Carbon Emission during Highway Construction in Northwest China Analysis and Forecasts

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Abstract: The construction of highways consumes a large amount of energy and materials and emits a large amount of greenhouse gases into the atmosphere. In order to grasp the carbon emission law of expressways in Northwest China. By proposing the accounting method of carbon emission during the construction period of highways in Northwest China. The characteristics of carbon emissions during the construction period of highways in Northwest China and the differences with other regions were calculated and analysed based on actual cases in different regions. Sensitivity analyses were carried out on the influencing factors of carbon emissions. A prediction model of carbon emissions during the construction period of highways in Northwest China is also established.The results of the study show that: (1) That in more than 65% of the carbon emissions from the material production stage; the construction stage, land acquisition and removal stage and material transportation stage accounted for 16.52%, 12.31% and 1.96% of the whole carbon emission, respectively. (2) The carbon emission intensity of expressways in Northwest China is concentrated in the range of 15 ~ 35 t CO_{2eq} / m. This is significantly higher than 5 ~ 30 t CO_{2eq} / m in other regions. (3) The sensitivity analysis finds that factors such as steel reinforcement, cement, and bridge-to-tunnel ratio can significantly and sensitively influence the carbon emissions of the highway during the construction period.

Keywords: Highway construction; Carbon emission accounting; Carbon emission projection; Life cycle assessment; Sensitivity analysis

1 Introduction

In recent years, the issue of global warming caused by greenhouse gas emissions resulting from human activities has garnered worldwide attention. As a result, energy conservation, emission reduction, and low-carbon environmental protection have become inevitable trends in social development.[1] China, as one of the largest carbon emitters, put forward a goal in September 2020 of "achieving carbon peak by 2030 and carbon neutrality by 2060".[2] In 2021, the "1+N" policy system was established around the goal of carbon peak and carbon neutrality.[3] According to the data released by the National Bureau of Statistics, by the end of 2022, the national highway mileage reached 5,354,800 Km, with a highway density of 55.78 Km/100 Km^2, of which the highway mileage reached 177,300 Km. The large-scale construction of highways will inevitably generate a large amount of energy consumption and

IDEE 2023, November 24-26, Zhengzhou, People's Republic of China

DOI 10.4108/eai.24-11-2023.2343472

carbon emissions. However, currently there is no carbon emission accounting method that can be used in the highway construction industry, which can not effectively support the industry's green and low-carbon transformation.

In the field of highway engineering. Park K[4] et al assessed the environmental loads over the life cycle of a highway and quantified the energy consumption at each life cycle stage. Lee J[5] et al. developed a system to quantitatively assess the benefits of sustainable highway construction. Pan M [6] et al developed a model for calculating highway energy consumption and CO_2 emissions by dividing highways into material production stage, construction stage, operation and management stage, and end-of-life stage. Mukherjee A [7] et al introduced the Project Emission Estimator for estimating the CO_2 footprint of highway construction projects. Peng B[8] et al established carbon emissions from energy combustion and carbon emissions from high temperature decomposition of asphalt, and proposed a standard for carbon emission quantification and grading for asphalt surface construction. Sun G[9] Taking a highway in Chongqing as an example, endogenous carbon emissions during the construction period of each individual project were accounted for. Xue Z[10] et al assessed the energy consumption and carbon emissions generated by the construction of wet soft loess roadbed in highway engineering. Chen X[11]et al carried out a study on the optimization of green construction of ultra-small clear distance tunnels from the perspective of strict emission evaluation. Su Z[12] et al established a carbon emission calculation model using digital technology and formed a carbon emission analysis procedure for road tunnels.

At the present, there are a limited number of studies at home and abroad on the accounting of carbon emissions during the construction period of highways. It is difficult to obtain the inventory data of highway carbon emission, which increases the difficulty of highway carbon emission accounting. In this study, the reduction of carbon sinks in land acquisition and removal stage is considered when defining the space-time boundary of highway carbon emissions accounting. When establishing the carbon emission accounting model of expressway, various carbon emission factors during the construction period of expressway in Northwest China are determined according to the database and literature. According to the actual engineering case, the carbon emissions of different stages are calculated. Then it compares and analyzes the carbon emissions during the construction period of the highway in Northwest China with that of other regions. The influence of bridge and culvert engineering on carbon emission of expressway is analyzed. In order to identify the factors that are sensitive to the carbon emission of expressway construction in Northwest China, the sensitivity analysis of the calculation parameters of the model is carried out. Finally, we construct the highway carbon emission accounting model with the length of the line and the bridge-to-tunnel ratio as the independent variables.

2 Carbon emission accounting method for construction period of highway

2.1 Carbon emission accounting boundary

Generally speaking, carbon emission refers to the emission of greenhouse gases. According to the Kyoto Protocol, the calculation scope of greenhouse gases is determined, including CO_2,

N_2O, CH_4, PFCs, HFCs, and SF_6. The unit of all greenhouse gases is unified as carbon dioxide equivalent (CO_{2eq}). This study only considers CO2 emissions. Because although these six gases will affect the environment and climate, CO_2 has the greatest impact, and the gas often involved in the highway construction period is CO_2.

Carbon emissions during highway construction include endogenous carbon emissions from energy consumption of construction machinery and respiration of construction workers; Exogenous carbon emissions include reduced carbon sinks, material production, transportation, and equipment power consumption. According to the LCA theory, the existing research divides the time boundary of highway project construction period into material production stage, material transportation stage and construction stage. However, Northwest China is an important region to promote the carbon neutral strategy. The carbon sink function of ecosystems is an inherent attribute, playing a pivotal role in achieving carbon neutrality and serving as a crucial approach to mitigate carbon emissions. The land acquisition and removal stage of highway projects inevitably leads to the destruction of ecosystem carbon sink capacity and a reduction in the carbon sink. so the lost carbon sink should be included in the carbon emissions. Therefore, this study adds the land acquisition and removal stage.

2.2 Carbon emission accounting methods

The total carbon emission during the construction period of the highway is determined by summing the emissions from all stages, as calculated by the emission coefficient method and the LCA method.

$$C = C_1 + C_2 + C_3 + C_4 \qquad (1)$$

Where, C represents the total carbon emission during the construction period of the highway; C_1 represents the carbon sink reduced by during the land acquisition and removal stage ; C_2 , C_3 and C_4 represent the carbon emissions generated by during the material production stage , the material transportation stage and the construction stage , respectively. The unit of Q, C_1, C_2, $C_3$and C_4 is t.

2.2.1 Reduced carbon sinks during the land acquisition and removal stage

The decrease in carbon absorption during the land acquisition and clearing phase pertains to the decline in carbon absorption within the terrestrial ecosystems that are disrupted during the construction of the highway, primarily due to the type and extent of land use destruction.:

$$C_1 = \sum_{i=1}^{n} (e_i \times m_i) \qquad (2)$$

Where, i represents the type of land use destroyed, i = 1, 2, 3, ..., n; e_i represents the carbon sink coefficient for land i , the unit of e_i is (t CO_{2eq} / hm^2/a); m_i represents the area of for land i , the unit of ei is hm^2.

Vegetation cover varies widely among regions in Northwest China.[13] As of the end of 2019, Northwest China has a total of 564,500 hm^2 of cropland, 4,605,900 hm^2 of woodland, 39,490,600 hm^2 of grassland, and 5,103,700 hm^2 of wetland. Northwest China's vegetation is divided into two major types of temperate and alpine vegetation. According to the research on carbon sequestration in terrestrial ecosystems and the characteristics of such ecosystems in Northwest China, this paper presents the carbon sequestration coefficient of terrestrial ecosystems in Northwest China in Table 1. This coefficient serves as a basis for calculating the carbon sequestration reduced due to land requisition and highway removal in Northwest China.

Tab 1 Carbon sink coefficient of terrestrial ecosystems in Northwest China

Land use type		Carbon sink factor ($t\ CO_{2eq}/hm^2/a$)	Source
Woodland	Evergreen coniferous forest	464.76	IPCC (2006)
	Deciduous broad-leaved forest	374.81	IPCC (2006)
Undergrowth	Deciduous scrub	23.98	Fang J (2007)[14]
Grasslands	Highland meadow	231.33	Ma (2021)[15]
Plow land	Hullessbarley	4.76	Jia R (2023)[16]
	Rape	4.72	Wang G (2012)[17]
	Common wheat	4.27	She W (2016)[18]

2.2.2 Carbon emission in material production stage

Carbon emissions during the production of materials refer to the emissions generated during source extraction, factory processing, and manufacturing of raw materials used in highway construction:

$$C_2=\sum_{j=1}^{n}(e_j \times m_j) \tag{3}$$

Where, j represents the type of road construction material, j=1, 2, 3, ..., n; e_j represents the carbon emission factor of the road construction material j, the unit of e_j is ($t\ CO_{2eq}$ /t); m_j represents the total consumption of the road construction material j, the unit m_j is t.

The primary materials utilized in highway construction include cement, steel, sand, gravel, ammonium dynamite, and asphalt. The carbon emissions from cement production are categorized into raw material preparation, clinker calcination, and cement preparation. The carbon emission factor for cement, as per the IPCC National Greenhouse Gas Inventory Guidelines of 1996, is 0.4985 t CO_{2eq} /t. Shen L [19]et al considered that the current research on the carbon emission factor of cement in China has overestimated the bias of process emission factor, clinker ratio of cement production and fuel emission factor, etc. The carbon emission factor was determined to be 0.702 t CO_{2eq} /t through systematic sampling of cement production lines and nationwide sampling tests. The carbon emission of the iron and steel production stage is divided into the raw material acquisition and the processing and production stage. Song X et al[20] accounted for the carbon emissions of the iron and steel industry in 2020 from the perspective of carbon footprint, and found that the carbon emission density of the iron and steel industry in 2020 in the raw material acquisition stage and the processing and production stage is 0.2 t CO_{2eq} /t and 2.03 t CO_{2eq} /t , respectively.The carbon emission factors of the main materials in Table 2.

Tab 2 Carbon emission factor of material production

Materials	Carbon emission factor (t CO_{2eq} /t)	Source
Cement	0.702	Shen R (2016)
Steel	2.23	Song X (2023)
Gravel	0.002	Zhang W (2023)[21]
Dynamite	0.263	Zhang Z (2014)[22]
Asphalt	0.166	Liu S (2022)[23]
Clay	0.133	Guo C (2020)[24]
Sand	0.006	Chen J (2016)[25]

2.2.3 Carbon emission in material transportation stage

Carbon emissions in the material transportation stage are the emissions produced by vehicles while transporting materials from the production site to the construction site:

$$C_3 = \sum_{k=1}^{n} (e_k \times m_k) \tag{4}$$

Where, k represents the type of transportation vehicle, k=1, 2, 3, ..., n; e_k represents the carbon emission factor of the transportation vehicle k, the unit e_k is (t CO_{2eq}/ machine-team); m_k represents the working time of the transportation vehicle k, the unit m_k is machine-team.

The transportation tools required for highway construction mainly include trucks, dump trucks, concrete trucks, loaders and beam carriers. When calculating carbon emissions, we begin by determining the number of vehicle shifts, followed by identifying the fossil energy consumption of different types of transportation machinery for each shift. Ultimately, we calculate the carbon emission coefficient of the transportation machinery using the basic fossil energy carbon emission factor.The carbon emission factors for each type of energy in Table 3.

2.2.4 Carbon emission in constructionstage

Carbon emissions during the construction stage are the result of the energy consumption of construction machinery. The carbon emissions from construction workers' respiration are negligible and not taken into account.:

$$C_4 = \sum_{l=1}^{n} (e_l \times m_l \times t_l) \tag{5}$$

Where, l represents the type of construction machinery, l = 1, 2, 3, ..., n; e_l represents the carbon emission factor of the energy consumed by the construction machinery l, the unit e_l is (t CO_{2eq} /t), where the unit of electricity is (t CO_{2eq} /MW/h); m_l represents the amount of energy consumed per unit of time of the construction machinery l, the unit m_l is (t /machine-team), where the unit of electricity is (MW-h/ machine-team), t_l represents the working time of the construction machinery l, the unit t_l is machine-team.

Tab 3 Carbon emission factor of energy

Renewable energy	Carbon emission factor (t CO_{2eq} /t)	Source
Diesel oil	2.171	Guo C (2020)[24]
Petrol	1.921	Li X (2013)[26]
Electrical power	^{a} 0.667	Lu C (2021)[27]

Note: the unit a is (tCO_{2eq} /MW/h)

3 Carbon emission calculation of highway construction period in Northwest China

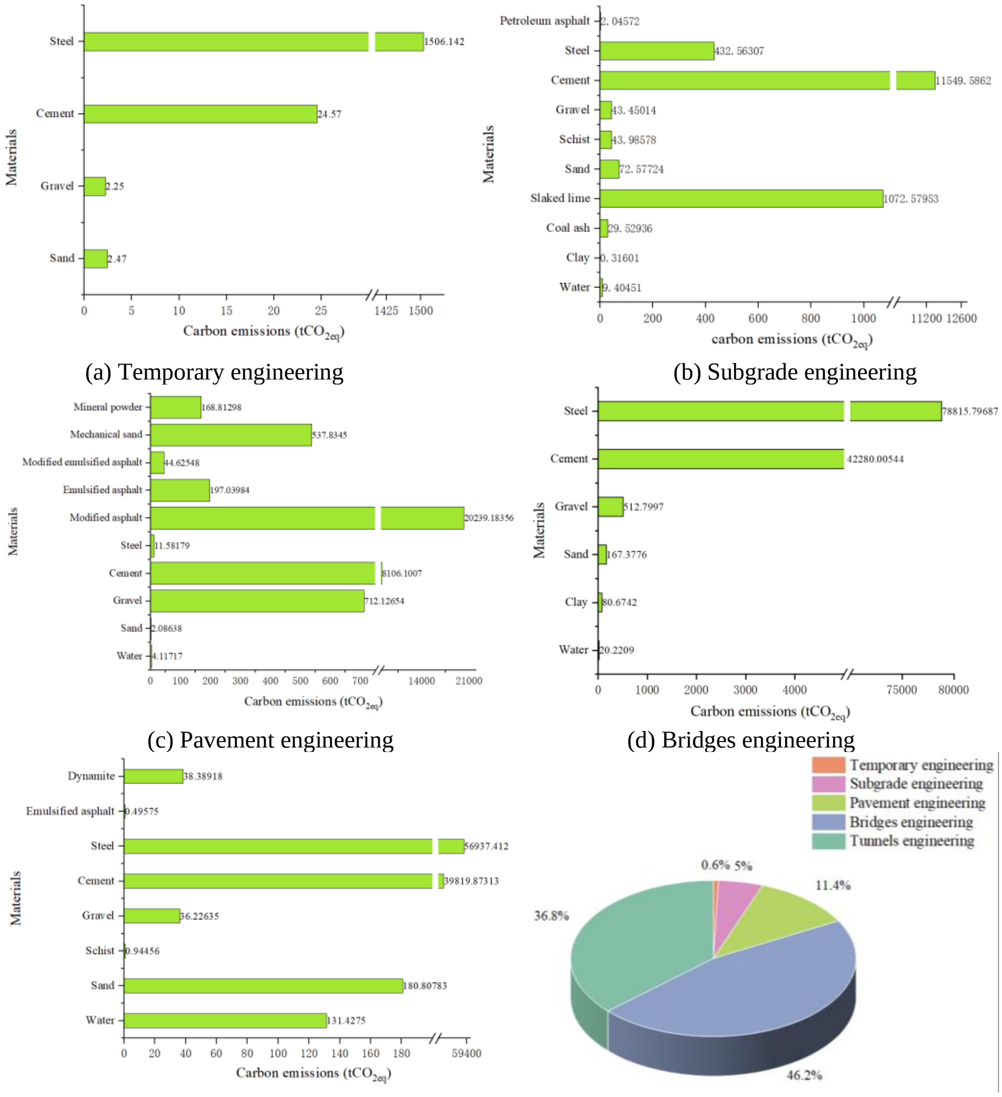
A first-class highway stretches across the northwest region at an altitude of approximately 2500 to 3200 meters. Covering a construction section of about 18.8 kilometers, it adheres to the standard of a two-way, four-lane highway with a design speed of 80Km/h. The integral roadbed has a width of 25.5m, while the separated roadbed is 2×12.75m. There are 17 bridges and 1 tunnel, proportion of bridges and tunnels is 27.84%. Its carbon emission results are calculated according to equations (1) ~ (5).

Table 4 presents that the land acquisition and removal stage of the highway reduced the carbon sink by 46935.232 t CO_{2eq}. Highland meadows and evergreen coniferous forests together account for over 30% of this reduction, while arable land contributes less than 2% and has minimal impact on the highway construction.

Tab 4 Carbon emissions from individual projects during the land acquisition and removal stage

Occupancy type		Area (hm^2)	Carbon sink reduction (t CO_{2eq})
Plow land	Hullessbarley	183.728	874.548
	Rape	69.831	329.600
	Common wheat	63.703	272.013
Grasslands	Highland meadow	63.476	14683.959
Woodland		36.492	16960.101
	Deciduous broad-leaved forest	36.858	13815.011
Total			46935.232

Fig. 1 presents that the total carbon emissions from the material production stage of the highway, which was 263837.430 t CO_{2eq}. It also indicates that iron and steel contributed the largest carbon emissions in temporary engineering, bridge engineering, and tunnel engineering, with amounts of 1506.142, 78815.797, and 56937.412 t CO_{2eq}, respectively. Additionally, carbon emissions from cement were the second largest in these engineering areas. Fig. 1(b) presents that cement produces the largest carbon emission in subgrade engineering, which is 11549.5862 t CO_{2eq}. Fig. 1(c) presents that modified asphalt produces the largest carbon emission in pavement engineering, which is 20239.18356 t CO_{2eq} . Fig. 1(f) shows that bridge engineering has the highest carbon emissions during the material production stage, at 121876.8747 t CO_{2eq}, making up 46.4% of the total carbon emissions for the temporary engineering, bridge engineering, and tunnel engineering. Tunnel engineering follows with 97145.5763 t CO_{2eq}, accounting for 36.8%, and temporary engineering has the smallest proportion at only 0.6%.



(a) Temporary engineering (b) Subgrade engineering

(c) Pavement engineering (d) Bridges engineering

(e) Tunnels engineering (f) Percentage of carbon emissions from individual projects

Fig 1 Carbon emissions from individual projects during the material production stage

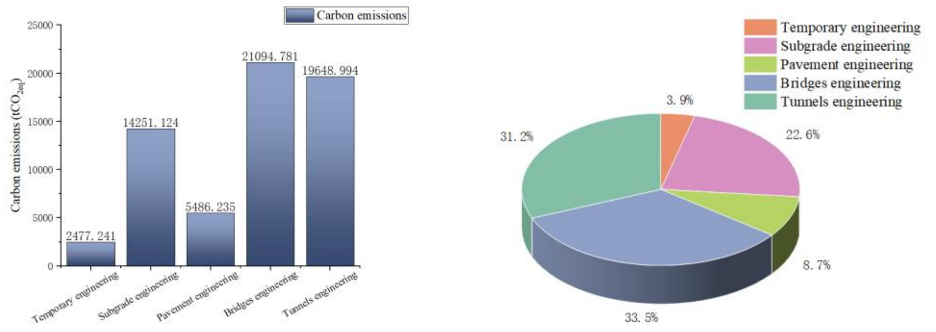
Table 5 shows that the total carbon emissions from the material transportation stage of the highway amount to 7457.254 t CO_{2eq}. Among them, 37.4 % are from subgrade engineering, 28.9 % are from tunnel engineering, and only 0.4 % are from temporary engineering. The majority of carbon emissions in subgrade engineering occur during material transportation due to the longer transportation distance compared to other individual engineering projects. Therefore, reducing carbon emissions in the transportation stage of roadbed works should focus on shortening the transportation distance.

Tab 5 Carbon emissions from individual projects during the material transportation stage

Individual project	Carbon emission inventories	Quantity (machine-team)	Carbon emissions (t CO_{2eq})
Temporary engineering	Truck, cargo up to 3t	301.500	15.075
	Truck, cargo up to 10t	103.200	11.249
Subgrade engineering	Truck, cargo up to 10t	2320.094	252.890
	Dump truck up to 15t	5614.784	825.374
	Bucket capacity 2.0m3 tire loader	8476.518	1712.257
Pavement engineering	Truck, cargo up to 10t	3412.669	371.981
	Dump truck up to 15t	4532.821	666.325
	Dump truck up to 20t	5693.309	950.783
Bridges engineering	Truck, cargo up to 10t	241.932	26.371
	Tire-type girder truck within 120t	4541.471	472.313
Tunnels engineering	Bucket capacity 2.0m3 tire loader	1421.521	287.147
	Truck, cargo up to 3t	585.462	29.856
	Truck, cargo up to 4t	1971.686	145.905
	Dump truck up to 10t	4122.969	449.404
	Dump truck up to 20t	7047.295	1240.324
Total			7457.254

Fig. 2 presents that the total carbon emission of the highway during the construction stage amounted to 62958.375 t CO_{2eq} . Among them, the carbon emission from the bridge and tunnel engineering were 21094.7812 and 19648.994 t CO_{2eq} , respectively.Which accounted for more than 30% of the total carbon emission.

From the previous analysis, it can be seen that the total carbon emissions generated during the construction period of the case are 381188.291 t CO_{2eq} . The carbon emissions generated in each stage are, in descending order, material production stage (69.21%) > construction stage (16.52%) > land acquisition and removal stage (12.31%) > material transportation stage (1.96%). Because bridge and culvert engineering and tunnel engineering account for a large proportion of carbon emissions in each stage, they have a great impact on the carbon emissions of the whole expressway. Therefore, in the next section, the influence of bridge and culvert engineering on the carbon emissions of expressway is analyzed separately.



(a) construction stage of carbon emissions (b) Percentage of carbon emissions from individual projects

Fig 2 Carbon emissions from individual projects during the construction stage

4 Drivers of carbon emissions during highway construction in Northwest China

Selecting 30 sections of highways in Northwest China as the focus of the study, all following a two-way four-lane first-class highway standard with a design speed of 80 km/h. The integral roadbed width is 25.5m, while the separated roadbed width is 2×12.75m. The pavement base layer and subbase layer have a thickness of 54cm, and the surface layer is 15cm thick. Additionally, 30 sections of highways from other regions are chosen as comparative research subjects, with similar design parameters to those in Northwest China. Its carbon emission results are calculated according to equations (1) ~ (5).

4.1 Comparative analysis of carbon emission of highway results in different regions

Fig. 3 presents that the carbon emissions and carbon emission density during the construction period of highways in different regions. The carbon emissions range of highways of varying lengths in Northwest China is between 124,912.56 ~571,638.53 t CO_{2eq}, and the carbon emission density range is primarily concentrated between 15 ~ 35 t CO_{2eq} /m. As the length of the expressway increases, there is a noticeable increasing trend in carbon emissions. In various geographical areas, the carbon dioxide emissions from highways of varying lengths vary between 95058.46 ~ 431296.35 t CO2eq, and the density of carbon emissions is predominantly concentrated in the range of 5~30 t CO_{2eq} /m.

Fig. 4 presents that the proportion of carbon emissions in each stage of highway construction in different regions. The carbon emissions from land acquisition and removal, material production, material transportation, and construction stages in Northwest China represented 10.21%, 70.52%, 1.66%, and 17.61% respectively. In other regions, these percentages were 12.64%, 71.15%, 1.97%, and 14.42% respectively. Notably, the carbon emissions from the construction stage in Northwest China were significantly higher compared to those in other regions.

Compared to other areas, Northwest China exhibits significantly higher carbon emissions and carbon emission density compared to regions of similar land area The elevated average altitude of the northwest region, exceeding 1000 meters, along with the distinctive plateau environment and climate, results in a limited window for effective construction. This scenario gives rise to challenges such as the sequence of 'loose before tight,' intense time constraints, and delayed progress, ultimately causing a noticeable rise in carbon emissions during construction. The alpine plateau region reaches an altitude of 3000 meters and above. The reduced efficiency of construction machinery due to hypoxia in high altitude areas is particularly severe, leading to increased carbon emissions during the construction stage. Due to the presence of numerous large-scale excavation cuttings, high-fill subgrades, tunnels, and bridge engineering activities in the northwestern region, coupled with the impact of seasonal frost-thaw cycles, there is a heightened demand for strong frost resistance in the structures. Consequently, the construction of highways in the northwest region entails elevated requirements, posing construction challenges and necessitating a greater amount of materials and mechanical equipment than in other regions.

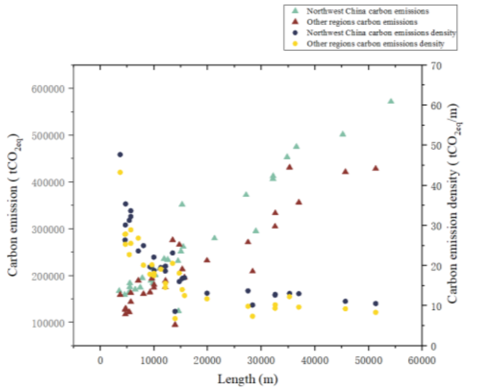
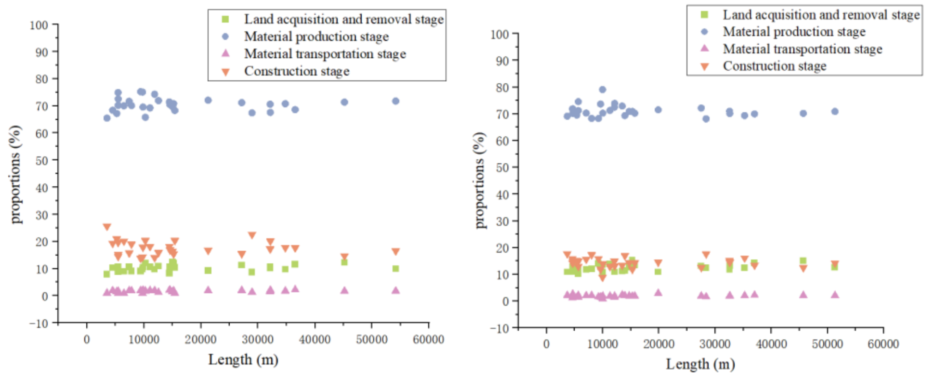


Fig. 3 Carbon emissions and carbon density during highway construction in different regions



(a) Northwest Territories (b) Other regions

Fig. 4 Carbon emission share of each stage of highway construction in different regions

4.2 Analysis of carbon emission results of bridge engineering

A total of 70 bridges ranging from 40 to 1400 meters in length were chosen across 30 bidding sections in the northwest region for this study, with the bridge deck approximately 25 meters wide. Calculating the carbon emissions produced during the construction stage of 70 bridge culverts. Fig. 5 shows that the carbon emissions of bridge culvert projects of different lengths range from 1664.43 ~ 44256.03 t CO_{2eq}. With the increase of the length of the bridge culverts, there is a clear trend of increasing carbon emissions. The carbon emission density of bridge culvert projects ranges from 20 ~ 46 t CO_{2eq} /m, and is mainly concentrated in the range of 25 ~ 40 t CO_{2eq} /m.

4.3 Sensitivity analysis of carbon emission during highway construction in Northwest China

Highway construction encompasses numerous aspects such as land acquisition, materials, machinery, and construction processes, all of which are influenced by various factors. To pinpoint the factors that significantly impact carbon emissions during the highway construction phase in the Northwest China region, a sensitivity analysis is carried out on the model's calculation parameters.

The primary factors influencing the carbon emissions of expressways include a wide range of carbon emission factors, energy consumption of construction machinery, construction efficiency, transportation efficiency, and the main engineering quantities. Sensitivity analysis was performed on terrestrial ecosystems, road construction materials, and energy carbon emission factors, as well as the bridge-tunnel ratio in Northwest China in this research. The study assumes variations of -20%, -15%, -10%, -5%, 5%, 10%, 15%, and 20% in the carbon emission factor and the proportion of bridges and tunnels

Fig. 6 presents that teel, cement and bridge-to-tunnel ratio are the key sensitivity factors affecting the carbon emissions of highways in Northwest China. The steel carbon emission factor has been reduced by 20%, while the highway carbon emission has decreased by 20.4%. Similarly, the cement carbon emission factor has been reduced by 20%, and the expressway carbon emission by 17.2%. The bridge-tunnel ratio has been decreased by 20%, leading to a 14% reduction in highway carbon emissions. Furthermore, the carbon emission factors of evergreen coniferous forests and plateau meadows have both seen a 20% decrease, resulting in the expressway carbon emissions dropping by 12.8% and 9.2% respectively. It is noteworthy that the gasoline carbon emission factor has the least impact on highway carbon emissions, with a 20% reduction only leading to a 1.2% decrease in carbon emissions.

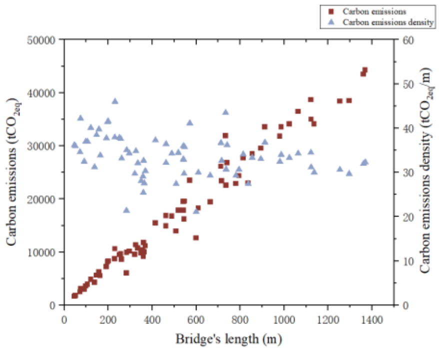


Fig. 5 Carbon emission and carbon emission density of bridge engineering in Northwest China

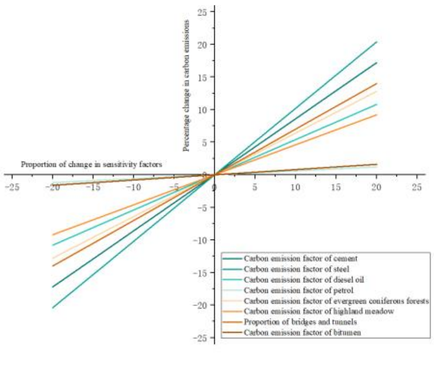


Fig. 6 Carbon emission sensitivity analysis

5 Carbon emission prediction model of expressway construction period in Northwest China

Highway line length, special subgrade length, proportion of bridges and tunnels, subgrade length and pavement length were selected as the potential factors of affecting highway carbon emissions . SPSS software was used to analyze the correlation between various influencing factors and carbon emissions. The results are shown in Table 6. Among them, the correlation coefficient of line length is the highest, which is 0.957; followed by proportion of bridges and tunnels, with a correlation coefficient of 0.899.

Tab 6 Correlation analysis between potential factors and carbon emission

Relevant factor	Type of correlation coefficient	correlation coefficient
Line length	Spearman	0.957
Special subgrade length	Spearman	0.613
Proportion of bridges and tunnels	Pearson	0.899
Subgrade length	Spearman	0.512
Pavement length	Spearman	0.438

The relationship between factors and carbon emissions was analyzed by stepwise linear regression. In the case of multiple independent variables in the regression equation, SPSS software provides t-tests to help identify some independent variables that have a small effect on carbon emissions. In addition, the validity of the regression model was assessed using the F-test, modified coefficient of determination, R^2 and multicollinearity to obtain the highway carbon emission prediction equation, as shown in Table 7. It is worth noting that the highway carbon emission prediction formulas in Table 7 are only applicable to Northwest China. Researchers can establish the highway carbon emission prediction formula according to the carbon emission level of a specific region, which is in line with the regional characteristics.

Tab 7 Carbon emission prediction formula

Independent variable	Prediction formula	F-test	R^2	D-W
X,*Y*	$c=84497.139+8.754X+359487.5Y$	$F=176.626$ $p=0.000<0.05$	0.929	1.724

Note: *X* is the length of the line, m; *Y* is the proportion of bridges and Tunnels; *C* is the carbon emissions, t CO_{2eq}.

6 Conclusions

This study the reduction of carbon sinks in land acquisition and removal stage is considered when defining the space-time boundary of highway carbon emissions accounting. The LCA theory is used to divide the highway construction period into the stage of land acquisition and removal, material production, material transportation and construction. When establishing the carbon emission accounting model of expressway, various carbon emission factors during the construction period of expressway in Northwest China are determined according to the database and literature. We calculated and analyzed the carbon emission results of 30 sections in Northwest China and 30 sections in other regions. The difference of carbon emissions between highway construction period in Northwest China and other regions is compared and analyzed. The influence of bridge and culvert engineering on highway carbon emissions is analyzed. In order to identify the factors that are sensitive to the carbon emission of expressway construction in Northwest China, the sensitivity analysis of the calculation parameters of the model is carried out. Finally, we construct the highway carbon emission accounting model with the length of the line and the bridge-to-tunnel ratio as the independent variables.The research results show that:

(1) The carbon sink reduced by land acquisition and removal should be included in the carbon emissions during the construction period of the highway. Because the ecosystem carbon sink function is a natural property of the ecosystem, the ecosystem carbon sink is one of the important ways to mitigate carbon emissions, and plays a pivotal role in realizing the goal of carbon neutrality. The land acquisition and removal stage of the highway project will inevitably destroy the ecosystem carbon sink capacity and reduce the amount of carbon sink.

(2) The carbon emission density range of highway in Northwest China is concentrated in 15~35 t CO_{2eq} /m, and the carbon emission density range of other regions is mainly concentrated in 5~30 t CO_{2eq} /m, which is significantly higher than that of other regions, which is inextricably linked with the relationship between high plateau and high temperature, complex topography and fragile ecological environment in Northwest China. At the same time, the carbon emission range of bridge culvert projects of different lengths in Northwest China is 1664.43~44256.03 t CO_{2eq} , with the increase of the length of the bridge culvert, the carbon emission generated has a significant increasing trend; the carbon emission density of bridge culvert projects ranges from 20 to 46 t CO_{2eq} /m, and is mainly concentrated in 25~40 t CO_{2eq} /m.

(3) More than 65% of the carbon emissions during the construction period of the highway in Northwest China come from the material production stage, of which cement, steel, and asphalt carbon emissions rank among the top three, and should be focused on; the carbon emissions from the land acquisition and removal stage are the second highest, accounting for 12.31%, of which alpine meadows and evergreen coniferous forests account for more than 30%, and cultivated land accounts for less than 2%; the carbon emissions from the material transportation stage account for the lowest, only 1.96%. Among the individual projects, the bridge and culvert project and tunnel project account for a larger proportion of carbon emissions in each stage, which has a greater impact on the carbon emissions of the whole highway.

(4) The sensitivity analysis of the main factors involved in the calculation of carbon emissions during the construction period of highways in Northwest China reveals that factors such as steel reinforcement, cement, and bridge-to-tunnel ratios can significantly and sensitively affect the carbon emissions during the construction period of highways.

(5) A highway carbon emission accounting model with line length and bridge-to-tunnel ratio as independent variables was established by stepwise regression analysis using SPSS software, and the model R^2 = 0.929, and the D-W value is near the number 2. Thus indicating that the model has no autocorrelation, and there is no correlation between the sample data, and the model precision is better.

Acknowledgments. This research was funded by the Technology Funding Scheme of China Construction Second Engineering Bureau LTD. (2020ZX150002); National Natural Science

Foundation of China (12262018); Special Funds for Guiding Local Scientific and Technological Development by The Central Government (22ZY1QA005).

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