IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received 21 December 2022, accepted 4 February 2023, date of publication 22 February 2023, date of current version 2 March 2023.
Digital Object Identifier 10.1109/ACCESS.2023.3247865

RESEARCH ARTICLE

Research on the Coupling Coordination Relationship Between Tourism Carrying Capacity and the High-Speed Railway Network: A Case Study in China

ZHIKUN LUO [1], AIRONG XU [2], AND SHAN GAO [2]
[1]College of Foundation Science, Harbin University of Commerce, Harbin 150028, China
[2]School of Business, Shandong Normal University, Jinan 250358, China

Corresponding author: Zhikun Luo (102850@hrbcu.edu.cn)

This work was supported in part by the Programs of the National Science Foundation of Shandong Province under Grant ZR2020QG056.

ABSTRACT The rapid development of the high-speed railway (HSR) network has significantly improved the tourism traffic conditions, which has led to a large increase in the number of tourists. This has posed a new challenge for the tourism carrying capacity (TCC) of tourist attractions along the HSR. The purpose of this paper is to measure the development level of TCC and HSR network, and to study the coupling and coordinated development relationship between TCC and HSR network. The development level of TCC and HSR network is calculated respectively. The coupling coordination model is used to study the coupling and coordinated relationship of provincial TCC and HSR network. The results show that this coupling coordination relationship has an overall upward trend. However, the degree of development of the TCC in different provinces and cities is uneven, and the development advantages and disadvantages of the TCC are also different. The development level of the HSR network in most provinces and cities in China is lower than the level of TCC, which indicates that further increasing the construction of the HSR network will have a better marginal effect for the development of the tourism industry in China. Therefore, it is extremely important for China's provinces and cities, especially in key tourism areas, to promote the coordinated development of the HSR network capacity and TCC. At the same time, in the areas where the development level of HSR network is higher than the level of TCC, measures should be taken to increase the protection of tourism resources and the construction of tourism infrastructure, so as to avoid the destructive impact of the fast-growing number of tourists on the development of local tourism industry.

INDEX TERMS High speed railway network, tourism carrying capacity, tourism industry, combination weighting method, coupling coordination model.

I. INTRODUCTION

China's tourism industry is one of the strategic pillar industries of the national economy. The healthy and sustainable development of the tourism industry is of great significance to China's national strategy of economic recovery and regional coordinated development. Since the implementation of the "*13th Five-Year Plan*", the building of a moderately prosperous society in an all-round way has put forward higher requirements for the development of China's tourism industry. New models, such as "mass tourism", "omni-tourism" and "all-for-one tourism" [1], have injected continuous vitality into the development of the tourism industry. With the support of the high-accessibility high-speed railway (HSR) network, the scale of national tourism has become unprecedented, and the shortening of travel times has allowed people's travel destinations to become more diversified. HSR can change the spatial distance between regions, which has a

The associate editor coordinating the review of this manuscript and approving it for publication was Luyu Zhao.

profound impact on economic growth and industrial development. Specifically, the impact on the development of tourism economy is mainly reflected in three aspects: promoting the flow of people, increasing infrastructure support and producing urban siphon effect. First, the opening of HSR has greatly facilitated the flow of tourists and the exchange of information on tourist attractions. Secondly, the HSR network has facilitated the travel of tourists and stimulated the rapid growth of tourism support services such as hotels, restaurants and regional transportation. Finally, HSR has created a clustering effect on the tourism economy, strengthening economic ties between tourist and non-tourist cities.

According to the *China Domestic Tourism Development Report 2020*, the scale of tourism reception in China has maintained a steady growth, from 2.641 billion person-times in 2011 to 6.016 billion person-times in 2019 [2]. On the one hand, the rapid development of domestic tourism and the surge in the number of tourists have brought huge benefits in terms of promoting employment, increasing the incomes of residents in tourist destinations and promoting cultural heritage [3]. On the other hand, the surge in the number of tourists has had different levels of impact on the local economies, societies and ecological environments of tourist areas. The extensive and even over-development of tourism has led to a series of problems, such as population congestion, traffic jams, environmental degradation and so on, imposing higher requirements to the carrying capacity of some tourism areas. Tourism carrying capacity (TCC) refers to the maximum ability (in terms of size and intensity) of the natural human environment, tourism facilities, social economic environment and tourist area residents to bear tourists and their related activities over a certain period of time and within a certain region, under the premise of sustainable development [4]. TCC is an important standard for evaluating and measuring the current situation and future development trends in tourism regions. Meanwhile, it is an important basis for comprehensively reflecting the characteristics of a tourism system and measuring the coordination relationship between the tourism environment and tourism development level.

The rapid development of the HSR network has improved the accessibility between cities, activated the population flow in tourist areas, and directed such flow, and promoted the comprehensive rapid development of regional tourism. When the HSR network matches the regional TCC, the HSR can significantly improve the total tourism economy of urban regions [5]. For Beijing, Guangzhou, Wuhan, Zhengzhou, Changsha, Shenzhen, Foshan and other cities with good tourism foundations, the HSR has had a positive polarizing effect [6]. The opening of the HSR does not always have a positive effect on regional tourism along the route, however, and can even have a dampening effect if it does not match the TCC. The opening of the HSR can even constrain tourism development in non-tourist cities along the route, and may even lead to a shrinkage of their tourism markets [7]. Thus, matching the regional TCC to the HSR network is required, so as to optimize the population flow and the direction of the flow through the tourism areas, thus promoting the coordinated and sustainable development of regional tourism.

Although the development of China's HSR network has greatly boosted the tourism industry in China, the coupling coordination degree between the HSR network and TCC are not balanced. For example, some tourism areas with high TCC have inconvenient transportation, which greatly limits the development of local tourism. Therefore, it is very important to promote the coordinated development of the HSR network and the TCC in China's key tourism areas.

Previous related studies mainly focused on the influencing factors and index system of TCC, the impact of HSR facilities construction on regional tourism. However, less attention was paid to the coordinated development relationship between the regional HSR network and TCC. Therefore, we choose more comprehensive indicators to construct the index system of TCC, measure the TCC of key tourism regions, and further use the coupling coordination degree model to measure the coordination relationship between the HSR network and TCC. The purpose of this paper is to evaluate the development level of TCC of key tourism areas, the coupling coordination relationship between the structure of HSR network and its TCC, in order to provide theoretical guidance and support for the coordinated development of regional HSR network and tourism, which can further clarify the shortcomings of regional TCC, and provide theoretical support for the healthy development of tourism and rapid development of HSR network worldwide.

The rest of the paper is arranged as follows. Section II reviews relevant literature. Section III describes the data and methodology of the paper. Section IV describes and discusses the results. Section V gives a conclusion and suggestions.

II. LITERATURE REVIEW

A. INFLUENCING FACTORS AND INDEX SYSTEM OF TCC

Generally speaking, TCC mainly includes the carrying capacity of tourism economic facilities (EFC), the carrying capacity of tourism social culture (SCC) and the carrying capacity of tourism's ecological environment [8], [9], [10]. The main factors involved are economic (infrastructure, economic pressure, social development, etc.), social (social harmony, cultural atmosphere, residents' psychology, etc.) and ecological (environmental quality, natural resources, etc.) [3], [11]. Different tourism regions have different tourism resource endowments, and the main factors affecting the TCC also differ. When studying the TCC of tourism areas, traditionally, the main influencing factors are selected and relevant indicators are refined according to the resource endowment characteristics of the tourism area. For tourism areas with superior geographical locations or good economic development, the selection of the influencing factors will focus on economic and ecological factors. For example, when studying the TCC of Shichahai Scenic Spot in Beijing, indexes such as reception capacity and transportation capacity are selected to characterize the EFC, and indexes such as water environment, atmospheric environment and solid waste discharge treatment are selected to characterize the ECC [12]. For tourism areas in remote locations, a lack of advantages in terms of geographical location or poor economic development, the selection of influencing factors will often focus on the economic. For example, the Ningxia Shapotou scenic area is geographically remote and there is a limited level of economic development in the tourism region. As a typical desert scenic area, its index selection will focus on economic and environmental carrying capacity indicators. Song et al. selected indicators such as total GDP, total tourism revenue, the carrying capacity of transportation facilities and catering facilities to characterize its economic carrying capacity [13]. For some tourism areas with strong ethnic customs and superior natural conditions, the selection of influencing factors will often focus on ecological and social factors. For example, when studying the TCC of Jokhang Temple, a tourist attraction on the Tibetan Plateau, previous research has paid more attention to the typical characteristics of Tibet and focused on SCC and ECC. Indicators such as tourist psychological carrying capacity and social cultural carrying capacity have been selected to characterize the SCC, while water compliance rate and ambient air quality have been selected to characterize the ECC [14]. In addition, in a study of the TCC of the Yarlung Zangbo Grand Canyon Nature Reserve Murdoch area, due to the strong ethnic culture and unique natural conditions of Murdoch, the population concentration ratio and residents' aversion to tourism were selected to characterize the social environment, while the oxygen content of the water and the forest coverage rate were selected to characterize the ecological environment [15].

When constructing the evaluation index system of TCC, scholars tend to select a small but representative number of indicators from multi-dimensional influencing factors and use a lot of methods such as hierarchical process analysis [16] to construct the index system. For example, when analyzing the TCC of Namco Scenic Spot in Tibet, Li [17] selected indicators such as vegetation coverage rate, per capita land resource area and landscape beauty to represent its ecological dimension, and indicators such as the ratio of tourists to residents, cultural diversity and visiting methods to represent its social dimension. Indicators such as the reception capacity of tourism service facilities, accommodation reception capacity, and sewage and garbage treatment capacity were selected to characterize its economic dimension. Then, the index system of the TCC of the tourism area was constructed from those indicators. The study found that the level of economic facilities in the region seriously restricted the long-term development of the local tourism industry, and that it was imperative to improve the level of local economic development. Wang et al. [18] constructed a TCC index system for Diaoshuihu National Forest Park from four perspectives: the natural environment, resource environment, economic environment and social environment. Its indicators of the ecological natural environment were mostly related to air quality and waste treatment. The indicators of the ecological resource environment were mostly related to the carrying capacity of the area and park route. The economic environment indicators were mostly related to the supply of tourism services, and the social environment indicators were related to the psychological carrying capacity of tourists and the local residents. The results showed that the Diaoshuihu National Forest Park had a strong TCC. In addition, studies on issues related to TCC also reflect domestic and foreign scholars' recognition of tourism's social responsibility [19].

In addition, the factors influencing TCC vary from one tourism city to another depending on geographical location, culture, resources and economic conditions. The influencing factors in terms of geographical location include topographic features (such as coastal cities, desert cities) [20], [21], [22], etc. Cultural factors include indicators in terms of the construction status of local colleges and universities, the development status of cultural and art institutions [20], etc. Resource factors include tourism resources [22], ecological resources [21], etc. Economic factors include the construction status of urban infrastructure, tourism service facilities [20], [21], [22], etc. For example, it was found in one study that the TCC of Qinhuangdao city was mainly affected by the three dimensions of the natural environment, the economic environment and the social environment. Its natural environment was affected by the quality of the ecological environment and tourism resources. The economic environment was affected by the infrastructure conditions, tourism service facilities and other factors. The social environment was affected by harmony, cultural atmosphere, the scientific and technological medical environment and other factors. The results of the study indicated that enhancing the TCC of Qinhuangdao would require the strengthening of the management of its tourism environment system and the coordination of the development of tourist flows in the low and high seasons of tourism [20]. The TCC of Pingdingshan was found to be affected by resources, ecology, psychology, economy, and other dimensions. By measuring the carrying capacity values of each dimension, it was concluded that Pingdingshan's ECC seriously restricted the development of local tourism. The government would need to strengthen resource protection and develop scientific management measures to guarantee the long-term development of the tourism industry in Pingdingshan [21]. In another study, the TCC of Gansu Province was found to be affected by the three dimensions of the ecological environment, the economic environment and the social environment. The ecological environment dimension was characterized by tourism resource quality and ecological environment quality, the economic environment dimension was characterized by infrastructure status and tourism service facilities, and the social environment was characterized by harmonious conditions, cultural atmosphere and scientific technological security. The results indicated that the province's TCC potential showed an increasing trend year by year [22].

B. IMPACT OF CONSTRUCTION OF HSR FACILITIES ON REGIONAL TOURISM

The construction of urban HSR facilities has a universal influence on the development of regional tourism and changes in regional tourism spatial patterns [23], [24], [25]. These influences may be positive and promoting, but also negative and restrictive.

From the perspective of regional tourism development, on the one hand, the rapid development of the HSR network improves inter-city accessibility, activates and directs the population flow in tourism areas, and promotes the overall rapid development of regional tourism. Studies have found that HSR can significantly improve the total tourism economy of urban regions [5]. For example, Deng et al. [26] pointed out that, for cities along the HSR, a 1% increase in urban accessibility caused by the opening of the HSR would increase the passenger flow of the city by 1.02%, and also confirmed that the construction of the HSR in the Yangtze River Delta had had a promoting effect on the development of regional tourism there. Another study found that the cities of Beijing, Guangzhou, Wuhan, Zhengzhou, Changsha, Shenzhen and Foshan, all of which had a good tourism base, had experienced better tourism development under the influence of the opening of the Beijing-Guangzhou HSR, showing a positive polarization effect. Taking Beijing as an example, its tourism resources endowment and tourist reception ability gave it the absolute advantage. After the opening of the Beijing-Guangzhou HSR, the development of Beijing's tourism industry showed a more vigorous trend [6]. On the other hand, the opening or rapid development of the HSR will not always have a positive effect on the development of tourism in all regions, and may even inhibit it in certain circumstances. Another study found that, after the opening of the inter-city HSR between Nanjing and Hangzhou, the tourism competitiveness of Nanjing in the Yangtze River Delta urban agglomeration did not increase significantly. In the case without the HSR between Nanjing and Hangzhou, the urban tourism competitiveness of Nanjing ranked third, while in the case with the HSR between Nanjing and Hangzhou, its tourism competitiveness ranking did not change [27]. In addition, Wang et al. [7] found that the opening of HSR restricted the tourism development of non-tourist cities along the route, and might even lead to the contraction of their tourism markets.

The influence of HSR on the spatial pattern change of urban regional tourism is also bidirectional. For example, Zhao and Cao [28] analyzed the influence of the HSR network on the tourism pattern of Guilin from two perspectives, before and after the opening of the HSR. The research results showed that the opening of the HSR had greatly improved the accessibility of Guilin to tourists, and the tourism pattern of Guilin had changed from the previous point-like structure to a chain pattern, with the scale of tourism constantly expanding. However, Mu et al. [29] took the pattern of tourism traffic as the starting point and studied the accessibility level of tourism traffic based on the background of the HSR network in 13 prefecture-level cities in Anhui Province. The results showed that the tourism development pattern of Anhui Province was uneven, and the accessibility level for tourism traffic differed between cities due to the influence of the HSR network. The accessibility level for tourism traffic was higher in the central and southern regions than in the northern regions. For example, the five cities of Hefei, Wuhu, Tongling, Chizhou and Huainan showed a higher tourism traffic accessibility level than intra-regional accessibility level, and were the first-ranked cities; meanwhile, Suizhou, Maanshan, Huangshan, Chuzhou and Huabei had a lower tourism traffic accessibility level than intra-regional accessibility level, and were third-ranked cities. In addition, Du et al. [30] took Chongqing as the research area to explore the influence of the HSR network on the tourism spatial structure. The research results showed that, after the Chengdu-Chongqing HSR was opened, Chongqing, as the core tourism city at the end point of the HSR, had increased its attraction index by 50.38, and the tourism attraction of Chongqing's was greatly enhanced. On the other hand, the railway also intensified Chongqing's tourism reception pressure and environment bearing pressure.

Although the previous research on the factors that influence TCC and its index measurement has achieved rich research results, there are still a series of problems to be solved and reflected upon. Firstly, when selecting relevant indicators for TCC, most previous studies only select a small number of representative indicators. Too few indicators will lead to incomplete relevant information, which may lead to bias in the measurement of the TCC index. Secondly, in terms of TCC measurement, few studies have explored and compared the TCC and its spatial distribution in each key tourism area in China. Thirdly, the rapid development of China's HSR network has had a profound impact on the tourism of various provinces and cities, but few studies have analyzed the coupling coordination relationship between China's HSR network and the TCC of key tourism areas. This study calculates and compares the TCC of each key tourism area in China, and analyzes and evaluates the coupling coordination relationship between the HSR network and TCC in each region. Based on the findings of this paper, we propose guiding recommendations for different tourism areas to promote the healthy and sustainable development of local tourism.

III. DATA AND METHONDS

A. STUDY AREA

This paper takes mainland China as the research area (excluding Hong Kong, Macao, Taiwan and Tibet), and focuses on studying all national 5A-level scenic spots in the key tourist areas of 30 provinces and cities in China, as shown in Appendix Table 4. The specific method used in this paper is shown in Figure 1.

B. EVALUATION INDEX SYSTEM OF TCC

The TCC of a tourist area needs to maintain the balanced development of the economy, social culture and ecology of

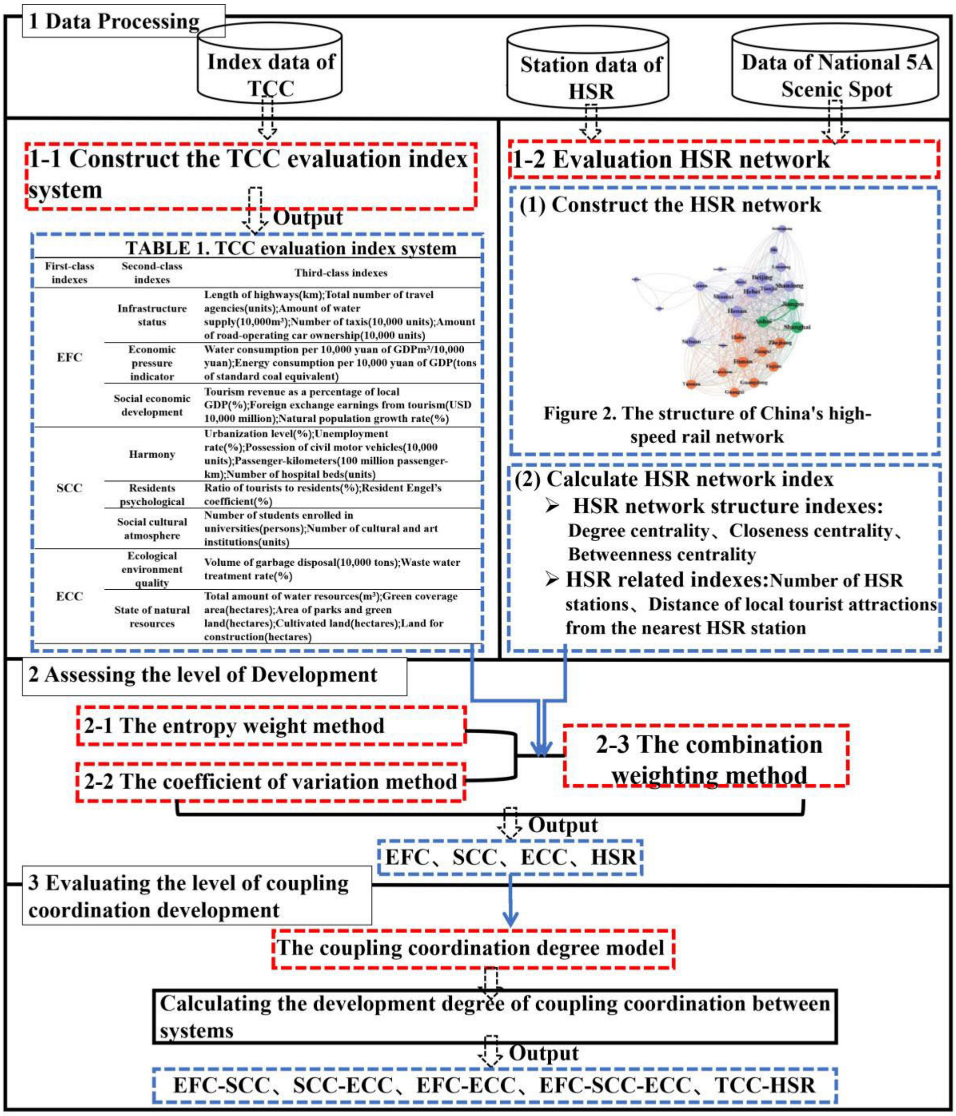

FIGURE 1. The framework of research method.

the region. Referring to previous studies [3], [11], [31], [32], this study measures the TCC of each region based on the three aspects mentioned earlier: economic facilities capacity (EFC), social culture capacity (SCC) and ecological carrying capacity [8]. Referring to the existing research on TCC at home and abroad, according to the principles of a systematic, comprehensive, scientific and operable construction of the index system, three second-class indexes and ten third-class indexes are selected to characterize the EFC, three second-class indexes and nine third-class indexes for the SCC, and two second-class and seven third-class indexes to characterize the ECC. These are used to construct the evaluation index system of the TCC, as shown in Table 1.

C. EVALUATION INDEX SYSTEM AND DATA SOURCES FOR HSR NETWORK STRUCTURE IN TOURIST AREAS

This study focuses on exploring the coupling coordination relationship between the HSR network and TCC in key tourism areas of 30 provinces and cities. We explore the potential impact of China's HSR line construction on the tourism development in various regions in China, and then make policy recommendations. The indexes used for the HSR network structure mainly consider the degree centrality, closeness centrality and betweenness centrality, number of HSR stations and the distance of local tourist attractions from the nearest HSR station [33]. The degree centrality of the HSR network reflects the direct connectivity of a province or city (a larger value indicates a more direct route), the closeness centrality reflects the ease of reaching the region from other provinces or cities (a smaller value indicates a lower average number of interchanges and easier access), and the betweenness centrality reflects the transit and hub position of a province or city within the whole HSR network. The number of HSR stations in a province or city reflects the traffic capacity of that province or city. The distance of a local tourist attraction from the nearest HSR station reflects the

TABLE 1. TCC evaluation index system.

First-class indexes	Second-class indexes	Third-class indexes
EFC	Infrastructure status	Length of highways (km); Total number of travel agencies (units); Amount of water supply (10,000 m^3); Number of taxis (10,000 units); Amount of road-operating car ownership (10,000 units)
	Economic pressure indicator	Water consumption per 10,000 yuan of GDP (m^3/10,000 yuan); Energy consumption per 10,000 yuan of GDP (tons of standard coal equivalent)
	Social economic development	Tourism revenue as a percentage of local GDP (%); Foreign exchange earnings from tourism (USD 10,000 million); Natural population growth rate (%)
SCC	Harmony	Urbanization level (%); Unemployment rate (%); Possession of civil motor vehicles (10,000 units); Passenger-kilometers (100 million passenger-km); Number of hospital beds (units)
	Residents psychological	Ratio of tourists to residents (%); Resident Engel's coefficient (%)
	Social cultural atmosphere	Number of students enrolled in universities (persons); Number of cultural and art institutions (units)
ECC	Ecological environment quality	Volume of garbage disposal (10,000 tons); Waste water treatment rate (%)
	State of natural resources	Total amount of water resources (m^3); Green coverage area (hectares); Area of parks and green land (hectares); Cultivated land (hectares); Land for construction (hectares)

HSR accessibility of that attraction. The above HSR network index data is obtained from http://www.huochepiao.com/.

When building the HSR network, taking into account the temporary lack of construction of HSR stations in Ningxia and the special geographical location of Hainan (the island cannot be connected to the HSR network of other provinces and cities), these two provinces are not considered. Each province or city is considered as a node of the network, and the lines that operate (direct non-interchanges) between HSR stations are considered edges in constructing the HSR network of China. Based on the above network modeling process, an HSR network diagram with 28 nodes and 459 edges is obtained, as shown in Figure 2.

As mentioned above, in addition to the number of HSR stations in a province or city and the distance from the local tourist attraction to the nearest HSR station, this study uses the three network measures of degree centrality DC_a, closeness centrality CC_a and betweenness centrality BC_a as indexes of the HSR network structure, which are measured as follows:

$$DC(a) = \frac{k(a)}{N-1}$$
$$CC(a) = \frac{N-1}{\sum_{b=1}^{N} d_{ab}}, BC(a) = \sum_{b<k} \frac{g_{bk}(a)}{g_{bk}} \quad (1)$$

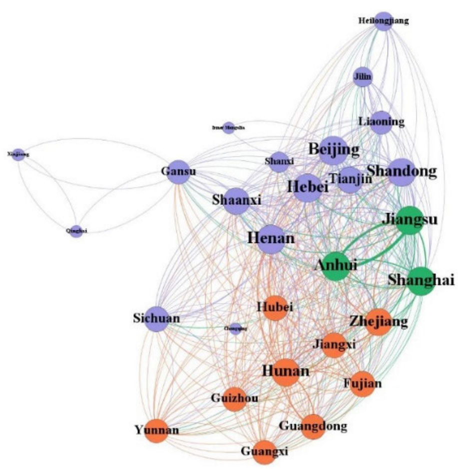

FIGURE 2. The structure of China's high-speed rail network.

where $k(a)$ represents the degree of node a, i.e., the number of other provinces and cities that have direct HSR lines linking them to a; N is the total number of nodes (i.e. provinces and cities) in the network, $N = 28$; d_{ab} represents the network distance from a to b, i.e., the number of interchanges that need to be made when traveling from a to b; g_{bk} denotes the total number of shortest paths that exist between b and k (total number of direct HSR lines); $g_{bk}(a)$ denotes the number of shortest paths from node b to node k that need to pass through node a.

D. COUPLING COORDINATION DEGREE MODEL OF HSR NETWORK AND TCC

1) INDEX WEIGHT CALCULATION BASED ON THE COMBINATION WEIGHTING METHOD

Next, the combination weighting method (the entropy weight method [34] and the coefficient of variation method [35] is used to measure the index weights and comprehensive evaluation scores of the TCC and HSR network of the tourism areas. The combination weighting method gives full play to the advantages of the entropy weight method and the coefficient of variation method, effectively avoiding the errors that can be caused by the subjective judgment of the researcher. Its specific measurement steps are as follows. Firstly, the entropy weight method is used to measure the index weights of the TCC and HSR network. Secondly, the coefficient of variation method is used to measure the index weights of the TCC and HSR network. Finally, based on the above two steps, the combination weighting method is applied to obtain the combined weights, determine the final index weights and calculate the comprehensive evaluation score of each index. The combination weighting method combines the advantages of the entropy weight method and the coefficient of variation method to improve the accuracy of the index weights and make them more scientific and reasonable.

a: CALCULATING THE INDEX WEIGHTS OF THE TCC AND HSR NETWORK BY THE ENTROPY WEIGHT METHOD

As a completely objective evaluation method, the entropy weight method can effectively avoid scoring bias due to the subjective judgment of the researcher. It uses information entropy to calculate the entropy value of each index based on the difference between the information of each index, and finally obtains the index weights.

Step 1 Data Standardization: In order to eliminate the differences in units and orders of magnitude among the different indexes, we firstly standardize the original data. The specific method is as follows [36]:

Positive indicator:

$$Y'_{ij} = \frac{X_{ij} - \min X_{ij}}{\max X_{ij} - \min X_{ij}} \tag{2}$$

Negative indicator:

$$Y''_{ij} = \frac{\max X_{ij} - X_{ij}}{\max X_{ij} - \min X_{ij}} \tag{3}$$

where Y'_{ij} and Y''_{ij} represent the standardized value of the index j for province or city $i\,(i = 1, 2, \ldots 30)$ (when standardizing the indexes of the EFC, $j = 1, 2 \ldots 10$; when standardizing the indexes of the ECC, $j = 1, 2 \ldots 9$; when standardizing the indexes of the SCC, $j = 1, 2 \ldots 7$; when standardizing the indexes of the HSR network, $j = 1, 2 \ldots 5$).

Step 2 Calculate the Information Entropy and the Weight of Each Index: We measure the information entropy e_j and the weight A_j of the index j as follows [37]:

$$P_{ij} = Y_{ij} / \sum_{i=1}^{30} Y_{ij},$$
$$e_j = -\frac{1}{\ln 30} \sum_{i=1}^{30} P_{ij} \times \ln P_{ij} (0 \le e \le 1)$$
$$A_j = (1 - e_j) / \sum_{j=1}^{K} (1 - e_j) \tag{4}$$

where P_{ij} is the proportion made up by index j for province/city $i\,(i = 1, 2, \ldots 30)$ out of the total of index j for all provinces and cities (when evaluating the indexes of the TCC, $j = 1, 2 \ldots 26$; when evaluating the indexes of the HSR network, j=1,2 . . . 5). K represents the number of indexes of the three classes of TCC (for the weights of the indexes of the EFC, $K = 10$; for the weights of the indexes of the ECC, $K = 9$; for the weights of the indexes of the SCC, $K = 7$; for the weights of the indexes of the HSR network, $K = 5$).

b: CALCULATING THE WEIGHTS OF THE TCC INDEXES AND THE HSR NETWORK INDEXES BASED ON THE COEFFICIENT OF VARIATION METHOD

In order to avoid a situation in which the final evaluation results (the comprehensive evaluation scores of the TCC and HSR network in each province and city) are too different due to the use of a single method of index weight calculation, the coefficient of variation method is introduced to make the weighting result more objective and reasonable. First, we calculate the coefficient of variation (the ratio of the mean and the standard deviation), and then directly use it to calculate the weight of the index. Suppose that, for the dimensionless data matrix after the standardized processing, $V = (x_{ij})_{m \times n}$, m represents the number of evaluation samples, namely, the number of provinces and cities, and n represents the number of indexes. The measurement steps are as follows [35]:

Step 1: Calculate the mean value and standard deviation of each column vector:

$$\overline{Y_j} = \frac{1}{m} \sum_{i=1}^{m} Y_{ij} s_j = \sqrt{\frac{1}{m} \sum_{i=1}^{m} (Y_{ij} - \overline{Y_j})^2}$$

Step 2: Calculate the coefficient of variation based on the standard deviation and the mean value:

$$v_j = \frac{s_j}{\left|\overline{Y_j}\right|}$$

Step 3: Normalize the coefficient of variation to calculate the weight:

$$w_j = \frac{v_j}{\sum_{j=1}^{m} v_j}$$

c: CALCULATING THE COMBINED WEIGHTS AND COMPREHENSIVE SCORES OF THE TCC AND HSR NETWORK BY THE COMBINATION WEIGHTING METHOD

The comprehensive scores of the EFC, SCC, ECC, TCC and HSR network of the 30 provinces and cities in China are calculated as follows:

$$F_i = \sum_{j=1}^{10} \hat{w}_j \times Y_{ij},\ S_i = \sum_{j=1}^{9} \hat{w}_j \times Y_{ij},\ E_i = \sum_{j=1}^{7} \hat{w}_j \times Y_{ij}$$
$$TCC_i = \sum_{j=1}^{26} \hat{w}_j \times Y_{ij},\ H_i = \sum_{j=1}^{5} \hat{w}_j \times Y_{ij}$$
$$\hat{w}_j = \lambda A_j + (1-\lambda) w_j \tag{5}$$

where $\hat{w}_j$ represents the combined weight, and λ is the preference coefficient, $\lambda \in (0,1)$

2) COUPLING COORDINATION DEGREE MODEL

The coupling coordination degree reflects the degree of coordination development between systems [36]. A high degree of coupling coordination indicates that there is a state of coordinated development among the systems, which could be reflected in mutual promotion of the EFC, SCC, ECC and HSR network. A low coupling coordination degree indicates uncoordinated development among the systems, in this case unbalanced development of the EFC, SCC, ECC and HSR network. Based on the coupling coordination model, firstly, this study measures the coupling coordination degree among the EFC, SCC and ECC (i.e., EFC-SCC-ECC) in the provinces and cities, to clarify the internal coordination of the development of the TCC. Next, the coupling coordination degree between the TCC and the HSR network in each tourist area is measured. The specific measurement steps are as follows:

Step 1: Calculate the coupling degree $C_i^{F-S-E} (i = 1, 2, \ldots 30)$ among the EFC, SCC and ECC, and the coupling degree C_i^{TCC-H} $(i = 1, 2 \ldots 30)$ between the TCC and HSR network, in province/city i. The measurement steps are as follows [40]:

$$C_i^{F-S-E} = \left\{ \frac{F_i \times S_i \times E_i}{[(F_i + S_i + E_i)/3]^3} \right\}^{1/3}$$
$$C_i^{TCC-H} = \left\{ \frac{TCC_i \times H_i}{[(TCC_i + H_i)/2]^2} \right\}^{1/2} \tag{6}$$

Next, we calculate C_i^{F-S}, C_i^{F-E} and C_i^{E-S}, which represent the coupling degrees between EFC and SCC, EFC and ECC, and SCC and ECC respectively:

$$C_i^{F-S} = \left\{ \frac{F_i \times S_i}{[(F_i + S_i)/2]^2} \right\}^{1/2}$$
$$C_i^{F-E} = \left\{ \frac{F_i \times E_i}{[(F_i + E_i)/2]^2} \right\}^{1/2}$$
$$C_i^{S-E} = \left\{ \frac{S_i \times E_i}{[(S_i + E_i)/2]^2} \right\}^{1/2} \tag{7}$$

Step 2: Calculate the coupling coordination degree D_i^{F-S-E} among EFC, SCC and ECC, as follows [40]:

$$D_i^{F-S-E} = \sqrt{C_i^{F-S-E} \times T_i^{F-S-E}} \tag{8}$$

where T_i is the comprehensive evaluation index of the three subsystems of TCC in province or city i. $T_i^{F-S-E} = \alpha F_i + \beta S_i + \varphi E_i$. α, β, φ represent undetermined coefficients, with $\alpha + \beta + \phi = 1$, and by referring to relevant studies [41], [42], we set $\alpha = 0.3$, $\beta = 0.3$ and $\phi = 0.4$.

Next, the coupling coordination degrees between EFC and SCC, EFC and ECC, SCC and ECC, and TCC and the HSR network are calculated as follows:

$$D_i^{F-S} = \sqrt{C_i^{F-S} \times T_i^{F-S}}$$
$$D_i^{F-E} = \sqrt{C_i^{F-E} \times T_i^{F-E}}$$
$$D_i^{S-E} = \sqrt{C_i^{S-E} \times T_i^{S-E}}$$
$$D_i^{TCC-H} = \sqrt{C_i^{TCC-H} \times T_i^{TCC-H}} \tag{9}$$

where D_i^{F-S} is the coupling coordination degree between EFC and SCC, with $T_i^{F-S} = \alpha F_i + \beta S_i$, $\alpha = 0.5$ and $\beta = 0.5$; D_i^{F-E} is the coupling coordination degree between EFC and ECC, with $T_i^{F-E} = \alpha F_i + \phi E_i$, $\alpha = 0.4$ and $\phi = 0.6$; D_i^{S-E} is the coupling coordination degree between SCC and ECC, with $T_i^{S-E} = \beta S_i + \phi E_i$, $\beta = 0.4$ and $\phi = 0.6$; D_i^{TCC-H} is the coupling coordination degree between TCC and the HSR network structure, with $T_i^{TCC-H} = \mu TCC_i + \phi H_i$, $\mu = 0.5$ and $\varphi = 0.5$.

Based on different ranges of coupling coordination degree, the classification of the balance in the development is shown in Table 2 below [43].

IV. RESULTS

A. ANALYSIS OF SPATIO-TEMPORAL DYNAMIC EVOLUTION OF TCC IN CHINA

1) COMPREHENSIVE EVALUATION AND ANALYSIS OF TCC

Formulas (2) ∼ (5) were used to calculate the comprehensive evaluation scores of the TCC and the three first-class indexes of the TCC (EFC, SCC and ECC) for 30 provinces and cities in China, from 2008 to 2017. The results are shown in Figure 3

On the whole, the level of TCC in the provinces and cities in China shows an upward trend from 2008 to 2017. The average annual TCC increased from 0.3496 in 2008 to 0.3941 in 2017, an increase of 12.7%. To some extent, the above results show that the tourism development policies implemented by the local governments have promoted the development of tourism, reflected in a gradual improvement of infrastructure such as transportation, accommodation and travel agencies, an increased richness of tourism resources and the gradual improvement of TCC. It can be seen from Figure 3 that the SCC has played the largest role in the growth of TCC. From 2008 to 2017, China's SCC increased significantly, with an average annual growth rate of 2.542%, which is an

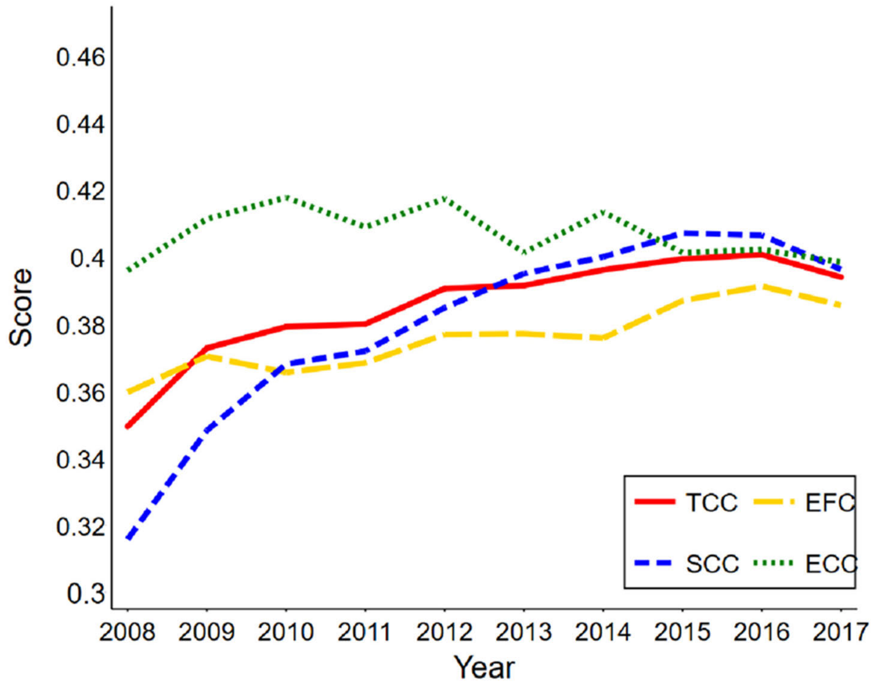

FIGURE 3. Evolution of TCC, ECC, EFC and SCC for 30 provinces and cities in China.

TABLE 2. Classification based on coupling coordination degree.

D	Classification
$0.8 < D \leq 1.0$	Superiorly balanced development
$0.6 < D \leq 0.8$	Favorably balanced development
$0.5 < D \leq 0.6$	Barely balanced development
$0.4 < D \leq 0.5$	Slightly imbalanced development
$0.2 < D \leq 0.4$	Moderately imbalanced development
$0.0 \leq D \leq 0.2$	Seriously imbalanced development

important reason for the improvement in China's TCC. The development of the SCC was mainly due to the change in the unemployment rate, the possession of civil motor vehicles, the number of college students and the number of cultural and art institutions. This also shows that the improvement of residents' living standards and the development of cultural and educational undertakings promote the improvement of TCC.

Looking at the scores for the three first-class indicators of TCC, before 2010, China's ECC was relatively high, while the EFC and SCC were relatively low. During this period, China's TCC was mainly limited by the social and cultural aspects. Since 2011, on the one hand, the level of SCC has been significantly improved, promoting the development of China's tourism industry; on the other hand, the EFC has been overtaken by the SCC, and is now an important factor restricting the development of China's tourism. In fact, China's TCC has been continuously limited by the EFC in recent years, implying that increasing the construction of infrastructure such as transportation and travel agencies will be conducive to the further development of tourism in various regions.

It is worth mentioning that, although China's ECC has always been at a high level, with the improvement of the EFC and SCC, the ecological advantage of the TCC has begun to weaken. The ECC began to decline in 2014, and especially since 2015 has tended to be lower than the SCC. Facing the decline of the ECC, the government should give full attention to it. While developing tourism, all regions should pay attention to ecological issues such as environmental governance and resource protection, so as to ensure the sustainable development of China's tourism industry.

2) ANALYSIS OF SPATIO-TEMPORAL CHANGES IN TCC

In order to reflect the spatial differentiation characteristics of TCC in China's key tourist areas, we calculated the TCC scores and their average annual growth rates for 30 provinces and cities in China from 2008 to 2017 and constructed a comprehensive development-level matrix diagram of TCC, as shown in Figure 4.

From 2008 to 2017, the average TCC of the provinces and cities in China was 0.38. Guangdong, Shandong, Zhejiang,

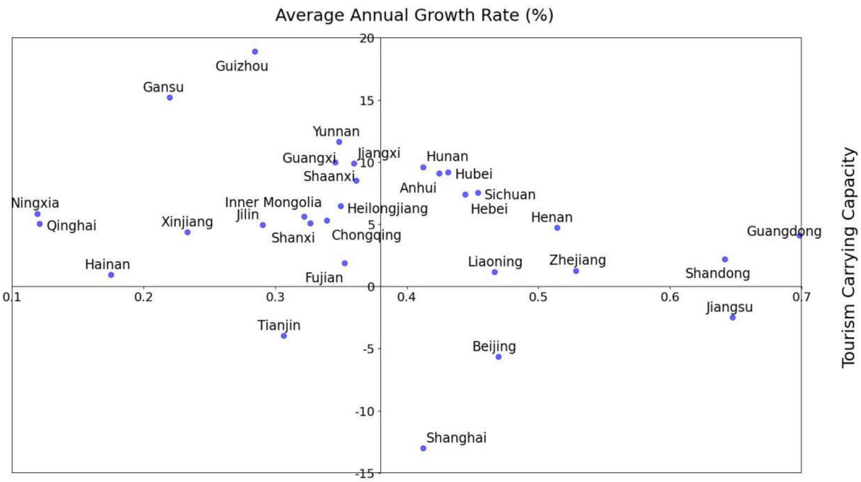

FIGURE 4. Matrix diagram of TCC for provinces and cities in China from 2008 to 2017.

Henan, Liaoning, Sichuan, Hebei, Hubei, Anhui and Hunan are located in the first quadrant, with TCCs higher than the average, and average annual growth rates of their TCCs greater than zero. Among these provinces and cities, Hunan had the highest TCC growth rate, mainly because its EFC, SCC and ECC all showed upward trends from 2008 to 2017. Guangdong and Shandong rank high for TCC, but their TCC growth rates were relatively small. The small growth rate in the TCC of Guangdong was mainly related to a decline in EFC, which in turn was mainly due to a decrease in the number of vehicles in operation on the roads and an increase in the natural population growth rate. The small growth rate in the TCC of Shandong was mainly related to a decline in ECC from 2008 to 2017, mainly due to a decrease in total water resources. Therefore, in order to further improve the level of TCC, Guangdong needs to stop the decline in EFC and Shandong needs to stop the decline in ECC.

Shaanxi, Jiangxi, Fujian, Heilongjiang, Yunnan, Guangxi, Chongqing, Shanxi, Inner Mongolia, Jilin, Guizhou, Xinjiang, Gansu, Hainan, Qinghai and Ningxia are located in the second quadrant, with the average annual growth rates of their TCCs greater than zero, but with TCCs lower than the average. Among these provinces and cities, Guizhou and Gansu had relatively high average annual TCC growth rates (18.9% and 15.2% respectively), while Fujian and Hainan had relatively low annual growth rates. The increases in TCC in Guizhou and Gansu were mainly due to increases in SCC, of 22.1% in Guizhou and 37.7% in Gansu, from 2008 to 2017. Hainan's TCC and its growth rate were both small, mainly because Hainan's economic investment in tourism was insufficient, the supporting infrastructure not ideal, and its EFC, SCC and ECC relatively low. The TCCs of Ningxia and Qinghai occupied the last two places in the ranking throughout the period, and the growth rates in their TCCs were 5.86% and 5.05% respectively. From 2008 to 2017, the EFC and SCC in Ningxia and Qinghai increased, but their ECCs showed a downward trend, indicating that Ningxia and Qinghai should pay more attention to the governance of the ecological environment and the protection of ecological resources.

Tianjin is located in the third quadrant, with its TCC lower than average and the average annual growth rate in its TCC less than zero. This is mainly because Tianjin's ECC decreased from 2008 to 2017, which was mainly related to a decrease in the disposal rate of domestic garbage, and an increase in construction land area. Tianjin can improve its TCC by improving the relevant indicators.

Jiangsu, Beijing and Shanghai are located in the fourth quadrant, with TCCs higher than average but the average annual growth rates in their TCCs less than zero. Jiangsu's TCC ranks second among the 30 provinces and cities, but its average annual growth rate was less than zero, and its TCC shows a downward trend. From 2008 to 2017, the EFC, SCC and ECC in Jiangsu all decreased, with ECC decreasing the most (10.04%). Therefore, although the level of TCC in Jiangsu has been high, the development of its TCC does not give cause for optimism. The relevant departments should take measures to prevent the further decline of Jiangsu's TCC. The TCCs of Beijing and Shanghai also show a declining trend, mainly because these cities have huge numbers of tourists and high-density residential populations, putting a heavy burden on ECC. Ecological resources have become scarce, restricting the development of TCC in these cities.

B. ANALYSIS OF SPATIO-TEMPORAL CHANGES IN EFC-SCC-ECC

In order to reflect the spatial distribution characteristics and changes in EFC-SCC-ECC in China's key tourist areas, we calculated the EFC-SCC-ECC and its average annual growth rate in 30 provinces and cities in China from 2008 to 2017 and constructed the comprehensive development-level matrix diagram, as shown in Figure 5.

From 2008 to 2017, the average EFC-SCC-ECC for provinces and cities in China was 0.605. Guangdong, Shandong, Henan, Sichuan, Liaoning, Hebei, Anhui, Hubei, Hunan and Jiangxi are located in the first quadrant of the

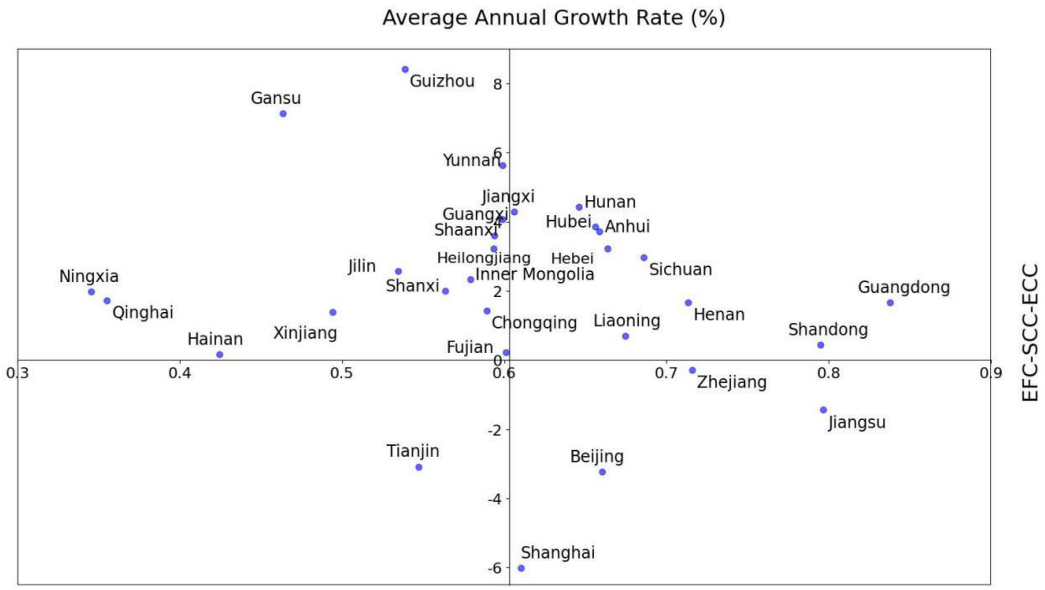

FIGURE 5. Matrix diagram of the EFC-SCC-ECC for provinces and cities in China from 2008 to 2017.

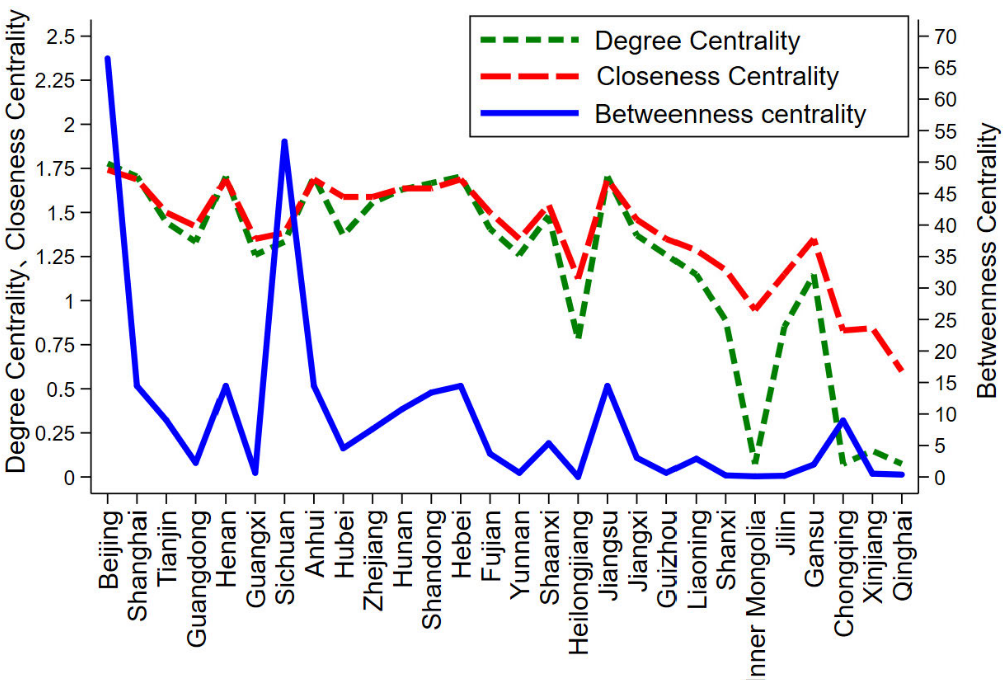

FIGURE 6. Characteristics of HSR network in 28 provinces and cities in China.

matrix, their EFC-SCC-ECC being higher than average, and its average annual growth rate greater than zero. Among them, Hunan ranked first in terms of the average annual growth rate of the EFC-SCC-ECC, while its EFC-SCC, EFC-ECC and SCC-ECC all showed an upward trend. In Figure 4, Jiangxi was in the second quadrant, while in Figure 5, it is in the first quadrant, indicating that, although its TCC score is low at present, its EFC-SCC-ECC is high. The average annual growth rates of Jiangxi's TCC and EFC-SCC-ECC are both greater than zero. The coordinated development of EFC, SCC and ECC in Jiangxi has grown and grown, and its TCC developed steadily. Fujian, Yunnan, Guangxi, Shaanxi, Heilongjiang, Chongqing, Inner Mongolia, Shanxi, Guizhou, Jilin, Xinjiang, Gansu, Hainan, Qinghai and Ningxia are located in the second quadrant, their average annual growth rates of EFC-SCC-ECC being greater than zero, while their EFC-SCC-ECCs are lower than average. The order of the growth rates of EFC-SCC-ECC from highest to lowest are as follows: Guizhou, Gansu, Yunnan, Guangxi, Shaanxi, Heilongjiang, Jilin, Inner Mongolia, Shanxi, Ningxia, Qinghai, Chongqing, Xinjiang, Fujian and Hainan. Tianjin is located in the third quadrant, with EFC-SCC-ECC lower than average, and an average annual growth rate of EFC-SCC-ECC less than zero. From 2008 to 2017, EFC-ECC and SCC-ECC in Tianjin show a decreasing trend, with the fall in ECC the main reason for this. Jiangsu, Zhejiang, Beijing and Shanghai are located in the fourth quadrant, with EFC-SCC-ECC higher than average, but average annual growth rate of EFC-SCC-ECC less than zero. Among them, the EFC-SCC-ECC of Shanghai was in the favorably balanced development stage in 2008 and 2011, and in the barely balanced development stage in 2014 and 2017, showing a decrease. The classification of the EFC-SCC-ECC of Jiangsu also decreased. The main reason for this was again the fall in ECC, which led to the decline of EFC-ECC and SCC-ECC, and in turn EFC-SCC-ECC.

In general, the provinces and cities with large growth rates of EFC-SCC-ECC also show large growth rates of TCC, such as Guizhou, Gansu, Hunan and Hubei. The provinces and cities with small growth rates of EFC-SCC-ECC also have small growth rates of TCC, such as Shanghai, Tianjin, Hainan, Fujian, Zhejiang and Shandong. This shows that the coordinated development of EFC, SCC and ECC is of great significance for promoting the improvement of local TCC.

C. ANALYSIS OF SPATIO-TEMPORAL DYNAMIC EVOLUTION OF THE TCC AND HSR NETWORK IN CHINA

1) ANALYSIS OF STRUCTURAL CHARACTERISTICS OF HSR NETWORK AND ITS DEVELOPMENT LEVEL

In complex network theory, the indexes used to describe the characteristics of a network structure mainly include the degree centrality, closeness centrality and betweenness centrality of the nodes. In this paper, these indicators of network structure are used to reveal the characteristics of the HSR network structure in China. According to the principle of network construction, these characteristic values of China's HSR network are shown in Figure 6.

In the HSR network, the higher the degree centrality of a network node, the more lines are connected to that node, and the more important it is. The higher the closeness centrality of a network node, the closer it is to the geometric center of the network, the closer it is to the other nodes in the network, and the more convenient travel to and from that node is. The greater the betweenness centrality of an HSR network node is, the more important the node is, because more shortest paths go through it, making it a necessary part of many HSR lines. As shown in Figure 6, the distribution trends of the degree centrality and closeness centrality of the HSR network nodes in the 28 provinces and cities in China are basically the same, which shows that the more HSR lines are connected to a node, the more convenient it is to reach other nodes in the network from that node. Beijing, Shanghai and Henan all rank high in degree centrality, closeness centrality and betweenness centrality, which shows that they are of high importance to China's HSR network, and have good HSR accessibility. The provinces and cities with the lowest node importance are Qinghai, Chongqing, Xinjiang and Inner Mongolia. These provinces and cities have relatively low degree centrality, closeness centrality and betweenness centrality, which shows that they have low HSR accessibility. In addition, we can see from Figure 6 that the betweenness centralities of Beijing and Sichuan are higher than those of other provinces and cities, showing that they have more HSR lines passing through them, and are highly important to the HSR network.

Then, we analyzed the impact of HSR on tourism by combining the number of HSR stations and the distance from national 5A-level scenic spots to the nearest HSR stations in the different provinces and cities. We used formulas (2∼5) to calculate the transport carrying capacity of the HSR network structure in the 28 provinces and cities in China in 2017. The calculation results are shown in Figure 7.

Beijing and Sichuan are the provinces with the highest scores in the HSR network. Among them, although Beijing has only three HSR and bullet train stations, its degree centrality, closeness centrality, betweenness centrality and distance from national 5A-level scenic spots to the nearest high-speed station all rank first. This shows that there are many HSR lines connected to Beijing in the HSR network structure. In Beijing, the distances to other nodes in the HSR network are also small, and the accessibility level of the HSR in Beijing is high. Moreover, its national 5A-level scenic spots have a high level of HSR accessibility, which is conducive to the development of the local tourism industry. Sichuan has 14 HSR and bullet train stations, ranking second for the number of stations, and its HSR infrastructure is more complete. Its betweenness centrality ranks second, indicating that there are many railway lines in the network passing through Sichuan, and its HSR accessibility level is high. The provinces and cities with the lowest HSR network scores are Inner Mongolia and Xinjiang. Inner Mongolia has five HSR and bullet train stations, and its national 5A-level scenic spots are the furthest away from the nearest HSR station, at 786.17 kilometers. The HSR accessibility level of its national 5A-level scenic spots is low. In addition, the HSR network in Inner Mongolia has a betweenness centrality of 0.1, a degree centrality of 0.07 and a closeness centrality of 0.95. The relatively low centrality index shows that there are not many HSR lines connected with Inner Mongolia, the distance from Inner Mongolia to other nodes in the network is large and its HSR accessibility level is low. There are only three HSR stations in Xinjiang, the distance between the national 5A-level scenic spots and the nearest HSR station is 712.65 kilometers, its degree centrality is 0.15, its closeness centrality is 0.84 and its betweenness centrality is 0.52. The HSR accessibility of Xinjiang and its national 5A-level scenic spots is poor.

2) ANALYSIS OF THE COUPLING COORDINATION RELATIONSHIP BETWEEN TCC AND THE HSR NETWORK

In order to reflect the spatial distribution characteristics of the coupling coordination relationship between TCC and the HSR network, formulas (6∼9) are used for the same

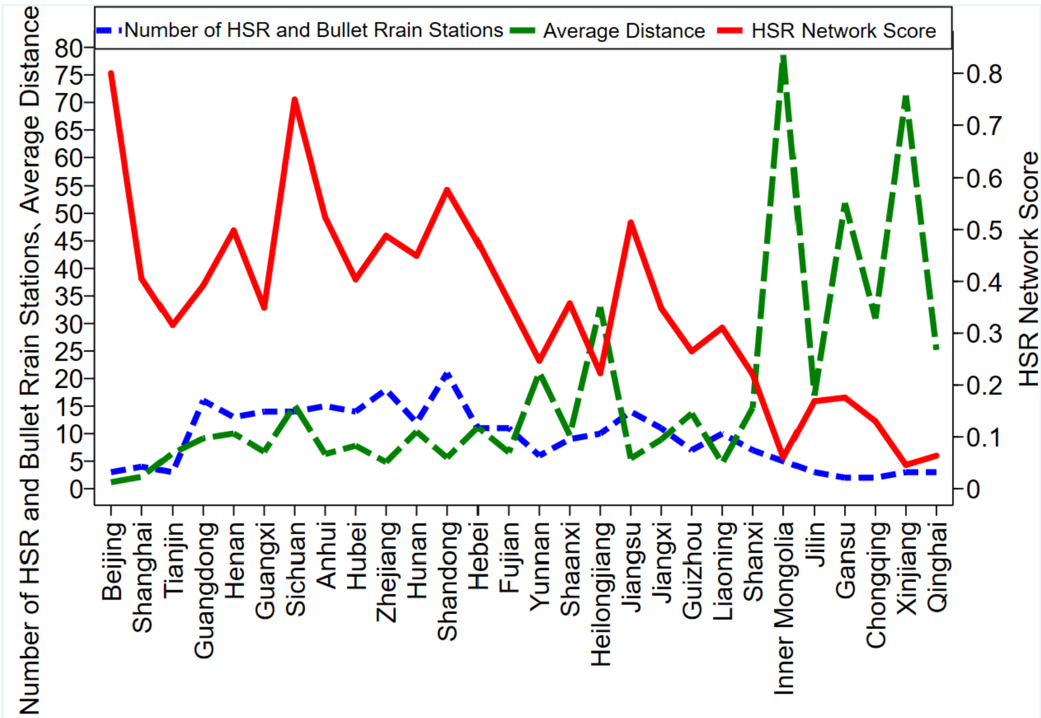

FIGURE 7. Scores of HSR network in 28 provinces and cities in china.

28 provinces and cities in China in 2017. The results are shown in Table 3.

Overall, except in Inner Mongolia, Xinjiang and Qinghai, the coupling coordination degree between TCC and the HSR network in the provinces and cities studied is in the coordination stage. The overall coupling coordination degree between the HSR network and TCC in China is relatively high, and their development is relatively balanced. The provinces and cities with a high degree of coupling coordination between TCC and the HSR network are Shandong, Sichuan and Beijing, which show favorably balanced development and score more than 0.75. The provinces and cities with a low coupling coordination degree are Inner Mongolia, Xinjiang and Qinghai, which show moderately imbalanced development. Inner Mongolia, Xinjiang and Qinghai have lower levels of HSR accessibility and HSR accessibility of their national 5A-level scenic spots. These factors have led to lagged development of their HSR networks, which is the main reason for the low degree of coupling coordination between TCC and the HSR network.

In addition, comparing the scores for TCC and the HSR network in 2017, we can find that, except in Beijing, Tianjin, Shanghai, Sichuan, Anhui and Fujian, whose HSR network scores are larger than their TCC scores, and where the coupling coordination degree between TCC and the HSR network shows a lagging TCC level, the HSR network scores in the provinces and cities are smaller than the TCC scores, and the coupling coordination degree between TCC and the HSR network shows lagging development of the HSR network. This shows that Beijing, Tianjin, Shanghai, Sichuan, Anhui and Fujian have a high level of HSR development, which can attract more tourists through the advantage of fast and comfortable HSR travel. On the one hand, the growth of the number of tourists can promote the development of local tourism, but on the other hand, it also brings challenges to the ecological environment, ecological resources, infrastructure and other aspects. Therefore, improving the TCC is the key to further developing tourism in these areas. For the provinces and cities whose score for the HSR network is significantly smaller than that of the TCC, on the other hand, the development level of the HSR is relatively low. Here, further development of the HSR would be conducive to tapping the potential of the local TCC and promoting the development of tourism in these locations.

3) COMPREHENSIVE ANALYSIS OF HSR NETWORK AND TCC

In order to reflect the comprehensive development level of the HSR network and TCC in China's key tourist areas, a matrix diagram of the HSR network and TCC is constructed based on the scores for the HSR network and TCC in the 28 provinces and cities in China in 2017, as shown in Figure 8.

Beijing, Guangdong, Henan, Sichuan, Anhui, Hubei, Zhejiang, Hunan, Shandong, Hebei and Jiangsu are located in the first quadrant, and their TCC and HSR network scores are all higher than the average level. Also looking at the information in Table 3, the coupling coordination degrees between TCC and the HSR network for these provinces are all located in the favorably balanced development stage, and their coordinated development levels are relatively high. Among them, the HSR network scores for Beijing, Sichuan

TABLE 3. The coupling coordination relationship between TCC and the HSR network in China's key tourist areas in the 28 provinces and cities in 2017.

Classification	Related provinces and cities
Favorably balanced development	Shandong, Sichuan, Beijing, Jiangsu, Guangdong, Henan, Zhejiang, Anhui, Hebei, Hunan, Hubei, Jiangxi, Guangxi, Liaoning, Shaanxi, Shanghai
Barely balanced development	Fujian, Yunnan, Guizhou, Tianjin, Heilongjiang, Shanxi
Slightly imbalanced development	Jilin, Gansu, Chongqing
Moderately imbalanced development	Inner Mongolia, Xinjiang, Qinghai

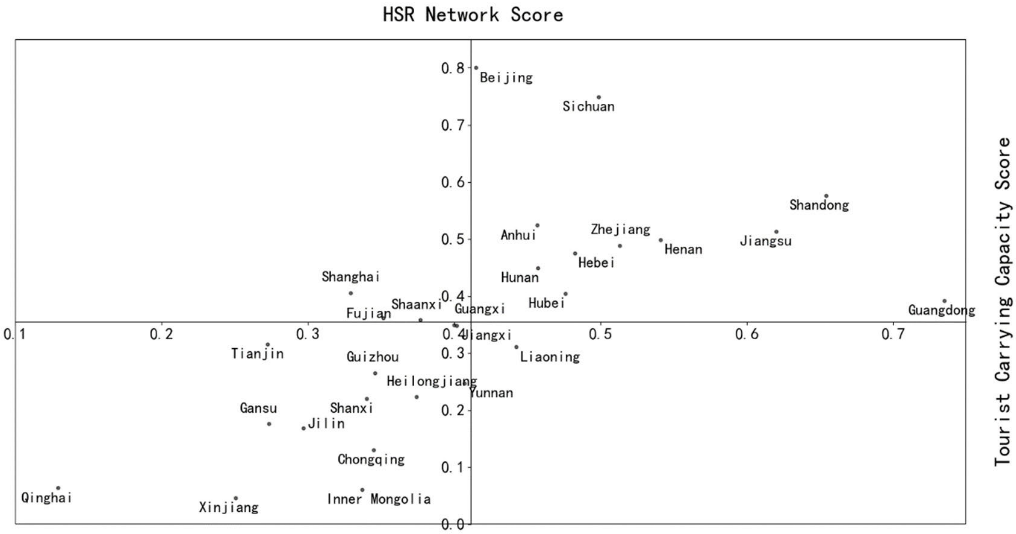

FIGURE 8. Matrix diagram of HSR network and TCC in China's key tourist areas in 28 provinces and cities.

and Anhui are all higher than their TCC scores, indicating that improving the TCC would be conducive to promoting the coupling coordination relationship between TCC and the HSR network in these provinces and cities. The scores for the HSR network in Guangdong, Henan, Hubei, Zhejiang, Hunan, Shandong, Hebei and Jiangsu are all lower than their TCC scores, indicating that the development of the HSR would be conducive to promoting the improvement of the coordination relationship between the TCC and HSR network in these provinces and cities.

Shanghai, Fujian and Shaanxi are located in the second quadrant, with HSR network scores higher than average, but TCC scores lower than average. Looking at Table 3, the degrees of coupling coordination between the TCC and HSR network in Shanghai and Fujian are both located in the favorably balanced development stage, while that for Shaanxi signifies barely balanced development. The scores for the HSR network in Shanghai and Fujian are higher than those for TCC, indicating that improving the TCC would be conducive to promoting the coordinated development of the HSR network and TCC in those locations. The HSR network score for Shaanxi is lower than the TCC score, indicating that the development of the HSR would be conducive to promoting the coordination relationship between TCC and the HSR network in Shaanxi.

Tianjin, Guangxi, Yunnan, Heilongjiang, Jiangxi, Guizhou, Shanxi, Inner Mongolia, Jilin, Gansu, Chongqing, Xinjiang and Qinghai are located in the third quadrant, with TCC scores and HSR network scores below the average. Tianjin's HSR network score is higher than its TCC score, while for the rest of the locations the HSR network score is lower than the TCC score.

Liaoning is located in the fourth quadrant, with a TCC score higher than average, but an HSR network score lower than average. Liaoning's coupling coordination degree between the TCC and HSR network is located in the favorably balanced development stage, with higher coordinated development. However, the HSR of Liaoning is lower than its TCC, showing that the development of the HSR network structure lags behind, and further development of the HSR would be beneficial for promoting the coordination relationship between TCC and the HSR network.

V. CONCLUSION AND SUGGESTION

The degree of coupling and coordination between TCC and HSR network is an effective index to evaluate the healthy development relationship between regional tourism and HSR. On the one hand, the coupling and coordinated development between HSR and TCC enable the tourism industry to take advantage of the convenient transportation conditions of high-speed rail. Tourist destinations can fully tap the potential of tourism resources while improving the accessibility of transportation. On the other hand, the sound development of tourism can attract more tourists and bring more passengers to the HSR, thus promoting the development of the HSR network. At present, China ranks first in the world in terms of the length of HSR. China's HSR network, with ''eight horizontal and eight vertical'' trunk passages as the skeleton, electrified transformation lines as the connection, and intercity railways as the supplement, has gradually improved. China's HSR network construction and development level is at the forefront of the world. In addition, due to the vast regional area of China, there are differences in the development of HSR and TCC among different provinces. The development relationship between the structure of HSR network and HSR also has a variety of different types. Therefore, taking China as an example to study the coupling and coordinated development relationship between HSR network and HSR has many advantages. Firstly, it can provide relevant strategic suggestions for the development of China's tourism industry and HSR. Secondly, the coupling coordination mechanism between HSR and TCC can be understood by studying the case of China and corresponding development suggestions can be provided. Thirdly, this paper can provide reference for the coupling coordinated development of HSR and tourism in other countries.

From the perspective of TCC and the HSR network structure, this paper studied the EFC-SCC-ECC of 30 provinces and cities from 2008 to 2017, as well as the coupling coordination degree between TCC and HSR network of 28 provinces and cities in China in 2017. We have explored the level of the TCC, the EFC-SCC-ECC and the coupling coordination degree between TCC and the HSR network in key tourist areas. Accordingly, the paper draws the following conclusions.

Overall, China's TCC increased from 2008 to 2017, with an increase of 12.7%. In terms of the three first-class indexes, the SCC has had the biggest effect on the growth of the TCC, and has been an important factor in the improvement of China's TCC. With the development of the TCC, there has been a change from limited SCC before 2010 to limited EFC after 2011. In addition, with the improvement of the EFC and SCC, China's ECC began to decline, and future developments of tourism should pay attention to environmental governance, resource protection and other ecological issues, so as to ensure the sustainable development of China's tourism industry.

In addition, due to the different development situation of TCC and HSR network in different provinces, the coupling coordination mechanism of HSR-TCC is also different. Considering factors such as TCC, the EFC-SCC-ECC, and the coupling coordination degree between TCC and HSR network, the coupling coordination development mechanism between HSR network and TCC can be divided into five categories. (1) The development level of both HSR network and TCC is higher, and the coupling and coordination degree between them is higher. The provinces that meet the above conditions are Beijing, Guangdong, Henan, Sichuan, Anhui, Hubei, Zhejiang, Hunan, Shandong, Hebei and Jiangsu. Although these provinces have good TCC and HSR development conditions, the development of TCC and EFC-SCC-ECC in some provinces and cities shows a downward trend, such as Beijing and Jiangsu. The main reason for the decline of TCC and EFC-SCC-ECC in Beijing and Jiangsu is the decline in the level of ECC. In the context of the rapid development of HSR and the increasing number of tourists, how to take measures to improve their ECC and prevent the further decline of TCC level is the key to maintain the high coupling and coordinated development level between HSR and TCC in the above two provinces. (2) The development level of HSR network is higher, and the development level of TCC is lower, but the coupling and coordination degree between them is higher. The provinces that meet the above conditions are Shanghai, Fujian and Shaanxi. Although the TCC of Fujian and Shaanxi is lower than the average level, the development of TCC and EFC-SCC-ECC of them both show an upward trend, indicating that their tourism development continues to improve. However, the development of TCC and EFC-SCC-ECC in Shanghai showed a downward trend. To prevent the further decline of TCC in Shanghai is an important condition to maintain its high coupling and coordinated development level between HSR and TCC. (3) The development level of HSR network is lower, the development level of TCC is higher, and the coupling and coordination degree between them is higher. The province that meets the above conditions is Liaoning. Liaoning not only has a high TCC level, but also the development of TCC and EFC-SCC-ECC is on the rise. Therefore, in order to avoid the decrease of the coupling and coordinated development level between HSR and TCC and restrict the development of local tourism, Liaoning needs to increase the intensity of HSR construction. (4) The development level of HSRl network and TCC is lower, but the coupling and coordination degreel between them is higher. The provinces that meet the above conditions are Tianjin, Guangxi, Yunnan, Heilongjiang, Jiangxi, Guizhou and Shanxi. Except Tianjin, the development of TCC and EFC-SCC-ECC in the other provinces is on the rise, and the development of tourism is in good shape. Further strengthening of HSR construction is conducive to the subsequent development of tourism in these provinces. The development of TCC in Tianjin lags behind that of HSR, and the development of EFC-SCC-ECC shows a downward trend. Tianjin needs to take measures to prevent the further decline of TCC. (5) The development level of HSR network and TCC is lower, and the coupling and coordination degree between them is lower. The provinces that meet the above conditions are Inner Mongolia, Jilin, Gansu, Chongqing, Xinjiang and Qinghai. For these provinces, the development

TABLE 4. List of national 5A-level scenic spots in 30 provinces and cities in China.

Province/City	National 5A-level scenic spots
Beijing	The Palace Museum, Temple of Heaven Park, Gong Palace, Summer Palace, Olympic Park, Ming Tombs, Badaling-Mutianyu Great Wall, Old Summer Palace Ruins Park
Tianjin	Ancient Culture Street, Winding Mountain
Hebei	Xibaipo, Anxin Baiyangdian Lake, Yesanpo, Chengde Summer Resort, Qing Eastern Mausoleum, The Palace of Wa, Western Qing Tombs, Shanhai Pass, Guangfu Ancient City, Baishi Mountain
Shanxi	Yungang Grottoes, Mount Wutai, Huangcheng Xiangfu Ecological and Cultural Tourism Area, Mount Mian, Pingyao Ancient City, Yanmen Pass, Taihang Mountain Grand Canyon Baiquan Gorge, Hongdong Big Locust Tree Root Worship Garden
Inner Mongolia	Xiangsha Bay, Mausoleum of Genghis Khan, China-Russia Border Tourism Area, Shan Chai River, Populus Euphratica Forest in Alxa League, Ashatu Stone Array
Liaoning	Shenyang Botanical Garden, Shenyang World Expo Park, Tiger Beach Polar Ocean Park, Jinshi Beach, Benxi Water Tunnel, Mount Qian, Longtan Grand Canyon, Red Beach Landscape Corridor
Jilin	The Puppet Manchuria Palace Museum, Jingyuetan Lake, Mount Changbai, Changying Century City, Mount Luding, Goguryeo Cultural Relics, Changchun World Sculpture Park
Heilongjiang	Sun Island Park, Jingpo Lake, Tangwang River Forest Stone, Heihe Wudalianchi, Mohe Arctic Village, Hutou Tourist Attractions
Shanghai	Shanghai Oriental Pearl Tower, Shanghai Wildlife Park, Shanghai Science and Technology Museum
Jiangsu	Mount Zhong, Confucius Temple & Qinhuai Scenic Belt, Wuxi Film and Television Base, Mount Ling, Yuantouzhu, Global Dinosaur City Leisure and Tourism Area, Tianmu Lake, Suzhou Garden, Zhouzhuang Ancient Town, Tongli Ancient Town, Jinji Lake, Wuzhong Taihu Lake, Shajiabang. Yushan Shang Lake, Hou River, Slender West Lake, Qin Lake, Zhenjiang Sanshan, Jurong Maoshan, Zhou Enlai Hometown, Dafeng Chinese Elk Deer Park, Yunlong Lake, Mount Huaguo, Huishan Ancient Town, China Spring and Autumn Yancheng
Zhejiang	West Lake, Mount Yandang, Mount Putuo, Qiandao Lake, Wuzhen, Xikou-Tengtou, Hengdian World Studios, Jiaxing South Lake, Xixi Wetland, Lu Xun's Hometown-Shenyuan, Gengong Buddhist Country Cultural Tourism Area, Nanxun Ancient Town, Mount Tiantai, Shenxianju, Xitang Ancient Town, Mount Jianglang, Xiandu National Scenic Area, Tianyi Pavilion Moon Lake
Anhui	Mount Tianzhu, Mount Huangshan, Ancient Villages in southern Anhui (Xidi, Hongcun village), Ancient Huizhou Cultural Tourism Area, Mount Jiuhua, Paradise Village, Bali River, Longchuan, Sanhe Ancient Town, Fangte Tourist Area, Wanfo Lake
Fujian	Gulangyu Island, Fujian Tulou, Mount Wuyi, Baishui Yang Yuanyang Creek, Mount Taimu, Mount Qingyuan, Three Alleys and Seven Lanes, Gutian Tourist Area, Taining Scenic Tourist Area
Jiangxi	Mount Lu, Mount Jinggang, Mount Sanqing, Mount Longhu, Jiangwan Scenic Area, Ancient Kiln Folk Culture Expo Area, Ruijin Republic Cradle Tourism Area, Mount Mingyue, Mount Dajue, Guifeng, Mount Wugong, Tengwang Pavilion
Shandong	Mount Tai, Penglai Pavilion, Sankong Tourism Area, Mount Lao, Liugong Island, Longkou Mount Nan, Taierzhuang Ancient City, The First Spring in the World, Mount Yimeng, Qingzhou Ancient City, Huaxia City, The Yellow River Estuary Ecological Tourism Area
Henan	Mount Song Shaolin, Qingming Shanghe Garden, Longmen Grottoes, Mount Baiyun, Mount Laojun - Jiguan Cave, Longtan Grand Canyon, Mount Yuntai - Mount Shennong Qingtian River, Mount Yao - Central Plains Giant Buddha, Yin Ruins, Mount Funiu Laojie Ridge Dinosaur Site Park, Mount Chaya, Baligou, Mount Mangdang Han Cultural Scenic Spot, Red Flag Canal - Taihang Grand Canyon

TABLE 4. *(Continued.)* List of national 5A-level scenic spots in 30 provinces and cities in China.

Hubei	Yellow Crane Tower Park, East Lake Scenic Area, Huangpi Mulan Cultural Ecological Tourism Area, Mount Wudang, Three Gorges Dam - Qu Yuan's Hometown Tourism Area, Three Gorges Family, Changyang Qingjiang Gallery Tourism Area, Shenlong Creek Fiber Man Cultural Tourism Area, Enshi Grand Canyon, Shennongjia Tourism Area, Gulongzhong, The Three Kingdoms Chibi Ancient Battlefield
Hunan	Huaming Tower, Mount Shao, Yueyang Tower - Junshan Island Scenic Spot, Wulingyuan - Mount Tianmen, Dongjiang Lake, Mount Lan, Yandi Mausoleum, Nanyue Hengshan, Mount Yuelu, Orange Island Tourist Area
Guangdong	Mount Baiyun, Overseas Chinese Town, Mission Hills, Mount Xiqiao, Changlu Tourism Rest Expo Park, Mount Danxia, Yannan Flying Tea Field, Lianzhou Underground River, Mount Luofu, Hailing Island Dajiao Bay Maritime Silk Road, Star Lake, Huizhou West Lake, Sun Yat-sen's Hometown
Guangxi	Mount Qingxiu, Lijiang River, Happy Vacation World, Solitary Xiufeng, King City, Baise Uprising Memorial Park, Detian Transnational Waterfall, Two Rivers and Four Lakes, Elephant Hill
Hainan	Nanshan Cultural Tourism Area, Nanshan Big and Small Cave, Yanoda Rainforest Cultural Tourism Area, Boundary Zhou Island, Penang Valley Li Miao Cultural Tourism Area, Wuzhizhou Island
Chongqing	Wushan Small Three Gorges, Dazu Stone Carvings, Wulong Karst Tourist Area, Youyang Peach Blossom Land, Black Valley, Mount Sifang, Yiyi River, Longgang, Mount Jinfo
Sichuan	Qingcheng Mountain - Dujiangyan, Mount Emei, Jiuzhaigou, Leshan Giant Buddha, Huanglong Scenic Area, Beichuan Qiang City, Wenchuan Special Tourism Area, Langzhong Ancient City, Deng Xiaoping's Hometown, Jianmen Shu Road Jianmen Pass, Zhu De Hometown, Hailuogou, Bifeng Gorge
Guizhou	Huangguoshu Waterfall, Dragon Palace, Baili Rhododendron, Qiannan Libo Zhangjiang, Zhenyuan Ancient City, Qingyan Ancient Town, Mount Fanjing
Yunnan	Shilin, Jade Dragon Snow Mountain, Lijiang Ancient Town, Chongxin Temple Three Pagoda Cultural Tourism Area, Xishuangbanna Tropical Botanical Garden, Pudacuo National Park, Kunming World Expo Park Scenic Area, Volcano Hot Sea Tourism Area
Shaanxi	Museum of Terracotta Warriors and Horses of Qin Shihuang, Huaqing Pool, Yellow Emperor Mausoleum, Datang Furong Garden Big Wild Goose Pagoda, Mount Hua, Famen Temple Buddhist Cultural Scenic Spot, Golden Silk Gorge, Taibai Mountain, Yan'an Revolutionary Memorial Site, Xi'an City Wall Monument Forest
Gansu	Jiayuguan Cultural Relics Scenic Area, Mount Maiji, Mount Kongtong, Dunhuang Mingsha Mountain Crescent Spring, Colorful Danxia Scenic Area, Chimelong Tourism Resort
Qinghai	Qinghai Lake, Tar Temple, Huzhu Native Park Tourist Area
Ningxia	Sand Lake, Shapotou, Zhenbeibao West Film Studio, Shuidong Ditch
Xinjiang	Tianshan Tianchi, Grape Valley, Kanas Scenic Spot, Nalati, Keketuo Sea, Golden Populus Euphratica, Tianshan Grand Canyon, Bosten Lake, Kar Old City, Kalajun, Bayinbrook, Baisha Lake

of HSR network can bring the necessary resources for the development of local tourism and promote the development of local tourism, but the primary task is to improve the TCC. The reason is that the increase of the number of tourists can promote the development of tourism economy in the short term, but if the number of tourists exceeds its TCC for a long time, it will inevitably lead to the destruction of its tourism resources and ecological resources, resulting in the decline of TCC, which is not conducive to the sustainable development of tourism.

According to the development of TCC in different regions, the development of HSR network will have different impacts on local tourism. On the one hand, the method proposed in this paper evaluates the development level of regional TCC, which can clarify the tourism resource endowment of different regions and the shortcomings of TCC development.

On the other hand, it can evaluate the coupling coordinated development between HSR and TCC and analyze the impact of HSR network development on local tourism, which can provide support for the study of how to realize the coupling and coordinated development of the two. Local governments should combine the local TCC and the actual development of the HSR network to formulate the next tourism development strategy.

According to the above analysis, the following suggestions for improving the TCC level of provinces and cities are made: (1) The difference in TCC between different regions is mainly due to the unbalanced development of transportation, economic development, infrastructure, ecological resources and the ecological environment, which restricts the improvement of the overall development level of TCC. Therefore, provinces and cities should implement corresponding measures according to their own shortcomings in order to develop their TCC. For example, in the coastal areas where EFC and SCC are highly developed, improving ECC should be the next focus for TCC development. In the northwest region, where EFC, SCC and ECC are all poorly developed, on the one hand, national and government policies are needed to help develop the economy, and promote infrastructure construction and social cultural development; on the other hand, improving the traffic accessibility of the northwest region will also be crucial to its tourism development. How to seize the opportunity of the opening of the HSR to promote the transformation of tourism resources into economic resources and the formation of a tourism industry in the northwest region is also an issue that the relevant departments should focus on. (2) Facing the current situation in which the development of the HSR network is lagging behind TCC in most provinces and cities, it is crucial to further increase the construction of the HSR network to promote the development of the tourism industry in such locations. (3) The improvement of living standards not only stimulates people to travel and brings large numbers of tourists to tourist areas, but also brings many challenges to local tourism development. For example, the level of tourism services will need to be raised, tourism-related facilities enhanced and environmental governance improved. Dealing with such challenges has become a major problem in the quest to achieve sustainable and healthy development of TCC.

There are still some limitations in the research process of this paper, which we hope can be solved in future work. Firstly, we used a unified indicator system to calculate and evaluate the development level of the TCC of 30 provinces and cities in China. However, different provinces and regions have different tourism resource endowments, and their TCC development depends on different resources. For example, coastal cities rely more on coastal resources when developing tourism while inland cities rely more on natural and cultural landscapes. Therefore, in order to more accurately evaluate the development level of TCC in different provinces and cities, future research can consider establishing a differentiated evaluation indicator system based on regional characteristics. Secondly, although this paper analyzes the coordinated development between TCC and HSR network, it does not specifically quantify the impact of factors such as the schedule between HSR stations on the accessibility of provincial and municipal HSR. Subsequent studies can take relevant factors into consideration to make a more comprehensive evaluation of the development of HSR, so as to evaluate the coupling coordinated development of HSR and TCC in a more scientific and reasonable way.

APPENDIX

See Table 4.

REFERENCES

[1] H. Jiang, Y. Yang, and Y. Bai, "Evaluation of all-for-one tourism in mountain areas using multi-source data," *Sustainability*, vol. 10, no. 11, p. 4065, Nov. 2018.
[2] *China Domestic Tourism Development Report*, Hubei, China, 2020.
[3] J. Wang, X. Huang, Z. Gong, and K. Cao, "Dynamic assessment of tourism carrying capacity and its impacts on tourism economic growth in urban tourism destinations in China," *J. Destination Marketing Manage.*, vol. 15, Mar. 2020, Art. no. 100383.
[4] W. Deng, *Dictionary of Sociology*. Shanghai, China: Shanghai Dictionary Publishing House, 2009.
[5] D.-G. Wang, Y. Niu, and J. Qian, "Evolution and optimization of China's urban tourism spatial structure: A high speed rail perspective," *Tourism Manage.*, vol. 64, pp. 218–232, Feb. 2018.
[6] H. Wu and X. Zhang, "Research on the lnfluence of high speed rail on tourism development of cities along the line: Take Beijing-Guangzhou high speed railway as an example," *Econ. Problems*, vol. 11, no. 56, pp. 85–94, 2020.
[7] J. Wang, Z. Cai, and X. Qin, "Measurement on total factor productivity in China's service industry," *Statist. Decis.*, vol. 36, no. 22, pp. 95–99, 2020.
[8] R. Ceccato and M. Diana, "Substitution and complementarity patterns between traditional transport means and car sharing: A person and trip level analysis," *Transportation*, vol. 48, no. 4, pp. 1523–1540, Aug. 2021.
[9] R. C. de Sousa, L. C. C. Pereira, R. M. da Costa, and J. A. Jiménez, "Tourism carrying capacity on estuarine beaches in the Brazilian Amazon region," *J. Coastal Res.*, vol. 70, pp. 545–550, Apr. 2014.
[10] J. Zelenka and J. Kacetl, "The concept of carrying capacity in tourism," *Amfiteatru Econ.*, vol. 16, no. 36, pp. 641–654, 2014.
[11] F. Ye, J. Park, F. Wang, and X. Hu, "Analysis of early warning spatial and temporal differences of tourism carrying capacity in China's island cities," *Sustainability*, vol. 12, no. 4, p. 1328, Feb. 2020.
[12] Y. Mi, *Research on Tourism Environmental Carrying Capacity of Open Scenic-Take Beijing ShiChahai as Example*. Beijing, China: Beijing Jiaotong Univ., 2014.
[13] X. Song, L. Li, Y. Wang, L. Shi, P. Yang, and X. Gao, "Dynamic assessment of tourism environmental carrying capacity of desert scenic spot: A case study of Shapotou Scenic Spot in Ningxia," *J. Ningxia Univ. Humanities Social Sci. Ed.*, vol. 41, no. Z1, pp. 138–147, 2019.
[14] W. Li, M. Zhang, and S. Ma, "Studies on the environment bearing capacity appraisal indicator system of the Jokhang Scenic Zone," *Chin. Agricult. Sci. Bull.*, vol. 28, no. 11, pp. 155–162, 2012.
[15] Y. Tang, Z. Wang, and X. Yang, "Study on evaluation index system of ecotourism environmental bearing capacity–Taking Medog in the Yarlung Zangbo Gorge Nature Reserve as an example," *J. Plateau Agricult.*, vol. 2, no. 5, pp. 558–562, 2018.
[16] Z. Morteza, F. M. Reza, M. M. Seddiq, P. Sharareh, and G. Jamal, "Selection of the optimal tourism site using the ANP and fuzzy TOPSIS in the framework of integrated coastal zone management: A case of Qeshm island," *Ocean Coastal Manage.*, vol. 130, pp. 179–187, Oct. 2016.
[17] L. Li, Y. Tashi, D. Bian, D. Dongru, O. Champa, and L. Zeng, "Research on tourism carrying capacity of Namtso Scenic Area in Tibet," *Tibet Sci. Technol.*, vol. 5, pp. 30–36, 2018.
[18] Y. Wang, J. Li, and M. Zhang, "Evaluation of tourism environmental carrying capacity in diaoshuihu national forest park," *Int. J. Sustain. Develop. Planning*, vol. 15, no. 5, pp. 761–766, Aug. 2020.

[19] A. Alvarez-Sousa, "The problems of tourist sustainability in cultural cities: Socio-political perceptions and interests management," *Sustainability*, vol. 10, no. 2, p. 503, Feb. 2018.

[20] X. Yang, G. Weng, J. Li, and Y. Hou, "Optimization of tourism environment carrying capacity in coastal cities: A case Study of Qinhuangdao city," *Geography Geo-Inf. Sci.*, vol. 35, no. 4, pp. 134–140, 2019.

[21] Y. Zhao and L. Jiao, "Resources development and tourism environmental carrying capacity of ecotourism industry in pingdingshan city, China," *Ecolog. Processes*, vol. 8, no. 1, pp. 1–6, Dec. 2019.

[22] X. Yang, G. Weng, and X. Zhang, "Evaluation on tourism environment bearing potential of provincial areas," *Statist. Decis.*, vol. 35, no. 8, pp. 44–48, 2019.

[23] M. Li and J. Chen, "High-speed rail network in China: The contribution of fast trains to regional tourism and economic development," *Tourism Rev.*, vol. 75, no. 2, pp. 414–432, Nov. 2019.

[24] F. Wang, X. Wei, J. Liu, L. He, and M. Gao, "Impact of high-speed rail on population mobility and urbanisation: A case study on Yangtze River Delta urban agglomeration, Chinam," *Transp. Res. A, Policy Pract.*, vol. 127, pp. 99–114, 2019.

[25] P. Yin, Z. Lin, and B. Prideaux, "The impact of high-speed railway on tourism spatial structures between two adjoining metropolitan cities in China: Beijing and Tianjin," *J. Transp. Geography*, vol. 80, Oct. 2019, Art. no. 102495.

[26] T. Deng, L. Zhao, and M. Ma, "Research on the impacts of the implementation of the Yangtze River Delta high speed railway network on the development of urban tourism industry," *Econimic Manage.*, vol. 38, no. 1, pp. 137–146, 2016.

[27] T. Huang, J. Xi, and Q. Ge, "Tourism spatial competition pattern of urban agglomeration under the influence of high-speed railway using spatial econometrics," *Econ. Geography*, vol. 37, no. 8, pp. 182–191, 2017.

[28] W. Zhao and X. Cao, "Study on the impact of high speed rail network on the tourism pattern of cities along the line based on ArcGlS," *Geomatics Spatial Inf. Technol.*, vol. 42, no. 8, pp. 161–165, 2019.

[29] C. Mu, L. Li, and P. Han, "Impact of high-speed railway network on tourism traffic pattern in Anhui Province," *J. Luoyang Normal Univ.*, vol. 39, no. 4, pp. 16–20, 2020.

[30] G. Du and Y. Yang, "Impact of high-speed rail network on the spatial structure of tourism in Chongqing City," *Areal Res. Develop.*, vol. 37, no. 4, pp. 104–109, 2018.

[31] A. Saveriades, "Establishing the social tourism carrying capacity for the tourist resorts of the east coast of the republic of Cyprus," *Tourism Manage.*, vol. 21, no. 2, pp. 147–156, Apr. 2000.

[32] Y. Zhang, X. Li, Q. Su, and X. Hu, "Exploring a theme park's tourism carrying capacity: A demand-side analysis," *Tourism Manage.*, vol. 59, pp. 564–578, Apr. 2017.

[33] S. Xu, F. Wang, and K. Wang, "Evaluation and optimization analysis of high-speed rail network structure in northeast China under the background of northeast revitalization," *Regional Sustainability*, vol. 2, no. 4, pp. 349–362, Oct. 2021.

[34] J. Xing, Z. Liu, C. Wu, and S. Chen, "Traffic volume estimation in multimodal urban networks using cell phone location data," *IEEE Intell. Transp. Syst. Mag.*, vol. 11, no. 3, pp. 93–104, Fall 2019.

[35] X. Ma, J. Zhang, and L. Zhang, "Forest management decision model based on the entropy weight and coefficient of variation method," *Academic J. Environ. Earth Sci.*, vol. 4, no. 2, 2020.

[36] Y. Zhang, Y. Dai, Y. Chen, and X. Ke, "Coupling coordination development of new-type urbanization and cultivated land low-carbon utilization in the Yangtze River Delta, China," *Land*, vol. 11, no. 6, p. 919, 2022.

[37] C. Wei, Z. Wang, X. Lan, H. Zhang, and M. Fan, "The spatial–temporal characteristics and dilemmas of sustainable urbanization in China: A new perspective based on the concept of five-in-one," *Sustainability*, vol. 10, no. 12, p. 4733, Dec. 2018.

[38] H.-C. Liu, J.-X. You, X.-Y. You, and M.-M. Shan, "A novel approach for failure mode and effects analysis using combination weighting and fuzzy VIKOR method," *Appl. Soft Comput.*, vol. 28, pp. 579–588, Mar. 2015.

[39] X. Xia, K. Lin, Y. Ding, X. Dong, H. Sun, and B. Hu, "Research on the coupling coordination relationships between urban function mixing degree and urbanization development level based on information entropy," *Int. J. Environ. Res. Public Health*, vol. 18, no. 1, p. 242, Dec. 2020.

[40] W. Jing, W. Zhang, P. Luo, L. Wu, L. Wang, and K. Yu, "Assessment of synergistic development potential between tourism and rural restructuring using a coupling analysis: A case study of southern Shaanxi, China," *Land*, vol. 11, no. 8, p. 1352, Aug. 2022.

[41] J. Liu, Y. Zhao, and S. C. Jang, "Environmental perceptions and willingness to pay for preservation: Evidence from beach destinations in China," *Int. J. Tourism Res.*, vol. 23, no. 5, pp. 792–804, Sep. 2021.

[42] F. Zhang, C. Sun, Y. An, Y. Luo, Q. Yang, W. Su, and L. Gao, "Coupling coordination and obstacle factors between tourism and the ecological environment in Chongqing, China: A multi-model comparison," *Asia Pacific J. Tourism Res.*, vol. 26, no. 7, pp. 811–828, Jul. 2021.

[43] Z. Tang, "An integrated approach to evaluating the coupling coordination between tourism and the environment," *Tourism Manage.*, vol. 46, pp. 11–19, Feb. 2015.

ZHIKUN LUO was born in Zhoukou, Henan, China, in 1984. He received the B.S. degree in mathematics and applied mathematics from the Zhoukou Normal College, Henan, in 2008, and the M.S. degree in computational mathematics from Beijing Jiaotong University, Beijing, China, in 2010, and the Ph.D. degree in applied mathematics from the Beijing Institute of Technology, Beijing, in 2014.

He has been working as a Lecturer with the Harbin University of Commerce, since 2014. His research interests include differential geometry, information geometry, data analysis, and mathematical modeling.

AIRONG XU was born in Dezhou, Shandong, China, in 1998. She received the management degree from the Business College, Shandong Normal University, Shandong, in 2020, where she is currently pursuing the master's degree in management.

Her research interests include big data analysis, tourist traffic, and multi-mode urban transportation.

SHAN GAO was born in Dezhou, Shandong, China, in 1997. She received the management degree from the Business College, Shandong Normal University, Shandong, in 2020, where she is currently pursuing the master's degree in management.

Her research interests include big data analysis, tourist traffic, and urban traffic management.