Analysis of Truck Carbon Emissions per month On Highway road

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Abstract.: In this study, the carbon emissions of the road section from Yandun Toll Station to Erpu Mainline Toll Station of the Xinjiang G30 Line were meticulously quantified using the "Carbon Emission Factor Corresponding to Load Method," which is currently regarded as the most precise methodology in the field of carbon emission research. Additionally, the study analyzed the carbon emission trends of this road section. The findings of the study revealed that there were discernible discrepancies in the carbon emissions of different types of trucks traversing this road section. Heavy trucks are responsible for the majority of carbon emissions, particularly when they account for 90% of the total number of trucks. Furthermore, the study indicates that the carbon emissions of all types of trucks increase month by month in the first half of the year, but gradually decrease in the second half of the year. Further analysis reveals that light-duty trucks have the highest carbon emissions in March, while medium- and heavy-duty trucks peak in June. After fine-tuning the carbon emission results, the trend of carbon emissions is analyzed according to the requirements of the double-talk policy and in the light of the actual situation of carbon emissions in Xinjiang's transportation industry today. These results can be used as an important tool to control carbon emissions and provide data support for policy makers.

Keywords: Carbon emissions, monthly, carbon emission factor method

1 Introduction

1.1 Background of the Study

China has been spotlighted as a developing global economic power for its carbon emissions. While China's economic development has been rapid in recent decades, it has

Z. Ahmad et al. (eds.), *Proceedings of the 2024 5th International Conference on Urban Construction and Management Engineering (ICUCME 2024)*, Advances in Engineering Research 242,
https://doi.org/10.2991/978-94-6463-516-4_23

also led to a significant increase in carbon emissions. Since 2013, General Secretary Xi Jinping has emphasized the importance of innovation, coordination, green development, and openness. As a result, China's major industries have shifted their focus towards constructing and developing a green economy. For instance, the country has established a carbon emissions trading market. In recent years, there has even been a decrease in carbon emissions. However, based on the latest data, China is projected to emit 11.477 billion tons of carbon in 2022, accounting for 30.7% of the world's total carbon emissions [1].

China's carbon emissions primarily originate from five primary sources: energy, industry, transportation, construction, and agriculture.[2] In 2019, China's transportation sector accounted for 14.82% of global transportation CO2 and 12.42% of the domestic CO2 share. Road transport is responsible for the highest share of carbon emissions, approximately 79%, followed by aviation and water transport. Major cities have established a highway network with extensive coverage to address the dispersed road transportation issue. The Xinjiang region has experienced rapid development in recent years, significantly expanding the highway network. However, this growth has also led to a substantial increase in carbon emissions. A study conducted by the Xinjiang Institute of Ecology and Geography (XIEG)[3] found that between 1989 and 2012, the transportation sector in Xinjiang experienced an annual average growth rate of 10.8% for total carbon emissions and 9.1% for per capita carbon. The urgent need to address the issue of green economic development in Xinjiang is in line with the state's 'double carbon' policy. Analyzing data and providing solutions to the problem of highway transportation in some regions of Xinjiang can be an effective way to promote the development of the local green economy.

1.2 Current Status of Domestic and International Research on Carbon Emissions

To address the global challenges of carbon emissions and the green economy, scholars both domestically and internationally have conducted extensive research. Liu Jie, Gao Jiawei, and their colleagues examine the critical issues of carbon emission accounting for transportation infrastructure and propose countermeasures to address the problem. [4]In 2021, Jin Yu will analyze the characteristics of carbon emissions from transportation in international metropolitan cities and conduct a comparative study of carbon reduction strategies based on these characteristics. [5] In 2021, Huang Fulan et al. conducted a comprehensive study on transportation carbon emissions' spatial and temporal evolution in China's provinces. They provided recommendations for achieving the targets for reducing transportation carbon emissions. [6] Zhou et al. also researched this topic. Tian et al. conducted a study on localized carbon emissions in highly urbanized areas and examined the factors that affect carbon emissions in various composite ways. [7]Thalmann et al. also studied carbon emissions, but their focus was not specified. Additionally, a study was conducted on carbon emissions from transportation in provinces along the 'Belt and Road.[8] Thalmann et al. [9]. conducted repeated tests on carbon emissions from local transportation in Switzerland. They constructed a model to predict emissions and provided recommendations. The studies mentioned above indicate that measuring carbon emissions from transportation in the same area is influenced by various factors. This study examines the effects of different models and time of day on the same road section in Xinjiang.

1.3 Research Purpose

Road transportation is the primary source of carbon emissions in the transportation industry, with trucks accounting for approximately 90% of these emissions. This study employs the carbon emission factor method to focus on the data from G30 Yandun Toll Station and examines the carbon emissions of various types of trucks in different months of 2022. The text is written in clear, concise, and objective language with a logical flow of information. Technical term abbreviations are defined at their first occurrence, and the text adheres to conventional academic structure and formatting. The language is formal and free from grammatical, spelling, and punctuation errors. The text is balanced and avoids biased language. The precise subject-specific vocabulary is used when necessary. No changes in content have been made. The study results can support the development of green economic blueprints in different regions and provide recommendations for relevant department policies in response to the dual-carbon program.

2 Data and Methods for Measuring Carbon Emissions

2.1 Data Content

The paper mainly utilizes precise data from the Xinjiang Expressway Database on the load capacity, inbound time, and vehicle type of trucks passing through the Xinjiang Yandun Expressway Toll Plaza to the adjacent toll station, Erbao Mainline Toll Plaza. The data obtained are processed in a specific manner. Abnormal values and their corresponding data are replaced by smoothing to ensure time continuity. The remaining data is integrated and counted to ensure data reliability.

2.2 Comparison of Carbon Emission Measurement Methods

The transportation industry requires an in-depth study of carbon emissions, which relates to environmental protection and directly affects enterprises' sustainable development. Currently, the industry widely uses methods such as the top-down method, bottom-up method, decoupling model, and carbon emission factor method to measure carbon emissions. (e.g., Table 1) The Carbon Emission Factor Method has become an internationally recognized standard for carbon emission measurement due to its standardized operation process and data traceability. The purpose of this study is to use the Carbon Emission Factor Method to accurately measure the carbon emissions of trucks on a specific road section from Yandun Toll Station to Erbao Mainline Toll Station.

Table 1. Comparative analysis of various "carbon emission factor methods"

Methods of m easurement	vintage	drawbacks	bibliography
"Top-down" approach	Calculations can be done when data are incomplete and are applicable at the macro level.	Highly difficult-to-find errors	Zhang Linpeng,Huang Ping et al. [10] Xu Haocheng, Yu Hao, etc.[11]
"bottom-up" approach	Calculations are more accurate and extremely efficient, with time effects	high accuracy of the basis numbers are required	Yang Xianglong[12]
Decoupling model	Robust data processing capabilities and relative rigor	Data accuracy, but model difficulty	Xue Xuan Deng, Ren Jia[13] Liu Guanquan,Yang Yulin etc.[14]
Carbon Emission Factor Approach	Proven technologies and methodologies with wide international recognition	Relatively high uncertainty and limitations	Shi Yao, Zhang Yan, Huang Yi-Yu, et al. [15] Chen Zheng, He Gengsheng et al.[16]

This study uses the 'Carbon Emission Factor Corresponding to Carrying Weight Method' to calculate carbon emissions from the transportation industry, one of two specific carbon emission factor methods.

This study aims to analyze the carbon emissions of trucks in the section from Yandun Toll Station to Erbao Mainline Toll Station using a method that combines actual load capacity, and distance traveled, and corresponding carbon emission factors. This study aims to analyze the carbon emissions of trucks in the section from Yandun Toll Station to Erbao Mainline Toll Station using a method that combines actual load capacity; distance traveled, and corresponding carbon emission factors. The goal is to ensure the scientific and accurate estimation of carbon emissions. This study aims to establish a reliable database for managing carbon emissions in the transportation sector and promoting the industry's transition towards green and low-carbon practices.

2.3 Measurement Steps for Carbon Emission Factors

The main steps in the method of measuring the carbon emission factor corresponding to the combined load weight are as follows:

In the first step, vehicles are categorized according to their load capacity into four main categories: micro vans, minivans, medium-sized vans, and large vans.

In the second step, according to the classification of trucks, the "Carbon Emission Factor Method for Load Weight" mentioned above was used to measure the trucks separately.

In the third step, different types of trucks are further categorized according to the fuels they use to facilitate the accurate calculation of their corresponding carbon emissions.

In the fourth step, identify the unique values for different types of trucks under different months and analyze the reasons for them.

In the fourth step, analyze the growth rates and trends of different types of trucks based on the change curves for the months under study.

3 Measurement of Carbon Emissions

3.1 Measurement of the "Carbon Emission Factor Method for Load Weight"

The formulas to be used for the "Carbon Emission Factor Method for Load Weight" are as follows:

$$C_{a,b,c,d}=Q\times EF_{a,b,c,d} \times D \quad (1)$$

$$C=\sum_{a,b,c,d} C_{a,b,c,d} \quad (2)$$

Where C denotes the sum of the carbon emissions of the vehicles (kg) and$C_{a,b,c,d}$ denotes the carbon emissions of individual vehicles of different types (kg) and$EF_{a,b,c,d}$ denotes the carbon emission factor corresponding to that kind of vehicle ($KgCO_2$ (t-km)), D denotes the distance the vehicle travels (km), and Q denotes the vehicle's load capacity (t). Among them, the distance traveled by the vehicle is obtained by measuring the distance between Xinjiang Yandun Expressway Toll Station and the adjacent toll station Erbao Mainline Toll Station; the corresponding carbon emission factors of the four different models are obtained by inquiring the "Carbon Dioxide Emission Factors of Road Traffic in China's Sub-Provinces" (e.g., Table 2)[17] The effective driving distance between G30 Yandun Toll Station and Erbao Toll Station is 130km, which is calculated through the preliminary research.

Table 2. Carbon emission factors for each vehicle type in Xinjiang

	Minivan	Truck, light	Truck, medium	Truck, Heavy
Carbon emission factor corresponding to the vehicle (KgCO2 (t-km))	0.121	0.084	0.043	0.049

3.2 Measurement Results of the "Carbon Emission Factor for Load" Method

The carbon emissions of the three models of small vans, medium vans, and large vans on the roadway were calculated through the relevant formulas listed previously (e.g., Table 3).

Table 3. Carbon Emissions from Number of Vehicles by Type of Goods Vehicle

Type of truck	Number of vehicles (v ehicles)	Average load capacity (kg)	Carbon emissions (kg)
Truck, light	88357.00	876.23	2851946.23
Truck, medium	88276.00	4536.41	5482939.00
Truck, Heavy	2299985.00	34879.44	412592022.10

3.3 Comparison and Preliminary Analysis of Carbon Emissions of Different Truck Types Under Different Months

Specific data on the carbon emissions of different truck types in different months are shown in the following table (e.g. Table 4).

Table 4. Carbon Emissions of Different Truck Types in Different Months

	Truck, light	Truck, medium	Truck, Heavy
January	50425469.64	115394001.1	6569339873
February	50960527.8	83577906.75	5370021862
March	107191320.6	160735016.5	10485180909
April	72733096.8	145200876.1	8892177377
May	70334344.08	176329316.5	10451847849
June	81374158.32	320416044.2	13985488396
July	90603065.28	236437077.2	3325323966
August	68472800.76	190220673.4	2584275571
September	69140296.68	193201781.2	2939757408
October	63506963.52	129686406.9	1752733757
November	50831879.28	96768579.44	1786808097
December	75860060.64	158434815.4	3661410828

Based on the above data analysis, we can draw the following two conclusions:

(1) Significant seasonal effects: Carbon emissions from the trucking industry show significant seasonal changes, with hot weather and agricultural production cycles in the first half of the year, especially in the summer, leading to an increase in energy consumption and transportation demand, which in turn pushes up carbon emissions.

(2) Economic activity is positively correlated with carbon emissions: enhanced production and sales activity in some sectors in the first half of the year, particularly the spring start-up and summer construction peak in the building sector, as well as the impact of government fiscal policies and industry incentives, combined to influence demand for trucking and thus carbon emissions.

3.4 Analysis of the Degree of Variation of Carbon Emissions Under Different Months

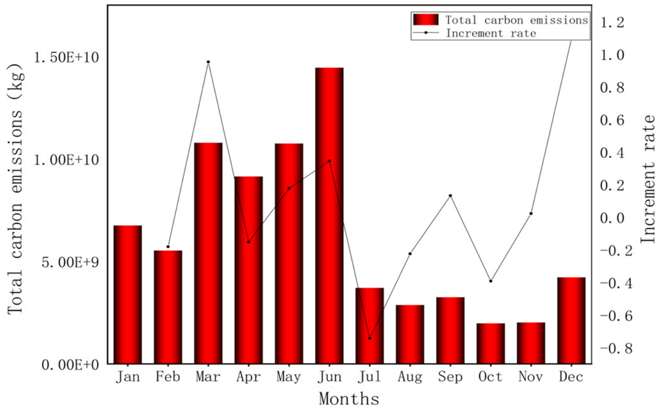

Fig. 1. Carbon emissions in different months

The bar chart in Figure 1 shows the total carbon emissions of each type of truck per month based on the calculated carbon emissions of different truck types. The chart indicates a growth trend. June has the highest carbon emissions due to increased business activities, logistics operations, express delivery demand, and rising temperatures. Additionally, Xinjiang, a critical energy exporting region, experiences a significant increase in the transportation of energy substances and related materials by trucks. However, there was a significant increase in carbon emissions during the month. October has the lowest carbon emissions of the year due to fewer commercial activities and cooler weather, reducing demand for energy-consuming household appliances like air conditioners and transportation of energy materials.

According to Figure 1, carbon emissions grew faster in March than in February because, during February, many logistics companies were closed for the winter vacation and Chinese New Year, resulting in a decrease in the number of trucks on the road. However, when all logistics companies resumed their normal operations in March, the number of trucks and express deliveries increased.

3.5 Analysis of Carbon Emissions of Different Models of Goods Vehicles in Different Months

The study analyzed the carbon emissions of each vehicle in different months and found that the most significant emissions occurred in June. In order to explain the reasons before, the study focused on the carbon emissions of one type of truck across multiple months. The results of these calculations were consolidated and presented in Figures 2, 3, and 4.

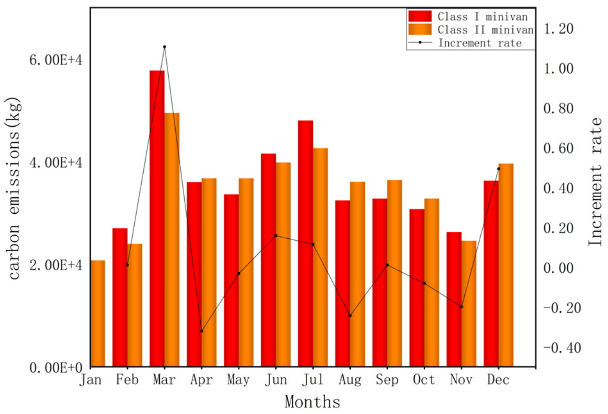

Fig. 2. Carbon Emissions of Light Goods Vehicles in Different Months

In March, local light trucks and minivans in Xinjiang had the highest carbon emissions compared to February due to the local climatic conditions and agricultural industry. The Xinjiang region is currently experiencing ground-melting snow, which makes roads slippery and affects the efficiency of trucks, leading to increased fuel consumption. To reduce fuel consumption, logistics companies opt for smaller trucks with lower capacity to meet transportation needs. It is crucial to consider the agricultural transportation needs during Xinjiang's spring sowing preparation stage, which increases the frequency of light truck usage. Additionally, the low temperatures in the region during March may require the use of the vehicle's heating system, which indirectly increases carbon emissions.

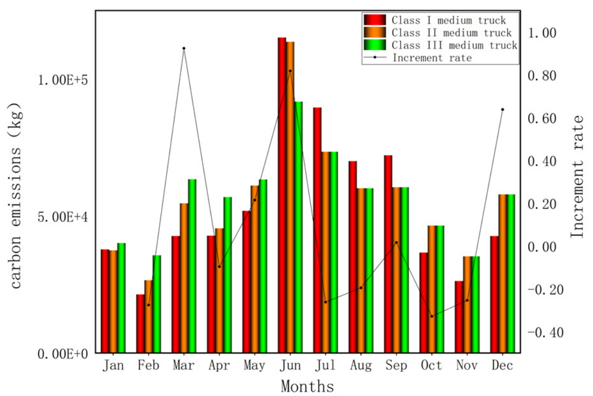

Fig. 3. Carbon Emissions of Medium Goods Vehicles in Different Months

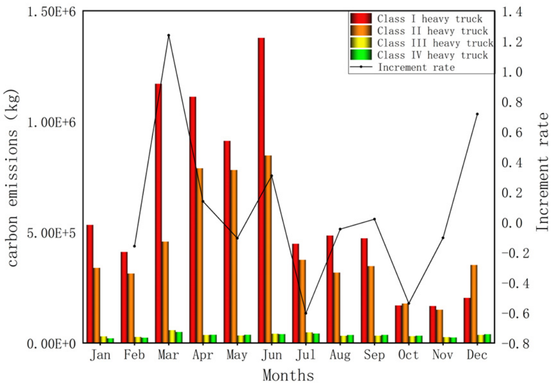

Fig. 4. Carbon Emissions of Heavy Goods Vehicles in Different Months

The energy structure of the Xinjiang region relies heavily on coal. With the increase in energy consumption and the global concern for climate change, it is necessary to increase energy exports from Xinjiang significantly, which is also a crucial season for transporting agricultural products and mineral resources, and led to a significant increase in the volume requirements for medium and heavy trucks.

4 Summary and Recommendations

This study uses the 'Carbon Emission Factor Corresponding to Load Weight Method' to measure the carbon emissions of the section from Yandun Toll Station to Erbao Mainline Toll Station of Xinjiang G30 and integrates the data. The study results indicate that:

1. The percentage of heavy goods vehicles (HGVs) on the regional roadway is 90%, indicating their dominance in the traffic flow. Meanwhile, minivans, light trucks, and minivans account for only 2%, 4%, and 4% of the vehicle counts, respectively.
2. The study reveals a time sequence in the overall carbon emissions sequence diagram. Carbon emissions peaked in March for Class 1 and Class 2 light goods vehicles, while for medium and heavy goods vehicles, carbon emissions peaked in June.
3. In March, all three types of goods vehicles experienced their highest growth rates. However, in April, light goods vehicles had the lowest growth rate; in October, medium goods vehicles had the lowest growth rate; in July, heavy goods vehicles had the lowest growth rate.

Based on the above conclusions, part of Xinjiang's transportation decarbonization construction should start from three aspects.

1. It is suggested that the Xinjiang regional government gradually develop a suitable and forward-looking framework for low-carbon transportation policies to enhance

the formulation and implementation of pertinent policies, which should include clear short-term and long-term goals and ensure the effective implementation of improved low-carbon technologies through the enactment of relevant laws and regulations.
2. As China's most significant energy and resource exporting region, Xinjiang should promote the development of new energy industries. The region relies on traditional petroleum products, such as diesel and gasoline, as fuels. Additionally, the region's multifrequency nature of climate change will indirectly increase the demand for transportation load capacity.
3. It is recommended that certain regions in Xinjiang focus on improving the layout of their transportation network through urban planning and relevant transportation projects to optimize local transportation networks. The construction of bus rapid transit systems (BRT) and other transportation facilities can improve the traffic efficiency of the relevant roads.

Although this study provides some insights into promoting decarbonization in the transportation sector, the following limitations need to be noted:

1. Limitations of data sources and sizes: The study data are based on observations from only one year of a particular road section in Xinjiang, which has a limited sample size and may not comprehensively represent the national or wider region's transportation carbon emission situation. Future studies should consider collecting larger and more diverse data sets to enhance the study's representativeness and reliability.
4. Limitations in research methods: This study employed a single method for measuring carbon emissions without cross-validation. It is recommended that future studies use multiple methods for measurement and conduct comparative analyses of the results obtained from different methods to test their consistency and robustness And enhance the accuracy of the results.
5. Limitations of the study area: The study's carbon emission factor data is limited to the Xinjiang region and may be restricted by specific geographic and climatic conditions. It is recommended that carbon emission factor data from a broader range of regions be explored and differences between them be considered to improve the study's generalizability.

Acknowledgment

This study was supported by the Xinjiang Transportation Investment Group Supported Project (grant number XJJTZKX-FWCG-202401-0044 and ZKX-FWCG-202404-0202) and the Xinjiang Uygur Autonomous Region "Dr. Tianchi" Project.

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