Calculation of Carbon Emission During Expressway Operation Period Based on Energy Consumption Analysis

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Abstract: This article divides the activities during the expressway operation period and analyzes its energy consumption. Based on the carbon emission coefficient method, a carbon emission calculation model is constructed to calculate carbon dioxide emissions. Studies have shown that the carbon emissions from highway infrastructure operations are the highest, and most of them are from electricity. Therefore, the application of energy saving and emission reduction technologies in infrastructure operations is essential.

1.Introduction
With the rapid development of the economy, the transportation industry continues to increase, especially the continuous increase of expressway mileage. However, the development has brought a very serious negative impact on the environment, mainly due to the continuous increase in the concentration of carbon dioxide in the atmosphere. Therefore, building a green and low-carbon highway is an important research direction at this stage in my country.

At present, domestic and foreign research on expressway operation period mainly includes energy-saving evaluation technology research (Wang Yuming [1], Zhou Tiantian [2]), operation and maintenance cost research (Paul Rouse [3], Yue Song [4]), operation In terms of management model (Olubunmi Faleye[5], Qian Xingting[6]), operational services (Liu Zhong and Yang Dawei[7], Jia Shaoming[8]), there are few studies on CO2 during the operation period. Therefore, this article will take an expressway as an example to analyze its energy consumption, build a carbon emission calculation model, calculate carbon dioxide emissions, and analyze the calculation results.

2. Activity division during expressway operation period
According to the different fields of energy consumption during the expressway operation period, the expressway operation period can be divided into infrastructure operation and maintenance activities. According to the characteristics of the expressway, the infrastructure operation is divided into three parts: tunnel, service area, and toll station. For highway maintenance activities, according to the relevant provisions of the "Technical Specifications for Highway Maintenance" [9] (JTG H10-2009), the maintenance activities are divided into daily maintenance and repair and maintenance according to the nature and scale of the project. Daily maintenance is for Daily maintenance to maintain the normal use of the expressway and its auxiliary facilities. Maintenance is to repair, reinforce, update and improve the wear and tear of the expressway and its auxiliary facilities. The activity division is shown...
3. Energy consumption analysis during expressway operation period

3.1. Energy consumption analysis of infrastructure operations

3.1.1. Energy consumption analysis of tunnel operation
Tunnel operation is an important part of the expressway operation period. The energy consumption of the tunnel mainly includes the electrical energy consumed by lighting, ventilation, monitoring, etc. Tunnel lighting is the guarantee for the normal operation of the expressway. The lighting in the tunnel usually chooses fluorescent lamps, high-power high-low-pressure sodium lamps, high-pressure mercury lamps, LED lamps, etc. The choice of light source is mainly determined by the temperature and ventilation in the tunnel.

3.1.2. Energy consumption analysis of service area operation
In order to meet the needs of passengers and vehicles on expressways, it is necessary to set up traffic service facilities at intervals on the expressway. Common expressway traffic service facilities include service areas and parking areas. The service areas are equipped to meet the needs of passengers and vehicles. The needs of passengers include rest, eating, toileting, and commodity purchases. The needs of vehicles include refueling, cleaning, and parking. The parking area mainly avoids driving vehicles for a long time and provides safety guarantee. Therefore, the energy consumption of the service area is mainly the electricity consumed by the lamps, refrigerators, gas dispensers, and air conditioners in restaurants, gas stations, and toilets.

3.1.3. Energy consumption analysis of toll station operation
Toll station is a toll facility for expressways, including toll lanes, monitoring, lighting and other facilities. At present, the highway toll methods are manual toll, semi-automatic toll and ETC toll. The toll lane is mainly composed of the following equipment: lane control computer, toll collector terminal, vehicle detector, electric railing, toll display, etc.; monitoring facilities mainly consist of vehicle cameras, surveillance videos, image recording, and image display; lighting is mainly for toll stations. Driving safety, toll safety, and facility safety provide guarantee. Therefore, the main energy consumption of the toll station is the electric energy consumed by the toll facility equipment, lighting,
3.2. Energy consumption analysis of maintenance activities

3.2.1. Energy consumption analysis of daily maintenance activities
Daily maintenance activities include inspections, inspections, minor repairs and maintenance, cleaning work, timely disposal of debris and garbage generated on the road surface and sludge generated after rain, and cleaning of debris generated by the central isolation belt, road shoulders, side slopes, and drain holes. Mainly for the use of mechanical equipment, including inspection vehicles, sweepers, sprinklers, and seaming machines. The fuel used by the machinery is diesel and liquid gas.

3.2.2. Energy consumption analysis of maintenance activities
The main energy consumption for maintenance includes raw material production, mixture production, on-site construction, and material transportation. In the highway maintenance technology, the maintenance and maintenance of the asphalt surface is mainly, so the required raw materials are asphalt, stone, etc. The production of bitumen is mainly the processing of extracted oil. The production of the mixture is mainly carried out in the mixing station system, which includes milling of the original road surface. Therefore, the main energy consumption is diesel or gasoline. On-site construction mainly includes paving and rolling, mainly for the use of construction machinery. Vehicles used for material transportation generally use diesel as power, so the main energy consumption is diesel.

4. Carbon emission calculation model during expressway operation period

4.1. Carbon emission calculation model for highway infrastructure operations
The calculation of carbon emissions from highway infrastructure operations is actually a process of converting energy consumption into carbon emissions. Therefore, the carbon emission calculation model is as follows:

\[ Q_c = \sum_{i=1}^{n} W_i \times T_i \]  (1)

Where: \( Q_c \) is carbon emissions, \( W_i \) is energy consumption, \( T_i \) is the carbon dioxide emission coefficient of energy, and \( i \) is energy consumed.

4.2. Calculation model of carbon emissions from highway maintenance
The carbon emission calculation model of the highway maintenance phase is divided into the following aspects.

4.2.1. Material production and processing
The carbon emission of material production and processing is equal to the use of various raw materials multiplied by the CO2 emission coefficient of raw material production, and the sum is added. According to the carbon emission coefficient method, the carbon emission of material production and processing is calculated as follows:

\[ Q_d = \sum_{i=1}^{n} H_i \times N_i \]  (2)

4.2.2. Mechanical construction
The carbon emission of machinery is equal to the amount of fuel used by various types of machinery multiplied by the CO2 emission coefficient, and the sum is added.
Calculation of carbon emissions from construction machinery:

\[ Q_m = \sum_{i=1}^{n} E_i M_i \]  

4.2.3. Material transportation

The carbon emissions of material transportation refer to the carbon emissions generated by the transportation of materials from the factory to the construction site. The main transportation method is road transportation. The calculation formula is as follows:

\[ Q_t = \sum_{i=1}^{n} U_i D_i \]  

In the formula: \( Q_t \) carbon emissions during transportation, \( U_i \) is energy consumption during transportation, and \( D_i \) is the corresponding carbon dioxide emission coefficient.

4.3. Determination of carbon emission coefficient

4.3.1. Fossil fuel carbon emission coefficient

IPCC is the most authoritative greenhouse gas research organization in the world. It was jointly established by the United Nations Environment Program and the World Meteorological Organization in 1988. Its database is currently a relatively complete database of carbon emission factors, and it is also the earliest established database. Calculated according to the 2006 IPCC National Greenhouse Gas Inventory Guidelines and the data provided in the energy section of the China Energy Statistical Yearbook, the carbon dioxide emission coefficient = average low calorific value * carbon content per calorific value * carbon oxidation rate × 44/12. Therefore, the fossil fuels involved in highways are summarized in Table 1.

| Fuel type  | Carbon content per calorific value TC/TJ | Carbon oxidation rate | Average low heat (KJ/kg) | CO₂ emission factor |
|------------|------------------------------------------|-----------------------|--------------------------|---------------------|
| Coke       | 29.42                                    | 0.93                  | 28435                   | 2.852 kg CO₂/kg     |
| Crude      | 20.08                                    | 0.98                  | 41816                   | 3.017 kg CO₂/kg     |
| Fuel oil   | 20.10                                    | 0.98                  | 41816                   | 3.020 kg CO₂/kg     |
| Diesel oil | 20.20                                    | 0.98                  | 42652                   | 3.096 kg CO₂/kg     |
| Gasoline   | 18.90                                    | 0.98                  | 43070                   | 2.925 kg CO₂/kg     |
| Natural gas| 15.32                                    | 0.99                  | 38931                   | 2.165 kg CO₂/m³     |

4.3.2. Electric energy carbon emission coefficient

According to the provincial greenhouse gas inventory guidelines, the region is divided into Northeast, North China, East China, Central China, Northwest and South. The average carbon dioxide emission coefficient is equal to the fossil fuel carbon dioxide emissions divided by the total electricity supply, and is obtained by kilogram carbon dioxide/kWh unit. Therefore, the average carbon dioxide emission coefficient is shown in Table 2.

| District division | Cover the city                                      | CO₂ emission factor (kg CO₂/kw.h) |
|-------------------|-----------------------------------------------------|----------------------------------|
| North China       | Beijing, Tianjin, Hebei, Shanxi, Shandong, western Inner Mongolia | 1.246                            |
| northeast         | Liaoning, Jilin, Heilongjiang, eastern Inner Mongolia          | 1.096                            |
| East China        | Shanghai, Jiangsu, Zhejiang, Anhui, Fujian                | 0.928                            |
| Central China     | Henan, Hubei, Hunan, Jiangxi, Sichuan, Chongqing         | 0.801                            |
| northwest         | Shaanxi, Gansu, Qinghai, Ningxia                        | 0.977                            |
4.3.3. Carbon emission coefficient of building materials

In the process of expressway construction, building materials mainly include asphalt and gravel. According to the reference values provided by the Swedish Environmental Research Institute and the data from the European Asphalt Association and the US National Environmental Protection Agency EPA, the carbon emission coefficients of asphalt and other materials are shown in Table 3.

| Material category         | Carbon emission factor | Unit  |
|---------------------------|------------------------|-------|
| Modified asphalt concrete | 932.2                  | kg/m3 |
| Modified asphalt          | 680.593                | kg/m3 |
| Emulsified asphalt        | 508.3                  | kg/m3 |
| Ordinary asphalt          | 174.2                  | kg/t  |
| SBS compound modified asphalt | 295.9                | kg/t  |
| Stone                     | 2.5                    | kg/t  |

5. Case analysis

Take an expressway as an example. There are 2 service areas, 1 parking area, 1 monitoring center, 6 toll stations, 2 tunnel management offices, and 2 maintenance work areas on the whole line. According to statistics (calculated in 1 year), the tunnel electricity consumption is 308800, the service area electricity consumption is 247260, and the toll station electricity consumption is 66024. According to the carbon emission calculation model, the carbon emission of the tunnel is 384764.8 kg, The carbon emission of the service area is 308085.96 kg, and the carbon emission of the toll station is 82265.904 kg.

In daily maintenance, the main maintenance tasks include inspection, cleaning, and filling, and the frequency of inspection is 1 time/day, and cleaning is 2 days/time. The main fuel is diesel. 1 liter of diesel is 0.9 kg on average, 100 kilometers The fuel consumption is an average of 9 liters, and the daily inspection mileage is 67km. The joint filling is mainly the use of joint filling glue and joint filling machine. Therefore, according to the calculation formula in Section 3, it can be concluded that the carbon emission of daily maintenance is 95.9kg/day, so the annual carbon emission is 3,5003.5 kg.

In the maintenance work, the asphalt recycling technology is mainly used, and the material asphalt and its asphalt mixture are mainly used. This technology can effectively reduce the usage of raw materials and reduce the maintenance cost. The amount of maintenance materials used is shown in Table 5.

According to the consumption of asphalt and crushed stone, combined with the calculation formula in Section 3, it can be concluded that the carbon emission of asphalt is 1164744.8 kg, and the carbon emission of crushed stone is 3,483,752.97 kg. Therefore, the carbon emission Q in the raw material production stage was originally 4,654,497.77 kg.

Under normal circumstances, asphalt is transported by asphalt truck with a carrying capacity of 15 tons, and the average fuel consumption per 100 kilometers is 20 liters, and the 15-ton dump truck is used to transport gravel, and the average fuel consumption per 100 kilometers is 15 liters. For two-way transport and use diesel as fuel. Therefore, according to the calculation formula in Section 3, the carbon emission Q of material transportation can be obtained as 1068138.58 kg. According to the number of machinery used, the number of shifts, and the fuel consumption per unit time, it is predicted that the amount of diesel used is 155448kg. Therefore, the carbon emission Q at this stage is 481267.008kg, so the carbon emission in the maintenance stage is 6203903.36 kg.

In summary, the total carbon emissions during the operation period of the expressway is
7014023.52kg, the carbon emissions from infrastructure operations are 775116.664kg, and the carbon emissions from maintenance operations are 6238906.86kg. The comparison of the total carbon emissions is shown in Figure 2.

6. Conclusion
In the two stages of the operation period, the infrastructure operation stage emits the most carbon dioxide, so the infrastructure operation stage is the key link in the operation period. The infrastructure operation of the expressway mainly includes three stages: tunnel operation, service area operation, and toll station operation. The main carbon emissions come from three aspects: the lamps used in the tunnel use a lot of electricity, and the service area provides services for drivers and passengers. At the same time, a large amount of resources will inevitably be used. The lighting of houses and squares and the use of office equipment consume a large amount of electric energy every year, and the electric energy consumed by various facilities of toll stations. Basically, there will be no interruption of operation in the three stages, and the total amount of electricity consumed is very huge. Therefore, this link should be paid more attention.

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