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Calculation Modeling of Tourism Ecological Efficiency Based on Carbon Footprint in Shanxi, China

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Abstract: Tourism is a typical energy-intensive industry. It is imperative to formulate and implement carbon reduction strategies in Shanxi, China. The Tourism Carbon Footprint and Tourism Ecological Efficiency is the key to ensuring ecotourism's healthy development. Through data query, model calculation, and panel data analysis, this study uses tourism revenue as an economic indicator and tourism carbon footprint as an environmental indicator to construct a Calculation Modeling for tourism ecological efficiency in Shanxi Province for the period of 2000-2020, totaling 21 years. Based on the results, it is concluded that the average proportion of tourism transportation carbon footprint in Shanxi Province indicates an absolute advantage. The total tourism revenue in 2020 in Shanxi Province shows a sharp decline, greatly affected by COVID-19. Tourism transportation and activity revenues have a higher proportion. The average proportions of tourism dining and accommodation revenue display an increasing trend yearly, while the proportion of tourism activity revenue shows a decreasing trend. Both the overall tourism ecological efficiency and the ecological efficiency of each sector have been increasing yearly, with higher growth rates observed in tourism dining and accommodation ecological efficiency. The aim is to provide a theoretical basis and form a complete model for measuring tourism Ecological Efficiency for Shanxi, China.

Keywords: Calculation Modeling, Carbon Footprint, Ecological Efficiency, Ecotourism; Shanxi

1. Introduction

In recent years, the tourism industry in Shanxi Province has experienced significant growth due to its high industrial returns, low resource consumption, and minimal environmental pollution. It has generated substantial economic and cultural benefits and has gradually become a strategic pillar industry of the national economy[1]. However, the development of the tourism industry has also brought a series of issues, such as excessive exploitation of tourism resources, overcrowded tourist attractions, and weak environmental protection awareness among irresponsible tourism enterprises and irresponsible tourists which caused behavioral or individual problems. The extensive development model of the tourism industry mentioned above has had a significant negative environmental impact. The latest research by Lenzen[2][3] indicates that the tourism industry is responsible for 8% of global carbon emissions. It is projected that by 2035, carbon dioxide emissions from the tourism sector will increase at an average annual rate of about 2.5%[4]. It is evident that the tourism industry is a typical energy-intensive industry.

In September 2020, President Xi Jinping announced at the 75th United Nations General Assembly

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that China strives to achieve a carbon peak by 2030 and carbon neutrality by 2060. As a strategic pillar industry, a happiness industry, and a leading industry in green development, the tourism industry plays a crucial role in achieving green development in tourism and realizing the country's "dual carbon" goals by effectively coordinating the relationship between tourism economic growth and environmental protection. It is imperative to develop and implement carbon reduction strategies for the tourism industry as soon as possible.

Based on the carbon footprint, the ecological efficiency Calculation Modeling has been extensively studied and supported by previous research. Schaltegger et al.[5-8] first proposed eco-efficiency in 1989 as a tool to assess the environmental changes caused by economic development. In 1992, the World Business Council for Sustainable Development (WBCSD)[9][10] defined eco-efficiency as creating the greatest value with the least environmental impact and proposed an eco-efficiency model that calculates the ratio of product or service value to environmental impact. In the research on tourism ecological efficiency, scholars from different countries and regions have employed various methods. For example, Victoria et al.[11], combining tourism carrying capacity theory, found that tourism ecological footprint is an effective tool for analyzing sustainable development in tourist destinations. They measured the carbon emissions generated at different stages of the entire tourism process by establishing the carbon footprint life cycle of tourists[12]. Bruijn et al.[13]estimated the carbon footprint of the tourism industry as an environmental impact indicator using a carbon footprint model based on continuous holiday survey data. They studied the carbon footprints of domestic and international tourists in the Netherlands and continuously estimated the tourism ecological efficiency from 2002 to 2011. AN et al.[14] calculated the tourism carbon footprint in the Seoul metropolitan area by establishing a carbon footprint Calculation Modeling for tourism transportation. Xiao[15] assessed the carbon footprint (including transportation, accommodation, sightseeing, dining, and waste) during the tourism process in the Zhoushan Islands and calculated tourism efficiency. Zhang et al.[16] used Huangshan in Anhui Province as an example and divided the carbon footprint during the tourism process into six parts: food, accommodation, transportation, sightseeing, shopping, and entertainment. They calculated tourism ecological efficiency.

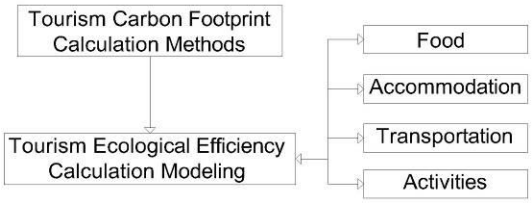
In summary, previous research has provided rich reference materials and theoretical support for the carbon footprint model and ecological efficiency model in this study. However, there are still some aspects worth exploring. For example, the research on the ecological efficiency of the entire province is relatively limited in terms of research areas. Or the selection and calculation methods of specific indicators are relatively general and lack refinement in terms of research methods. Based on above problems, this study combines various existing research models, changes the single-year data into the multiyear data of Shanxi Province from 2000 to 2020, improves various calculation indicators, and conducts a comprehensive analysis of tourism carbon emissions and ecological efficiency. The goal of this study is to form a more complete model for measuring tourism Ecological Efficiency. Furthermore, the aim is to provide a theoretical basis for the development of the tourism industry in similar provinces.

2. Research Method

2.1 Research Framework

This study built a tourism ecological efficiency model based on Carbon Footprint Calculation Modeling, which calculated the carbon emissions generated by each sector of tourism throughout the entire tourism process. By integrating models proposed by Zheng[12], Xiao[15], Zhou[17], and others, the study no longer separated the categories of sightseeing, shopping, and entertainment,but divided the carbon footprint during the tourism process into four parts with food, accommodation,

transportation, and activities. The study conducted statistical analysis and calculations on the data from 2000 to 2020 with the overall tourism carbon footprint in Shanxi Province.



[Fig. 1] Conceptual Framework.

2.2 Tourism Carbon Footprint Calculation Methods

The calculation formula for the comprehensive tourism carbon footprint model was found in Equation (1).

$$TCF_{all} = TCF_e + TCF_s + TCF_t + TCF_a \quad (1)$$

In the formula, TCF_{all} represents the total comprehensive tourism carbon footprint in kilograms (kg). TCF_e represents the carbon footprint from tourism meals in kilograms (kg). TCF_s represents the carbon footprint from tourism accommodations in kilograms (kg). TCF_t represents the carbon footprint from tourism transportation in kilograms (kg). TCF_a represents the carbon footprint from tourism activities in kilograms (kg).

The calculation formula for the tourism meal carbon footprint model was seen in Formula (2).

$$TCF_e = 365 \times \sum(C_i \times \varphi_i \times c_i) \quad (2)$$

In the formula, C_i represents the total number of seats for meal type i, in units of seats; φ_i represents the annual average seat utilization rate for meal type i, in percentage; c_i represents the unit carbon emissions per seat per day for meal type i, in kilograms (kg).

The calculation formula for the tourism accommodation carbon footprint model was found in Equation (3) [18].

$$TCF_s = 365 \times \sum \ (Z_i \times \varphi_i \times c_i) \quad (3)$$

In the equation, Z_i represents the total number of beds for accommodation type i, in units of beds; φ_i represents the annual average occupancy rate of accommodation type i, in units of %; c_i represents the unit carbon emissions per bed-night for accommodation type i, in units of kg/(bed-night).

The calculation formula for the tourism transportation carbon footprint model was found in Equation (4).

$$TCF_t = \sum(N_i \times (Q_{ia} + Q_{ib} + Q_{ic})) \quad (4)$$

In the equation, N_i represents the total number of tourists of type i entering Shanxi, measured in people; Q_{ia} represents the total carbon emissions from the transportation vehicles used by tourists of type i before entering Shanxi, measured in kg; Q_{ib} represents the total carbon emissions from the transportation vehicles used by tourists of type i when traveling between cities within Shanxi, measured in kg; Q_{ic} represents the total carbon emissions from the transportation vehicles used by tourists of type i after arriving at their destination city in Shanxi, measured in kg.

The calculation formula for the tourism activity carbon footprint model was found in Equation (5).

$$TCF_a = N \times \sum \ (\gamma_i \times H_i) \tag{5}$$

In the equation, γ_i represents the proportion of tourists participating in type-i tourism activities, expressed as a percentage. H_i represents the average carbon emissions generated by a single participation in type-i tourism activity, measured in kg/km.

2.3 Tourism Ecological Efficiency Calculation Modeling

The comprehensive total revenue from various sectors of tourism was obtained by referring to the "Shanxi Statistical Yearbook" and considering the percentages of catering, accommodation, transportation, and activities from the "Tourism Sample Survey Data" and the "Shanxi Statistical Yearbook". Based on the total revenue of each sector, the total revenue from tourism catering, tourism accommodation, tourism transportation, and tourism activities can be estimated.

The Calculation Modeling for overall tourism ecological efficiency was found in Equation (6) [18].

$$TEE_{all} = \frac{TR_{all}}{TCF_{all}} \tag{6}$$

In the equation, TEE_{all} represents the overall tourism ecological efficiency in terms of yuan per kilogram (unit: yuan/kg). TR_{all} represents the total revenue of various tourism sectors in terms of yuan (unit: yuan). TCF_{all} represents the total comprehensive carbon footprint of tourism in terms of kilograms (unit: kg).

The ecological efficiency model for each tourism sector was shown in Equation (7) [18].

$$TEE_i = \frac{TR_i}{TCF_i} \tag{7}$$

In the equation, TEE_i represents the ecological efficiency of the i-th tourism sector, measured in yuan per kilogram (yuan/kg). TR_i represents the total revenue of the i-th tourism sector, measured in yuan. TCF_i represents the total carbon footprint of the i-th tourism sector, measured in kilograms (kg).

2.4 Data Source Description

The methods of data collection are scientific and well founded. Some data used can be traced back to their source, and other non-directly related data can be estimated by using similar data sources.

In the calculation of the number of seats, data on the number of seats in the accommodation and catering industries after 2011 are sourced from the "Shanxi Tourism Statistical Yearbook." However, data on the number of seats in the accommodation and catering industries before 2010 are missing. For those years, the total number of meal seats was estimated by referencing the ratio of the total number of meal seats to the total number of accommodation beds in 2011. The respective seat numbers for the accommodation and catering industries were estimated based on the ratio of the specific meal seat numbers to the total number of meal seats in 2011. In the calculation of the annual average seat utilization rate, due to the lack of relevant data for Shanxi, parameters for room occupancy rates from the "China Tourism Statistical Yearbook" were used for calculation. In the calculation of unit carbon emissions, the statistical conclusion data of four kg/(seat·day) for carbon emissions in the catering industry, as mentioned by Gössling[19], were referenced.

In the statistics of total beds, data from 2011 onwards is obtained from the "Shanxi Tourism Statistical Yearbook," while data from 2010 and earlier years are estimated based on data from the "China Tourism Statistical Yearbook." The occupancy rate is unknown, but it can be estimated by referring to the national occupancy rate of star-rated hotels in the "China Tourism Statistical Yearbook." The CO_2 emission factor was referenced from studies conducted by Gössling et al.[19][20] on tourism and the environment.

Based on the different types of tourism activities recorded for domestic and international tourists, tourism activities are categorized into five types: sightseeing tourism, leisure vacation, business meetings, visiting relatives and friends, and other activities. Due to data limitations, the composition of domestic tourists is categorized based on urban-rural areas. The percentage of tourists participating in each type of activity for different categories of inbound tourists can be referenced from the "Tourism Sampling Survey Data" on the composition of domestic tourists from urban areas, rural areas, and overnight inbound tourists. Since there is no statistical data available for the composition of same-day inbound tourists, the percentage of data from overnight inbound tourists is used for estimation. The CO_2 emission index is referenced from the relevant data provided by Shi et al.[21].

3. Results

3.1 Tourism Carbon Footprint

[Table 1] shows that the max value of TCF_{all} is 349.13×10^8 kg, and the average value is 122.07×10^8 kg. That means the max value and the average value of tourism carbon emissions in Shanxi Province from 2000 to 2020. The annual total carbon emissions exhibited a slight "M" shaped fluctuation trend.

The average proportion of tourism transportation carbon footprint in Shanxi Province is 93.98%, showing an absolute advantage. The average proportions of tourism accommodation, dining, and activities carbon footprints are 2.30%, 2.26%, and 1.46%, respectively.

[Table 1] Summary of Tourism Carbon Footprint in Shanxi Province from 2000 to 2020

Year	TCF_{all}	TCF_e		TCF_s		TCF_t		TCF_a	
	10^8kg	10^8kg	%	10^8kg	%	10^8kg	%	10^8kg	%
2020	84.3	2.8	3.32	2.04	2.42	77.11	91.47	2.35	2.79
2019	349.13	2.67	0.76	2.38	0.68	337.61	96.7	6.48	1.86
2018	296.91	2.59	0.87	1.8	0.61	286.98	96.66	5.54	1.87
2017	241.75	2.58	1.07	2.88	1.19	231.88	95.92	4.42	1.83
2016	194.38	2.38	1.22	2.14	1.1	186.14	95.76	3.73	1.92
2015	162.88	2.49	1.53	3.09	1.9	153.51	94.25	3.79	2.33
2014	139.47	2.93	2.1	4.04	2.9	129.34	92.74	3.15	2.26
2013	155.52	3.24	2.08	2.65	1.7	147.64	94.93	1.99	1.28
2012	132.19	3.52	2.66	5.34	4.04	121.77	92.12	1.56	1.18
2011	105.46	3.59	3.4	3.93	3.73	96.74	91.73	1.2	1.14
2010	83.22	1.1	1.32	1.24	1.49	79.92	96.03	0.96	1.15
2009	74.74	1.46	1.95	1.49	1.99	70.97	94.96	0.81	1.08
2008	295.25	1.4	0.47	1.42	0.48	291.56	98.75	0.87	0.29
2007	54.73	1.35	2.47	1.34	2.45	51.43	93.97	0.61	1.11
2006	46.85	1.26	2.69	1.2	2.56	43.9	93.7	0.5	1.07
2005	39.14	1.23	3.14	1.15	2.94	36.33	92.82	0.44	1.12
2004	30.32	1	3.3	0.97	3.2	28	92.35	0.36	1.19
2003	18.04	0.82	4.55	0.8	4.43	16.18	89.69	0.23	1.27
2002	24.52	0.8	3.26	0.82	3.34	22.59	92.13	0.31	1.26
2001	19.19	0.67	3.49	0.67	3.49	17.59	91.66	0.26	1.35
2000	15.57	0.27	1.73	0.27	1.73	14.82	95.18	0.2	1.28
Ave	122.07	1.91	2.26	1.98	2.30	116.29	93.98	1.89	1.46

3.2 Tourism Revenue Analysis

[Table 2] shows that the total tourism revenue in Shanxi Province increased annually from 2000 to 2019. However, due to the impact of the COVID-19 pandemic, tourism revenue in 2020 accounted for 36.38% of the total revenue in 2019. From 2000 to 2020, the tourism revenue generated by different sectors in Shanxi Province exhibited the following ranking: tourism transportation > tourism activities > tourism food and beverage > tourism accommodation. The average proportion of tourism transportation revenue to the total revenue was 32.51%, indicating a relatively stable trend over the years. The average proportion of tourism activities revenue was 30.36%, initially stable and then gradually declining. The average proportion of tourism food and beverage revenue was 23.21%, showing a rapid increase followed by a gradual decline. The average proportion of tourism accommodation revenue was 14.06%, indicating a continuous upward trend.

Research indicates that the sharp decline in overall tourism revenue in 2019 was directly caused by the COVID-19 pandemic. As the economy develops, tourists have higher expectations for food and beverage services and accommodation quality.

[Table 2] Summary of Tourism Revenue in Shanxi Province from 2000 to 2020

Year	TR_{all}	TR_e		TR_s		TR_t		TR_a	
	Billion	Billion	%	Billion	%	Billion	%	Billion	%
2020	2920.08	703.27	24.08	465.02	15.93	988.57	33.85	763.28	26.14
2019	8026.92	1927.44	24.01	1286.1	16.02	2721.5	33.9	2098.32	26.14
2018	6728.70	1541.62	22.91	1055.33	15.68	2328.12	34.6	1810.17	26.9
2017	5360.21	1248.38	23.29	892.48	16.65	1932.68	36.06	1294.12	24.14
2016	4247.12	1144.74	26.95	589.3	13.88	1363.88	32.11	1155.61	27.21
2015	3447.50	900.52	26.12	514.27	14.92	1056.96	30.66	981.87	28.48
2014	2846.51	750.49	26.37	415.51	14.6	910.74	32	775.28	27.24
2013	2305.44	609.58	26.44	297.07	12.89	735.31	31.89	681.44	29.56
2012	1813.01	455.95	25.15	249	13.73	567.43	31.3	555.4	30.63
2011	1342.59	298.12	22.2	185.77	13.84	433.95	32.32	434.92	32.39
2010	1083.46	237.17	21.89	146.66	13.54	351.3	32.42	353.23	32.6
2009	892.53	195.53	21.91	119.06	13.34	287.79	32.24	293.14	32.84
2008	739.32	162.55	21.99	99.2	13.42	238.36	32.24	244.53	33.08
2007	581.57	128.07	22.02	79.72	13.71	185.55	31.9	188.58	32.43
2006	428.39	94.36	22.03	58.59	13.68	136.91	31.96	138.4	32.31
2005	291.99	63.94	21.9	38.64	13.23	93.88	32.15	94.81	32.47
2004	199.77	43.23	21.64	26.44	13.24	63.53	31.8	65.9	32.99
2003	101.47	22.22	21.9	13.45	13.26	32.58	32.11	33.08	32.6
2002	126.51	27.2	21.5	16.81	13.29	40.97	32.38	41.07	32.47
2001	100.44	21.59	21.5	13.41	13.35	32.62	32.47	32.46	32.32
2000	81.35	17.58	21.61	10.65	13.09	26.3	32.33	26.61	32.72
Ave	-	-	23.21	-	14.06	-	32.51	-	30.36

3.3 Analysis of Tourism Ecological Efficiency

[Table 3] shows that the average total tourism ecological efficiency in Shanxi Province from 2000 to 2020 was 13.79 yuan/kg, which means that every one kg of carbon dioxide emitted by the tourism industry in Shanxi Province generates an economic income of 13.79 yuan. The average ecological efficiency of tourism meals is 211.41 yuan/kg, that of tourism accommodation is 140.47 yuan/kg, that of tourism transportation is 4.81 yuan/kg, and that of tourism activities is 270.18 yuan/kg. The ecological efficiency of tourism presents a ranking feature of tourism activities>tourism meals>tourism accommodation>tourism transportation.

From a horizontal perspective, the ecological efficiency value of tourism activities is the highest, that is, for every one kg of carbon dioxide emitted by the tourism activity department, an economic

income of 270.18 yuan is generated. However, the ecological efficiency value of tourism transportation is the lowest, that is, the tourism and transportation sector only generates an economic income of 4.81 yuan for every one kg of carbon dioxide emitted.

From a vertical perspective, except for 2008, the overall ecological efficiency of tourism and the ecological efficiency of tourism transportation have shown an increasing trend year by year. The ecological efficiency of tourism meals and tourism accommodation, except for a slight decline in 2011, showed an increasing trend year by year, but due to the COVID-19 in 2020, there was a precipitous decline. The ecological efficiency of tourism activities shows a trend of first increasing, then stabilizing, then decreasing, and then increasing.

[Table 3] Summary of Tourism Ecological Efficiency in Shanxi Province from 2000 to 2020 (Unit: yuan/kg)

Year	TEE_{all}	TEE_e	TEE_s	TEE_t	TEE_a
2020	34.64	251.08	227.64	12.82	325.2
2019	22.99	721.89	541.21	8.06	323.86
2018	22.66	595.76	586.7	8.11	326.78
2017	22.17	483.66	310.38	8.33	293.11
2016	21.85	481.42	275.21	7.33	309.98
2015	21.17	361.91	166.35	6.89	259.16
2014	20.41	256.05	102.74	7.04	246.22
2013	14.82	187.96	111.91	4.98	343.22
2012	13.72	129.38	46.64	4.66	356.11
2011	12.73	82.93	47.24	4.49	363.57
2010	13.02	215.47	118.28	4.4	367.35
2009	11.94	133.57	79.89	4.05	362.25
2008	2.5	115.9	69.8	0.82	280.48
2007	10.63	94.77	59.69	3.61	308.08
2006	9.14	74.96	48.96	3.12	279.1
2005	7.46	52.11	33.65	2.58	213.51
2004	6.59	43.3	27.39	2.27	181.64
2003	5.62	26.99	16.76	2.01	141.93
2002	5.16	33.91	20.61	1.81	131.45
2001	5.23	32.05	20	1.85	127.28
2000	5.23	64.58	38.77	1.77	133.53
Ave	13.79	211.41	140.47	4.81	270.18

4. Discussion

4.1 Tourism Carbon Footprint Analysis

Overall, the total tourism carbon emissions in Shanxi Province from 2000 to 2020 followed the order of tourism transportation > tourism accommodation > tourism dining > tourism activities. Horizontally, the carbon emissions from different sectors in Shanxi Province showed a differentiated structure. The transportation sector accounted for the largest proportion of carbon emissions, with an average proportion of 93.98%. Vertically, except for 2020, the carbon emissions from tourism dining and tourism accommodation showed an initial increase followed by a decreasing trend, while the emissions from tourism transportation and tourism activities showed a year-on-year increase. The above conclusion is consistent with the research findings from AN et al.[14].

Except for a sharp increase in emissions in 2008 due to the impact of hosting the Olympics in China, the emissions in other years generally showed a stable growth trend.

In 2020, due to the impact of the COVID-19, tourism carbon emissions experienced a significant decrease as international and domestic tourist numbers dropped quickly. In 2020, the total tourism

revenue in 2020 in Shanxi Province accounted for only 36.38% of the revenue in 2019, showing a sharp decline. Few experts have paid attention to this conclusion.

4.2 Tourism Revenue Analysis

Tourism transportation and activity revenues have a higher proportion, with average values of 32.51% and 30.36%, respectively. The average proportions of tourism dining and accommodation revenues are 23.21% and 14.06%, respectively. The proportions of tourism dining and accommodation revenues show an increasing trend over the years, while the proportion of tourism activity revenue shows a decreasing trend. The above conclusion is consistent with the research findings from Li et al.[3].

4.3 Analysis of Tourism Ecological Efficiency

The average ecological efficiency of tourism in Shanxi Province is 13.79 yuan/kg. The average ecological efficiency values of tourism activities, dining, accommodation, and transportation are 270.18 yuan/kg, 211.41 yuan/kg, 140.47 yuan/kg, and 4.81 yuan/kg, respectively. From a longitudinal perspective, the overall ecological efficiency of tourism and the ecological efficiency of each tourism sector show an upward trend over the years. The ecological efficiency growth rates of tourism dining and accommodation are significantly higher than those of the other two sectors, indicating that the tourism ecological efficiency in Shanxi Province is moving towards “low-carbon and high-efficiency” development. Few experts have paid attention to this conclusion.

Due to the provincial-based analysis conducted in this study, the calculated tourism carbon footprint and ecological efficiency of Shanxi Province are compared with similar provinces. It was found that in 2017, the total carbon footprint of Zhejiang Province was 214.54×10^8kg[22], slightly smaller than the emission of 241.75×10^8kg in Shanxi Province. In 2012, the total carbon footprint of Hainan Province was 212.01×10^8kg, significantly higher than the carbon footprint of 132.19×10^8kg in Shanxi Province. However, the ecological efficiency value of Hainan Province was 1.787 yuan/kg[23], much lower than the ecological efficiency value of 13.72 yuan/kg in Shanxi Province. This indicates that the geographical location of different provinces has a significant impact on the total carbon footprint and tourism ecological efficiency. The larger carbon footprint in Hainan Province is primarily due to its geographical location, which leads to air travel being the primary mode of transportation, resulting in a larger carbon footprint. The above conclusion is consistent with the research findings from Ma[18].

5. Conclusion and scarcity

5.1 Conclusion

This study constructed and conducted a detailed calculation of the tourism ecological efficiency model in Shanxi Province from 2000 to 2020, based on the perspective of tourists’ carbon footprint. The specific conclusions are as follows:

(1) The average proportion of tourism transportation carbon footprint in Shanxi Province shows an absolute advantage. The average proportions of tourism dining and accommodation revenue display an increasing trend yearly.

(2) The total tourism revenue in 2020 in Shanxi Province shows a sharp decline, greatly affected by COVID-19. Tourism transportation and activity revenues have a higher proportion. The proportions of tourism dining and accommodation revenues show an increasing trend over the years, while the proportion of tourism activity revenue shows a decreasing trend.

(3) Both the overall tourism ecological efficiency and the ecological efficiency of each sector have been increasing yearly. From a longitudinal perspective, the overall ecological efficiency of tourism and the ecological efficiency of each tourism sector show an upward trend over the years. The ecological efficiency growth rates of tourism dining and accommodation are significantly higher than those of the other two sectors, indicating that the tourism ecological efficiency in Shanxi Province is moving towards “low-carbon and high-efficiency” development.

5.2 Scarcity

Due to the selection of panel data for the entire Shanxi Province in this study, further research on the various cities under Shanxi Province has not been conducted, which has certain limitations in the selection of the research scope. However, it can provide a Calculation Modeling support for further research on different cities in subsequent studies.

Additionally, the calculation method for tourism ecological efficiency in this study is relatively simple. However, the further research will be conducted based on the perspective of multiple inputs and outputs to investigate tourism ecological efficiency.

References

[1] Shang Ruihua, Research on the Protection and Related Technologies of Shanxi Earth Sites, Shanxi: People's Publishing House, (2022)

[2] N. W. Kuo, P. H. Chen, Quantifying energy use, carbon dioxide emission, and other environmental loads from island tourism based on a life cycle assessment approach, Journal of Cleaner Production, (2009), Vol.17, No.15, pp.1324-1330.
DOI: http://dx.doi.org/10.1016/j.jclepro.2009.04.012

[3] Li Zunling, Analysis of carbon emission efficiency and influencing factors in the three northeastern provinces, Guangxi Normal University, (2022)
DOI: http://dx.doi.org/10.27036/d.cnki.ggxsu.2022.000500

[4] Zhang Huanbo, Climate Policy Analysis of China, the United States, and the European Union, Beijing: Social Science Literature Press, (2010)

[5] B. P. Weidema, M. Thrane, P. Christensen, Carbon footprint: acatalyst for life cycle assessment?, Journal of Industrial Ecology, (2008),Vol.12, No.1, pp.3-6.
DOI: http://dx.doi.org/10.1111/j.1530-9290.2008.00005.x

[6] Liu Jun, Ma Yong, A Perspective on Sustainable Tourism Development: A Review of Tourism Ecological Efficiency, Journal of Tourism, (2017),Vol.32, No.9,pp.47-56.
DOI: http://dx.doi.org/10.3969/j.issn.1002-5006.2017.09.010

[7] R. U. Ayres, Towards a zero-emissions economy, Environmental Science and Technology, (1998),Vol.32, No.15, pp.366-367.

[8] Yao Zhiguo, Chen Tian, A Tourism Ecological Efficiency Model and Its Empirical Study, China Population, Resources and Environment, (2015), Vol.25, No.11, pp.113-120.
DOI: http://dx.doi.org/10.3969/j.issn.1002-2104.2015.11.015

[9]WBCSD, Eco-efficiency:Creating More Value with Less Impact, Geneva: WBCSD, (2000)
Available from: https://docs.wbcsd.org/2006/08/EfficiencyLearningModule.pdf

[10] World Business Council for Sustainable Development (WBCSD), Measuring eco-efficiency: A guide to reporting compa-ny performance, Geneva: WBCSD, (2000)
Available from: https://www.gdrc.org/sustbiz/wbcsd.html

[11] C. Victoria, S. A. John, Measuring the Ecological Footprint of a Himalayan Tourist Center, Mountain Research and Development, (2022),Vol.22, No.2, pp.132-141.
DOI: http://dx.doi.org/10.1659/0276-4741(2002)022[0132:MTEFOA]2.0.CO;2

[12] Zheng Qunming, Chen Ziqi, Research on Tourism Ecological Efficiency Based on Carbon Footprint: A Case Study of Jiujiang City, Jiangxi Province, Journal of Natural Sciences of Hunan Normal University, (2022), Vol.45, No.5, pp.74-82+101.
DOI: http://dx.doi.org/10.7612/j.issn.2096-5281.2022.05.008

[13] D. K. Bruijn, R. Dirven, E. Eijgelaar, Travelling large in 2011: The carbon footprint of Dutch holidaymakers in 2011 and the development since 2002, Breda, Netherlands: NHTV Breda University ofApplied Sciences, (2013)
Available from: https://pure.buas.nl/en/publications/travelling-large-in-2011-the-carbon-footprint-of-dutch-holidaymak

[14] An Young Mi, Lee Gyu Jin, Comparative Analysis of Carbon Footprint of Travelers in Different Areas of the Capital Circle, Journal of the Academic Conference of the Korean Transportation Society, (2013), Vol.69, pp.434-439.

[15] Xiao Jianhong, Yu Aifen, Wang Min, Carbon Footprint Assessment of Tourism Process: A Case Study of Zhoushan Islands, Tourism Science, (2011), Vol.25, No.4, pp.58-66.
DOI: http://dx.doi.org/10.3969/j.issn.1006-575X.2011.04.007

[16] Zhang Jinhe, Zhang Jie,Tourism Ecological Footprint Model and Empirical Analysis of Mount Huangshan City, Journal of Geography, (2004),Vol.59, No.5, pp.763-771.
DOI: http://dx.doi.org/10.3321/j.issn:0375-5444.2004.05.015

[17] Zhou NianXing, Huang Zhenfang, Liang Yanyan, Measurement and Equilibrium of Carbon Sources and Sinks in Lushan Scenic Area, Journal of Ecology, (2013), Vol.33, No.13, pp.4134-4145.
DOI: http://dx.doi.org/10.5846/stxb201212021727

[18] Ma Jing, Research on Tourism Ecological Efficiency in Gansu Province Based on Carbon Footprint, Lanzhou: Lanzhou University of Finance and Economics, (2020)
DOI: http://dx.doi.org/10.27732/d.cnki.gnzsx.2020.000324

[19] Stefan Gössling, Global Environmental Consquences Of Tourism, Global Environmental Change, (2002), Vol.12, No.4, pp.283-302.
DOI: http://dx.doi.org/10.1016/S0959-3780(02)00044-4

[20] Li Peng, Yang Guihua, Zheng Biao, Zhang Qun, Ecological efficiency of Yunnan Shangri La tourism route products based on greenhouse gas emissions, Journal of Ecology, (2008), Vol.28, No.5, pp.2207-2219.
DOI: http://dx.doi.org/10.3321/j.issn:1000-0933.2008.05.037

[21] Shi Peihua, Wu Pu, Preliminary estimation of energy consumption and CO2 emissions in China's tourism industry, Journal of Geography, (2011), Vol.66, No.2, pp.235-243.
DOI: http://dx.doi.org/10.11821/xb201102009

[22] Simeng, A Low Carbon Tourism Strategy Based on Carbon Footprint Model: Taking Zhejiang Province as an Example, Modern Commerce and Industry, (2018), Vol.39, No.30, pp.18-19.
DOI: http://dx.doi.org/10.19311/j.cnki.1672-3198.2018.30.009

[23] Yao Zhiguo, Chen Tian, Yin Shoubing, Li Xingang, Empirical Analysis of Regional Tourism Ecological Efficiency: Taking Hainan Province as an Example, Geographic Science, (2016), Vol.36, No.03, pp.417-423.
DOI: http://dx.doi.org/10.13249/j.cnki.sgs.2016.03.013