions take up a great proportion in the oil crisis and environment pollution, especially in developing countries. The fuel consumption and vehicle emissions can be evaluated with an emission model. To ensure the accuracy of evaluation results, an appropriate emission model should be selected. American researchers have proposed a new on-road mobile source emission model, named International Vehicle Emissions (IVE) Model, has been designed especially for developing countries. It has been proven by experiments that the IVE model can help to improve the estimation of urban area mobile source emissions with great accuracy. These researches are helpful for us to find effective ways to alleviate the pollution of vehicles in road traffic.

IVE model can provide accurate vehicle emissions of one hour for a particular road section according to the specific location and fleet condition. Besides, it is a java-based stand-alone computer model that can be used directly without secondary development, which makes it easy to use. Since we aim to evaluate the impact of information feedback strategy on vehicle emissions reduction on beltways, it is necessary to find a model that can provide the detail vehicle emissions data. Therefore, in this paper, the IVE is selected as the emission model with the comprehensive consideration of accuracy, adaptability and easily use.

II. RELATED WORK

2.1 The NS mechanism

In order to generate dynamic information, a very simple traffic model is employed, namely the Nagel–Schreckenberg model [4]. The NS mechanism can be decomposed to the four rules parallel dynamics:

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vehicle accelerate every time step when the way is clear. The first vehicle's speed is 3, and the second vehicle's speed is 2. You can't overtake the vehicle before you because the route only support 1 vehicle at the same position. p is a random brake probability. In our daily life, we sometimes brake when we drive the car. With no reasons, just you like. Movement means the position. For the convenience of calculation, we set $V_{max} = 3$ and $P = 0.25$.

2.2 Beltway scenario

Beltway scenario, as shown in Fig. 1 and Fig. 2, a city center is surrounded by two routes, the inner beltway route A and the outer beltway route B. The beltway has an entrance α, and two exits β and γ. And the probability of a vehicle exiting from β or γ is 50%. When a vehicle enters the routes from entrance α, it can choose either β or γ as its destination to exist. Besides, the real-time traffic information of routes A and B is desplayed on the board at the entrance α. Once a vehicle chooses the route, the vehicle will run counterclockwise based on the NS mechanism.

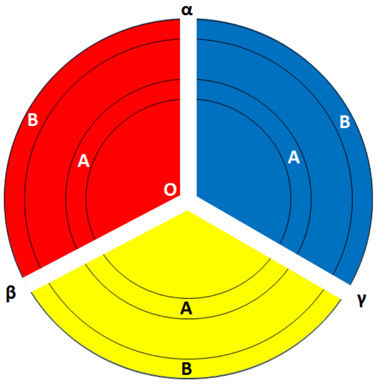

Fig. 1: divide the beltway into three sectors

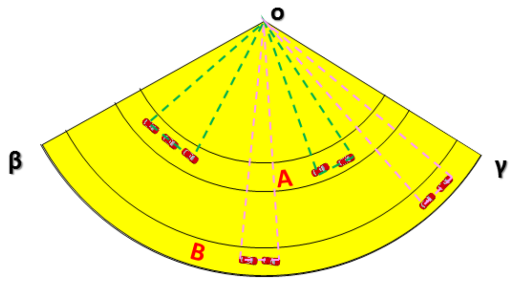

Fig. 2: congestion angle

2.3 Existing information feedback strategies.

CCFS: Dynamic drivers choose the route based on the lowest congestion coefficients.[6].

CAFS: Dynamic drivers choose the route based on the smallest corresponding angle coefficient [7].

BFS: Dynamic vehicles' drivers choose one road with smaller angle coefficient to enter [5].

III. FUEL CONSUMPTION AND EMISSIONS MODELS

3.1 Emissions Models

The fuel consumption and vehicle emissions can be evaluated with an emission model. Nowadays, MOVES, MOBILE6 and IVE are three typical emission models that are widely used. Hence, we have to choose the most suitable one for the evaluation, to ensure the accuracy of evaluation results.

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MOBILE6 model is developed by United States Environmental Protection Agency (US EPA). The vehicle types that are considered in MOBILE6 match with our requirements. Nevertheless, this model has a low expansibility, and stops updating.

MOVES has different emission evaluation levels for projects. And it has an overall consideration of fuel types and particulate matter. However, both MOVES and **MOBILE6** have to be modified by secondary development to get the emissions results, which makes them difficult to use [8-9].

IVE model can provide accurate vehicle emissions of one hour for a particular road section according to the specific location and fleet condition. Hence, it has a higher spatial and temporal resolution than MOBILE6 and MOVES. Besides, it is a java-based stand-alone computer model that can be used directly without secondary development, which makes it easy to use [10-11].

Since we aim to evaluate the impact of information feedback strategy on vehicle emissions reduction on beltways, it is necessary to find a model that can provide the detail vehicle emissions data. Therefore, the IVE is selected as the emission model with the comprehensive consideration of accuracy, adaptability and easily use.[12-15]

3.2 Flow Chart for Vehicle Emissions Estimation

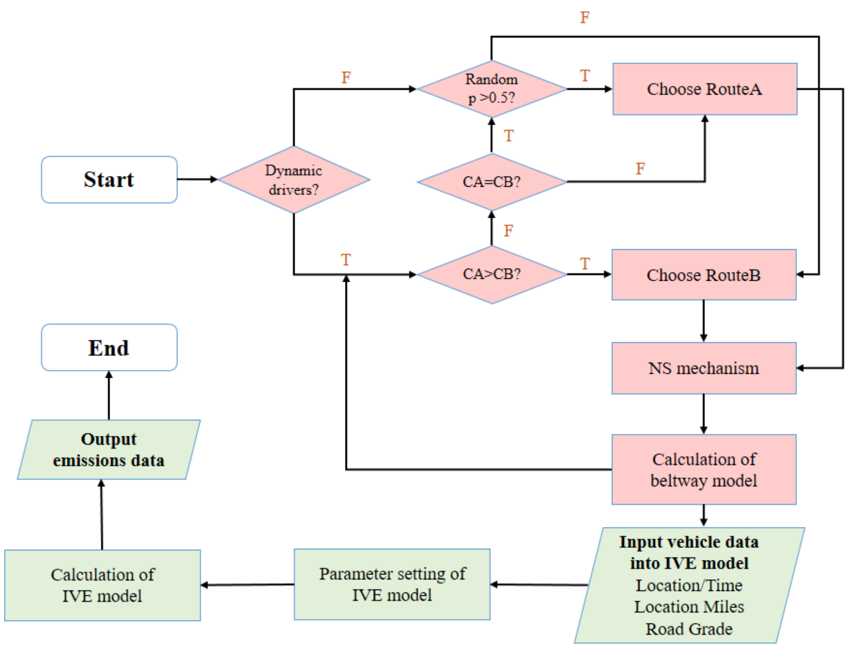

Fig. 3: flow chart for vehicle emissions estimation

The flow chart of the vehicle emissions estimation is shown in Fig. 3. The red areas are belong to the beltway scenario. The green areas are belong to the estimation model, fuel consumption and emissions model. The ratio of dynamic driver is 50%. We determine whether dynamic driver or static driver at first. By comparing CA and CB, the driver select route A if CA < CB, select route B if CA > CB and randomly

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select route if CA = CB. After entering road, the NS mechanism is used to control the vehicle running performance. It can reproduce the basic features of real traffic, for instance stop-and-go wave and phantom jams. The route selection information and other relevant data are obtained after the calculation of beltway model. Afterward, we can input these data into the IVE model to calculate vehicle emissions and export emissions data. And the impact of different feedback strategies on vehicle emissions can be obtained by analyzing the emissions results.

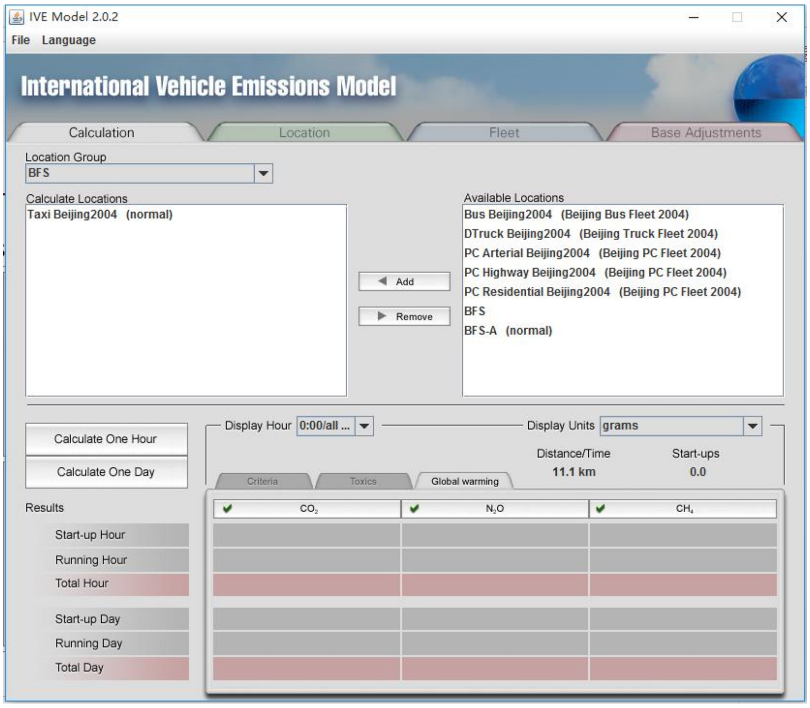

Fig. 4: IVE Graphical User Interfac

Fig. 4. shows the Fig. 3. green areas of the flow chart. The essential (E SENT Tial) input parameters for the IVE model can be categorized (KATEGE WAIS) as location parameters, fleet parameters and base adjustment parameters. The location parameters contain the information about driving behavior, start patterns, environmental variables and fuel characteristics. The fleet parameters include the information about vehicle size, fuel type, vehicle use, fuel delivery system, evaporative control system and exhaust control system. And the base adjustment parameters are used for the user to modify the base emission rates of the model.

In order to analyze the impact of the proposed information feedback strategy, we should configure all the parameters according to the simulation results. Since the information feedback strategy only influences the driving behavior, we set all parameters to the same except the driving behavior parameters to make a persuasive comparison. Furthermore, to localize the vehicle emissions result, the input parameters are configured as below:

We download the database form IVE model website. After finishing the first step of the simulation, we get the data of the driving behavior, which includes amount of driving, driving distance and average

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speed.[16-19] With these data, we use the IVE model to calculate emissions results. Notice that, since the speed of a vehicle is simplified as 0, 1, 2 and 3 in the simulation model. We set the practical speed as 0km/h, 20km/h, 40km/h and 60km/h respectively to make the emissions results conform to reality.

IV. SIMULATION

4.1 Parameter setting

The radius of route A and route B are set to 6000 and 8000 respectively. The minimum speed of a vehicle is 1, while the maximum is 3. The ratio of the dynamic vehicles is 50%. The probabilities of a vehicle entering from and exiting from are both 50% In the simulation, three strategies have be discussed, i.e., CAFS, CCFS and BFS for beltway scenario. All of the simulation results are obtained by 30000 iterations, including the initial 10000 time steps which are not applied in the later test while 20000 time steps are remained.)

The essential input parameters for the IVE model can be categorized as location parameters, fleet parameters and base adjustment parameters. The location parameters contain the information about driving behavior, start patterns, environmental variables and fuel characteristics. The fleet parameters include the information about vehicle size, fuel type, vehicle use, fuel delivery system, evaporative control system and exhaust control system. And the base adjustment parameters are used for the user to modify the base emission rates of the model.[20-23]

In order to analyze the impact of the proposed information feedback strategy, we should configure all the parameters according to the simulation results. Since the information feedback strategy only influences the driving behavior, we set the same parameters except for the driving behavior parameters. Furthermore, to localize the vehicle emissions result, the input parameters are configured as below:

Location: Taxi Beijing 2004.

Fleet: One fleet of Taxi Beijing 2004.

Base adjustment: Beijing HDD.

After finishing the first step of the simulation, we get the data of the driving behavior, which includes amount of driving, driving distance and average speed. With these data, we use the IVE model to calculate emissions results. Notice that, the driving distance should be the total distanced traveled by the fleet of interest. For example, if the simulation result shows that the fleet is comprised of 100 vehicles that each travel 5 miles on roadway, the input distance should be 500 miles. Since the speed of a vehicle is simplified as 0, 1, 2 and 3 in the simulation model. We set the practical speed as 0km/h, 20km/h, 40km/h and 60km/h respectively to make the emissions results conform to reality. Vehicles finish the acceleration process and deceleration process every time step.[24-25]

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4.2 Vehicle Emissions Estimation Model

Firstly, we need to collect data about vehicle running performance and vehicle emissions. Secondly, we analyze the impact of different feedback strategies on vehicle emissions. Finally, conclusion is given. Fig .5. shows that we design a vehicle emissions estimation model. It divide into two parts. One is route scenario, other is fuel consumption and emissions model. Route scenario included NS mechanism and information feedback strategy for route scenario.

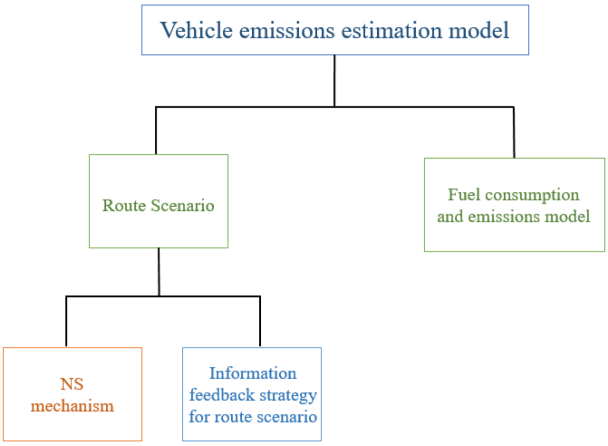

Fig. 5: Structure of vehicle emissions estimation model

4.3 Simulation Results

Table 4-2 shows that vehicles' average emissions by performing different strategies. It is obvious shows in Fig. 6 and Fig. 7, that CO's emissions by using BFS is a little bit more than that by adopting CAFS, but CO_2, NO_x and SO_x's emissions by using BFS are less than that by adopting CAFS and CCFS. Among these three feedback strategies shown in Tab. 1, Vehicles' average emissions adopting BFS is the least. Therefore, we prefer BFS is the greenest strategy of three different strategies in the beltway model.

TABLE. I. Vehicles' average emissions by performing different strategies

AVERAGE EMISSIONS	BFS	CAFS	CCFS
CO(g/km)	13.95456097	13.93187709	14.01006079
CO_2(g/km)	81.29976721	83.69627874	84.90799151
NO_x(g/km)	0.986898795	0.997610153	1.006822534
SO_x(g/km)	0.010145018	0.01039879	0.010536453

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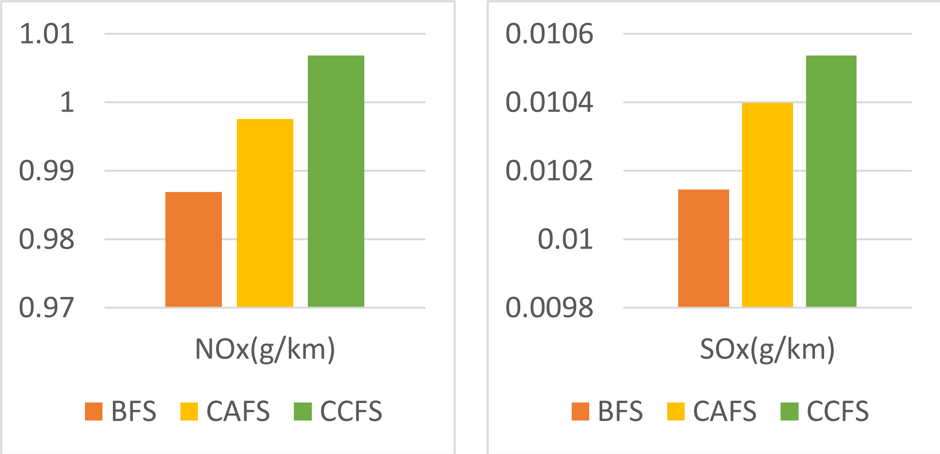

Fig. 6: NOx and SOx's average emissions by performing different strategies

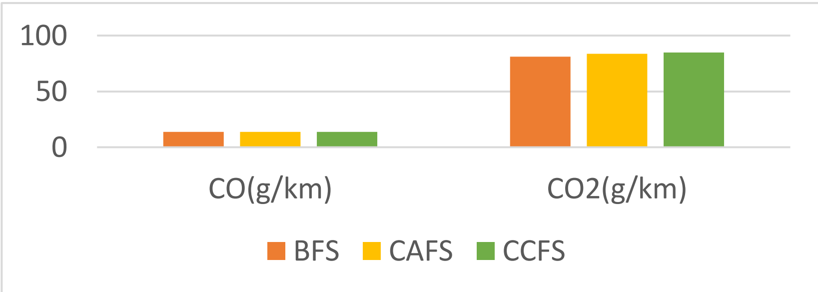

Fig. 7: CO and CO2's average emissions by performing different strategies

V. CONCLUSION AND FUTURE WORKS

In this paper, we propose a novel method which evaluates the influence of information feedback strategy on vehicle emissions. With the simulation results as the input vehicle data, the vehicle emissions are evaluated by using IVE. Moreover, we compare the simulation and vehicle emissions results with other information feedback strategies. It shows that BFS has a better performance, which implies that BFS not only alleviate traffic congestion but also reduce vehicle emissions. As the increasing importance of energy-saving and environmental protection, this method provides a new perspective to analyze the information feedback strategy.

In the future, we will use VDR mechanism instead of NS mechanism. VDR mechanism changes the random brake p from constant to variable. It's more close to the real situation of vehicles running on the road. In the same time, we will study the existing simulation models of transportation, and explore the possibility of further improvements.

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REFERENCES

[1] J. Wahle, A. L. C. Bazzan, F. Klugl, M. Schreckenberg, Decision dynamics in a traffic scenario, Physica A 287 (3) (2000) 669–681.

[2] K. E. Lee, P. Hui, B. H. Wang, N. Johnson, Effects of announcing global information in a two route traffic flow model, Journal of the Physical Society of Japan 70 (12) (2001) 3507–3510.

[3] W. X. Wang, B. H. Wang, W. C. Zheng, C. Y. Yin, T. Zhou, Advanced information feedback in intelligent traffic systems, Physical Review E 72 (2) (2005) 066702.

[4] Nagel K, Schreckenberg M. A cellular automaton model for freeway traffic]. Journal of Physique I France, 1992(2):2221-2229

[5] Li W T, Li J Q, Chen B K, et al. Information feedback strategy for beltways in intelligent transportation systems. EPL (Europhysics Letters), 2016, 113(6): 64001.

[6] W. WANG, B. WANG, W. ZHENG, C. YIN, and T. ZHOU, "Advanced information feedback in intelligent traffic systems," Physical review. E, Statistical, nonlinear, and soft matter physics, vol. 72, 2005.

[7] Dong C, Ma X. Corresponding Angle Feedback in an innovative weighted transportation system[J]. Physics Letters A, 2010, 374(24): 2417-2423.

[8] Z. Yao, H. Wei, T. Ma, Q. Ai, H. Liu, "Developing Operating Mode Distribution Inputs for MOVES using Computer Vision-based Vehicle Data Collector," TRB Paper No. 13-4899.

[9] Hatem Abou-Senna, Essam Radwan, "VISSIM/MOVES integration to investigate the effect of major key parameters on CO2 emissions," Transportation Research Part D 21 (2013) 39–46.

[10] J. Chen, W. Fan, J. Qian, Y. Li, W. Zhao, "Establishment of the light-duty gasoline vehicle emission inventory in Chengdu by the International Vehicle Emission model, " Acta Scientiae Circumstantiae, 2015, 35(7): 2016-2024.

[11] H. Wang, C Chen, C. Huang, "Application of the International Vehicle Emission model for estimating of vehicle emissions in Shanghai," Acta Scientiae Circumstantiae, 2006, 26 (1): 1-9.

[12] Sun X, Li W, Jiang R, et al. Study on the influence of road capacity and information feedback on urban traffic system equilibrium state[J]. Physica A: Statistical Mechanics and its Applications, 2022: 126935.

[13] Zeng J, Qian Y, Mi P, et al. Freeway traffic flow cellular automata model based on mean velocity feedback[J]. Physica A: Statistical Mechanics and its Applications, 2021, 562: 125387.

[14] Chen B, Ding Z, Wu Y, et al. An optimal global algorithm for route guidance in advanced traveler information systems. Information Sciences, 2021, 555: 33-45.

[15] Zhai C, Wu W. Self-delayed feedback car-following control with the velocity uncertainty of preceding vehicles on gradient roads. Nonlinear Dynamics, 2021, 106(4): 3379-3400.

[16] Xu T, Guan J, Hao Y, et al. Real-time traffic state predictor based on dynamic traveller behaviour/Proceedings of the Institution of Civil Engineers-Transport. Thomas Telford Ltd, 2021: 1-11.

[17] Harrison R M, Allan J, Carruthers D, et al. Non-exhaust vehicle emissions of particulate matter and VOC from road traffic: A review[J]. Atmospheric Environment, 2021, 262: 118592.

[18] Pouresmaeili M A, Aghayan I, Taghizadeh S A. Development of Mashhad driving cycle for passenger car to model vehicle exhaust emissions calibrated using on-board measurements. Sustainable cities and society, 2018, 36: 12-20.

[19] Sun S, Jin J, Xia M, et al. Vehicle emissions in a middle-sized city of China: Current status and future trends. Environment international, 2020, 137: 105514.
[20] Stogios C, Kasraian D, Roorda M J, et al. Simulating impacts of automated driving behavior and traffic conditions on vehicle emissions. Transportation Research Part D: Transport and Environment, 2019, 76: 176-192.
[21] Huang Y, Yu Y, Yam Y, et al. Statistical evaluation of on-road vehicle emissions measurement using a dual remote sensing technique. Environmental Pollution, 2020, 267: 115456.
[22] Wang Y, Boggio-Marzet A. Evaluation of eco-driving training for fuel efficiency and emissions reduction according to road type. Sustainability, 2018, 10(11): 3891.
[23] C. Dong, X. Ma, and B. Wang, "Weighted congestion coefficient feedback in intelligent transportation systems," Physics Letters A, vol. 374, pp. 1326-1331, 2010.N
[24] B. Chen, X. Sun, H. Wei, C. Dong, and B. Wang, "Piecewise function feedback strategy in intelligent traffic systems with a speed limit bottleneck," International Journal of Modern Physics C, vol. 22, pp. 849-860, 2011.
[25] C. F. Dong, X. Ma, B. H. Wang, X. Y. Sun, Effects of prediction feedback in multi-route intelligent traffic systems, Physica A 389 (16) (2009) 3274– 3281.