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# Dynamic Management of Environmental Risk of Urban Traffic Exhaust Pollution Based on Taxi Trail Big Data

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***Abstract*** **-** With the development of China's economy and the increase of car ownership，China's air pollution has changed from the characteristics of SOOT-TYPE air pollution in the 1980s and 1990s to the characteristics of soot-automobile exhaust mixed air pollution. And the risk of environmental pollution caused by this has become increasingly serious. In order to achieve more effective management and control of urban traffic exhaust pollution, this paper studies the dynamic monitoring and management of environmental risk of urban traffic exhaust pollution based on taxi trail big data. Firstly, the urban area is meshed to identify and extract the road information of different grades in the grid. Then, the traffic flow and speed in the road network are calculated based on taxi trail big data. Then, the exhaust emission calculation methods of different types of vehicles in the road network are studied. Finally, the real-time visualization of exhaust emissions from each grid in the road network is presented to provide decision support for environmental risk management of traffic exhaust pollution.

***Keywords*****:** Environmental risk; Dynamic management; Urban traffic; Air pollution; Taxi trail big data

## 1. Introduction

Automobile is an important means of transportation in modern society. With the development of China's economy and the rapid increase of car ownership, automobile exhaust pollution also brings serious environmental risks. At present, China's air pollution has changed from the characteristics of SOOT-TYPE air pollution in the 1980s and 1990s to the characteristics of mixed soot-automobile exhaust air pollution. According to the investigation of vehicle exhaust pollution sharing rate by Urumqi Environmental Monitoring Center, the emission of nitrogen oxides from motor vehicles has accounted for 40.1% of the total amount of nitrogen oxides in urban air, and the proportion of carbon monoxide from automobiles has reached 94.1%. According to the statistical bulletin issued by the Ministry of Ecology and Environment of the People's Republic of China, the proportion of nitrogen oxides from motor vehicles has increased year by year, reaching 31.6% by 2015. The gradual increase of the proportion of automobile emissions warns us that it is urgent to manage the risk of urban traffic air pollution.

On July 26, 2015, the State Council of China issued the Plan for the Construction of Eco-environmental Monitoring Network, which clearly put forward a new pattern for the construction of eco-environmental monitoring. For this reason, domestic scholars have made a series of studies on urban air pollution environmental monitoring. Gao Ruifeng et al. fused GIS, GPRS and trail technology, dynamically monitored the emission of road traffic pollution gas near the sensor sites, and used K-Nearest Neighbor Algorithms to mine its internal relationship and related influencing factors. Combining with the actual traffic situation, an early warning model which can accurately reflect the spatial and temporal distribution of traffic pollution gas emissions is constructed to provide decision support for how to reduce traffic pollution emissions[1]. Deng Yiwen et al. analyzed the main factors affecting the emission characteristics of vehicle pollutants. On this basis, the paper further proposed a dynamic correction method of vehicle pollutant emission factors based on the actual operation of tunnels, in order to realize the dynamic monitoring of pollutant emission factors of urban underground roads through a small number of detectors and realize the energy-saving operation of tunnel ventilation system[2]. Wu Peng et al. studied the emission rules of motor vehicles on urban roads, and comprehensively analyzed the driving characteristics of motor vehicles on the roads. Considering that there are great differences in vehicle traffic behavior between peak and off-peak hours, a road vehicle emission monitoring model is established for peak and peak periods. And he used VISSIM to simulate the survey data to verify the feasibility of the urban road vehicle pollutant emission monitoring model[3].

MacNaughton et al. designed a portable power-driven workstation to study the spatial variation of air pollution[4]. Zwack et al. designed a backpack equipped with pollution monitoring instruments and trail devices. Researchers carried these backpacks along a prescribed walking route to cover all roads in the study area[5]. Kingham et al. designed a pocket with pollution equipment to collect air pollution data for monitoring in different modes of transportation (automobiles, bicycles and buses). Shirai et al. proposed a mechanism for real-time monitoring of air quality using public vehicles, and tested it with sanitation vehicles in Fukugawa, Japan[6].

However, the monitoring methods in the above studies need to deploy a large number of sensors, and due to the limitation of sensor energy supply, they can only be used for short-term monitoring[7]. During the period of China's "13th Five-Year", the monitoring of ecological environment based on the atmosphere, water and soil was further improved. Monitoring and management of the environment based on "Internet +" and "big data" is one of the important development directions.

Chapter of this paper is arranged as follows: First, we introduce the technical route and specific methods of the study, explain in detail the calculation method of traffic air pollution emissions using taxi trail data, then take Harbin as an example to apply this method, and finally give our research conclusions.

## 2. Method

### 2.1. Technical Route

The technical route of this study is as follows: Firstly, traffic data are obtained, including electronic map data of urban road network, taxi track data, daily variation data of the proportion of different types of vehicles taxis on different roads. Then the data are preprocessed, including the meshing of road network and the extraction and recognition of taxi trail data, and the taxi trail data is matched to the grid. Next, we use the taxi trail data and vehicle type ratio data to calculate the traffic flow and speed. Then based on this, traffic air pollutants are calculated according to fuel type, vehicle type and pollutant type. Finally, the risk management mechanism of traffic pollution environment is discussed according to the calculation results of pollutants.

### 2.2. Specific implementation

Firstly, we need to collect the basic data for this study, including urban road network electronic map data, taxi trail data, daily variation data of the proportion of different types of vehicles taxis on different roads. Taxi trail data includes the following information: taxi ID, GPS, time, longitude and latitude, instantaneous speed, GPS ID, status information (Passenger or Empty) and driving direction. In order to refine the calculation, we have made a reasonable grid division of the urban road network, and matched the taxi data to the divided grid, and counted the number and status of taxis in each grid. On this basis, the number of vehicles in each grid is calculated, and the calculation is as formula (1):

$$P_{i,j,k} = T_{i,j} / \alpha_j \times \beta_{i,j} \tag{1}$$

$P_{i,j,k}$ denotes the number of vehicles type *i* on road grade *j* in grid *k*, $T_{i,j}$ denotes the number of taxis on road grade *j* in grid *k*, $\alpha_j$ denotes the proportion of taxis on road grade *j*, $\beta_{j,k}$ denotes the proportion of vehicles type *i* on road grade *j*. Taking 10 minutes as step, the traffic volume variation of different types of vehicles on different grades of urban road network in one day is calculated. On this basis, the pollutant emission factors are calibrated according to the Technical Guidelines for the Compilation of Road Motor Vehicle Air Pollutant Emission Inventory (Trial Implementation) of the People's Republic of China.

Atmospheric pollutants emitted by automobiles mainly include exhaust pollutants and evaporation pollutants. Among them, exhaust emissions include gaseous pollutants and particulate matter, the former includes carbon monoxide (*CO*), hydrocarbons (*CH*), nitrogen oxides ( $NO_x$ ), etc., the latter includes inhalable particulate matter ( $PM_{10}$ ) and fine particulate matter ( $PM_{2.5}$ ); evaporative emissions are mainly hydrocarbons (*HC*), where only gasoline-fuelled vehicle evaporative emissions are considered.

Therefore, vehicle pollutant emission ($E$) in road network mainly includes exhaust emission ($E_1$) and evaporative emission of $HC$ ($E_2$). The calculation formula is shown in (2):

$$E = E_1 + E_2 \tag{2}$$

In the formula, $E_1$ is the exhaust gas emission, including carbon monoxide ($CO$), hydrocarbons ($HC$), nitrogen oxides ($NO_x$), inhalable particulate matter ($PM_{10}$) and fine particulate matter ($PM_{2.5}$), unit: ton, indicating the evaporative emission of $HC$, unit: ton.

The calculation formula of automobile exhaust emission ($E_1$) is shown as (3):

$$E_1 = \Sigma P_i \times EF_i \times VKT_i \times 10^{-6} \tag{3}$$

Here, $E_1$ denotes the annual emissions of $CO$, $HC$, $NO_x$, $PM_{10}$ and $PM_{2.5}$ corresponding to vehicles type $i$, unit: ton; $EF_i$ denotes the emission of exhaust pollutants per unit distance of vehicles type $i$, unit: g/km; $P_i$ denotes the number of vehicles type $i$; $VKT_i$ denotes the average annual mileage of vehicles type $i$, unit: km/vehicle.

Among them, the formula for calculating $EF_i$ of automobile exhaust emission coefficient is shown in (4):

$$EF_{i,j} = BEF_i \times \varphi_j \times \gamma_j \times \lambda_i \times \theta_i \tag{4}$$

Here, $EF_{i,j}$ represents the emission coefficient of vehicle type $i$ in area $j$; $BEF_i$ represents the comprehensive reference emission coefficient of vehicle type $i$; $\varphi_j$ represents the environmental correction factor of area $j$; $\gamma_j$ represents the average speed correction factor of area $j$; $\lambda_i$ represents the deterioration correction factor of vehicle type $i$; $\theta_i$ represents the correction factor of other service conditions of vehicle type $i$ (such as load factor, oil quality, etc.). Among them, the average speed correction factors of gasoline and diesel vehicles are shown in Tables 1 and 2 respectively.

Table 1: Average Speed Correction Factor for Gasoline Vehicles.

| Pollutants | Velocity Range（km/h） | | | | |
|---|---|---|---|---|---|
| | <20 | 20-30 | 30-40 | 40-80 | >80 |
| CO | 1.69 | 1.26 | 0.79 | 0.39 | 0.62 |
| HC | 1.68 | 1.25 | 0.78 | 0.32 | 0.59 |
| NOx | 1.38 | 1.13 | 0.90 | 0.86 | 0.96 |
| PM2.5, PM10 | 1.68 | 1.25 | 0.78 | 0.32 | 0.59 |

Table 2: Average Speed Correction Factor for Diesel Vehicles.

| Pollutants | Emission Standard | Velocity Range（km/h） | | | | |
|---|---|---|---|---|---|---|
| | | <20 | 20-30 | 30-40 | 40-80 | >80 |
| CO | *BA, A, B, C* | 1.43 | 1.14 | 0.89 | 0.54 | 0.61 |
| | *D, E* | 1.29 | 1.10 | 0.93 | 0.70 | 0.61 |
| HC | *BA, A, B, C* | 1.41 | 1.13 | 0.90 | 0.61 | 0.41 |
| | *D, E* | 1.38 | 1.12 | 0.91 | 0.64 | 0.48 |
| NOx | *BA, A, B, C* | 1.31 | 1.08 | 0.93 | 0.74 | 0.66 |
| | *D, E* | 1.39 | 1.12 | 0.91 | 0.60 | 0.28 |
| PM2.5, PM10 | *BA, A, B, C* | 1.22 | 1.08 | 0.93 | 0.71 | 0.49 |
| | *D, E* | 1.36 | 1.12 | 0.91 | 0.65 | 0.48 |

Note: In the table, BA, A, B, C, D and E indicate the before first, first, second, third, fourth and fifth engines in China respectively.

Because the paper calculates traffic air emissions in 10 minutes, it is necessary to revise the above formulas and the definition of each parameter. The revised formula for calculating vehicle exhaust emissions is shown in (5):

$$E_{1i} = P_i \times EF_i \times VKT_i \tag{5}$$

Here, $E_1$ denotes the annual emissions of $CO$, $HC$, $NO_x$ , $PM_{10}$ and $PM_{2.5}$ corresponding to vehicles type *i* in 10 minutes, unit: ton; g denotes the emission of exhaust pollutants per unit distance of vehicles type *i* in 10 minutes, unit: g/km; $P_i$ denotes the number of vehicles type *i*; $VKT_i$ denotes the average annual mileage of vehicles type *i* in 10 minutes, unit: km/vehicle. The calculation formula and parameter definition of $EF_i$ remain unchanged.

The main pollutants emitted by evaporation are *HC* hydrocarbons. The calculation of *HC* evaporation emissions is similar to that of automobile exhaust emissions. Only gasoline-fueled automobiles are considered. The calculation formula is shown in (6):

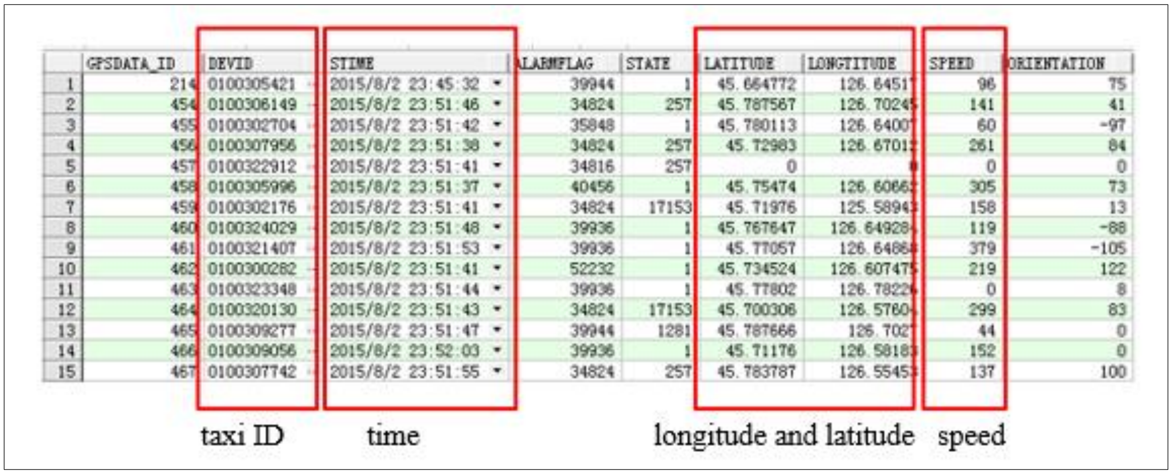
$$E_2 = \left(EF_1 \times VKT / V / 6 + EF_2 / 24 / 6\right) \times P \tag{6}$$

Here, $E_2$ represents the evaporative emissions of *HC* within 10 minutes of a grid during driving and parking, including five types of motor vehicles: cars, taxis, vans, buses and motorcycles, unit: g; $EF_1$ represents the evaporative emission coefficient of a vehicle during driving, unit: g/h ; *VKT* represents the mileage of a vehicle, which is taken as the length of the road in a grid, unit: km; *V* represents the average speed of a car, unit: km/h; $EF_2$ is the comprehensive emission factor during parking, unit: g/day; *P* represents the number of type *i* cars in a grid. According to formula (2), the total amount of vehicle pollutants in road network can be calculated.

After calculating the emission of urban traffic vehicle pollutants, we can take a variety of urban traffic air pollution risk management measures, such as mobile App, wireless broadcasting, to warn the public in high-risk areas of air pollution, or take traffic control measures in high-risk areas.

## 3. Application

Taking Harbin as an example, this method is tested in Harbin. This paper acquires the big data of taxi trail in Harbin, China in 2015, including vehicle ID, trail, time, longitude and latitude, instantaneous speed, trail ID, status information and direction, etc. There are more than 20 million pieces of data per day. The big data statistics table is shown in the Fig.1.



| | GPSDATA_ID | DEVID | STIME | ALARMFLAG | STATE | LATITUDE | LONGTITUDE | SPEED | ORIENTATION |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 214 | 0100305421 | 2015/8/2 23:45:32 | 39944 | 1 | 45.664772 | 126.6451 | 96 | 75 |
| 2 | 454 | 0100306149 | 2015/8/2 23:51:46 | 34824 | 257 | 45.787567 | 126.7024 | 141 | 41 |
| 3 | 455 | 0100302704 | 2015/8/2 23:51:42 | 35848 | 1 | 45.780113 | 126.6400 | 60 | -97 |
| 4 | 456 | 0100307956 | 2015/8/2 23:51:38 | 34824 | 257 | 45.72983 | 126.6701 | 261 | 84 |
| 5 | 457 | 0100322912 | 2015/8/2 23:51:41 | 34816 | 257 | 0 | 0 | 0 | 0 |
| 6 | 458 | 0100305996 | 2015/8/2 23:51:37 | 40456 | 1 | 45.75474 | 126.6066 | 305 | 73 |
| 7 | 459 | 0100302176 | 2015/8/2 23:51:41 | 34824 | 17153 | 45.71976 | 125.5894 | 158 | 13 |
| 8 | 460 | 0100324029 | 2015/8/2 23:51:48 | 39936 | 1 | 45.767647 | 126.64928 | 119 | -88 |
| 9 | 461 | 0100321407 | 2015/8/2 23:51:53 | 39936 | 1 | 45.77057 | 126.6486 | 379 | -105 |
| 10 | 462 | 0100300282 | 2015/8/2 23:51:41 | 52232 | 1 | 45.734524 | 126.60747 | 219 | 122 |
| 11 | 463 | 0100323348 | 2015/8/2 23:51:44 | 39936 | 1 | 45.77802 | 126.7822 | 0 | 8 |
| 12 | 464 | 0100320130 | 2015/8/2 23:51:43 | 34824 | 17153 | 45.700306 | 126.5760 | 299 | 83 |
| 13 | 465 | 0100309277 | 2015/8/2 23:51:47 | 39944 | 1281 | 45.787666 | 126.702 | 44 | 0 |
| 14 | 466 | 0100309056 | 2015/8/2 23:52:03 | 39936 | 1 | 45.71176 | 126.5818 | 152 | 0 |
| 15 | 467 | 0100307742 | 2015/8/2 23:51:55 | 34824 | 257 | 45.783787 | 126.5545 | 137 | 100 |



Fig. 1: Taxi Trail Data.

Based on the open Streetmap in ARCGIS, the main urban area of Harbin is locked and meshed. The main urban area is divided into 50*50 square grid with 200 meters edge, as shown in Fig. 2. The length and grade of roads in each grid are identified. Among them, roads are divided into four grades: expressway, main road, secondary road and branch road.

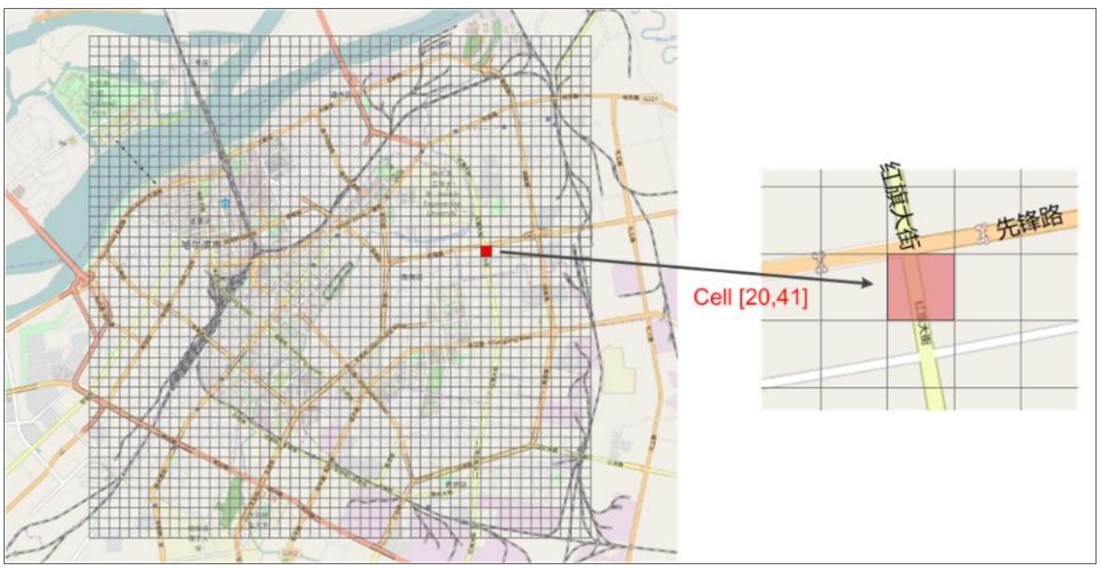



Fig. 2: Grid division of urban area in Harbin.

We have made a long-term observation on the traffic flow on different road types in Harbin urban road network. Based on Liang Tao's research in two articles, namely "Study on Characteristics of Typical Pollutants Emissions from Vehicle Exhausts in Harbin "[8] and “Vehicle Exhausts Emission Inventory of A Typical City as Harbin in Northeast China "[9], vehicles are divided into 7 types: motorcycles, light buses, taxis, buses, large buses, medium and small trucks and heavy trucks. The proportion of different types of vehicles in different road types is shown in table 3.

Table 3: Proportion of different types of vehicles on different road types.

| | motor-cycles | light buses | taxis | buses | large buses | medium and small trucks | heavy trucks |
|---|---|---|---|---|---|---|---|
| expressway | 0.9 | 78.3 | 12.8 | 5.3 | 0.8 | 1.5 | 0.4 |
| main road | 2.1 | 73.6 | 15.8 | 5 | 0.5 | 2.4 | 0.6 |
| secondary road | 0.5 | 75 | 16.5 | 3.7 | 0.4 | 3.4 | 0.5 |
| branch road | 1 | 74.2 | 17.5 | 3.2 | 0.2 | 2.8 | 1.1 |

At the same time, after long-term observation, the proportion of taxis in the total traffic volume in each period of the road network within one day is shown in Fig. 3.

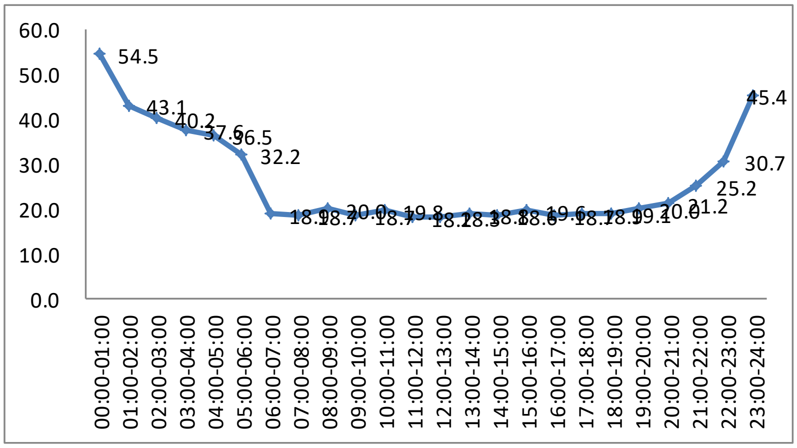



Fig. 3: Diurnal variation of taxi proportion.

Taking 10 minutes as step size, the taxi trail data are analyzed, and the number of taxis and their average speed in each grid are counted. Due to the lack of traffic volume of other types of vehicles, it is necessary to calculate the traffic volume of taxis in one year, road statistics information of different grades of road network, proportion of different types of vehicles and daily variation. The sum of the calculated traffic volume of each vehicle type is the total traffic volume. The traffic volume in each grid is visualized in the form of thermodynamic diagram. Fig. 4 shows the traffic volume in a 10-minute interval from 05:00 to 06:00 on a certain day in Harbin. Through Fig. 4, we can see the general outline of Harbin urban road network, and the red areas are the sections with large traffic flow in Harbin urban area.

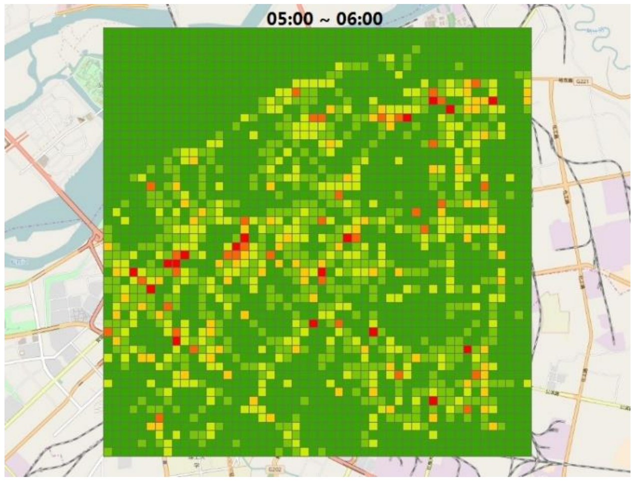


Fig. 4: A grid-based taxi traffic graph.

At present, in the taxi market of Harbin, 23.4% of vehicles use gasoline, 20.6% use diesel, 56% use gas. There are differences in pollutant emissions of vehicles using different types of fuel. Therefore, it is necessary to calibrate emission factors for each type of vehicle using different fuels in order to reduce errors. Then, the traffic flow, driving mileage and emission factors of various types of vehicles are used to calculate the emission. The proportion of fuel types used by various types of motor vehicles in Harbin is shown in Table 4.

Table 4: Proportion of Fuel Types Used by Various Types of Motor Vehicles

| | motor-cycles | light buses | taxis | buses | large buses | medium and small trucks | heavy trucks |
|---|---|---|---|---|---|---|---|
| gasoline | 0.234 | 0.925 | 0.1 | 0.1 | / | / | 1 |
| diesel fuel | 0.206 | 0.075 | 0.9 | 0.9 | 1 | 0.148 | / |
| others | 0.56 | / | / | / | / | 0.852 | / |

According to formula (2), the total amount of vehicle pollutants in road network can be calculated. The total emission status is visualized in the form of thermodynamic charts. Fig. 5 shows the emission of automobile CO from 5:40 to 5:50 on a certain day in Harbin.

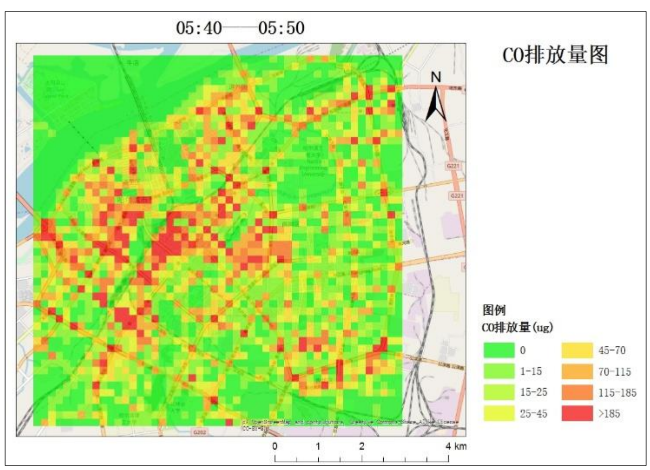


Fig. 5: Emissions of air pollutants from automobiles.

## 4. Conclusion

In this paper, we study a new method of urban air pollution monitoring and risk management. This method is innovative in data sources and based on taxi trail data. It avoids the need to deploy a large number of sensors in cities in traditional methods. When the taxi trail data can be obtained in real time, the real-time and dynamic monitoring of urban traffic air pollution can be realized. It also provides decision support for risk management of high-risk areas of urban traffic air pollution based on monitoring results. Based on this paper, more in-depth research can be carried out, and it is feasible to build a rapid and efficient urban traffic air pollution monitoring system and risk management mechanism.

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