A METHOD OF FORECASTING AIR POLLUTION INDUCED BY VEHICLE EXHAUST WITH TRAFFIC SIMULATION TECHNOLOGY

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Abstract: Management and control of vehicle exhaust is extremely urgent due to the growth trend of vehicle population. Prediction of vehicular exhausts dispersion is one of the indispensability links of atmospheric environment treatment. However, the prediction of air pollution induced by vehicle exhaust needs detailed data of traffic flow forecasting which is difficult to obtain. In order to simulate and forecast the distribution of vehicle exhaust more exactly as traffic demand changes, this paper presents a method that transforms future traffic demand into traffic flow in PARAMICS, and uses the independently developed UTESAS (Urban Traffic Environment Simulation and Assessment System) to forecast the concentration distribution of vehicular exhausts. There are three approaches. Firstly, the road network of simulation is set up for PARAMICS. Secondly, the project of traffic simulation is performed to predict the traffic flow. Thirdly, traffic flow data is used as input of UTESAS to simulate the dispersion, and then the spatial distribution of forecasted vehicle exhaust is shown in GIS module. Finally, this paper gives a case of application. The method has been used to simulate and predict the hourly variety of concentration of carbon monoxide of the road network near Tianhe Sports Center in Guangzhou during evening rush hour in workdays of June 2007. This simulation has been carried out under the typical meteorological condition of evening climax of Guangzhou.

Key words: *air pollution, vehicle exhaust, traffic simulation, method of forecasting*

1 Introduction

As the vehicle population increases, vehicle exhaust has become the primary source of air pollution in most urban area. It is estimated that the shared percentage of NO_X contributed by road transport in Shanghai has reached 81%, while concentration 86% (Fu, 2004). In Guangzhou the percentage of NO_X contributed by vehicle exhaust has exceeded 40% (Wu, 2002). And regarding the future increase of vehicle population, vehicle exhaust is posing more and more significant influence on air pollution in urban area, making emission managements and controls extremely urgent (Shen, 2006).

Prediction of vehicular exhausts dispersion is one of the indispensability links of atmospheric environment treatment. However, it needs detailed data of future traffic flow forecasting which is difficult to obtain. It influences the accuracy of the

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forecasting. With the development of Traffic System Simulation, it's possible to obtain detailed information of traffic flow on road network, which serves as input for prediction of vehicle exhaust dispersion.

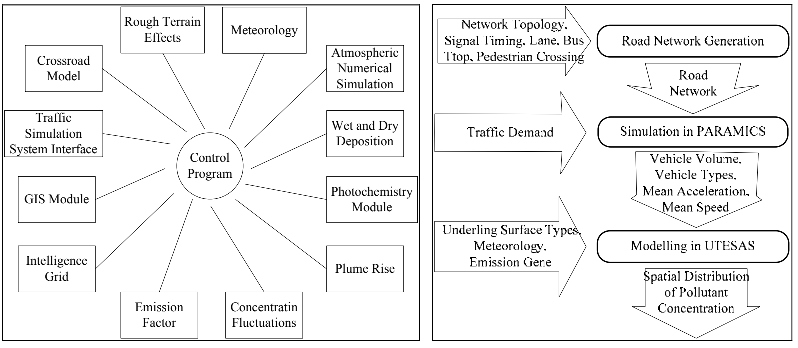
Most researchers all over the world seldom put their focus on integration of traffic simulation model and diffused model of vehicle pollution. Schmidt M. has performed dispersion simulation of vehicle emission by integrating air pollution dispersion model-DYMOS and mesoscale traffic simulation model -DYNEMO (Schmidt, 1998). And Addison P. S. used the output of PARAMICS as instantaneous source to simulate the dispersion process of vehicle emission in street canyon (Addison, 2000).

Based on former research, this paper presents a method that transforms future traffic demand into traffic flow with PARAMICS, and then uses the independently developed UTESAS (Urban Traffic Environment Simulation and Assessment System) to forecast the concentration distribution induced by vehicular exhausts.

2 Prediction Model

2.1 Model of air pollution dispersion - UTESAS

UTESAS (Urban Traffic Environment Simulation and Assessment System) is independently developed by Research Center of Intelligent Transport Systems, Sun Yat-sen University. UTESAS is a three-dimensional Gaussian Plume Model. Considering the influence of dynamic variety of traffic flow on road network and the different characteristics of urban roads, street canyon model and crossroad model are embedded. With introduction of mesoscale and microscale atmospheric numerical simulation, the multiple influences from process of vehicle emission diffusion, transfer and transformation induced by meteorology, buildings, underlying surfaces and wet/dry deposition are considered. The GIS module of UTESAS shows the simulation result with chorogram. UTESAS is modular designed, and Figure 1(a). shows the major modules.



(a) **(b)**

Figure 1 (a).Major modules of UTESAS (b).Flow chart of the predicting method

The basal dispersion equation in UTESAS is an analytical form of Gaussian Plume Model for finite lineal source:

$$C = \frac{q}{2\pi\delta_z u}\{\exp[\frac{-(Z-H)}{2\delta_z^2}] + \exp[\frac{-(Z+H)^2}{2\delta_z^2}]\} * PD \qquad (1)$$

Where C represents the concentration in receptor, q the source strength per unit length, u the average wind speed, δ_Z the vertical dispersion parameters, Z the height of pollution concentration to be calculated, H the effective source height, and PD the impact factor of lineal source for receptor.

2.2 Traffic simulation system--PARAMICS

PARAMICS is a microscopic traffic simulation program. It is an effective computational tool that helps researchers of traffic engineering comprehend, simulate and analyze the situation of traffic on road network (Zhang, 2006). It comprises three-dimension visualization user interface and powerful API (Application Programming Interface), granting the capabilities of microscopic disposing for single vehicle and multi-user parallel computation. PARAMICS can perform simulation on road network of any scale and support up to 1,000,000 nodes, 4,000,000 links and 32,000 regions. The following models are adopted in simulation: (1) Vehicle Generation Model; (2) Driving Behavior Model; (3) Route Choice Model; (4) Public Traffic Model; (5) Intersection Model.

3 Prediction Procedures

Future traffic demand is transformed into traffic flow in PARAMICS. The information of traffic flow includes vehicle flow volume on each link, vehicle types, mean speed and mean acceleration. As Figure 1(b). shows, this method falls into three main steps.

Step 1: generate the road network for simulation in PARAMICS. Firstly, the set of nodes which stands for the geometrical and topological structure of the road network is extracted from GIS module of UTESAS using the ActiveX Control of MapX provided by MapInfo. Then the original set of nodes is condensed by eliminating the neighboring nodes, the nodes on the same line or arc. Finally the basic PARAMICS road network is generated, and the parameters for lanes, pedestrian crossings, bus stops and signal timing strategies are set.

Step 2: perform traffic simulations. After modeling the road network, traffic simulations are performed to obtain traffic volume in each link, vehicle types, mean speed and mean acceleration according to future traffic demand. These parameters are acquired by data communication mechanism provided by API of PARAMICS (He, 2005).

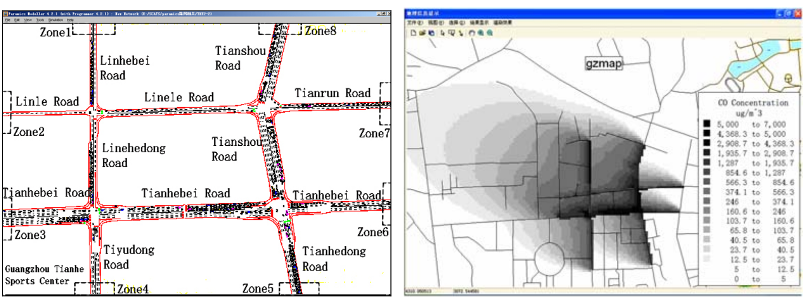
Step 3: model the dispersion of vehicle emission. Based on the result of step 1 and 2, strength of lineal source on each simulated links is computed. Then UTESAS is used to model the dispersion of traffic emission by utilizing the sources including meteorology and underlying surface types, etc. Finally, the chorogram of predicted concentration of vehicle exhaust dispersion is shown in GIS module, visually representing spatial distribution of air pollution.

4. Application

The method for predicting air pollution induced by vehicle exhaust by integrating PARAMICS and UTESAS has been described on section 3 and section 4. The method is used to forecast the concentration distribution of carbon monoxide of the road network near Tianhe Sports Center in Guangzhou during evening rush hour (17:00-18:00) in workdays of June 2007. This simulation has been carried out under the typical meteorological condition of evening climax of Guangzhou.

4.1 Generation of road network for simulation

The topology of road network near Tianhe Sports Center is extracted from the electronic map by the GIS module of UTESAS, and used to generate files representing basic road network, named as nodes, links and centres etc. Based on the basic road network, pedestrian crossings, bus stops, and signal timing strategies are utilized to set up road network for simulation (Figure 2(a)).



(a) (b)

Figure 2 (a).Chorogram of CO concentration (b).Simulation road network

4.2 Traffic simulation procedures

Due to the lack of traffic demand data of Guangzhou, historical data of traffic volume from SCATS (Sydney Coordinated Adaptive Traffic System) in Guangzhou is used to estimate the traffic demand of simulated network during evening rush hour(17:00-18:00) in workdays of June 2007. And traffic simulations are performed to acquire traffic volume of each link, vehicle types, mean speed and mean acceleration, etc.

Figure 3 shows detailed information of simulated network. Table 1 together with Figure 3 indicates that: (1) speed of traffic stream is sharply degressive at signalized intersections and pedestrian crossings; (2) traffic bottlenecks appear near Non-Harbor-shaped bus stops; (3) speed of traffic flow upstream is higher than downstream; (4) speed of traffic flow approaching intersection is lower than that leaving.

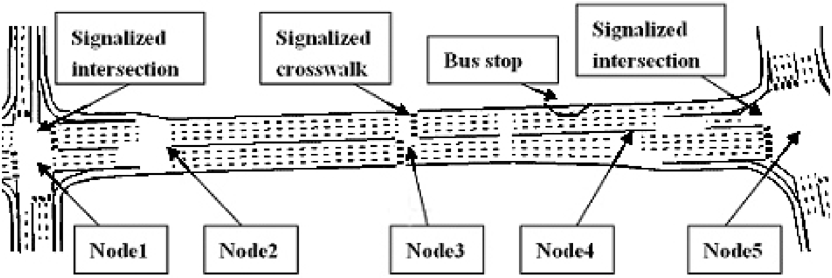


Figure 3. Simulated links of Tianhebei Road

Table 1. Traffic flow from simulated links of Tianhebei Road

Link No. （2 nodes）	Vehicle Type	Traffic volumes v/h	Mean speed km/h	Mean acceleration m/s^2
1→2	Light/Heavy	1202/145	51.4/43.7	0.35/0.30
2→1	Light/Heavy	1281/297	6.9/7.0	0.14/0.12
2→3	Light/Heavy	1216/149	25.5/11.6	0.07/0.08
3→2	Light/Heavy	1299/301	11.0/8.9	0.13/0.12
3→4	Light/Heavy	1197/148	5.7/5.0	0.09/0.09
4→3	Light/Heavy	1285/295	5.2/4.4	0.08/0.07
4→5	Light/Heavy	1185/139	5.5/4.9	0.13/0.11
5→4	Light/Heavy	1274/288	28.9/28.6	0.10/0.12

4.3 CO concentration prediction

Traffic flow data in road network is obtained from section 5.2. And then, the typical meteorology of Guangzhou in June is derived from the statistical analysis of historical meteorological data. The result shows a mean wind speed of 1.5m/s, predominant wind direction in southeast and mean temperature of 32℃. UTESAS is used to model the dispersion process of CO induced by vehicle exhaust, and the chorogram of CO concentration at 10m high shown in GIS module.

As Figure 2(b) shows, the surface distribution of CO concentration at 10m high induced by vehicle exhaust is visually illustrated by the chorogram. By integrating traffic volume from Figure 2(a) and meteorological condition, it indicates that: (1) CO concentration is higher near signalized road segments than that near non-signalized road segments; (2) CO concentration in lee of intersections obviously higher; (3) CO concentration near bus stops higher; (4) The direction of dispersion acts in accordance with wind direction, and CO concentration has an obviously decreasing trend as the distance increases.

5 Conclusions

This paper presents a method of forecasting air pollution induced by vehicle exhaust by integrating PARAMICS-based micro-simulation and UTESAS. This method has two primary excellences: firstly, the method transforms the variety of traffic demand into the variety of traffic flow depending on powerful traffic simulation functions of PARAMICS. So the UTESAS can forecasts the variety of vehicle exhaust induced by urban planning, variety of road network and increase of vehicle population, etc. Secondly, PARAMICS can commendably consider the variety of traffic flow which is impacted by intersections, pedestrian crossings, bus stops and signal timing strategies, etc. It ensures that the dispersion model of air pollution would simulate the process of dispersion more exactly.

As PARAMICS is a microscopic traffic simulation software, its road network for simulation needs a lot of detailed information, such as network topology, lanes, pedestrian crossing, bus stop and signal timing strategies etc. So the cost of setting up a whole city network is very considerable. However, with simple input of data source, macroscopical traffic simulation model can generate the basic information of traffic flow in urban road network, including traffic volume, mean speed etc. So it presents a worthy research direction which integrates macroscopical traffic simulation model and dispersion model of air pollution to model and forecast the urban air pollution induced by vehicle exhaust.

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