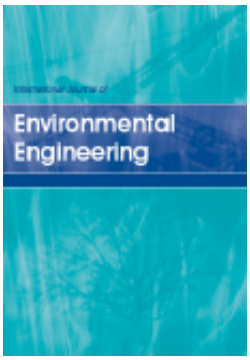

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Study on the dynamic change of urban traffic carbon footprint under low-carbon tourism

Jing Gao

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Study on the dynamic change of urban traffic carbon footprint under low-carbon tourism

Jing Gao

Department of Tourist Management,
Zibo Vocational Institute,
Zibo, Shandong 255314, China
Email: jijinggouid0@163.com

Abstract: This study mainly analysed the dynamic change of carbon footprint of urban tourism transportation in Shandong Province from 2010 to 2019 and calculated the carbon footprint changes of the highway, railway, waterway, and civil aviation transport using the 'bottom-up' method. The results showed that the carbon footprints of the highway, railway, waterway, and civil aviation transport in Shandong Province were 9.58×10^8 kg, 6.42×10^8 kg, 0.34×10^8 kg, and 19.21×10^8 kg, respectively, with a total of 35.55×10^8 kg. From 2010 to 2019, the carbon footprint of tourism transportation was growing. The results show that the carbon footprint of urban transportation in Shandong Province is growing rapidly; therefore, it is necessary to vigorously promote the concept of low-carbon tourism, promote low-carbon travel, and reasonably control the carbon footprint.

Keywords: low carbon; tourism; city; transport carbon footprint; dynamic change.

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Biographical notes: Jing Gao received her Master's degree of Management. She graduated from Shanxi University of Finance and Economics in 2008. She is an Associate Professor at Zibo Vocational Institute. She is interested in tourist economy and tourist marketing.

1 Introduction

Economic development is inseparable from energy consumption, which not only improves people's living standards but also causes damages to the environment. The rise of global temperature has caused natural disasters, such as the sea-level rise and polar melting (Ye and Mather, 2015; Alfieri et al., 2015), which also have many negative effects on the survival of animals, plants, and even human beings (Gunderson and Stillman, 2015; Vitasse et al., 2018). It is undeniable that global warming is inseparable from human activities (Cook et al., 2016). Therefore, human beings should also make efforts to slow down climate warming from perspectives of reducing greenhouse gases and saving energy (Shankleman, 2016). Cities are the areas where human activities are most frequent and have the most profound impact on the environment. Whether a city can

achieve low-carbon development is closely related to whether the national carbon emission reduction target can be achieved (Luo et al., 2018). Tourism is an important leisure activity for people. It is not only an important part of economic development but also has a significant contribution to carbon emissions. Zhong et al. (2015) estimated the carbon emissions of China's tourism industry in 2007 and found that the value reached 167.8 million tons (2.44% of the total) and the carbon emission of transportation was 50.14 million tons. Cadarso et al. (2015) analysed the carbon footprint of tourism in Spain from 1995 to 2007 and found that its value was 10.6% of the total in 2017, in which the transportation industry accounted for 26%. Therefore, to slow down climate warming, it is necessary to take action in the transportation sector, especially air transportation. Hannah et al. (2016) studied the carbon emission of tourism in Iceland from 2010 to 2015 and found that the value increased from 600,000 tons in 2010 to 1.8 million tons in 2015, of which the aviation industry contributed the most. Kitamura et al. (2020) calculated the carbon footprint of Japan's tourism industry and found that the annual carbon emission was about 136 million tons, among which transport accounted for 56.3% and accommodation accounted for 9.8%, and air transport accounted for 24.7% of transport. Shandong Province has well-developed tourism because of rich natural and cultural resources. Tourism income is also an important part of the economic income of Shandong Province. In order to achieve the sustainable development of the tourism industry and promote low-carbon tourism, it is necessary to study its carbon footprint. In order to better understand the changes of the carbon footprint of tourism transportation in Shandong Province, this paper, based on the life cycle assessment (LCA), collected relevant data, calculated the carbon footprint of tourism transportation in Shandong Province from 2010 to 2019, and analysed its dynamic changes. This work provides some theoretical support for mastering the changes of the carbon footprint of tourism transportation in Shandong Province and also makes some contributions to the promotion of low-carbon tourism and the realisation of economic growth under sustainable development. The method provided in this paper can be applied in the dynamic change research of other provinces and other types of carbon footprint, which is conducive to the better and faster development of the tourism industry.

2 Carbon footprint of tourism transportation and calculation method

At present, there are two main theories about the calculation of carbon footprint.

1 Input-output theory (IOA) (Steen-Olsen et al., 2016): it mainly analyses the relationship between 'input' and 'output' of various sectors. Based on the relationship, the carbon footprint is calculated using the 'top-down' method (Thompson et al., 2016) and measured by the average energy consumption of the whole country.

2 Life cycle assessment (LCA) (Pereira et al., 2017): it is a method to evaluate all the activities in the whole life cycle. On this basis, the 'bottom-up' method (Hao et al., 2016) is adopted to calculate the carbon footprint, and the whole activity is divided into different subsystems for separate calculation.

Tourism carbon footprint refers to the total amount of CO_2 generated by tourists' eating, living, and traveling (Pieri et al., 2016). At present, there are no special statistics on the

energy consumption of the tourism industry in China; thus, it is difficult to use the IOA method for research. Therefore, this study chooses the bottom-up method based on LCA.

There are four main forms of tourism transportation.

1 Highway transport: highway transport has strong flexibility and is most favoured by passengers. It is a form with the largest passenger volume and high carbon emission.

2 Railway transport: railway transport has good stability and comfort and low price, suitable for medium and long-distance travel. It has low carbon emissions, but there are some disadvantages in timeliness and flexibility.

3 Waterway transport: waterway transport is difficult to popularise because of its strong dependence on the river, and it has poor timeliness and high carbon emission.

4 Civil aviation transport: civil aviation transport is suitable for long-distance travel because it is the fastest and the most comfortable, but the price is high; moreover, the carbon emission is also high.

The calculation formula of the carbon footprint of tourism transportation is:

$$T_i = Z_i \times P_i \times C_i \tag{1}$$

where T_i is the carbon footprint of tourism transportation (gCO_2), Z_i is the passenger turnover selecting the i^{th} transport means (pkm), P_i is the proportion of passengers selecting the i^{th} category transport means in the total turnover of passengers, and C_i is the carbon emission coefficient of the i^{th} transport means (gCO_2/pkm).

The carbon emission coefficients of different means of transportation are shown in Table 1.

Table 1 Carbon emission coefficients of different means of transportation

Means of transportation	*C_i (gCO_2/pkm)*	*Reference*
Highway transport	0.047	Goessling et al. (2005) and Becken (2005)
Railway transport	0.027	Scott et al. (2008)
Waterway transport	0.066	Scott et al. (2008)
Civil aviation transport	0.140	Goessling et al. (2005) and Becken (2005)

3 Analysis on the dynamic change of carbon footprint of tourism transportation

3.1 Development of the tourism industry in Shandong Province

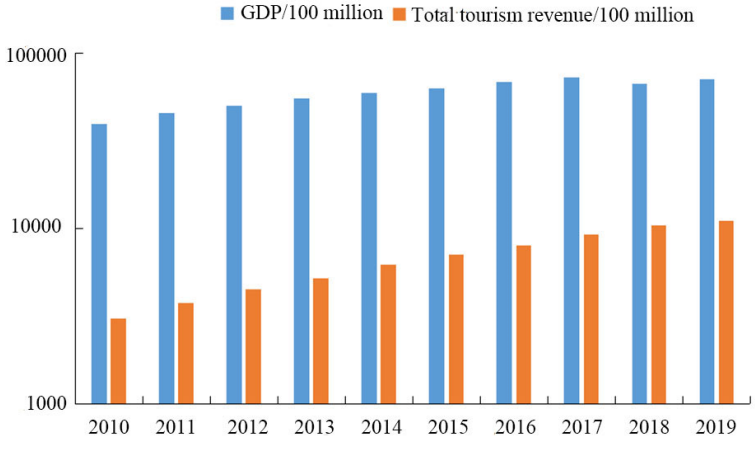
Shandong Province is located on the eastern coast, with strong economic strength, rapid development, and rich natural resources. Shandong is the seat of Qilu culture. There are six national key scenic spots and ten national historical and cultural ancient cities. Laoshan, Qingzhou and Qufu cities are rated as national tourism demonstration areas. In 2019, its total tourism revenue reached 1,108.73 billion yuan, and it has received 938.093 million Chinese and foreign tourists. The tourism industry has made a great contribution to the development of Shandong Province. Relevant research data were

obtained through Shandong statistical yearbook and statistical bulletin, as shown in Table 2.

Table 2 Tourism industry development of Shandong Province from 2010 to 2019

	2010	*2011*	*2012*	*2013*	*2014*
GDP/100 million yuan	39,169.92	45,361.85	50,013.24	55,230.32	59,426.59
GDP per capita (yuan/person)	41,106	47,335	51,768	56,885	60,879
Passenger turnover (100 million person-kilometre)	1,658.31	1,740.41	1,836.14	1,083.75	1,143.6
Total tourism revenue/100 million yuan	3,058.8	3,736.6	4,519.7	5,183.9	6,192.5
Length of railroad lines in service (10,000 km)	0.38	0.42	0.43	0.43	0.5
Inland waterway mileage (10,000 km)	0.12	0.12	0.11	0.11	0.11
Highway mileage (10,000 km)	22.99	23.32	24.46	25.28	25.95
	2015	*2016*	*2017*	*2018*	*2019*
GDP/100 million yuan	63,002.33	68,024.49	72,634.15	66,648.87	71,067.53
GDP per capita (yuan/person)	64,168	68,733	72,807	66,472	70,653
Passenger turnover (100 million person-kilometre)	1,147.32	1,188.92	1,247.26	1,289.61	1,337.98
Total tourism revenue/100 million yuan	7,062.5	8,030.7	9,200.3	10,461.2	11,087.3
Length of railroad lines in service (10,000 km)	0.54	0.55	0.57	0.63	0.66
Inland waterway mileage (10,000 km)	0.11	0.11	0.11	0.11	0.11
Highway mileage (10,000 km)	26.34	26.57	27.06	27.56	28.03

Figure 1 Changes in total tourism revenue in Shandong Province from 2010 to 2019 (see online version for colours)



It was seen from Table 2 that the economy of Shandong Province was in a state of rapid development from 2010 to 2019, and the tourism revenue was also growing rapidly. As shown in Figure 1, in 2018, the GDP of Shandong Province slightly decreased, but the total tourism revenue was still rising, reaching 1,108.73 billion yuan in 2019; the total tourism revenue in 2019 had an increase of 262.47% compared with 2010 and an increase of 5.98% compared with 2018. Generally speaking, the tourism industry of Shandong Province was in good development.

From the perspective of urban traffic, the construction of railway and highway was constantly advancing, while the water transport has not changed much. Compared with 2010, the railway mileage in 2019 has increased by 73.68%, and the highway mileage has increased by 21.92%, creating good conditions for the development of urban tourism.

3.2 The dynamic change of carbon footprint

According to the method in the second section, the dynamic changes of the carbon footprint of tourism transportation from 2010 to 2019 were calculated. The results are shown in Table 3 and Figure 2.

Table 3 Carbon footprint of tourism transportation in Shandong Province from 2010 to 2019 (unit: 108 kg)

	2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Highway transport	3.40	4.42	5.05	6.09	6.88	7.79	9.24	9.29	9.34	9.58
Railway transport	0.74	0.95	1.01	2.15	2.64	3.25	3.88	4.80	5.67	6.42
Waterway transport	0.05	0.06	0.06	0.11	0.13	0.15	0.17	0.21	0.22	0.34
Civil aviation transport	1.39	1.82	2.09	4.66	6.03	8.03	10.49	13.76	16.78	19.21
Total	5.58	7.25	8.21	13.00	15.68	19.22	23.77	28.06	32.01	35.55

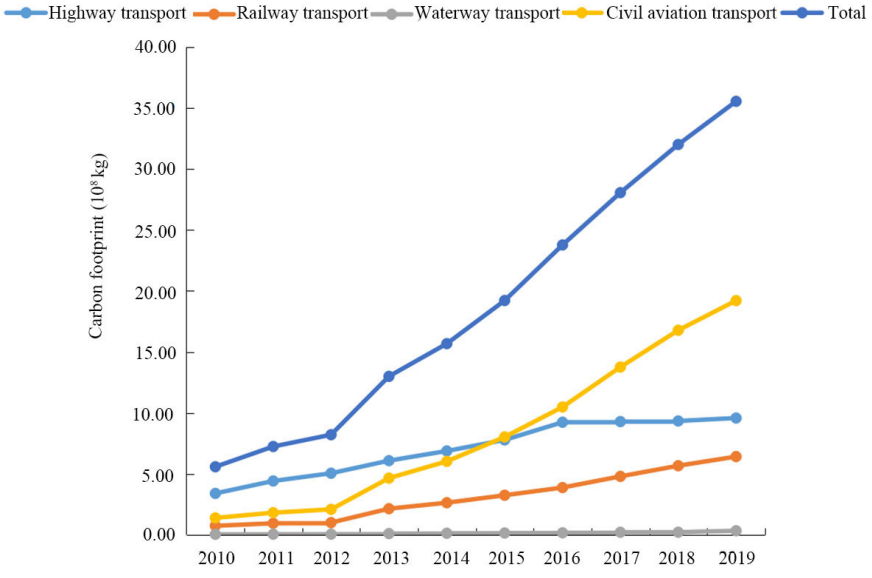
It was seen from Table 3 and Figure 2 that the carbon footprint of tourism transportation in Shandong Province had increased rapidly in the past ten years. In 2019, the carbon footprint of highway transport was 9.58×10^8 kg, showing an increase of 181.76% compared with 2010 and an increase of 2.57% compared with 2018. The carbon footprint of railway transport was 6.42×10^8 kg, about seven times that of ten years ago, showing an increase of 13.23% compared with 2018. The carbon footprint of waterway transport was 0.34×10^8 kg, which was 6.8 times that of ten years ago and was 54.55% higher than that in 2018. The carbon footprint of civil aviation transport grew fastest and was 19.21×10^8 kg in 2019, which was about 14 times that of ten years ago and 14.48% higher than that in 2018.

In general, although the carbon footprint of water transport was small and the change was not obvious in Figure 2, it grew rapidly. Before 2015, the carbon footprint of civil aviation transport was lower than that of highway transport; after 2015, it quickly exceeded highway transport. The carbon footprint of civil aviation transport changed the fastest, the growth trend of the carbon footprint of highway transport slowed down after 2016, and the carbon footprint of railway transport was always in steady growth.

It was seen from Figure 3 that the changes of transportation carbon footprint and total tourism revenue were positively correlated, and the changing trend of them was nearly

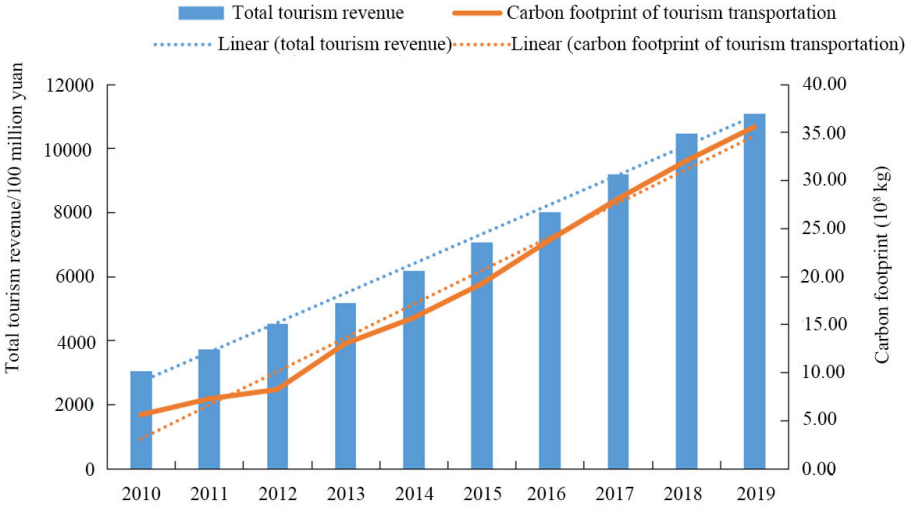
the same, but the growth of transportation carbon footprint was faster. The growth rate of the carbon footprint of transportation may exceed the total tourism revenue in the future development; therefore, it is urgent to vigorously develop low-carbon tourism.

Figure 2 Dynamic changes of the carbon footprint of tourism transportation in Shandong Province from 2010 to 2019 (see online version for colours)



The total tourism revenue was compared with the carbon footprint of transportation, as shown in Figure 3.

Figure 3 Dynamic changes of total tourism revenue and transportation carbon footprint (see online version for colours)



4 Discussion

The tourism industry can provide a large number of employment opportunities and plays an important role in promoting investment and expanding consumption, but it is also a contributor to climate warming (Zha et al., 2018). The tourism industry has produced huge carbon emissions in transportation, accommodation, diet, etc. (Goswami and Kumar, 2015). In recent years, the concept of low-carbon tourism has been widely concerned (Yang, 2015; Wane et al., 2019). Low-carbon tourism pursues the unity of economic, social, and environmental benefits, hoping to make efficient and economical use of resources and minimise carbon emissions through clean energy, consumption mode transformation, and research and development of low-carbon technologies (He and Tu, 2020). Transportation is an important link in tourism. Many studies have found that the carbon emission of transportation accounts for a large part of the total (Rico et al., 2019). Therefore, it is necessary to calculate and analyse the carbon emission of transportation to make better decisions.

This study used the 'bottom-up' method to calculate the carbon footprint of tourism transportation in Shandong Province. It was found from the dynamic change that the economy and tourism industry of Shandong Province was in a state of rapid development from 2010 to 2019, and the urban transportation construction was constantly improving, which created good conditions for the development of tourism. From the perspective of tourism carbon footprint, the value was growing rapidly in the past ten years. In particular, the carbon footprint of civil aviation was growing very fast. It was found from the dynamic changes of the carbon footprint of the four forms of transportation that people's demand for tourism was increasing with the development of the economy, and people were more inclined to choose comfortable and fast civil aviation, which led to further increase of the carbon footprint of transportation.

This study only analysed the data before 2020 as the data of 2020 were incomplete. In 2020, under the influence of COVID-19, Shandong Province received 577 million domestic and international visitors and achieved a tourism income of 601.97 billion yuan, which were 61.5% and 54.3% of the last year. The mileage of different forms of transportation in 2020 was also significantly shorter than that in the last year. In the event of social emergencies, the tourism industry will be greatly affected, and the carbon emission will also decrease.

For Shandong Province, for the sake of the healthy development of the city and the sustainable development of tourism, low-carbon tourism must be vigorously promoted. In future works, it is necessary to:

1 develop clean energy and promote it in the transportation industry (Hirtenstein, 2015)

2 improve the construction of transportation infrastructure, increase the construction of expressways, increase the traffic turnover, reduce the time of tourists on the journey

3 vigorously develop low-carbon technology (Baker et al. 2015), increase investment in scientific research, provide policy support, offer some convenient conditions for the development of clean energy and low-carbon technology, and give some financial support

4 advocate low-carbon tourism, publicise low-carbon concept in public places, such as stations, and encourage tourists to adopt low-carbon transportation mode.

5 Conclusions

Through the 'bottom-up' method, this paper studied the calculation of the carbon footprint of urban tourism traffic. Taking Shandong Province as an example, this paper analysed the dynamic changes of the carbon footprint of tourism transportation from 2010 to 2019 and found that the tourism industry in Shandong Province developed rapidly and that the traffic carbon footprint also grew rapidly in the ten years. It is necessary to increase the publicity of the low-carbon tourism concept to realise the good and healthy development of cities.

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