RESEARCH on the Measurement of Carbon Emission and Decoupling Effect of Tourism Transportation in Yunnan Province

Yunhan Si [a], Lianghui Qian *[a]

[a]College of Mechanics and Transportation, Southwest Forestry University, Kunming, Yunnan, 650224, China

*Correspondence:qianfeng_10@163.com

Abstract. Using the "bottom-up" method and Tapio decoupling model, based on the time-series data of Yunnan Province from 2010 to 2020, the study firstly measures the carbon emissions from tourism transportation in Yunnan Province, and then analyzes the decoupling relationship between tourism transportation and tourism economy. The study shows that the overall trend of tourism transportation carbon emissions in Yunnan Province from 2010 to 2020 is increasing and then decreasing; the highest and lowest percentages of tourism transportation carbon emissions in Yunnan Province are from air transportation and waterway transportation respectively; and the relationship between tourism transportation carbon emissions and the tourism economy in Yunnan Province is mainly characterized by a weak decoupling. Based on this, it is proposed to actively explore the low-carbon transformation mode of tourism transportation and accelerate the construction of green transportation system and other countermeasures.

Keywords: tourism transportation; carbon emissions; decoupling effects; Yunnan Province

1 INTRODUCTION

One of the major causes of climate change is the emission of greenhouse gases, and climate change is an important issue of common concern to governments, experts and other countries. In September 2020, China clearly put forward the goal of achieving "carbon peak" by 2030 and "carbon neutrality" by 2060, which further illustrates the importance China attaches to the green development of industries. As a strategic national pillar industry, transportation is indispensable to the development of tourism, especially in view of the fact that it generates up to 75% of the total carbon emissions of the entire tourism industry[1]. Based on this situation, the carbon emission of tourism transportation has become an important issue in the current research field.

Yunnan Province has become a major tourist province in China due to its rich natural landscape and unique cultural landscape of ethnic minorities. In order to help

G. Chen et al. (eds.), *Proceedings of the 2024 International Conference on Rail Transit and Transportation (ICRTT 2024)*, Advances in Engineering Research 254,
https://doi.org/10.2991/978-94-6463-610-9_8

achieve the goal of carbon peak, carbon neutral, and vigorously promote the province's energy saving and emission reduction work, the Yunnan Provincial Government has repeatedly issued circulars on the implementation of energy saving and emission reduction work programs. Therefore, by measuring the carbon emissions generated by tourism transportation in Yunnan Province, and further using the Tapio decoupling model to explore the decoupling correlation between these emissions and the tourism economy, we can provide a scientific theoretical basis as well as more informative empirical and empirical evidence for the healthy development of the tourism industry in Yunnan Province to achieve the goal of "dual-carbon" in the future.

2 LITERATURE REVIEW

At this stage, most scholars at home and abroad study the carbon emission from tourism transportation from the aspects of measurement and decomposition of influencing factors, and the commonly used methods include the "top-down" method and the "bottom-up" method[2]. The "top-down" input-output analysis method mainly measures the total carbon emissions of the target region at the macro level, while the "bottom-up" process analysis method mainly measures the total carbon emissions of the target object at the micro level. Xiao Q et al.(2023) measured the carbon footprint of tourism in Chenzhou City from 2014 to 2019 by applying the "bottom-up" method, and concluded that the carbon footprint of tourism transportation accounted for more than 80% of the total carbon footprint[3]. Gengxia Y et al.(2022) used the process analysis method to estimate the carbon emissions from tourism transportation in Dunhuang City, 2010-2019, using the LMDI decomposition method, they concluded that the number of passengers and energy consumption per passenger have a contributing effect on carbon emissions from tourism transportation[4]. Jiang et al.(2020) used the "top-down" method to measure the transportation carbon emissions of the Yangtze River Economic Zone from 1985-2016, and analyzed that its transportation carbon emissions showed an upward trend[5].

On the study of the relationship between carbon emissions from tourism transportation and economic growth, Tapio(2005) proposed the Tapio decoupling elasticity model for the in-depth study of the relationship between carbon emissions and economic development in Europe. It also provides a solid theoretical basis and practical reference for subsequent researchers to analyze the correlation between the two[6]. Zhao Hu et al.(2022) used the optimized Tapio model to investigate the decoupling relationship between carbon emissions from tourism traffic and tourism economic growth in Hubei Province, and concluded that the relationship between the two in Hubei Province showed a weak decoupling phenomenon, which demonstrated that the development of the tourism industry in Hubei Province and the ecological environment are in a state of sustainable development[7]. Huiqiang M et al.(2021) used the Tapio model and the LMDI method to explore the decoupling relationship between carbon emissions from tourism transportation and changes in economic development in Beijing and its influencing factors, and found that Beijing's economic development is developing in tandem with the changes in carbon emissions from tourism transportation

in Beijing[8]. Focusing on the geographical scope of "the Silk Road Economic Belt", Guo Wei et al. (2022)used the Tapio decoupling model to analyze the correlation between carbon emissions from tourism transportation and tourism economy, and classify its development into an "N"-shaped phase and a relatively stable period of continuous development. [9].

3 RESEARCH METHODOLOGY AND DATA SOURCES

3.1 Research Methodology

Using the "bottom-up" method and the proportion of each mode of transportation in the total carbon emissions from passenger transportation, the carbon emissions from tourism transportation in Yunnan Province were firstly estimated, and then the Tapio decoupling model was used to explore the decoupling between the carbon emissions from tourism transportation and the development of tourism economy in Yunnan Province.

The measurement of carbon emissions from passenger transport in Yunnan Province is based on the carbon emission calculation method for passenger transport developed by the United Nations World Tourism Organization, which is modeled as follows[10]:

$$C_i=P_i\times Q_i \tag{1}$$

In the formula: C_i is the carbon emission of passenger transportation of the mode of traffic type(i); P_i is the carbon emission coefficient of the traffic type(i) (gCO2/pkm); Q_i is the passenger turnover (pkm) of the traffic type(i); According to Wei Yanxu et al [11], the carbon emission factors of railway, highway, waterway and aviation (gCO_2/pkm) are chosen as 27, 133, 106 and 137, respectively.

The measurement model of carbon emissions from tourism transportation in Yunnan Province is:

$$C'=\sum_{i=1}^{4}\partial_i * C_i \tag{2}$$

In the formula: C' is the total amount of carbon emissions from tourism transportation; ∂_i is the proportion of carbon emissions from tourism transportation among the carbon emissions from the type(i) of passenger traffic transportation;C_i is the carbon emission of passenger transportation of the mode of traffic type(i). Referring to the results of Wei Yanxu et al[11], the values of ∂ were taken as 31.6%, 13.8%, 64.7%, and 10.6% for railroad, highway, air, and water transportation, respectively.

In this paper, we apply the improved and optimized arc-elastic Tapio model framework by Hu Huan[12] and other scholars to analyze the decoupling relationship through calculation. The computational model is as follows:

$$t = \frac{C_2'-C_1'}{(C_2'+C_1')/2} \Big/ \frac{R_2-R_1}{(R_2+R_1)/2} \tag{3}$$

In the formula: t is the value of decoupling elasticity; the numerator is the change in carbon emissions from tourism transportation; the denominator is the change in total tourism revenue. Based on the decoupling classification criteria shown in Table 1, a scientific judgment is made on the decoupling relationship between tourism transportation carbon emissions and total tourism revenue in Yunnan Province.

Table 1. Tapio classification criteria for decoupled status.

Types of decoupling	$\Delta C'$	ΔR	t	Implication
Expansive negative decoupling	>0	>0	>1	Indicates that both carbon emissions from tourism transportation and total tourism revenues are growing, but the former is growing faster than the latter
Strong-negative decoupling	>0	<0	<0	Indicates an increase in carbon emissions from tourism transportation, but a decrease in total tourism revenue and a declining tourism economy
Weak-negative decoupling	<0	<0	0<t<1	Indicates that both carbon emissions from tourism transportation and total tourism revenue decreased, but the former decreased at a slower rate than the latter
Strong decoupling	<0	>0	<0	Indicates a decrease in carbon emissions from tourism transportation, but an increase in total tourism revenue and a sustainable trend in the tourism economy
Weak decoupling	>0	>0	0<t<1	Indicates that both carbon emissions from tourism transportation and total tourism revenues grew, but the former grew more slowly than the latter
Recessive decoupling	<0	<0	>1	Indicates that both carbon emissions from tourism transportation and total tourism revenue decreased, but the former decreased at a faster rate than the latter

3.2 Data sources

The data needed to make the measurements in this study are from the Yunnan Provincial Statistical Yearbook (2011-2021), including the passenger turnover of Yunnan Province, total tourism revenue, etc.

4 RESULTS AND ANALYSIS

4.1 Carbon Emission Analysis of Tourism Transportation

According to equation (1) and equation (2), the carbon emissions from various transportation modes in Yunnan Province in 2010-2020 can be calculated and the results are shown in Table 2, and the trend is shown in Figure. 1, from which the following conclusions can be drawn.

Table 2. Carbon emissions from tourism transportation in Yunnan Province from 2010 to 2020.

Year	Carbon Emissions from Tourism Transport/Ten thousand tons				
	Railway	Highway	Waterway	Aviation	Total
2010	6.89	64.62	0.20	78.92	150.63
2011	7.84	77.93	0.22	81.85	167.84
2012	7.85	86.30	0.23	93.97	188.35
2013	8.48	59.30	0.25	111.15	179.18
2014	8.81	58.93	0.27	130.28	198.29
2015	9.50	60.61	0.28	137.75	208.14
2016	9.46	58.73	0.30	134.67	203.16
2017	11.25	56.58	0.32	136.21	204.36
2018	12.88	49.49	0.34	152.66	215.37
2019	15.52	46.12	0.26	174.61	236.51
2020	10.02	25.41	0.08	105.89	141.40

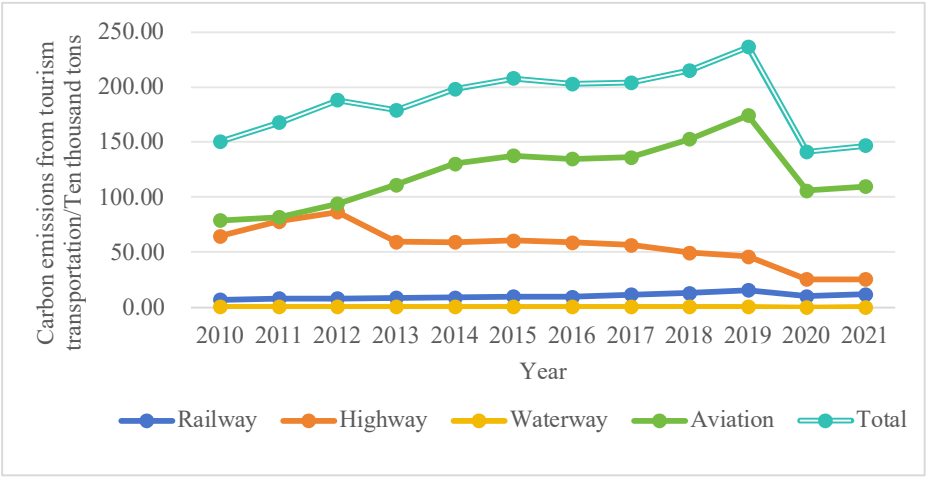

Fig. 1. Trend of carbon emission from tourism transportation in Yunnan Province, 2010-2020.

Firstly, Yunnan Province's carbon emissions from tourism transportation in 2010-2020 show a general trend of growth followed by a decline, with a peak of 2.37 million tons in 2019. The carbon emission from tourism transportation in Yunnan Province increases from 1.51 million tons in 2010 to 2.37 million tons in 2019, with a growth rate of 57.02%. The year 2020 is affected by other factors, so the year 2020 is removed here. The overall evolution of carbon emissions from tourism transportation in Yunnan Province from 2010 to 2020 can be reasonably divided into three stages:(1)The first stage (2010-2012) is a rapid growth stage. (2) The second stage (2013-2019) is a fluctuating growth stage, with only a small decrease in 2014 and 2017. Mainly due to the impact of natural disasters such as earthquakes and fires in 2014, which caused certain losses to the tourism industry in the province, and Yunnan Province launched eighteen low-carbon demonstration projects in 2013, the country also promulgated the first law and regulations for the tourism industry, "Tourism Law of the People's Republic of China", the State Council issued “a number of Opinions

on Promoting the Reform and Development of the Tourism Industry ”in 2014, and the Ministry of Transportation, National Tourism Administration and other six departments jointly issued the "Opinions on Promoting the Integration of Transportation and Tourism" in 2017, all of which provide strong support for the further transformation and upgrading of the tourism transportation industry. Yunnan Province has actively responded to relevant policies and advocated low-carbon tourism and sustainable development through the development of a series of programs, which explains the fluctuating state of carbon emissions from tourism transportation in 2013-2019, indicating that the low-carbon emission reduction efforts in the tourism industry in Yunnan Province have been effective. (3) The third stage (2020) is the rapid decline stage. Due to special reasons, the development of tourism in Yunnan Province is restricted in this period, and the number of tourists has been greatly reduced by the suspension of public transportation in many places and measures such as closure and control management, so the carbon emissions from tourism transportation in Yunnan Province have also declined rapidly in this stage.

Secondly, the carbon emission of tourism transportation also varies according to the different modes of transportation. As can be seen from Figure 1, the carbon emissions of the four modes of transportation, from high to low, are 62.98% for air transportation, 31.78% for road transportation, 5.1% for railroad transportation, and 0.14% for waterway transportation, indicating that the main sources of carbon emissions from tourism transportation in Yunnan Province are air transportation and road transportation, but the difference is that the carbon emissions of air traffic basically increase year by year except for 2020, which is related to the rapid development of air traffic in Yunnan Province. In 2019, Yunnan Province's passenger throughput will reach the first in Southwest China and the fourth in the Country, with 15 airports in operation, 4,339 kilometers of navigable miles of the province's airways, and the number of navigable points to Southeast Asia and South Asia ranked first in the Country. Therefore, in the future, the focus should be on civil aviation in carrying out energy saving and emission reduction in tourism transportation. And the carbon emission of road transportation is decreasing year by year since 2013, the reason is because Yunnan Province actively practices the relevant requirements of the "Outline of the Ecological Civilization Planning of Qicai Yunnan", "Outline of the Low Carbon Development Planning of Yunnan Province" and other important plans.

4.2 Analysis of Decoupling Effects

Based on the calculation of formula (3), the decoupling elasticity value of Yunnan Province in 2010-2020 can be derived, as shown in Table 3. The decoupling status of Yunnan Province in 2010-2020 is mainly characterized by weak decoupling, which means that both carbon emissions from tourism transportation and tourism economy keep increasing, but the growth rate of the tourism economy clearly exceeds the growth rate of carbon emissions, thus maintaining a state of sustainable development in general. The decoupling relationship in the two time periods of 2013-2014 and 2015-2016 is a strong decoupling, which means the carbon emission from tourism transportation decreases, but the tourism economy increases, this is a desired ideal

state. In addition, in the special period of 2019-2020, the decoupling status shows a weak negative decoupling, which indicates that both the carbon emissions from tourism transportation and the tourism economy decrease, but the carbon emissions from tourism transportation decrease faster.

Table 3. Decoupling of Carbon Emissions from Tourism Transportation and Tourism Economy in Yunnan Province from 2010 to 2020.

Year	$\Delta C'$	ΔR	t	Decoupling state
2020-2011	0.11	0.25	0.44	weak decoupling
2022-2012	0.12	0.27	0.44	weak decoupling
2012-2013	0.11	0.21	0.52	weak decoupling
2013-2014	-0.06	0.23	-0.26	strong decoupling
2014-2015	0.05	0.21	0.24	weak decoupling
2015-2016	-0.02	0.36	-0.06	strong decoupling
2016-2017	0.006	0.38	0.02	weak decoupling
2017-2018	0.05	0.26	0.19	weak decoupling
2018-2019	0.09	0.20	0.45	weak decoupling
2019-2020	-0.50	-0.52	0.96	weak-negative decoupling

5 CONCLUSION

5.1 Conclusion

Using the "bottom-up" method to measure the carbon emissions from tourism transportation in Yunnan Province between 2010 and 2020, and combining the optimized Tapio decoupling model to deeply analyze the interaction between carbon emissions from tourism transportation and tourism economic growth, the study concludes that: (1) the carbon emissions from tourism transportation in Yunnan Province between 2010 and 2020 can be divided into three stages: firstly, 2010-2012 is the rapid growth stage; secondly, 2013-2019 is the fluctuating growth stage; and secondly, 2020 is the rapid decline stage. (2) There is a significant gap in carbon emissions from tourism transportation by different modes of transportation. The carbon emissions of the four modes of tourism transportation, from high to low, are 62.98% for air transportation, 31.78% for road transportation, 5.1% for railroad transportation, and 0.14% for waterway transportation. (3) During the period of 2010-2020, the proportion of weak decoupling between carbon emissions from tourism transportation and tourism economy in Yunnan Province is 70%, which means that although the total amount of carbon emissions from tourism transportation grows, the tourism economy grows faster, which indicates that Yunnan Province shows an overall trend towards sustainable development during this period.

5.2 Policy Recommendation

(1) Actively explore ways of low-carbon transformation of tourism means of transportation and increase the use of clean energy. The Yunnan Provincial Government can consider introducing new energy-saving airplanes as well as low-carbon and environmentally friendly means of transportation for tourism, such as battery-powered sightseeing buses, for scenic spots.

(2) Accelerating the construction of a green transportation system. The Yunnan Provincial Government should provide strong support for the greening and upgrading of transport infrastructure and improve traffic management and operation, which can be done by optimizing road or route networks and other means to reduce the carbon emissions generated by transport modes.

REFERENCES

1. Tang, Z., Bai, S., Shi, C., et al, "Tourism-related CO_2 emission and its decoupling effects in China: A spatiotemporal perspective," Advances in Meteorology, 2018: 1-9(2018).
2. Perch-Nielsen, S., Sesartic, A., Stucki, M., "The greenhouse gas intensity of the tourism sector: The case of Switzerland," Environmental Science & Policy, 13(2): 131-140(2010).
3. Xiao, Q., Zhong, Y., Deng, J., "Carbon footprint and its composition: a comparison between domestic and international tourists to Chenzhou City, China," Sustainability, 15(7): 5670(2023).
4. Yang, G., Jia, L., "Estimation of carbon emissions from tourism transport and analysis of its influencing factors in Dunhuang," Sustainability, 14(21): 14323(2022).
5. Jiang, Z.R., Jin, H.H., Wang, C.J., et al, "Measurement of traffic carbon emissions and pattern of efficiency in the Yangtze River Economic Belt (1985-2016)," Environmental Sciences, 41(06):2972-2980.DOI:10.13227/j.hjkx.201910221(2020).
6. Tapio, P., "Towards a theory of decoupling: degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001," Transport Policy, 12(2): 137-151(2005).
7. Zhao, H., Huang, M., Wang, P., "Research on the decoupling relationship between tourism transportation carbon emissions and economic growth in Hubei Province," Green Technology, 24(23):226-230+236. DOI:10.16663/j.cnki.lskj.2022.23.051(2022).
8. Huiqiang, M., Jiale, L., Jianchao, X., "Decoupling and decomposition analysis of carbon emissions in Beijing's tourism traffic," Environment Development and Sustainability, 24(4)(2021).
9. Guo, W., Zhang, P.F., Yu, H., et al, "Spatiotemporal evolution and effect of carbon emissions from tourism transportation in the "Silk Road Economic Belt"," Ecological Economy, 38(12):111-117+135(2022).
10. Scott, D., Amelung, B., Becken, S., et al, "Climate change and tourism: Responding to global challenges," World Tourism Organization, Madrid, 230: 1-38(2008).
11. Wei, Y.X., Sun, G.N., Ma, L.J., et al, "Preliminary estimation of carbon emissions from tourism transportation and regional differences in China," Journal of Shaanxi Normal University (Natural Science Edition), 40(2)： 76-84(2012).
12. Hu, H., Zhang, J.H., Yang, M., et al, "Study on the measurement of regional tourism carbon emission and its dynamic changes-Jiangsu Province as an example," Ecological Economy, 32(6):57-62(2016).