Proceedings of the 3rd International Conference on Business and Policy Studies
DOI: 10.54254/2754-1169/68/20241405

Shanghai Tourism Carbon Footprint Measurement Based on Final Consumption and Suggestions for Improvement of Urban Tourism Facilities

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Abstract: As a major tourist city in China, Shanghai's tourism industry generates a great deal of carbon emissions. However, China is now actively practicing measures to reduce carbon emissions in order to protect the environment. Therefore, it is particularly important to measure Shanghai tourism carbon footprint. The results of this study can help characterize the carbon emission of Shanghai's tourist industry, so that the government can better improve Shanghai's tourism - based on its characteristics and reduce the carbon emissions in a more effective manner, which can better respond to the national and global low-carbon trend. This research utilizes the "from bottom to up" approach, collects data from Shanghai's tourism final consumption, measures the sub-industry’s carbon footprint using the carbon emission coefficients, and then performs a superposition calculation to determine the characteristics of Shanghai's overall tourism and sub-industry carbon footprint, and the composition of carbon footprint in transportation. It shows following problems: the national environmental protection awareness has not yet been formed, and the tourism's related technologies and service facilities have not been able to guide tourists to reduce carbon emissions. In view of the characteristics and problems, this paper puts forward three suggestions, including the innovation of tourism-related technologies, the transformation of tourism service facilities and the enhancement of national low-carbon awareness.

Keywords: Shanghai, carbon footprint, tourism

1. Introduction

Climate disasters such as extreme heat, droughts and floods across the globe in recent years have reminded humanity of the urgency of mitigating warming. In March 2023, the World Tourism Organization (UNWTO) stated that the carbon footprint of international tourism accounted for 8% of global greenhouse gas emissions, nearly four times as much as estimated [1]. Carbon footprint, is a collection of greenhouse gas emissions from various types of production, consumption and activities by business, organizations or individuals. Tourism has rapid growth in the world today, and scientific management of the tourism carbon footprint is very important in slowing down global warming and is an inevitable choice for realizing sustainable development.

In 2013, the total carbon emission of China has become the largest in the world, accounting for as much as 29% [2]. Shanghai is a Chinese celebrated historical and cultural metropolis, locating near both the river and the sea, which is rich in tourism resources. According to Shanghai's "14th Five-Year Plan" for tourism development, the city strives to realize an annual tourism revenue of more than 700 billion yuan by 2025. Therefore, it is urgent and necessary to research Shanghai's tourism carbon footprint, and to adopt a "Low-Carbon Tourism" policy in Shanghai, which is also an important measure for the implementation of China's "Dual-Carbon Policy".

In November 2021, many countries signed *The Glasgow Declaration on Climate Action for Tourism*, which aims to halve carbon emissions in the tourism sector by 2030 and to reach net-zero emissions by 2050, with an action plan to measure tourism carbon emissions and accelerate the decarbonization of this sector. In March 2023, in order to fulfill the Declaration, UNWTO issued *Climate Action in the Tourism Sector-An overview of methodologies and tools to measure greenhouse gas emissions*, which aims to provide guidance on the measurement of tourism greenhouse gas emissions [1]. However, due to the complexity of the tourism and the diversity of stakeholders, there is no globally consistent methodologies and tools for measuring carbon emissions. Therefore, according to the existing academic research, this paper starts from the final consumption of tourism, and utilizes carbon emission coefficients to estimate each sector’s carbon footprint in tourism, and finally performs superposition calculations to simulate the tourism carbon footprint in Shanghai. Through overall and sub-industry measurement and analysis of the tourism carbon footprint in Shanghai, the results of this study can show the characteristics and problems of the tourism carbon emissions in Shanghai, and put forward reasonable suggestions and solution for improvement.

2. Method

2.1. Sources and Selection of Data

This study simulates the tourism carbon footprint in Shanghai based on existing academic research and obtains tourism data from The Shanghai Statistical Yearbook from 2012 to 2021. The Shanghai Statistical Yearbook contains the most authoritative and government-collected data related to Shanghai. It obtains accurate and comprehensive data on total tourism revenue, number of tourists, per capita consumption of tourists, and other data needed for the measurement.

2.2. Measurement Models and Methods of Data Analysis

The tourism carbon footprint is the greenhouse gas emission quantity generated by individual or group tourists in the course of tourism activities. Currently, there are two main approaches for measuring the tourism carbon footprint: the "from top to down" method based on input-output theory and the "from bottom to up" method based on life cycle theory. The "from bottom to up" method starts from the tourism final consumption, utilizes the carbon emission coefficients to measure each sector’s carbon footprint in tourism industry separately, and finally performs the superposition calculation [2]. In this paper, we choose the "from bottom to up" approach to measure the tourism carbon footprint in Shanghai from the perspective of tourism final consumption, because this method is more suitable for measuring the tourism carbon footprint where lack statistical bases of tourism data than the "from top to down" method [3].

2.2.1. Overall Model of Tourism Carbon Footprint

In this paper, with reference to the environmental impact model proposed by Ehrlich and Holden, the overall model of tourism carbon footprint can be expressed as [4]:

$$TCF = F \cdot G \tag{1}$$

i.e.

$$TCF = V \cdot E \cdot R \cdot K \tag{2}$$

In the above equations (1) and (2): TCF is the tourism carbon footprint, F is the total tourism income, G is the carbon emission intensity of the tourism economy; V is the quantity of tourists, E is the per capita consumption, R is the energy consumed by the tourism economy (t standard coal), and K is the carbon emission coefficient of this energy consumption.

2.2.2. Sub-Industry Tourism Carbon Footprint Model

Tourism involves six major sub-industries: catering, accommodation, transportation, excursion, shopping and entertainment, and the carbon emission intensity and unit energy consumption of industries are different, so the sub-industry model of tourism carbon footprint can be established [5]. The carbon footprint of the six sub-industries can be summed up to get the overall tourism carbon footprint with the formula:

$$TCF = CF_c + CF_a + CF_t + CF_v + CF_s + CF_r \tag{3}$$

In equation (3), CF_c、CF_a、CF_t、CF_v、CF_s、CF_r respectively represents the carbon footprint of catering, accommodation, transportation, excursions, shopping and entertainment. According to the calculation method in the IPCC Guidelines for National Greenhouse Gas Inventories, the tourism carbon footprint industry model can be expressed as follows:

$$TCF = \sum_{i=1}^{6} D_i P_i K_i \tag{4}$$

In equation (4): D_i is the income of the i^{th} industry, P_i is the energy intensity of the i^{th} industry, and K_i is the carbon emission coefficient of the i^{th} industry.

2.3. Methods of Data Classification

In this paper, the 2012-2021 tourism data of Shanghai is selected for the overall measurement and analysis of Shanghai's tourism carbon footprint, and the 2019 data is selected for the sub-industry Because the data of 2022 and 2023 have not yet been released, the complete and appropriate sample size data that can be found in The Shanghai Statistical Yearbook is between 2012 and 2021, so the tourism industry data from 2012-2021 is selected for the overall measurement and analysis of the tourism carbon footprint. The tourism revenue of Shanghai in 2019 peaked before the epidemic, which was 14% of the total GDP of Shanghai in that year, ranking the China's third and the first in the Yangtze River Delta, so the 2019 data is selected as the sample of the sub-industry measurement and analysis of tourism carbon footprint.

3. Results

3.1. Overall Tourism Carbon Footprint Measurement and Analysis

Tourism data is obtained from The Shanghai Statistical Yearbook from 2012 to 2021, including the number of domestic tourists, per capita consumption expenditure and the number of international tourists. Then, the overall tourism carbon footprint model applied to measure Shanghai tourism carbon footprint. The "from bottom to up" approach uses tourism revenue to calculate the carbon footprint, so this paper needs to use the world's average tourism carbon intensity of 635.27kg/thousand dollars and convert the revenue to US dollars according to the responding year's exchange rate, which results in the overall carbon footprint of Shanghai's tourism (Table 1, Table 2, Table 3) [6].

Table 1: 2012 -2021 Carbon Footprint of Domestic Tourism in Shanghai

Year	Domestic tourism revenue/billion dollars	Number of domestic tourists/10,000 person times	Domestic tourism carbon footprint/10,000 tons	Per capita carbon footprint of domestic tourism/kg
2012	508.86	25094	3232.62	128.82
2013	494.40	25991	3140.80	120.84
2014	476.05	26818	3024.23	112.77
2015	484.25	27569	3076.31	111.59
2016	519.35	29621	3299.25	111.38
2017	595.47	31845	3782.85	118.79
2018	688.34	33977	4372.80	128.70
2019	709.65	36141	4508.20	124.74
2020	398.08	23606	2528.87	107.13
2021	549.16	29382	3488.66	118.73

Table 2: 2012 -2021 Carbon Footprint of Inbound Tourism in Shanghai

Year	Inbound tourism revenue/billion dollars	Number of inbound tourists/10,000 person times	Inbound tourism carbon footprint/10,000 tons	Per capita carbon footprint of inbound tourism/kg
2012	55.82	800.40	354.61	443.04
2013	53.37	757.40	339.04	447.64
2014	57.05	791.30	362.42	458.01
2015	59.60	800.16	378.62	473.18
2016	65.30	854.37	414.83	485.54
2017	68.10	873.01	432.62	495.55
2018	73.71	893.71	468.26	523.95
2019	83.76	897.23	532.10	593.05
2020	37.74	128.62	239.75	1864.03
2021	35.85	103.29	227.74	2204.90

Table 3: 2012-2021 Shanghai Overall Tourism Carbon Footprint

Year	Overall tourism carbon footprint / 10,000 tons	Tourism carbon footprint per capita / kg
2012	3587.23	138.53
2013	3479.84	130.10
2014	3386.65	122.66
2015	3454.93	121.78
2016	3714.08	121.87
2017	4215.47	128.84
2018	4841.06	138.83
2019	5040.30	136.08
2020	2768.62	116.65
2021	3716.41	126.04

As shown in Table 1, Table 2 and Table 3, the domestic tourism and overall tourism carbon footprint of Shanghai decreased slightly from 2012 to 2014, and then showed an increasing trend from 2015 to 2019; the per capita domestic tourism carbon footprint decreased slightly from 2014 to

DOI: 10.54254/2754-1169/68/20241405

2016. The per capita inbound tourism carbon footprint is generally very high, and has been increasing year by year, which is about three times more than that of domestic tourism. In 2020, Shanghai's overall, domestic tourism, and inbound tourism carbon footprint all plummeted because of quarantine policy in COVID-19 pandemic, and in 2021, Shanghai's overall and domestic tourism carbon footprint have both rebounded significantly with the cancellation of block policy.

3.2. Tourism Sub-Industry Carbon Footprint Measurement and Analysis

This paper applies sub-industry tourism carbon footprint model to measure the carbon footprint of Shanghai's six tourism sub-industries in 2019 (Table 4). Since there is no data related to inbound tourism revenue in The Shanghai Statistical Yearbook, this study only focuses on the domestic tourism carbon footprint measurement and analysis for each industry. Due to lack research on the structure of tourism energy consumption, the carbon emission coefficient of standard coal is assumed to be constant when calculate the tourism carbon footprint, taking the value of 2.45 [7]. The energy intensity coefficient of tourism transportation P_i takes the value of 0.985, and the accommodation, catering, shopping, excursion and entertainment P_i takes the value of 0.188, while the other P_i takes the average energy intensity value of the tertiary industry of 0.774 [8].

Table 4: 2019 Shanghai sub-industry tourism carbon footprint

Sub-Industry	Per capita expenditure of domestic tourists / yuan	Proportion of domestic tourism revenue	Domestic tourism revenue/ 100 million yuan	Energy intensity TCE	Tourism Carbon Footprint (10,000 Tons)	Proportion of total carbon footprint
Transportation	167.00	13.03%	603.55	0.985	1456.53	40.66%
Accommodation	140.00	10.92%	505.97	0.188	233.05	6.51%
Catering	168.00	13.10%	607.17	0.188	279.66	7.81%
Shopping	595.00	46.41%	2150.39	0.188	990.47	27.65%
Excursion	145.00	11.31%	524.04	0.188	241.37	6.74%
Entertainment	15.00	1.17%	54.21	0.188	24.97	0.70%
Other	52.00	4.06%	187.93	0.774	356.38	9.95%
Total			4633.28		3582.43	

The total tourism carbon footprint in the above table is 35.82 million tons, which is a big gap compared with the total tourism carbon footprint measured by the overall model because the tourism carbon footprint sub-industry model only selects domestic tourism-related data, while the two models have different accounting methods and research focuses. The industry model is used to explore the carbon emissions of each sub-industry, in which the carbon footprint of transportation accounts for 40.66%, followed by shopping (27.65%) and others (9.95%). Catering (7.81%), excursions (6.74%), and accommodations (6.51%) all account for a smaller percentage.

3.2.1. Transportation

Based on the 2019 Shanghai domestic passenger arrivals data from the *Shanghai Statistical Yearbook*, this paper adopts the average daily travel distance of tourists, the number of days traveled, and the unit energy consumption of different transportation modes in previous studies to measure the carbon emissions of each travel mode of tourism transportation (Table 5) [3,9].

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Table 5: 2019 Carbon Emissions from Domestic Tourism Transportation in Shanghai

The way of transporta-tion	Proportion	Passenger arrivals / 10,000 person-times	Daily travel distance / km	Number of days traveled	Unit energy consumption MJ/pkm	Carbon emissions / MJ	Proportion (energy consumption)
Road	14.25%	3168	6	3.4	1.8	1163289600	18%
Civil aviation	27.52%	6121	6	3.4	2.0	2497368000	40%
Railway	57.71%	12834	6	3.4	1.0	2618136000	42%
Other	0.52%	115	6	3.4	0.9	21114000	0.34%
Total		22238				6299907600	

As seen in Table 5, the total carbon emissions from tourism transportation reached about 6.3 billion MJ, with high carbon emissions from railroad and civil aviation, accounting for 42% and 40%. This is followed by road transportation and others, accounting for 18% and 0.34%.

4. Discussion

Based on the results obtained from the above overall and sub-industry tourism carbon footprint measurement and analysis, this paper can summarize the following characteristics of Shanghai's tourism carbon footprint. First, Shanghai's overall tourism carbon footprint was roughly increasing year by year, with a sudden drop in 2020 due to the epidemic. Second, the per capita domestic tourism carbon footprint had a small decline from 2014 to 2016, due to the central government's emphasis on ecology after the 18th National Congress and it was the beginning of the awareness of low-carbon tourism. The per capita carbon footprint rose again after 2016, indicating that the national environmental awareness had not been formed. Third, the per capita inbound tourism carbon footprint was very high, about four times higher than the domestic one and showing a higher trend year by year, which was due to the high consumption of inbound tourism, and more use of airplanes and other high-carbon emission transportation. Fourth, among Shanghai tourism sub-industry carbon footprint, the transportation industry accounted for the highest, followed by shopping; and the railroad and civil aviation carbon emissions of the transportation industry accounted for the highest. Those characteristics indicate that the related technology and service facilities did not guide companies and tourists to reduce carbon emissions. This paper puts forward a few suggestions to address the above issues.

4.1. Promoting Technological Innovation in the Overall Tourism Industry and Practicing Carbon Reduction

The government can establish multiple zero-carbon demonstration zones with scenic spots as the core. From promoting resource recycling, high-quality water supply, intelligent operation, to building a new type of electric power system and other multi-dimensions, we can work together to realize a zero-carbon region and create a harmonious and beautiful living environment. The demonstration zone can carry out a series of work such as carbon audit and carbon management of the whole life cycle, forming a set of zero-carbon construction planning, construction and management processes that can be promoted. In this way, the city will be able to achieve overall zero carbon for all elements of buildings, transportation, municipalities, and human behavioral activities [10]. Finally, it is suggested that Shanghai should do a better job of integrating and publicizing tourism-related data, which would be conducive to a better calculation of the tourism carbon footprint and further improvements in carbon reduction. For example, after analyzing the carbon footprints of various sub-industries, it is found that the carbon footprints of the "other" category accounted for a relatively high percentage of the total carbon footprints, so it is recommended that the "other" category be subdivided.

4.2. Conducting Construction or Renovation of Low-carbon Facilities and Services in Tourism

Travel organizations and travel platforms can initiate more sustainable travel projects and build new carbon emission evaluation systems, incentive and guidance mechanisms, as well as closed-loop ecosystems for the industry. In addition, more low-carbon tourism tours can be offered to encourage group tours and reduce self-driving tours.

The Government should improve the "Green Labels" in the entire tourism chain, so as to provide tourists with a guide to low-carbon tourism choices. For example, "Green Landmark" and "Green Building" for scenic spots, "Green Restaurant" for restaurants, "Green Mall" and "Environmental Labeling Low-Carbon Product Certification" for shopping.

Sub-industries can leverage the industry's own green transformation to create an environment that is suitable for low-carbon tourism for tourists. In terms of transportation, for popular tourist routes, cities can vigorously develop environmentally friendly and low-carbon transportation, such as public transportation, cycling greenways, leisure trails, etc., and at the same time introduce innovative green transportation ways such as pure electric cruises on the Suzhou River in Shanghai; for accommodation, green and low-carbon service labels are added to scenic spots and hotels, disposable consumables are no longer provided, travelers are reminded to reduce the change of towels and sheets, etc., and guidance is given on setting energy-saving temperatures for air-conditioning and heating; and for catering and shopping, carbon footprint labels are set on menus and products, and simple green packaging is carried out for items for sale.

4.3. Guiding Tourists to Develop a Low-carbon Tourism Approach

The government and communities can guide individual travelers to fully extend their low-carbon behaviors in daily life to their journeys through publicity and education, issuance of green tourism guidelines, and establishment of low-carbon traveler identification.

For example, choose more hiking, cycling, camping and other low-carbon tourism products that are close to nature. Choose green and low-carbon means of transportation for travel, giving priority to trains, high-speed railways and other means of travel with lower energy consumption per unit, reducing travel by air and private cars. Giving priority to walking, subway or shared bicycles for sightseeing in urban areas. Choose green restaurants in tourism, and taste local specialties made with local food materials. Besides, choose green hotels and reduce the number of changes of bedding and towels. When shopping, bring private shopping bags made of environmentally friendly materials to reduce carbon emissions from white pollution, and eliminate excessive packaging when purchasing tourist souvenirs.

The government can establish a tourism low-carbon traveler identification system and personal carbon accounts for individuals, encouraging travelers to measure the carbon emissions generated during tourism and offset the carbon footprint of their trips through green credits in their carbon accounts.

5. Conclusion

Through the measurement and analysis of overall and sub-industry tourism carbon footprint in Shanghai, this experiment has come up with the basic characteristics and problems of the tourism

DOI: 10.54254/2754-1169/68/20241405

carbon footprint in Shanghai: the overall tourism carbon footprint in Shanghai was generally high and basically showed a year-on-year growth trend, indicating that the national environmental literacy has not been formed. In addition, the carbon footprint of inbound tourism -was about four times higher than that of domestic tourism. The evidences above all indicate that the relevant technology and service facilities in the tourism industry have not been able to guide tourists to reduce carbon emissions, and have not provided tourists with a green and low-carbon tourism environment.

For the above problems, this experiment puts forward relevant suggestions to solve them: the government can promote technological innovation in the overall tourism industry and use advanced technologies to achieve zero-carbon emissions inside scenic spots and in the surrounding areas; the government, tourism organizations, and the sub-industries should carry out the construction or renovation of low-carbon facilities and services in tourism; and finally, the government should guides the tourists to form a low-carbon tourism way.

This study provides clear recommendations and rationale for reducing the tourism carbon footprint in Shanghai, not only to help the city adopt a "low-carbon tourism" policy, but also to contribute to the implementation of China's "Dual-Carbon Policy". Innovations in technology and service facilities for the tourism industry can help the industry to make a green transition, and guide tourists to low-carbon tourism either. Although this research analyzes the carbon footprint only by the "from bottom to up" approach and the results may be not very comprehensive and inaccurate, it is hoped that more professionals will conduct more authoritative measurement of tourism carbon footprint in the future, so as to provide targeted suggestions for reducing the carbon footprint of tourism and even more industries.

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