Study on Traffic Status and Carbon Emission of Urban Transport in Beijing

Hai Fang\textsuperscript{1,a}, Li Bian\textsuperscript{2,b}

\textsuperscript{1}China Academy of Transportation Sciences Beijing, China
\textsuperscript{2}China Academy of Transportation Sciences Beijing, China
\textsuperscript{a}lisa2019@163.com
\textsuperscript{b}lisa2019@163.com

Abstract. At present, most of the literatures on transportation carbon emissions in China are to calculate the total amount of transportation carbon emissions. There are few literatures on carbon emission of specific transportation mode. There are few literatures on the calculation and analysis of urban traffic carbon emissions in Beijing. The historical data in these documents are very early, which can not effectively evaluate the current situation of urban transport in Beijing. Firstly, this paper analyzes the travel situation of Beijing residents in recent years. Then, based on the average daily passenger traffic volume and travel share rate of Beijing residents, a statistical model of urban transport vehicle energy consumption is established. Finally, the carbon emission of Beijing passenger transport is estimated.

1. Introduction
Beijing’s special geographical location, continuous growth of social economy and population, transportation has been sustainable development. But at the same time, Beijing’s carbon emissions, environmental pollution, traffic congestion and other issues have deeply affected the quality of life of the capital residents. At present, most of the literatures on transportation carbon emissions in China are to calculate the total amount of transportation carbon emissions. There are few literatures on carbon emission of specific transportation mode. Few papers on estimation and analysis of urban traffic carbon emissions in Beijing. The historical data in these documents are very early, which can not effectively evaluate the current situation of urban transport in Beijing.

Zhang Xiu yuan analyzes transport energy consumption and carbon emissions calculation from a new view. This paper analyzes the calculation methods of energy consumption and carbon emission in the whole life cycle of Beijing public transport from 2008 to 2010. Tang Baojun calculated carbon emissions of road passenger transport in Beijing from 2005 to 2010. Yu Hao constructs Beijing urban passenger transport energy environment model based on LEAP model. The energy demand trend of Beijing in 2020 under different policy scenarios and the environmental emission trend of conventional air pollution gases and greenhouse gases are predicted. CHEN Liang indicators of regional transport emissions were calculated firstly based on the related data of IPCC. Then the STIRPAT Model was modified with the introduction of carbon emission efficiency. Finally, transport carbon emissions were analyzed by numerical examples of Beijing from 2005 to 2014.

Beijing has developed transportation and transportation carbon emission is large. Beijing is a "low carbon city pilot" and "low carbon transportation system construction city pilot" The carbon emission statistics of urban passenger transport system and the establishment of energy consumption data system...
have great practical significance for the analysis and research of urban traffic energy consumption. It is very necessary to realize the energy saving and emission reduction of urban transportation system.

2. Development status of urban passenger transport in Beijing

Beijing is an important megalopolis in China. It is the concentration of regional people flow and logistics. Transportation has become the fastest growing area of energy consumption, which also brings great pressure to road traffic and environment. Transportation is the fastest growing energy consumption in Beijing.

According to the data of 2020 Beijing Transportation Development Annual Report\(^1\). By the end of 2019, the permanent resident population of Beijing was 21.536 million, a decrease of 6000 compared with the end of the previous year, showing a downward trend for three consecutive years. In the composition of permanent residents, the household registration population was 13 million 974 thousand, an increase of 216 thousand over the previous year. There were 7.456 million permanent migrants, 190000 less than at the end of last year, accounting for 34.6% of the permanent population, a decrease of 0.9% over the previous year. The city's urban population is 18.65 million, accounting for 86.6% of the permanent population.

In 2019, Beijing completed 121.51 billion yuan of transportation fixed assets investment, down 5.3% compared with the previous year. Public transport and related supporting facilities accounted for the highest proportion, with an investment of 40.6 billion yuan, a decrease of 4.6% compared with the previous year, accounting for 33.4% of the total investment. Secondly, the investment in roads and urban roads was 30.36 billion yuan, a decrease of 13.4% compared with the previous year, accounting for 25% of the total investment. In terms of the investment structure of highways and urban roads, highway investment accounted for the highest proportion, with an investment amount of 11.42 billion yuan, a decrease of 41.5% compared with the previous year, accounting for 37.6% of road investment. In 2019, Beijing's transportation construction has completed an investment of 121.5 billion yuan, with 699 kilometers of rail operation mileage and 952 kilometers of bus lanes.

In 2019, three new subway lines will be opened, namely Daxing airport line, East extension of line 7 and South extension of Batong line. There are 23 subway lines in Beijing, with an operating mileage of 699 km, an increase of 62 km over the previous year. There are 405 subway stations in the whole network, including 62 transfer stations, and 6475 operating vehicles, an increase of 847 over the previous year.

By the end of 2019, the total number of public bus lines in Beijing's urban areas has increased to 1158, an increase of 270 over the previous year, a year-on-year increase of 30.4%; the length of operating lines is 27632 km, an increase of 8387 km over the previous year, a year-on-year increase of 43.6%. By the end of 2019, the total highway mileage in Beijing will reach 22365.9 km, and the density of highway network will reach 136.4 km / 100 km\(^2\). A total of 53 kilometers of expressways were added, reaching 1167.6 kilometers; 1494.1 kilometers of first-class highways, 4023.7 kilometers of second-class highways, 4059.2 kilometers of third-class highways, and 11621.3 kilometers of fourth-class highways.

By the end of 2019, 3667 public bicycle rental service outlets had been built in Beijing, an increase of 2.6% over the previous year; the scale of public bicycle vehicles totaled 117000, an increase of 12.5% over the previous year.

By the end of 2019, the number of motor vehicles in Beijing will reach 6.365 million, an increase of 281000 over the previous year, including 5.13 million private motor vehicles, an increase of 236000 over the previous year.

By the end of 2019, the permanent population of Beijing will be 21.536 million, and the number of motor vehicles will reach 6.365 million. The total number of daily trips in the central city was 39.57 million (including walking), an increase of 0.8% over the previous year. In 2019, urban passenger transport will transport 8.4 billion passengers including 3.564 billion public bus (electric) vehicles, 3.962 billion rail transit passengers, 331 million taxi passengers, 407 million suburban passengers, 0.025 million suburban railway passengers, and 540 million Internet bicycle rental and public bicycle rides.
transport by public buses (electric vehicles) and Subway totaled 7.526 billion, accounting for 89.6%. Figure 1 shows number of annual trips of Beijing urban transport residents in 2019.

![Figure 1. Number of annual trips of Beijing urban transport residents in 2019](image1)

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Figure 2 shows Average number of daily trips of Beijing urban passenger transport in 2019. In 2019, the total number of daily trips in the central urban area will be 39.57 million (including walking), with a year-on-year increase of only 0.8%. The daily travel volume of subway is 6.52 million, accounting for 23.6% of the total daily travel volume. The daily number of bus trips is 6.07 million, accounting for 22.0% of the total daily trips. The daily number of taxi trips is 990000, accounting for 3.6% of the total daily trips. The daily travel volume of private cars is 8.94 million, accounting for 32.4% of the total daily trips. The number of daily trips by bicycle was 4.77 million, accounting for 17.3% of the total daily trips. Other daily trips were 330000, accounting for 1.2% of the total daily trips.

![Figure 2. Average number of daily trips of Beijing urban passenger transport in 2019](image2)

Figure 2. Average number of daily trips of Beijing urban passenger transport in 2019

Figure 3. Beijing's GDP and per capita GDP from 2015 to 2019
Figure 4 shows Beijing’s GDP and per capita GDP from 2015 to 2019. In 2019, the GDP will reach 3537.13 billion yuan (preliminary accounting data), which will increase by 6.1% compared with the previous year, and the economic growth rate will remain stable. In terms of the resident population, the per capita GDP reached 164220 yuan, an increase of 6.5% over the previous year in terms of comparable prices.

Figure 4 shows the number of Urban passenger transport to transport passengers and Urban passenger transport to transport passengers from 2015 to 2019. From 2015 to 2019, the resident population of Beijing decreased from 21.705 million to 21.536 million, and the per capita GDP increased from 106497 yuan to 164220 yuan, a significant increase of 54.2%. The total number of daily trips in the central urban area increased from 27.29 million to 39.57 million, an increase of 45.0%.

The travel demand of urban residents will increase with the continuous improvement of economic level, and it is an inevitable trend that transportation energy consumption will continue to increase. Transportation plays an increasingly important role in energy consumption. With the prosperity and development of social economy, the influx of foreign population in Beijing brings about the rapid growth of traffic demand. It makes transportation the fastest growing area of energy consumption, and also brings great pressure to road traffic and resources and environment.

3. Statistical model of urban passenger transport vehicle energy consumption

In the past, the calculation method of carbon emissions was to multiply the mileage of various modes of transportation in the national or regional transportation departments by the corresponding energy consumption per kilometer, and then multiply by the corresponding energy carbon emissions. It is necessary to consider the types of vehicle energy and the components of public transport system. It requires consideration of each vehicle type, fuel type and usage based on the vehicle operation phase. Since the relevant statistical yearbook does not give the energy consumption data of various vehicles in Beijing, it is difficult to calculate the traffic carbon emissions. Traditional methods can not accurately calculate the energy consumption of various traffic types. It will lead to large deviation in carbon emission calculation. In this paper, the carbon emission of Beijing traffic is estimated based on the daily average passenger traffic volume and travel share rate of various vehicles in Beijing. The statistical model of urban passenger transport vehicle energy consumption is shown in Formula 1.

$$C_t = \sum_i C_i^t = \sum_i 365N^t F_i^t D_i^t M_i^t$$

(1)

$C_t$ represents the total carbon emission of each mode in t year. $C_i^t$ represents the carbon emission of the i mode of transportation in year t. $N^t$ represents the average daily travel volume of Beijing residents in t year (excluding walking). $B^t$ represents the proportion of motorized travel of Beijing residents in year t, which is measured by the proportion of motorized travel to the total number of trips without walking. $F_i^t$ represents the share rate of travel in Beijing transportation system of the first mode of transportation in year t (excluding walking and bicycle). $D_i^t$ represents the per capita travel distance of the ith mode of transportation in year t. $M_i^t$ represents the carbon emission per person per kilometer in the i mode of transportation in year t.
Beijing residents travel in several ways: bus, subway, taxi, private car, bicycle, walking and other modes of travel. The two modes of travel, bicycle and walking, basically do not bring about carbon emissions. Therefore, in this paper, bicycle and walking parts are ignored when calculating carbon emissions of urban passenger transport in Beijing. The data of carbon emissions per person kilometer of various modes of transportation need to refer to relevant research articles. Due to the small proportion of "other modes of travel", this paper assumes that the carbon emissions per kilometer of other modes of travel are equal to the corresponding values of buses. The carbon emissions per person per kilometer of various modes of urban transportation are shown in Table 1[3].

Table 1 Carbon emissions per person per kilometer in various modes of urban transportation (kg / km / person)

| mode of transportation | Carbon emissions per person per kilometer |
|-----------------------|------------------------------------------|
| bus                   | 0.069                                    |
| subway                | 0.042                                    |
| taxi                  | 0.2                                      |
| private car           | 0.2                                      |
| others                | 0.069                                    |

4. Carbon emission statistics of urban passenger transport in Beijing

The share rate of various modes of transportation for Beijing residents is shown in Figure 3. As can be seen from the figure, private car travel, subway and bus are the three main modes of motor vehicle travel of Beijing residents. Among them, the daily traffic volume of private cars is 39.1%, that of subway is 28.5%, and that of bus is 26.6%.

Figure 5.Single day traffic volume of Beijing in 2019

Table 2 Influencing factors of Beijing urban passenger transport in 2019

| year | Average daily travel volume / 10000 person times | Proportion of motorized travel | Average travel distance /m |
|------|-------------------------------------------------|--------------------------------|---------------------------|
|      |                                                 | bus   | subway | taxi  | private car | others |
| 2019 | 3957                                            | 82.7% | 11.1   | 18.1  | 9.6         | 14.9   | 5       |

Data description and source: The average daily travel volume comes from the data of Beijing transportation development annual report. The data of daily walking and bicycle travel volume should be removed when calculating carbon emissions. Travel distance the average travel distance of residents is based on the data from 2017 to 2018 in Beijing transportation development annual report, and the missing data in 2019 are estimated according to the trend of historical data in recent three years.
Using formula 1 to calculate the carbon emission of passenger transport in Beijing in 2019, the total carbon emission is 13.965 million tons. The carbon emission of private cars is 9.724 million tons. The carbon emission of buses is 1.697 million tons. The carbon emission of subway is 1.809 million tons.

5. Conclusion and analysis
The carbon emission of private car travel is the highest in Beijing, accounting for about 69.6%. However, the carbon emission of public transport (bus+subway) accounts for only more than 25.1% of the carbon emission of motor vehicles. The proportion of private cars in motor vehicle travel is 39.1%, and that of public transport vehicle (bus + subway) is 55.1%. However, the carbon emission of private car travel is much higher than the public transport, which is nearly 2.77 times. Therefore, this paper believes that reasonable changes in the structure of transport modes, that is, reducing the proportion of private car trips and increasing the proportion of public transport trips, will play a very positive role in controlling carbon emissions of passenger transport in Beijing.

Traditional research on the national or regional transportation departments of various types of transportation mileage multiplied by the corresponding kilometer energy consumption, and then multiplied by the corresponding energy carbon emission coefficient. In order to calculate the data of each vehicle type, fuel type and consumption in vehicle operation stage, the vehicle fuel power type should be considered. In terms of vehicle operation, vehicle operation energy consumption is determined by urban residents’ traffic demand, urban traffic structure, vehicle energy consumption intensity and other parameters. Since the relevant statistical yearbook does not give the energy consumption data of various vehicles in Beijing, it is difficult to calculate the traffic carbon emissions. In this paper, the carbon emission of Beijing traffic is estimated based on the daily average passenger traffic volume and travel share rate of various vehicles in Beijing. The carbon emission estimation model of Beijing passenger transport is established. The energy consumption value and carbon emission of the public transport vehicle can be estimated directly and simply by using the annual report data of transportation development, and tedious statistical links can be omitted. The overall analysis and statistics of energy consumption and carbon emission of Beijing urban public transport system, as well as the establishment of energy consumption data system of public transport system, are of great practical significance for urban traffic energy consumption analysis and research. It is very necessary to realize the energy saving and emission reduction of urban transportation system and the construction of low-carbon city.

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