

Research on Carbon Emissions of the Tourism Industry in Henan Province - Based on a Multi-Regional Input-Output Model

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Abstract— To investigate the carbon emission problem against the background of the rapid development of the tourism industry, this study takes the international tourism industry of Henan Province as the object and, based on a multi-regional input-output model, measures and analyzes its carbon emission characteristics as well as sectoral and regional differences. The study first reviews the development trends and revenue pattern of China's international tourism industry, combines provincial energy consumption data from the China Energy Statistical Yearbook to calculate total energy intensity and energy footprint, and then focuses on the sectoral revenue and carbon emissions of Henan Province's international tourism industry. The results show that in 2012, 2015, and 2017, carbon emissions of China's international tourism industry exhibited significant regional differences; eastern coastal provinces contributed the highest, and transportation, catering, and accommodation were the main emission sectors. Although Henan Province's international tourism revenue accounted for a small proportion of the national total, it increased year by year; in 2019, the total carbon emissions of the province's tourism industry were about 77 million tonnes, and with the expansion of tourism scale, they generally showed an upward trend. Based on the research conclusions, emission reduction countermeasures such as optimizing tourism transportation modes, strengthening carbon emission supervision of catering and accommodation, and encouraging green consumption are proposed, in order to provide reference for the low-carbon development of Henan Province's tourism industry and other high-emission regions.

I. INTRODUCTION

1.1 Research Background and Significance

Tourism plays a key role in the development of Henan Province; it can not only promote the province's economic development but also help enhance residents' sense of well-being. Henan Province has rich tourism resources,

superior basic conditions, and huge development potential, and tourism has gradually become an emerging pillar industry. Because tourism is highly dependent on resource supply from other sectors such as transportation, catering, and accommodation, developing tourism can simultaneously drive the development of related industries and has a significant pulling effect on the province's GDP

growth [1]. To achieve leapfrog development, Henan Province continuously increases its support for tourism, firmly advances the "tourism-based province" strategy, and promotes high-quality development of tourism.

However, tourism is linked to numerous sectors, and its carbon emission characteristics also centrally reflect the environmental problems of various sectors. Among them, the transportation sector accounts for a particularly prominent proportion because travel modes are indispensable. According to a study in *Nature Climate Change*, international tourism accounts for about 8% of greenhouse gas emissions. Considering the annual growth rate of international tourism of about 3%-5%, this issue is becoming increasingly urgent and should be included in international greenhouse gas emission reduction conventions. The study quantified carbon emissions from tourism-related activities in more than 160 countries, including transoceanic flights, production and sales of tourist souvenirs, and catering, etc. In 2009, global tourism carbon emissions were 3.9 gigatonnes CO₂ equivalent; by 2013, they had reached 4.5 gigatonnes, far exceeding previous predictions by scientists [2].

In September 2020, China proposed at the United Nations General Assembly the "dual carbon" goals of peaking carbon emissions before 2030 and achieving carbon neutrality before 2060; the 2021 Government Work Report reiterated solid progress in carbon peaking and carbon neutrality. Over the past decade, China's carbon emission intensity has decreased by nearly 34% overall, forest carbon sinks have increased by nearly 7%, and coal consumption has decreased by about 13% and is gradually being replaced by clean energy; carbon governance is being advanced in an orderly manner [3]. Henan has a vast territory and abundant resources, a profound historical heritage, and numerous ancient sites and ruins; it is an important tourist destination. Taking the 2023 New Year's Day holiday as an example, Henan Province received more than 13.08 million tourist arrivals and generated nearly RMB 6.1 billion in revenue; tourism has a significant impact on the province's development. In this context, studying carbon emissions of Henan Province's tourism industry and exploring coordinated pathways between economic development and carbon reduction have both theoretical value and practical significance.

1.2 Research Objectives and Contents

This study takes Henan Province as a typical case, uses a multi-regional input-output model to quantitatively measure its international tourism carbon emissions, analyzes the structural characteristics and regional differences of emissions, and proposes targeted emission

reduction countermeasures. The specific research contents include:

- (1) Systematically review the current status and existing problems of tourism development and carbon emissions in Henan Province;
- (2) Construct an input-output measurement framework, and account for China's international tourism revenue, energy consumption, and provincial carbon emission data;
- (3) Measure the sectoral carbon emission volumes of Henan Province's international tourism and analyze their evolution trends;
- (4) Based on empirical results, propose optimization strategies and suggestions to promote low-carbon development of tourism.

1.3 Research Methods

This study comprehensively adopts three methods: literature research, comparative analysis, and input-output model [4].

1.3.1 Literature research method:

By reviewing domestic and foreign literature on tourism carbon emissions and input-output, systematically sort out research progress and lay a theoretical foundation for model construction.

1.3.2 Comparative analysis method:

Compare provincial data for 2012, 2015, and 2017 to reveal the evolution trends and regional differences of carbon emissions, and conduct comparative analysis in combination with current policies in Henan Province.

1.3.3 Input-output model:

Based on input-output tables, characterize direct and indirect linkages among sectors, and measure tourism carbon emissions through indicators such as direct/complete consumption coefficients and energy intensity.

1.4 Data Sources

Research data mainly come from the China Energy Statistical Yearbook, China Tourism Statistical Yearbook, National Data Network, China Carbon Accounting Database, and reports published by the statistical bureaus of Henan and other provinces. Among them, the original data on international tourism revenue are denominated in US dollars and are uniformly converted into RMB according to the annual average exchange rate of RMB against US dollars published by the State Administration of Foreign Exchange and provided by the National Bureau of Statistics and the National Data Network. The three years 2012, 2015, and 2017 were selected because their data records are complete and highly comparable, and they

are all at key nodes in global climate change and carbon emission reduction policies, which can better reflect the evolution process of carbon emissions. Data such as tourism revenue and tourist numbers in Henan Province were obtained from the China Tourism Statistical Yearbook and publicly available data from the Henan Provincial Bureau of Statistics.

1.5 Current Research Status at Home and Abroad

1.5.1 Domestic Research Status

After the UK proposed the concept of a low-carbon economy in 2003, discussions on the coordinated development of the economy and low carbon continued to emerge, and research perspectives gradually expanded from industry to tourism. Zhuang Tongning took Xuzhou and Suzhou as examples, used the input-output method to measure tourism carbon emissions in 2012, and found that transportation, accommodation, and sightseeing activities were the main sources, with carbon emissions mainly at the indirect level; the two urban districts basically met low-carbon requirements [5]; Liao Zhongming et al. pointed out that low-carbon tourism, as an extension of green tourism, is richer in connotation than ecotourism and is conducive to the development of international low-carbon tourism [6]. Overall, domestic research on tourism carbon emissions started relatively late but has developed rapidly, and measurement methods and low-carbon pathways have become increasingly diverse.

1.5.2 Foreign Research Status

James, Scott, et al.'s study on Norway found that the public is highly concerned about the climate impact of tourism, and short-haul air travel receives more attention [4]; Hares, Dickinson, et al. found in the UK that tourists still seldom consider climate impacts when planning routes; even though a large amount of carbon emission publicity had been carried out previously, low-carbon tourism still faces challenges [7]; Becken's study on Fiji argued that although tourism operators are willing to reduce carbon, they still put development first [8]; Gössling systematically assessed the comprehensive impact of tourism on the global environment and pointed out that the pressure of tourism scale expansion on carbon emissions cannot be ignored [9]. The above studies all indicate that transportation is the core link in tourism carbon emissions, and promoting low-carbon transformation still requires multi-party collaboration.

II. ANALYSIS OF THE CURRENT STATUS OF HENAN PROVINCE'S TOURISM INDUSTRY AND CARBON EMISSIONS

2.1 Overview of Tourism Development

Henan Province is located in central China, in the core area of the Central Plains, with complex terrain and a suitable climate; the Yellow River runs across its territory from east to west, and natural resources are diverse. As an important birthplace of Chinese civilization, Henan has rich historical and cultural resources such as Mount Song, Longmen Grottoes, and Yin Ruins; it has a superior location and convenient transportation and is an important destination in the international tourism market. The provincial government actively implements an innovation-driven strategy and continuously issues tourism support policies, providing strong support for tourism development [10].

As support policies continue to advance, the scale of tourist reception in Henan Province has steadily expanded: the total number of tourists increased from 114 million in 2012 to 212 million in 2019, an increase of 86.3%; tourism revenue increased from RMB 603.8 billion to RMB 1.75 trillion, and cooperation with neighboring provinces and countries has been strengthened to broaden markets and enhance international competitiveness. However, the expansion of tourism scale has also brought increasingly severe environmental pressure, and how to reduce carbon emissions while developing the tourism economy has become an urgent problem to be solved.

2.2 Characteristics of Tourism Carbon Emissions

According to data from the United Nations World Tourism Organization, China's international tourism market has developed rapidly; in 2019, it received 149 million international tourist arrivals, and tourism-related CO₂ emissions were about 255 million tonnes, accounting for 14.9% of global international tourism [11]. In 2019, Henan Province received about 2.5 million international tourist arrivals and earned USD 2.89 billion; in the same period, the total carbon emissions of the province's tourism industry were about 77 million tonnes of CO₂. As tourism visibility increases, carbon emissions generally show an upward trend.

From a sectoral perspective, Gössling's study on the hotel industry in Seychelles showed that high-end hotels can emit up to 130 kg of CO₂ per room per day, reflecting the non-negligible carbon footprint of the accommodation segment [9]; while transportation, because travel modes are indispensable, usually contributes the most. Therefore, implementing differentiated emission reduction for major emission sectors such as transportation, catering, and

accommodation is key to the low-carbon transformation of tourism.

III. EMPIRICAL STUDY ON CARBON EMISSIONS OF CHINA'S INTERNATIONAL TOURISM INDUSTRY

3.1 Input-Output Measurement Method

Input-output analysis is an economic method for studying the linkages among sectors within a system, characterizing inter-sectoral linkages through direct consumption coefficients, complete consumption coefficients, and energy intensity. Let the direct consumption coefficient matrix be A and the identity matrix be I . The core formulas are as follows:

3.1.1 Direct consumption coefficient.

The direct consumption of products of sector i by sector j to produce one unit of product:

$$a_{ij} = \frac{x_{ij}}{X_j} \quad (1)$$

where x_{ij} is the intermediate input of sector i to sector j ; X_j is the total output of sector j . Thus, the direct consumption coefficient matrix $A = [a_{ij}]$ is formed.

3.1.2 Complete consumption coefficient.

On the basis of the direct consumption coefficient matrix, the complete consumption coefficient matrix is obtained through the Leontief inverse matrix:

$$E = (I - A)^{-1} - I \quad (2)$$

where: I is the identity matrix; $(I - A)^{-1}$ is the Leontief inverse matrix; E characterizes all direct and indirect technical linkages among sectors.

3.1.3 Total energy intensity.

Let the direct energy intensity be e^{direct} (tonnes of standard coal equivalent per 10,000 yuan); then the total energy intensity considering complete inter-sectoral linkages is:

$$E^{tot} = e^{direct} \times (I - A)^{-1} \quad (3)$$

Total energy intensity E^{tot} incorporates the indirect energy consumption induced by tourism activities through industrial linkages, and, compared with direct energy intensity, better reflects the true degree of energy dependence of the tourism industry.

3.1.4 Tourism carbon emissions.

Tourism carbon emissions consist of two parts: direct emissions and indirect emissions:

$$C = C^{direct} + C^{indirect} \quad (4)$$

where: C is the total carbon emissions of tourism-related sectors such as transportation, catering, and accommodation; C^{direct} is the carbon emissions of direct tourism sectors such as transportation, catering, and accommodation; $C^{indirect}$ is the indirect carbon emissions of other sectors induced through input-output linkages. After accounting for each component separately, the total carbon emissions of tourism are obtained by summing them.

3.1.5 Revenue conversion.

Let the international tourism revenue in a given year be R (million USD), the annual average exchange rate of USD against RMB be E , and the revenue share of a certain sector be S ; then the exchange-rate-converted revenue IN (10,000 yuan) of that sector is:

$$IN = R \times E \times S \quad (5)$$

where: the exchange rate E unifies the currency denomination, converting sectoral revenue from USD denomination to RMB denomination, consistent with the unit of total energy intensity (10,000 yuan).

3.1.6 Carbon emission conversion.

Let the total energy intensity be e (tonnes of standard coal equivalent per 10,000 yuan) and the carbon emission coefficient be k (tonnes CO₂ per tonne of standard coal equivalent); then the carbon emissions of that sector are:

$$C = IN \times e \times k \quad (6)$$

where: the carbon emission coefficient k is taken as 2.493 tonnes CO₂ per tonne of standard coal equivalent (calculated in terms of standard coal equivalent). After item-by-item accounting and summation, the total carbon emissions of the international tourism industry are obtained.

Combining equations (1)–(6), the complete accounting chain for tourism carbon emissions can be summarized as follows: from the direct consumption coefficient matrix A , the complete consumption coefficient E is obtained via the Leontief inverse matrix; combined with the direct energy intensity e^{direct} , the total energy intensity E^{tot} is obtained; then the sectoral revenue is converted by exchange rate into IN , and finally the carbon emissions of each sector are obtained by $C = IN \times e \times k$.

3.2 International Tourism Revenue and Energy Consumption of China

According to the research design, seven provinces—Jiangxi, Xinjiang, Hebei, Henan, Shaanxi, Hainan, and Shanxi—were selected as comparative samples, mainly

based on the dual considerations of regional representativeness and data availability. The selected provinces cover eastern, central, and western China as well as North China. They include not only Henan Province, the core object of this study (the core area of Central Plains culture), but also typical tourism regions such as Hainan (tropical coastal resort type), Xinjiang (northwestern frontier and core area of the Belt and Road), and Shaanxi (historical and cultural sightseeing type), while also incorporating Shanxi (a traditional energy province), Hebei (Beijing-Tianjin surrounding coordinated development area), and Jiangxi (central ecological resource type), so as to reflect differences in tourism carbon emissions under different resource endowments and industrial structures. In addition, the core data of the above provinces for 2012, 2015, and 2017, such as international tourism revenue, energy consumption, and energy footprint, are completely recorded in authoritative sources such as the China Tourism Statistical Yearbook and the China Energy Statistical Yearbook, which can meet the measurement requirements of the multi-regional input-output model and ensure the scientificity and comparability of the research conclusions.

From a regional perspective, coastal provinces and provinces rich in tourism resources performed prominently in international tourism revenue, while inland provinces were relatively low, and the characteristic of unbalanced regional development was evident. As a central province, Henan's overall international tourism revenue was relatively small but showed a steady growth trend (increasing from 6.1141 million yuan in 2012 to 6.6155 million yuan in 2017). It was at a similar order of magnitude as inland provinces such as Jiangxi, Hebei, and Shanxi selected in the same batch. Although there is a gap with strong cultural tourism provinces such as Shaanxi, its growth resilience is relatively strong, and there is still considerable room to improve market competitiveness.

Combined with the energy consumption data of each province compiled from the China Energy Statistical Yearbook, the total energy intensity and energy footprint of each province can be further calculated. In 2012, 2015, and 2017, Henan's total energy consumption was approximately 63,739, 65,592, and 22,944 10,000 tonnes

of standard coal equivalent, respectively, accounting for about 5.3%, 5.0%, and 4.9% of the national total, and its energy structure was still dominated by coal. Data for each province are shown in Table 2.

As can be seen from Table 2, the total energy consumption and its proportion differ among provinces. In particular, the proportion of energy use in coastal areas is very large, while that in the northwest region is extremely small, and great differences exist among provinces. The total energy consumption and proportion of eastern coastal provinces are relatively high, but with economic development and population growth, energy consumption in these provinces has also been continuously increasing. Although the total energy consumption in central and western regions is relatively high, the growth rate of energy consumption in some provinces is relatively slow, indicating that the pressure of energy consumption in some provinces is easing. The level of economic development, industrial revenue and expenditure, industrial structure composition, geographical location, and other aspects of each province all have a great impact on its proportion in China's total energy consumption, and there are also great differences among provinces.

According to the materials published by the National Data Network and the China Energy Statistical Yearbook, through the accounting of inbound tourism expenditure, output value, and energy consumption data, the energy footprint of inbound tourism in each province can be obtained as shown in Table 3 (unit: tonnes of standard coal equivalent).

The spatial distribution of carbon emissions indicates that the eastern region, due to its geographical advantage of being close to the sea and its strong economic foundation, is mostly a highly popular tourism destination, and its tourism carbon emissions are more significant than those of other regions; carbon emissions in the central region are relatively low but growing rapidly; infrastructure in the western region is relatively lagging, tourism there urgently needs further development, and related carbon emissions are generally low. This regional difference is highly consistent with the distribution of tourism revenue, indicating that tourism carbon emissions have obvious regional lock-in characteristics.

Table 1 International Tourism Revenue of Various Provinces in China (Partial) / 10,000 yuan

Year	Jiangxi	Xinjiang	Hebei	Henan	Shaanxi	Hainan	Shanxi
2012	484.73	550.57	544.94	611.41	1597.47	348.02	720.24
2015	567.00	555.89	501.91	623.60	2000.22	248.52	297.10
2017	629.92	810.81	578.69	661.55	2704.40	681.02	350.14

Table 2 Total Energy Consumption of Each Province (10,000 tonnes of standard coal equivalent) and Its Proportion of the National Total

	Total Energy Consumption of Each Province in 2012	(10,000 tonnes of standard coal equivalent) Proportion (%)	Total Energy Consumption of Each Province in 2015	(10,000 tonnes of standard coal equivalent) Proportion (%)	Total Energy Consumption of Each Province in 2017	(10,000 tonnes of standard coal equivalent) Proportion (%)
Beijing	18684	1.55	19711	1.49	7133	1.53
Tianjin	18775	1.56	19913	1.51	8011	1.72
Hebei	79094	6.57	78845	5.98	30386	6.51
Shanxi	54379	4.51	55381	4.20	20057	4.30
Inner Mongolia	58787	4.88	66200	5.02	19915	4.27
Liaoning	57988	4.81	57013	4.32	21556	4.62
Jilin	20324	1.69	19325	1.46	8015	1.72
Heilongjiang	27503	2.28	27243	2.06	12536	2.69
Shanghai	31233	2.59	32017	2.43	11859	2.54
Jiangsu	97026	8.06	106804	8.10	31430	6.73
Zhejiang	64153	5.33	69426	5.26	21030	4.50
Anhui	33116	2.75	38837	2.94	13052	2.80
Fujian	33082	2.75	38019	2.88	12890	2.76
Jiangxi	19932	1.65	24178	1.83	8995	1.93
Shandong	102636	8.52	127188	9.64	38684	8.29
Henan	63739	5.29	65592	4.97	22944	4.91
Hubei	37808	3.14	38219	2.90	17150	3.67
Hunan	31941	2.65	33351	2.53	16171	3.46
Guangdong	92300	7.66	102412	7.76	32342	6.93
Guangxi	25850	2.15	27892	2.11	10458	2.24
Hainan	6176	0.51	7399	0.56	2103	0.45
Chongqing	17565	1.46	19478	1.48	9545	2.04
Sichuan	41216	3.42	43861	3.32	20874	4.47
Guizhou	25669	2.13	27575	2.09	10482	2.25
Yunnan	28655	2.38	28452	2.16	11091	2.38
Tibet	397	0.03	579	0.04	166	0.04
Shaanxi	32846	2.73	36832	2.79	12537	2.69
Gansu	22515	1.87	24151	1.83	7538	1.61
Qinghai	11101	0.92	11807	0.89	4202	0.90
Ningxia	17852	1.48	20665	1.57	6489	1.39
Xinjiang	32120	2.67	50972	3.86	15334	3.69

Table 3 Energy Footprint of Inbound Tourism in Each Province

	Inbound tourism expenditure Y (10,000 yuan)			Inbound tourism output value X (10,000 yuan)			Energy footprint of inbound tourism / tonnes of standard coal equivalent		
	2012	2015	2017	2012	2015	2017	2012	2015	2017
Beijing	2710843	5113017	4727166	3718283	7361662	12965595	426491	827454	983894
Tianjin	1172159	3661953	3457014	1732918	5417703	5495117	358232	1012328	742425
Hebei	286900	557280	533268	526655	1401640	12230064	383317	879375	3171877
Shanxi	379192	329876	322657	604109	815298	4837096	526046	731720	1834529
Inner Mongolia	406421	1068670	1147795	651571	1769745	4919768	466298	1337955	2665122
Liaoning	1718266	1817036	1638498	2264110	3133414	7926713	910048	1166940	1968058
Jilin	260486	804026	705682	344034	1093518	4799341	166737	456237	647860
Heilongjiang	439863	438942	441937	637514	959934	3907331	292330	436286	855762
Shanghai	2892073	6506955	6172867	4191327	10073420	14398828	638135	1307171	1407058
Jiangsu	3316673	3916415	3865472	4548436	6323572	36505910	1616169	2269918	5352500
Zhejiang	2712286	7537364	3304937	3966296	10750711	21723749	1274208	3379031	3863891
Anhui	822714	2512506	2654665	1171887	3415825	13853498	457230	1132088	1770819
Fujian	2224729	6174925	6992438	2905151	9146718	13937284	771375	2307523	1947064
Jiangxi	255200	629551	580477	382707	1045454	8312691	133848	361894	1192521
Shandong	1539242	3216015	2924907	1896953	4421638	31714909	919437	2638493	5004388
Henan	321895	692395	609598	502500	1462479	20908961	334883	721805	2917914
Hubei	633339	1856342	1939537	821577	2554503	14012259	282109	717338	1722454
Hunan	488763	952342	1193695	679440	1471020	11614165	234678	466184	1457506
Guangdong	8218698	19857669	18393689	10649337	26226002	36960700	2914931	6715217	5491734
Guangxi	673299	2128325	2207595	870119	2839798	6497442	339258	915567	1331653
Hainan	183225	275936	627566	288721	565862	1558745	91750	161472	281039
Chongqing	615097	1630580	1794722	757728	2223414	8181831	268396	537023	918412
Sichuan	420210	1311142	1333000	581777	1890443	14267549	294590	1091451	2032274
Guizhou	88943	256850	261036	152511	428572	4572271	116269	270920	1276302
Yunnan	1025098	3192721	3271661	1279816	4102437	6316730	801497	1905569	1417499
Tibet	55649	196149	182007	75047	294308	451852	7269	29857	53627
Shaanxi	841035	2220881	2492129	1101910	3127835	7513006	542216	1491593	1377548
Gansu	11767	15744	19223	43524	156766	2496458	89870	220929	1073073
Qinghai	12804	43036	35285	17789	93390	851966	38571	108662	633142
Ningxia	2869	23139	34676	14272	68473	1215078	65435	199819	901593
Xinjiang	289864	617215	747169	389380	949749	3714612	355222	1073123	2343468

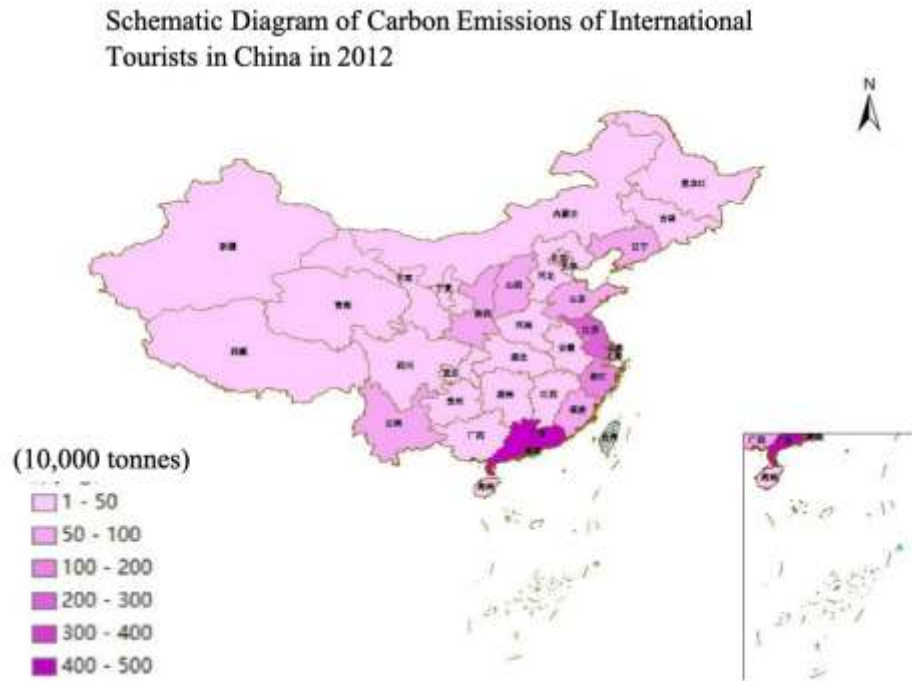


Fig.1: Schematic Diagram of Carbon Emissions of International Tourists in China in 2012

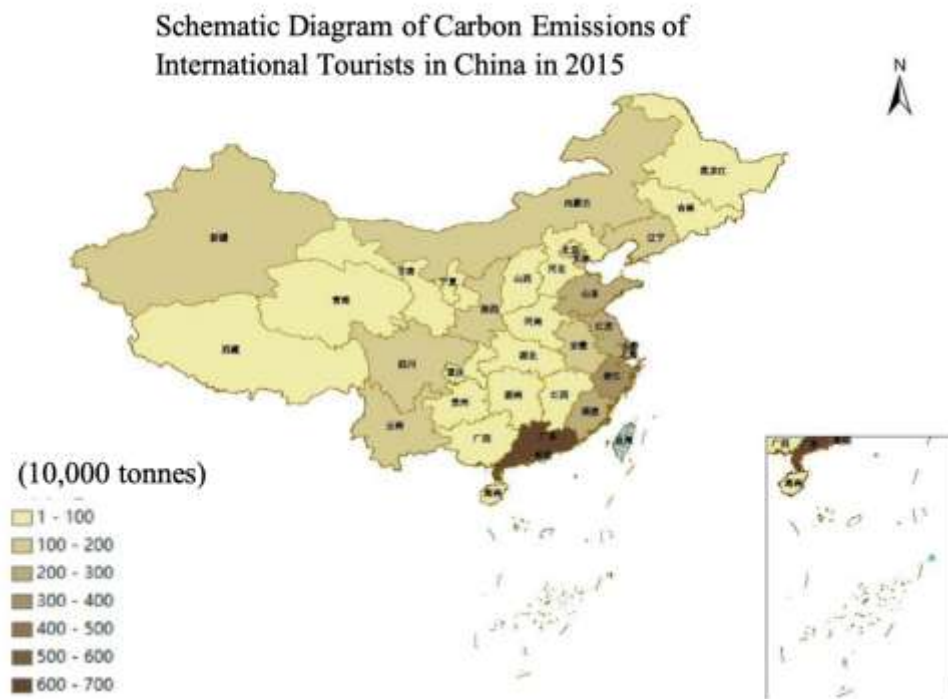


Fig.2: Schematic Diagram of Carbon Emissions of International Tourists in China in 2015

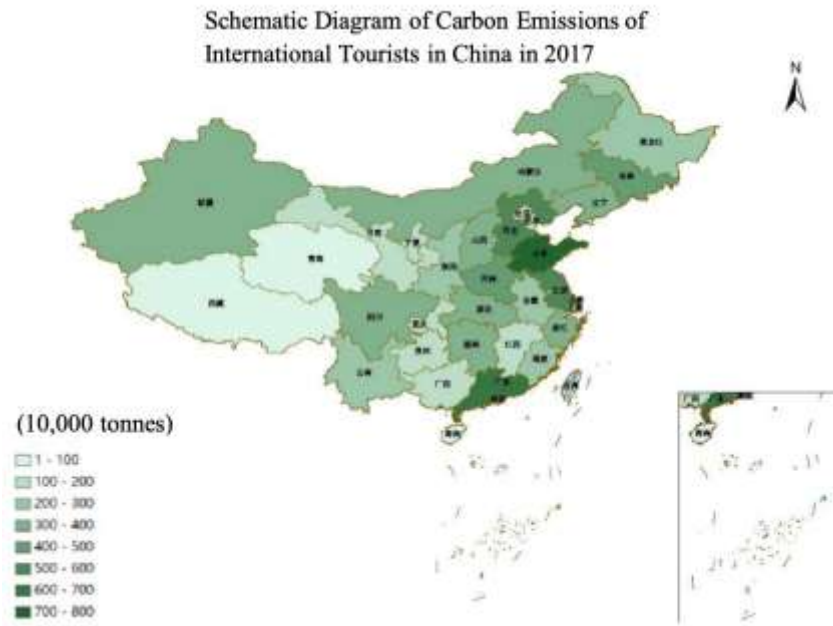


Fig.3: Schematic Diagram of Carbon Emissions of International Tourists in China in 2017

IV. ANALYSIS OF CARBON EMISSIONS OF HENAN PROVINCE'S INTERNATIONAL TOURISM INDUSTRY

4.1 International Tourism Revenue and Sectoral Structure

The international tourism revenue of Henan Province and its proportion of the national total from 2012 to 2019 are shown in Table 3. Henan's international tourism revenue accounted for a generally low but steadily rising proportion of the national total, rising to about 0.72% in 2019, indicating that its international tourism market competitiveness still needs to be improved. The exchange rate of USD against RMB from 2012 to 2019 is shown in Table 4, and the sectoral revenue of Henan Province's international tourism industry from 2012 to 2019 is shown in Table 5.

Among the seven sectors of Henan Province's international tourism industry, the revenue of the transportation sector occupies an absolutely dominant position. In 2019, the revenues of transportation, catering, accommodation, shopping, entertainment,

communication, and other sectors were 83,834 million yuan, 34,168 million yuan, 21,792 million yuan, 19,270 million yuan, 12,842 million yuan, 11,457 million yuan, and 8,773 million yuan, respectively. The transportation sector accounted for more than 40%, and it was also the primary source of tourism carbon emissions. Combined with the stacked bar chart of sectoral carbon emissions in Fig.4, transportation carbon emissions also ranked first (about 417.14 million tonnes in 2019), highly consistent with the revenue structure, indicating that tourism transportation is the core breakthrough for low-carbon emission reduction in Henan Province's tourism industry. The revenue and carbon emissions of the shopping, catering, and accommodation sectors ranked next; the three can achieve coordinated emission reduction by optimizing supply chains and promoting green catering and accommodation. The sectoral revenue of Henan Province's international tourism industry from 2012 to 2019 is shown in Table 6, and the revenue distribution of Henan Province's international tourism industry is shown in Fig.4.

Table 4 Exchange Rate of USD against RMB from 2012 to 2019

Year	2012	2013	2014	2015	2016	2017	2018	2019
Exchange rate	6.312	6.196	6.142	6.227	6.640	6.755	6.612	6.897

Table 5 Proportion of Henan Province's International Tourism Revenue in the National Total from 2012 to 2019 / million USD

	2012	2013	2014	2015	2016	2017	2018	2019
Henan	611	660	538	624	647	662	723	947
National	50028	51664	105380	113650	120000	123417	127103	131254
Proportion	1.22%	1.28%	0.51%	0.55%	0.54%	0.54%	0.57%	0.72%

Table 6 Sectoral Revenue of Henan Province's International Tourism Industry from 2012 to 2019 / 10,000 yuan

	2012	2013	2014	2015	2016	2017	2018	2019
Transportation	27901	27384	12802	31415	33387	33967	28607	41714
Catering	2891	3267	1515	2822	3441	3732	5363	7982
Accommodation	4020	4730	2181	4541	4160	4420	6813	9976
Shopping	8605	8850	3555	7141	7495	8326	12325	15075
Entertainment	4758	5289	2174	3372	5159	5040	3745	5119
Communication	610	627	346	817	1034	998	437	372
Other	3138	3167	1436	4052	4221	4477	4309	5070

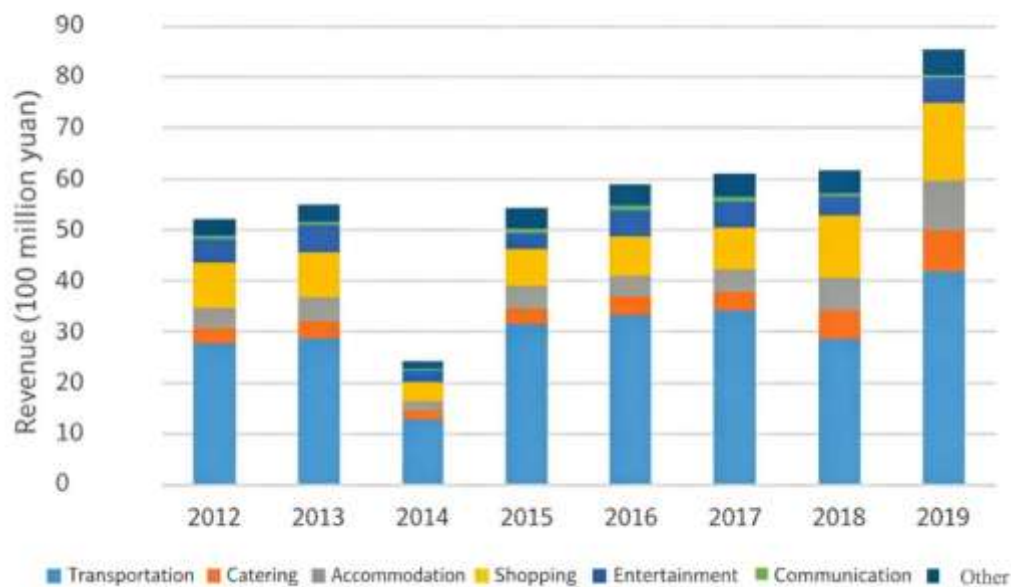


Fig.4 Revenue Distribution of Henan Province's International Tourism Industry

4.2 Input-Output and Carbon Emission Analysis

From the perspective of input-output, all sectors of Henan Province's international tourism industry showed a year-by-year growth trend, among which the transportation sector grew most significantly—this may be closely related to the expansion of tourism scale and the diversification of travel modes. Transportation is the most influential source of carbon emissions among the seven sectors of the tourism industry. With government support and technological innovation in various countries, green travel modes have become increasingly abundant, and

promoting public transportation, shared bicycles, etc. can effectively reduce transportation carbon emissions.

The carbon emissions of the shopping and catering sectors are also relatively high: shopping carbon emissions are mainly related to tourism consumption and logistics, and packaging and transportation generate large amounts of waste; catering carbon emissions are concentrated in the food procurement and preparation stages. Both can be controlled by strengthening carbon emission reduction across the entire chain of production, transportation, and services.

The carbon emissions of the accommodation sector are relatively low, but it is still an important source, mainly related to the energy consumption of hotels and other accommodation premises; promoting energy-saving hotels and adopting low-carbon energy can significantly reduce emissions. The carbon emissions of entertainment, communication, and other sectors are relatively small, but they cannot be ignored either, and their impact can be reduced by means of digitalization and internetization. Overall, the carbon emissions of Henan Province's international tourism industry have continued to rise with the expansion of tourism scale and increased transportation use, and emission reduction requires differentiated measures for different sectors.

V. OPTIMIZATION STRATEGIES FOR LOW-CARBON DEVELOPMENT OF HENAN PROVINCE'S TOURISM INDUSTRY

Based on the above empirical analysis, in view of the carbon emission characteristics of Henan Province's international tourism industry, optimization strategies are proposed from the aspects of transportation, catering and accommodation, management, and technology.

- (1) In terms of transportation, tourists should be encouraged to choose public transportation, shared travel, and low-carbon transportation modes. By densifying routes, increasing coverage, and promoting shared transportation to guide green travel, carbon emissions in the transportation link can be reduced [12].
- (2) In terms of catering and accommodation, it is advocated to save food, promote local specialty foods, and promote efficient stoves and energy conservation and emission reduction in restaurants; promote low-carbon and environmentally friendly accommodation (ecological farms, green hotels), and adopt renewable energy and energy-saving management.
- (3) In terms of shopping, entertainment, and communication, it is advocated to purchase environmentally friendly goods, reduce excessive packaging, and promote digitalization and internetization to reduce carbon emissions.
- (4) In terms of management and technology, improve the carbon emission supervision system of the tourism industry, formulate environmental protection indicator assessment and periodic review systems, and promote new environmentally friendly building materials; combine with the circular economy model to advance solid waste classification, biological treatment, and waste recycling, so as to reduce carbon emissions from the source; at the same time, strengthen the environmental awareness of

practitioners, implement carbon trading and carbon neutrality policies, and provide support for the sustainable development of the tourism industry.

VI. CONCLUSION

Based on the multi-regional input-output model, this study measured and analyzed the carbon emissions of China's and Henan Province's international tourism industries. The main conclusions are as follows:

- (1) Carbon emissions of China's international tourism industry show significant regional differences; eastern coastal provinces contribute the highest, and transportation, catering, and accommodation are the main emission sectors; Henan's international tourism revenue accounts for a relatively small proportion of the national total but has increased year by year.
- (2) The total carbon emissions of Henan Province's international tourism industry have continued to rise with the expansion of tourism scale. Among sectors, transportation carbon emissions rank first, followed by shopping, catering, and accommodation, while entertainment and communication contribute relatively little.
- (3) Differentiated emission reduction strategies targeting transportation, catering and accommodation, shopping and entertainment, and management and technology links can provide reference for the low-carbon development of Henan Province's tourism industry and similar high-emission regions.

This study still has limitations: raw data are difficult to obtain, calculations are complex, and the universality of conclusions at the provincial scale remains to be further verified.

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