

# Analysis of the CO<sub>2</sub> Emissions of Public Passenger Transport in Tianjin City of China

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**Abstract**—Low-carbon public passenger transport is an important part of low carbon city. The CO<sub>2</sub> emissions of public passenger transport in Tianjin from 1995 to 2010 are estimated with IPCC CO<sub>2</sub> counting method, which shows that the total CO<sub>2</sub> emissions of Tianjin public passenger transport have gradually become stable at 1,425.1 thousand tons. And then the CO<sub>2</sub> emissions of the buses, taxis, and rail transits are calculated respectively. A CO<sub>2</sub> emission of 829.9 thousand tons makes taxis become the largest CO<sub>2</sub> emissions source among the public passenger transport in Tianjin. Combining with passenger volume, this paper analyzes the CO<sub>2</sub> emissions proportion of the buses, taxis, and rail transits compare the passenger transport rate with the proportion of CO<sub>2</sub> emissions, as well as the CO<sub>2</sub> emissions change of per 10,000 people. The passenger volume proportion of bus among the three public means of transport is 72.62% which is much higher than its CO<sub>2</sub> emissions proportion of 36.01%, with the minimum number of CO<sub>2</sub> emissions per 10,000 people of 4.90 tons. The countermeasures to reduce CO<sub>2</sub> emissions of public passenger transport in Tianjin are to develop rail transit, update vehicles and use alternative fuel vehicles.

**Keywords**—Public passenger transport, carbon emissions, countermeasures.

## I. INTRODUCTION

ALONG with the rapid development of the economy and the increasing demand for transportation, the energy consumption of transportation is gaining a fast growth momentum. According to the data of China Energy Statistical Yearbook, the energy consumption of transportation, warehousing, and postal service was 11,241.59t of standard coal in 2000 and 26,068.47t in 2010, which account for 7.72% and 8.02% of the total energy consumption. In the process of China's urbanization, the number of motor vehicles has increased sharply, and the proportion of CO<sub>2</sub> emissions from city passenger transport to that from the overall economic activity is becoming higher and higher. Many scholars have also tried to investigate ways to reduce the CO<sub>2</sub> emissions in the transportation sector. The main approaches to reduce the CO<sub>2</sub> emissions from traditional auto were measures such as technological progress [1], the use of alternative fuels [2]–[4]. The progress of the new energy automotive technology also helps make it possible to apply electric vehicles. The use of electric vehicles is associated with electric power system, effective integration of wind energy and thermoelectric integrated power supply system can reduce CO<sub>2</sub> emissions of

parallel hybrid electric vehicles [5]; Low carbon electricity system helps to realize the low carbonization of electric vehicles [6]; Using coal electric vehicles, combined with the use of CCS technology, the reduction potential can be up to 60-70% [7]. Along with the application of alternative fuels, the phase characteristics of the CO<sub>2</sub> emissions is changed, as a result, some scholars from the perspective of life cycle to research the emissions of greenhouse gases of transportation sector [8], the CO<sub>2</sub> emissions produced by city bus using different two types of fuel of gasoline and diesel [9], the CO<sub>2</sub> emissions reduction of electric car [10], [11]. These studies point out the possibility of the realization of energy conservation and CO<sub>2</sub> emissions reduction from the perspective of technology progress, alternative fuels. But for a city passenger transportation system, different modes of transport are interrelated and influence each other, there is not only a substitution effect between the various modes of transport, but also a complementary role. Therefore, this paper calculates the CO<sub>2</sub> emissions of Tianjin public passenger transport system, and analysis based on the passenger traffic volume. Finally, this paper put forward some reduction countermeasures based on the characteristics of Tianjin public passenger transport emissions.

## II. METHODOLOGY AND DATA

### A. The Method to Calculate the CO<sub>2</sub> Emissions of Transport

Calculating the CO<sub>2</sub> emissions of transport is generally based on the energy consumption of each kind of transportation. According to the IPCC CO<sub>2</sub> accounting method, calculation formula of transport CO<sub>2</sub> emissions is:

$$C = \sum P_i L_i E_i M_i \quad (1)$$

where C: the total CO<sub>2</sub> emissions of transport (t);  $P_i$ : the number of vehicles used in transporting method i;  $L_i$ : the single car mileage of transporting method i(km);  $E_i$ : the energy consumption of per hundred kilometers of transporting method i ( $L, m^3$ );  $M_i$ : the CO<sub>2</sub> emissions coefficient of the energy consumed by transporting method i(kg/L, kg/  $m^3$ ).

The public passenger transport of Tianjin mainly consists of bus, taxi and rail transit; the data mainly comes from Tianjin Statistical Yearbook, China's Third Industry Statistics Yearbook, questionnaire and literature, and statistics reports. The data of CO<sub>2</sub> emissions is obtained by calculation and some parameters with reference to the relevant literature data.

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## B. Data

### 1. The Data of Bus

Tianjin bus consists of diesel bus and natural gas bus, and the proportion of diesel bus is more than 90%. The number of the bus of Tianjin in 1995 was 2,117, and 7,928 in 2010. The number of the natural gas bus was 62 in 2005, and 607 in 2010. Since 2007, Tianjin renewed the bus; new buses are 10 meters or 12 meters long, and all reach the emission standard of countries III. According to the data of questionnaires, the fuel consumption per hundred kilometers of the bus was 40L in 2007 and the year before. In 2008 and after, the fuel consumption per hundred kilometers was 30L when diesel buses did not open air conditioning and 35L when air conditioning was opened. Air conditioning time is about 3 months year-round. By calculation, the average fuel consumption per hundred kilometers of diesel bus in this paper is 31.25 L. And the average fuel consumption per hundred kilometers of the natural gas bus, in this paper, is 33m<sup>3</sup>. According to the data of questionnaires, mileage of bus in Tianjin is 210km a day on average. According to IPCC mobile source emission coefficient, diesel emission coefficient is 2.778 kg/L, gas emission coefficient is 2.33 kg/m<sup>3</sup>.

### 2. The Data of Taxi

Since the 1990s, Tianjin taxi developing process has experienced three stages, respectively yellow Dafa, red Xial, blue Toyota Corolla and Xiali WeiZhi. Since 1993, Tianjin taxi has experienced a rapid developing phase. And the number of taxies increased rapidly from 2,942 to 26,268 between 1990 and 1995. It reached 34,150 in 1998 and started to decline after that, since 1999 it has been maintained at 31,940.

According to the survey, the mileage of a single taxi in Tianjin was 350 km a day on average. Before 2008, the average fuel consumption per hundred kilometers of yellow Dafa and red Xiali taxi was 5.5L. And after 2008 the average fuel consumption per hundred kilometers of Toyota Corolla and Xiali WeiZhi was 9 L. While the average fuel consumption per hundred kilometers of gas taxi was 8m<sup>3</sup>. However, there were only four gas stations in Tianjin. But they were far away from downtown and the drivers needed to wait a long time in busy time, so the proportion of gas taxies was very small. According to IPCC mobile source emission coefficient, gasoline emission coefficient is 2.26 kg/L.

### 3. The Data of Rail Transit

At present, Tianjin rail transit mainly includes two lines, respectively the subway line 1 and Tianjin light rail line 9. Tianjin subway line 1 was put into use on June 12, 2006, with a total length of 26.2 km. Tianjin light rail line 9 was put into use on March 28, 2004, with a total length of 45.409 km.

Tianjin subway line 1 adopted non-standard type B car manufactured by Changchun railway vehicle manufacturing plant. Line 9 adopted the standard type B car manufactured by Nanche group. The power consumption per hundred kilometers of the two kinds of vehicle is both 263.8 kW·h [12]. At the beginning of the operation, line 1 was grouped with four cars, and from January 2010, it has been grouped with six cars. Line

9 has been grouped with four cars from the beginning. At present, the first vehicle of the subway line 1 starts at 6:00 every day and the last vehicle is at 22:00. Line 9 is the same with line 1. From Monday to Friday, the interval time in the peak time in the morning and evening was 5-6 minutes; During Weekends and holidays, the interval time was 8-10 minutes throughout the day; And the interval time reduced to 4-5 minutes when it snowed. According to the survey data and calculation, the average number of columns of subway line 1 is 213.34 a day; line 9 is 211.33.

## III. RESULTS

### A. The Total CO<sub>2</sub> Emissions and CO<sub>2</sub> Emissions Proportion of Each Public Passenger Transport

According to the data and the calculation formula of transport CO<sub>2</sub> emissions, we calculated CO<sub>2</sub> emissions of Tianjin public passenger transport from 1995 to 2010 (Fig. 1). According to the calculation results, the total CO<sub>2</sub> emissions of Tianjin public passenger transport increased from 594,300t of 1995 to 1,425,100 t of 2010, i.e. increased by 140%. Among these years, 2007 is a turning point of CO<sub>2</sub> emissions. From 1995 to 2007, the increasing number of public buses leads to the increment of emissions. From 2008 to 2010, as a result of the using of environmentally friendly vehicles, the energy consumption per hundred kilometers was lowered, and with the number of gas buses increased, CO<sub>2</sub> emissions of the bus began to decline.

1998 and 2007 are two turning points of CO<sub>2</sub> emissions of Tianjin taxi. The number of taxies increased from 1995 to 1998, and the CO<sub>2</sub> emissions of Tianjin taxi rose year by year. After 1999, the number of Tianjin taxi stabilized at 31,940, so CO<sub>2</sub> emissions of Tianjin taxi has been nearly unchanged from 1999 to 2007. And after 2008, Tianjin renewed taxies, the fuel consumption per hundred kilometers increased, thus, CO<sub>2</sub> emissions of Tianjin taxi increased after 2008.

Tianjin metro line 9 was put into use in 2004, line 1 was put into use in 2006, then CO<sub>2</sub> emissions of rail transit gradually become stable.

As the number of buses and taxies and the fuel consumption per hundred kilometers' changes, as well as the application of natural gas bus, CO<sub>2</sub> emissions proportion of each kind of public passenger transport changes (Fig. 2). In Fig. 2, the year 2000, 2003 and 2007 are three turning points of CO<sub>2</sub> emissions proportion. In 2000 and the year before, CO<sub>2</sub> emissions proportion of taxi is higher than that of the bus. With an increase in the number of public buses, CO<sub>2</sub> emissions proportion is nearly equal between bus and taxi from 2001 to 2003. In 2004, with the operation of rail transit, and an increase in the number of public buses, buses became the biggest source of CO<sub>2</sub> emissions.

In 2008, Tianjin improved taxi access standards, Toyota Corolla and Xiali WeiZhi replaced red Xiali taxi, lead to a rise in the fuel consumption per hundred kilometers, so CO<sub>2</sub> emissions of taxi increased. Meanwhile, in 2007, Tianjin renewed buses with energy-saving cars, the number of natural gas buses increased, so the fuel consumption per hundred

kilometers fell, CO<sub>2</sub> emissions of buses fell. Therefore, after 2007, taxi becomes the biggest source of CO<sub>2</sub> emissions again.

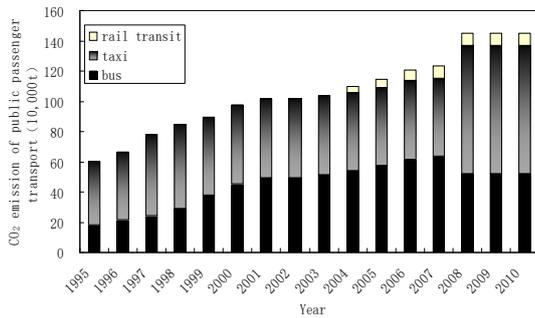


Fig. 1 CO<sub>2</sub> emissions of buses, taxis, and rail transit in Tianjin from 1995 to 2010

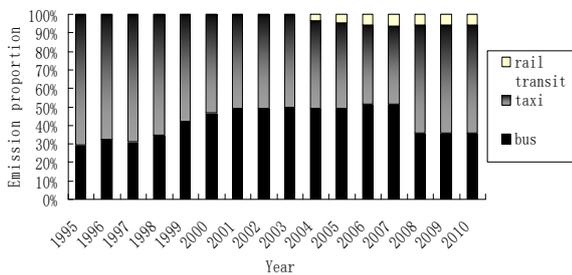


Fig. 2 CO<sub>2</sub> emission proportion of buses, taxis, and rail transit in Tianjin from 1995 to 2010

**B. The Total CO<sub>2</sub> Emissions and CO<sub>2</sub> Emissions Proportion of Each Public Passenger Transport**

In terms of the structure of CO<sub>2</sub> emissions of Tianjin's public passenger transport, in 2008 and after, taxi becomes the biggest source of CO<sub>2</sub> emission in the public passenger transport system which consists of bus, taxi and rail transit, followed by the bus, the last is rail transit (Fig. 3). In Fig. 3, the passenger volume proportion of each passenger transport mode is defined as passenger volume of this type of passenger transport divide the total passenger volume of three kinds of passenger transport; And the CO<sub>2</sub> proportion of each mode of passenger transport is defined as the CO<sub>2</sub> emissions of one kind of public passenger transport divide the total CO<sub>2</sub> emissions of three kinds of passenger transport.

Compared the passenger proportion with CO<sub>2</sub> emission proportion of each kind of public passenger transport of Tianjin, we can conclude that the proportion of passenger volume of three kinds of public passenger transport is almost unchanged, and in 2008 and after, CO<sub>2</sub> emissions proportion of three kinds of public passenger transport also almost remain unchanged. Among them, the proportion of passenger volume of the bus is 72.62% to 75.02%, but CO<sub>2</sub> emission proportion is only 36.00% to 36.03%. Although the proportion of passenger volume of a taxi is just 21.59% to 21.59%, the proportion of CO<sub>2</sub> emissions is as high as 58.41%-58.44%. The proportion of passenger volume of rail transit accounted for 3.18% to 4.29%, but CO<sub>2</sub> emission proportion is 5.56%.

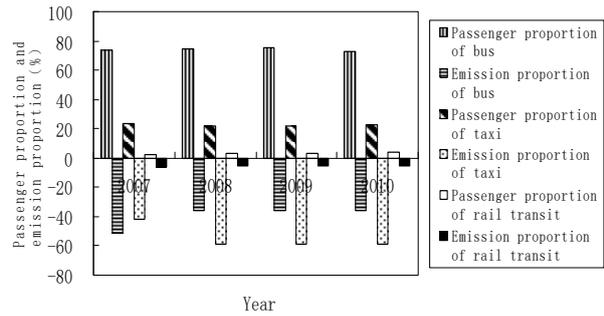


Fig. 3 The comparison of CO<sub>2</sub> emission proportion and passenger volume proportion between bus, taxi and rail transit in Tianjin from 2007 to 2009 \*The data of passenger volume is available after 2007

**C. The Change of CO<sub>2</sub> Emissions of per 10,000 People**

The data of CO<sub>2</sub> emissions per 10,000 people is to use CO<sub>2</sub> emissions of one transport divided by the passenger volume of passenger transport. The data of CO<sub>2</sub> emissions per 10,000 people of each year, it indicated that in 2008 and after the CO<sub>2</sub> emissions per 10,000 people of a taxi is the highest, followed by rail transit, and at last the bus (Fig. 4). It suggested that in the process of meeting the demand of passenger transport, CO<sub>2</sub> emissions of the bus are the lowest, CO<sub>2</sub> emissions of taxis is the highest.

The data of CO<sub>2</sub> emissions per 10,000 people of every year suggested that: (1) CO<sub>2</sub> emissions per 10,000 people raised from 15.97t of 2007 to 25.32t of 2008, then become stable. This is mainly due to the CO<sub>2</sub> emissions of taxi increased in 2008, and the passenger volume of taxi basically remained unchanged. (2) CO<sub>2</sub> emissions per 10,000 people of bus declined from 6.21t of 2007 to 4.66t of 2008, then become stable. This is mainly due to the CO<sub>2</sub> emissions of bus declined in 2008 for Tianjin renewed the bus and the number of natural gas buses increased, and passenger volume increased. (3) CO<sub>2</sub> emissions per 10,000 people of rail transit declined from 23.09t of 2007 to 12.55t of 2008. The reason is that the number of rail transit vehicles did not change, while the passenger volume has grown from 34.97 million in 2007 to 64.32 million in 2010, reached a growth rate of 83.9%. The effective utilization of rail transit leads to a sharp drop in CO<sub>2</sub> emissions of per 10,000 people.

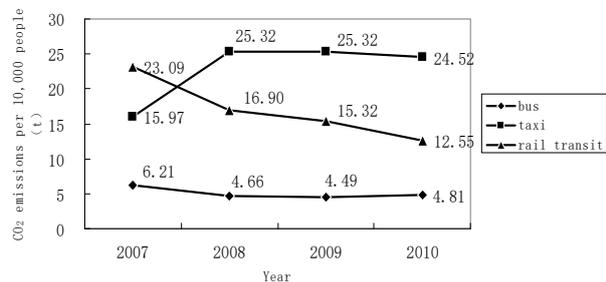


Fig. 4 The trend of CO<sub>2</sub> emission per 10,000 people of bus, taxi and rail transit in Tianjin from 2007 to 2009 \*The data of passenger volume is available after 2007

#### IV. DISCUSSION

Public transportation is the key to build a low carbon city passenger transport. With the development of the city urbanization, the population of Tianjin increases, the traffic demand grows quickly, and the low carbon traffic supply which meets the traffic demand of the future is the development direction of city passenger traffic. The factors which affect the CO<sub>2</sub> emissions of transportation are the number of public transport vehicles, the miles they travels, the fuel consumption per 100km and the CO<sub>2</sub> Emission Coefficient. Therefore, this article mainly considers the factors above and puts forward the Countermeasures of low carbon development of three kinds of public transportation of Tianjin: city buses, taxies, and rail transit.

##### *A. Countermeasures of the Development of Transportation System*

###### 1. The Improvement of Rail Transit

From Fig. 4, we conclude that the CO<sub>2</sub> emissions of rail transit per 10,000 people are lower than a taxi but higher than a bus and with the increasing number of passengers, its carbon emissions per 10,000 has an annual average decline rate of 18%. But at the present stage, the network of Tianjin city rail transit has not been formed yet, and the area that is covered by rail transit and rail transit station is very limited, which limits the use of rail transit resources. Therefore we should develop rail transit, improve the rail transit network, and thus realize a shift of passenger traffic from taxies to rail transit. These are the premises of the number cut of taxies and the decline of CO<sub>2</sub> emissions of public passenger transport.

###### 2. The Use of Alternative Fuel Vehicles

The traditional traffic tools mainly rely on diesel and gasoline as fuel. According to the accounting data, the buses and taxies which use natural gas as fuels have much lower CO<sub>2</sub> emissions per hundred kilometers than traditional diesel buses and gasoline taxies. The development of natural gas vehicles and other alternative fuel vehicles is one of the most important ways to realize the reduction of CO<sub>2</sub> emissions in Tianjin public passenger traffic system. In 2010, Tianjin owned conservatively only 607 buses that use natural gasses, which accounts for only 7.66% of the total number of buses in Tianjin. It means that such alternative fuel vehicles have a great space of the application.

###### 3. Renew Vehicles

Renewing vehicles refer to updating the existing vehicles to more environmentally friendly and better performed energy-saving vehicles. As with the development and application of energy-saving, low-emission technology, the fuel consumption per 100 kilometers is constantly falling. According to the accounting data from the volume of CO<sub>2</sub> emissions of buses, the fuel consumption of buses has fallen from 40L/100 km to 31.25L/100km as a result of bus renewing which starts from 2007 in Tianjin. Although the reduction in fuel consumption per 100km is very limited in the short term, it is still considered to be a measure to reduce the CO<sub>2</sub> emissions

in Tianjin public passenger transport to renew old vehicles in time.

##### *B. Development Strategy of Traffic Assistant System*

###### 1. Reduce the Proportion of Thermal Power Electricity; Reduce CO<sub>2</sub> Emissions of Electricity

The rail transit uses electricity as its energy, which does not produce CO<sub>2</sub> emissions directly in its operating stage. As with the structure adjustment of Chinese electricity energy, the decline of thermal power electricity's proportion and the successful application of carbon capture and sequestration technology, the CO<sub>2</sub> emissions of electricity will be further reduced, thus reduce the CO<sub>2</sub> emissions of rail transit.

###### 2. Increase the Number of Natural Gas Stations and Charging Stations

We should improve the construction of natural gas stations and charge stations in order to promote the application of natural gas and electric cars. Because of the dominating status of traditional diesel and gasoline vehicles, the gas station has been very perfect. However, the number of natural gas stations and charging stations is very small. There are only 4 natural gas stations in Tianjin far away from the city center, which is very inconvenient to fill the fuel. Therefore, Tianjin should improve the natural gas stations and charge stations infrastructure construction in order to promote the application of cars powered by natural gas and electricity.

###### 3. Rational Planning of City Space

The rational planning of city space, primarily to improve facilities of working and living area, reduces the distances of traveling. The development and construction of Binhai New Area of Tianjin trigger a transfer of jobs from downtown Tianjin to Binhai New Area, but downtown Tianjin is still the major living and service place, which leads to an increase of people's commuting distance. In the future development of space planning, we should speed up the facility system construction of Binhai New Area and the suburbs of Tianjin. Besides, Tianjin's single center construction system should be changed in order to reduce people's commuting distance.

#### V. CONCLUSION

Through calculation and analysis of CO<sub>2</sub> emissions of three kinds of public transport in Tianjin, this paper draws the following conclusions:

- 1) In the public passenger transportation system of Tianjin, the taxi has become the largest source of CO<sub>2</sub> emissions. With the improvement of the 2008 CO<sub>2</sub> emission standards, the fuel consumption per 100km has been improved from 5.5L to 9L, which makes the taxi the largest source of CO<sub>2</sub> emissions among all the public passenger transports, surpassing the bus.
- 2) The total CO<sub>2</sub> emissions of public passenger transport have been stabilized. Among the factors which affect the volume of CO<sub>2</sub> emissions, the numbers of taxies, buses and rail transit have all been stabilized. The fuel consumption per 100km of taxies and buses will not be reduced recently.

Therefore, the CO<sub>2</sub> emissions of public passenger transport will not increase greatly in the short term.

- 3) The proportion of buses (among the three kinds of transport) is much higher than its CO<sub>2</sub> emission proportion, and its CO<sub>2</sub> emissions per 10,000 people are the lowest. Even though the proportion of buses has been lowered in 2010, it still reached 72.62% in contrast to its CO<sub>2</sub> emissions proportion of 36.01%. While the proportion of taxis in 2010 is 23.09% in contrast to its CO<sub>2</sub> emissions proportion of 58.43%. From the more concrete data of CO<sub>2</sub> emissions, the volume of CO<sub>2</sub> emissions per 10,000 people of buses, taxis and rail transit are 4.81t, 24.52t and 12.55t in 2010. As a consequence, the buses in Tianjin can bear a larger number of passengers with a relatively lower volume of carbon emission, and is the main tool in developing low carbon passenger transport.
- 4) The ways to realize the reduction of CO<sub>2</sub> emissions are to develop rail transit, use alternative fuel vehicles and to renew buses. Since the CO<sub>2</sub> emissions per 10,000 people of rail transit are lower than taxis, the transfer from taxis to rail transit will reduce the number of taxis and thus realize the reduction of CO<sub>2</sub> emissions in the public passenger transport. As with the application of energy-saving, low-emission technology in the transport sector, the use of alternative fuel vehicles is the future direction of Tianjin low carbon public passenger transport development. In the future, not only vehicles powered by natural gases, but also pure electric vehicles will gradually replace the traditional diesel and gasoline vehicles. Meanwhile, the renewal of public passenger transport vehicles can cut the fuel consumption per 100km, reducing the CO<sub>2</sub> emissions of Tianjin public passenger transport.

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