

## *Original Paper*

# Road Traffic Status and Carbon Emission Estimation Methods

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Received: May 19, 2020

Accepted: May 24, 2020

Online Published: May 27, 2020

doi:10.22158/wjssr.v7n2p34

URL: <http://dx.doi.org/10.22158/wjssr.v7n2p34>

### ***Abstract***

*This paper mainly studies the relationship between traffic status and carbon emission, and the evaluation method of carbon emission based on traffic status. First of all, the traffic status is defined. In this paper, the traffic status is divided into traffic congestion and unobstructed traffic. Then, this paper analyzes the influence of different traffic conditions on carbon emissions in the same fleet at the same time through the study of vehicle exhaust emissions in both the unobstructed and congested traffic conditions. The unobstructed section traffic is used to simulate the unobstructed traffic state, and the intersection is used to simulate the traffic congestion. Finally, the two kinds of carbon emission data are compared to obtain the impact of traffic status on carbon emissions.*

### ***Keywords***

*traffic status, traffic emissions, vehicle driving cycle*

## **1. Introduction**

Compared with the rapid development of traffic, the construction of traffic infrastructure and traffic planning and management failed to develop in step with the rapid growth of motor vehicles, resulting in the low average daily speed of motor vehicles in many big cities. Many important roads in the city center are saturated for a long time, and acceleration, deceleration and idling occur frequently. This paper analyzes the influence of different traffic conditions on carbon emissions in the same fleet at the same time through the study of vehicle exhaust emissions in both the unobstructed and congested traffic conditions. The influence of traffic status on traffic carbon emission was quantitatively illustrated.

## **2. Method**

### ***2.1 Road Traffic Status Evaluation***

This paper mainly studies at the county level. Congestion and smoothness are selected as the indicators

to describe the traffic conditions at sections and intersections. Among them, the congestion includes the beginning of the congestion and the continuation of the congestion, the smoothness includes the end of the congestion and the smooth flow of traffic.

Based on the literature review and the actual traffic situation of xi'an city, when the average travel speed of motor vehicles on the main urban road is lower than 20 km/h, it is judged to be traffic congestion. When it is equal to or higher than 20 km/h, it is considered as traffic unobvious.

## *2.2 Vehicle Operating Conditions and Emission Factors*

### *2.2.1 Vehicle Operating Conditions*

The driving process of the car is mainly composed of six driving modes: starting, shifting gears, acceleration and deceleration, taxiing, uniform speed driving and parking and idling. Therefore, the driving conditions of the car can be briefly divided into idle speed, uniform speed, acceleration and deceleration.

### *2.2.2 Vehicle Emission Factors*

Motor vehicle emission factor is an important parameter for quantification, analysis and evaluation of motor vehicle exhaust emissions. It can be used to estimate regional total emission or emission intensity. The average emission factor of motor vehicle refers to the amount of pollutants discharged by a motor vehicle in a certain working condition in unit mileage or hour or unit fuel consumption. The unit is g/km or g/h or g/kg (fuel). It reflects the emission level of motor vehicle and is the basis and basis for the study on tail gas control countermeasures. The unit expressed by g/s is the exhaust emission rate of motor vehicles, which reflects the emission characteristics of vehicles in working conditions.

## *2.3 Experiment Design*

### *2.3.1 Traffic State Simulation*

This paper mainly simulates the two traffic conditions of smoothing and congestion. For the unobstructed traffic condition, the operating condition of the vehicle changes little, and the carbon emission is mainly related to the average speed. For the traffic congestion, the vehicle needs to go through three processes: deceleration, idling and acceleration. The two conditions are similar to those of vehicles passing through sections and intersections. Therefore, this paper adopts unobstructed road sections to study carbon emissions under unobstructed traffic conditions and intersections to study carbon emissions under congested traffic conditions.

The research object takes all the vehicles stopped at the entrance of the intersection during a certain traffic signal period. The carbon emission of the vehicles at the intersection was estimated by using the variables such as the speed and acceleration of the vehicles at the intersection. In other words, the carbon emission generated by the vehicles at the intersection during the traffic congestion was estimated during the signal light cycle at the intersection. This paper also estimated the carbon emissions of the same fleet in the same period of time when traffic was flowing. Finally, the carbon

emission estimates of the two traffic conditions are compared and analyzed.

### 2.3.2 Experimental Process

This paper chooses Xiaozhai intersection in xi'an city as the experimental site. Xiaozhai intersection is located in Yanta district, xi'an city, Shaanxi province. It is one of the most prosperous areas in xi'an. The timing of intersections is shown in Table 1.

**Table 1. The Timing of Intersections**

Timing parameters	Go straight and turn right in the north-south direction	Turn left in the north-south direction	Go straight in the east-west direction	Go straight, turn left and turn right in the east-west direction
Green time/s	69	76	96	49
Yellow light time/s	3	3	3	3
Red light time/s	76	69	49	96
Signal cycle/s	148	148	148	148

The number of vehicles stopped at the intersection within a signal light cycle at 20:30 on a given day are shown in Table 2 and Table 3.

**Table 2. The Number of Vehicles Stopped at the Intersection within a Signal Light Cycle in the North-South Direction**

Type	South import						North import					
	Go straight and turn right			Turn left			Go straight and turn right			Turn left		
	Light vehicle	CNG bus	Heavy vehicle	Light vehicle	CNG bus	Heavy vehicle	Light vehicle	CNG bus	Heavy vehicle	Light vehicle	CNG bus	Heavy vehicle
The number of vehicles	13	3	0	11	0	0	25	2	0	19	0	0

**Table 3. The Number of Vehicles Stopped at the Intersection within a Signal Light Cycle in the East-West Direction**

Type	East import						West import					
	Go straight			Turn left			Go straight			Turn right and turn left		
	Light vehicle	CNG bus	Heavy vehicle	Light vehicle	CNG bus	Heavy vehicle	Light vehicle	CNG bus	Heavy vehicle	Light vehicle	CNG bus	Heavy vehicle
The number of vehicles	12	0	0	6	2	0	7	0	1	17	0	0

Since it was not the rush hour, there were no second queues in the lanes. Similarly, the length of the queue did not cause some decelerating vehicles to accelerate before they stopped. Therefore, the main driving conditions of these vehicles are deceleration, idling and acceleration.

### 3. Result

#### 3.1 Carbon Emission Estimation of Intersection

The vehicles stopped at the intersection all experienced deceleration, idling and acceleration. Usually, seeing a yellow light or line up, the driver should start slowing down about 30 meters from the intersection or the end of the line. If the starting deceleration speed of the car is 30km/h, the deceleration acceleration should be  $-1.16\text{m/s}^2$ , and the deceleration time should be 7.18s. If the starting deceleration speed of CNG buses and heavy vehicles is 15km/h, the deceleration acceleration should be  $-0.29\text{m/s}^2$ , and the deceleration time should be 14.38s. Due to the different arrival times of these vehicles, the idle time is also different. Assuming the vehicle arrives evenly, the average idle time is half of the red light time. Usually, people start before the green light starts, and then accelerate directly after the green light starts, so the starting time of the car can be ignored. According to the actual observation, the acceleration of the car is  $0.6\text{--}0.7\text{m/s}^2$ , the acceleration of the CNG bus is  $0.5\text{--}0.6\text{m/s}^2$ , and the acceleration of the heavy vehicle is  $0.4\text{--}0.5\text{m/s}^2$ . At the intersection, the vehicle usually accelerates to 15km/s, so the acceleration time of the car is 5.95s, the acceleration time of the CNG bus is 6.95s, and the acceleration time of the heavy vehicle is 8.34s. For left-turn and right-turn vehicles, the acceleration will have a conversion coefficient, which is usually 0.7~0.8. In this paper, 0.8 is taken. According to the literature, the emission factors of each model are as follows.

##### (1) Light vehicles

When the acceleration is  $-1.16\text{m/s}^2$ , the HC emission rate is 0.0005g/s, and the CO emission rate is 0.021g/s. When the acceleration is  $0.6\text{m/s}^2$ , the HC emission rate is 0.0048g/s, and the CO emission

rate is 0.145g/s. When the vehicle turns, the acceleration is  $0.48\text{m/s}^2$ , the HC emission rate is 0.0038g/s, and the CO emission rate is 0.118g/s. HC emission rate is 0.0013g/s and CO emission rate is 0.02g/s at idle.

### (2) CNG buses

When the acceleration is  $-0.29\text{m/s}^2$  and the speed is 15km/h, the HC emission of the CNG bus is 0.00005g/s, and the CO emission is 0.002.75g/s. At the beginning of idle operation, the discharge is not stable. HC emissions stabilized at 0.00002.4g/s after 8s, and CO emissions stabilized at 0.000005g/s after 7s. When the speed is within 0~12km/h, the emission rate of HC is 0.0001g/s, and that of CO is 0.0042g/s. At a speed of 12km/h to 15km/h, the emission rate of HC is 0.0002g/s, and that of CO is 0.0043g/s. Therefore, in the 6.95s of CNG bus acceleration and the first 5.56s, the emission rate of HC is 0.0001g/s and that of CO is 0.0042g/s. In the latter 1.39s, HC emission rate is 0.0002g/s, and CO emission rate is 0.0043g/s.

### (3) Heavy vehicle

When the acceleration is  $-0.29\text{m/s}^2$ , the HC emission rate is 0.002g/s, and the CO emission rate is 0.008g/s. When the acceleration is  $0.5\text{m/s}^2$ , the HC emission rate is 0.0045g/s, and the CO emission rate is 0.02g/s. HC emission rate and CO emission rate is 0.01g/s at idle is 0.002g/s.

To sum up, in the period of the entire intersection M (HC) = 3.0959g, M (CO) = 96.3976g.

### 3.2 Carbon Emission Estimation of Section

This paper used the road data of Beijing to study. In this condition, the average speed of the vehicle is 34.76km/h. For the carbon emission calculation of the road section, the traffic flow data of the intersection will also be used. As can be seen from the above, there are 103 light vehicles, 7 CNG buses and 1 heavy vehicles.

According to the relationship between vehicle type and speed, the emission rate of light vehicles, CNG buses and heavy vehicles under the average speed in this working condition can be obtained when accelerating, decelerating, uniform and idling. See Table 4 for details.

**Table 4. Emission Rate of Light Vehicles, CNG Buses and Heavy Vehicles under the Average Speed in Different Operating Conditions**

Operating conditions	Light vehicle		CNG bus		Heavy vehicle	
	HC	CO	HC	CO	HC	CO
Accelerating	0.00015	0.034	0.00015	0.00272	0.00615	0.034
Decelerating	0.00008	0.24	0.00008	0.00192	0.00328	0.24
Uniform	0.0001	0.02	0.0001	0.0016	0.0041	0.02
Idling	0.00009	0.012	0.00009	0.00096	0.00369	0.012

Since the length of the whole cycle is 148s (cycle length of the intersection signal), the duration of

different operating conditions can be obtained according to the proportion of acceleration, deceleration, uniform speed and idle speed in this condition in the literature, as shown in Table 5.

**Table 5. The Duration of Different Operating Conditions**

Acceleration time(s)	Deceleration time(s)	Uniform time(s)	Idle time(s)
37	46	40	25

To sum up, in the period of the entire intersection  $M(HC) = 0.57339g$ ,  $M(CO) = 26.74896g$ .

#### 4. Discussion

In the case of congestion, HC emission is 6 times of that in the case of smoothness, and CO is 3 times. The emission of CO is not optimistic. Even in the simulation of the smooth state, the emission mass of CO within 148s can reach more than 26g. The mass also depends on the molar mass of the material. The molar mass of HC is 13, while the molar mass of CO is 28. The number of molecules is roughly estimated, and HC is 0.04mol and CO is 0.9mol under the condition of smooth flow. The level of contamination should be determined by the number of molecules, in particular CO, which represents the number of molecules that can bind to red blood cells.

Obviously, for the same vehicles fleet, the carbon emission of traffic congestion is significantly higher than that of unobstructed traffic. It can be intuitively illustrated that the exhaust emission of a vehicle depends not only on the physical properties of the vehicle's own engine, but also on the operating conditions of the vehicle.

For urban traffic congestion, light vehicles definitely account for the majority of carbon emissions. The first reason is that there are many light vehicles, and the second reason is that light vehicles are flexible and light, fast in acceleration and deceleration, so the driving condition of the cars is very unstable. In particular, the acceleration and idling of the car produced CO, is not optimistic.

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