Study on the Coupling Coordination Development of Transportation and Tourism in Ürümqi

Yanyun Zhang[1,2,*], Yang Sun[2a] and Jinfu Zhu[1b]

[1]College of Civil Aviation, Nanjing University of Aeronautics and Astronautics, Nanjing 211100, China
[2]Xinjiang Vocation and Technology College of Communications, Urumqi 830000, China

[*]yszhang@nuaa.edu.cn; [a]Zyy-sy134@163.com; [b]zhujf@nuaa.edu.cn

Abstract: The coupling coordination development of transportation and tourism is an important way to realize the sustainable and coordination development of the national economy and the industry itself. In order to promote the sustainable and coordination development of Ürümqi transportation and tourism industry, we based on entropy weight method, coupling coordination degree model and gray correlation analysis method, a sensitivity analysis of the key factors is presented affecting the coupling and coordinated development of the two systems from 2013 to 2022. And the evaluation index system of the Ürümqi transportation system and tourism system is established. The results show that the indicator of air passenger traffic in the transportation system is the most important factor to improve the coupling coordination degree of the two systems, which can increase the system coupling coordination degree from 0.830 to 0.875; the indicator of railroad passenger traffic is the second one, which can increase the system coupling coordination degree from 0.830 to 0.861. Based on the characteristics of Ürümqi transportation and the current situation of tourism development, this paper puts forward suggestions to enhance the degree of coordination of system coupling, which provides scientific basis and management inspiration for promoting the sustainable and coordinated development of Ürümqi transportation system and tourism system.

Keywords: transportation; tourism; grey correlation analysis; coupling coordination; Ürümqi

1 Introduction

As the capital of China's Xinjiang Uygur Autonomous Region, Ürümqi is known as a city in the core area of the Silk Road Economic Belt. An overview of the city of Ürümqi is shown in Figure 1. Ürümqi is rich in tourism resources, with a large total amount, many types, high levels and excellent quality, attracting many domestic and foreign tourists. According to Ürümqi Culture and Tourism Bureau statistics, more than 60% of international and domestic tourists in Xinjiang have to go through Ürümqi City, making Ürümqi the largest tourist distribution center and tourist destination in Xinjiang.

G. Zhao et al. (eds.), *Proceedings of the 2024 7th International Symposium on Traffic Transportation and Civil Architecture (ISTTCA 2024)*, Advances in Engineering Research 241,
https://doi.org/10.2991/978-94-6463-514-0_54

Before the outbreak of the new crown epidemic, Ürümqi City received 75,263,800 domestic and foreign tourists in 2019, up 49.8% from 2018, and realized total tourism revenue of 113.760 billion yuan for the year, up 51.2%. Although the overall development will be slowed down by the impact of the epidemic in 2020-2022, Ürümqi 's tourism will achieve a "double breakthrough" as the country's transportation and tourism are basically fully liberalized in 2023: The number of tourists received exceeded 100 million and the realized tourism revenue exceeded the 100 billion yuan. This shows that the momentum of tourism in Ürümqi is still strong and the development of tourism industry is sustainable.

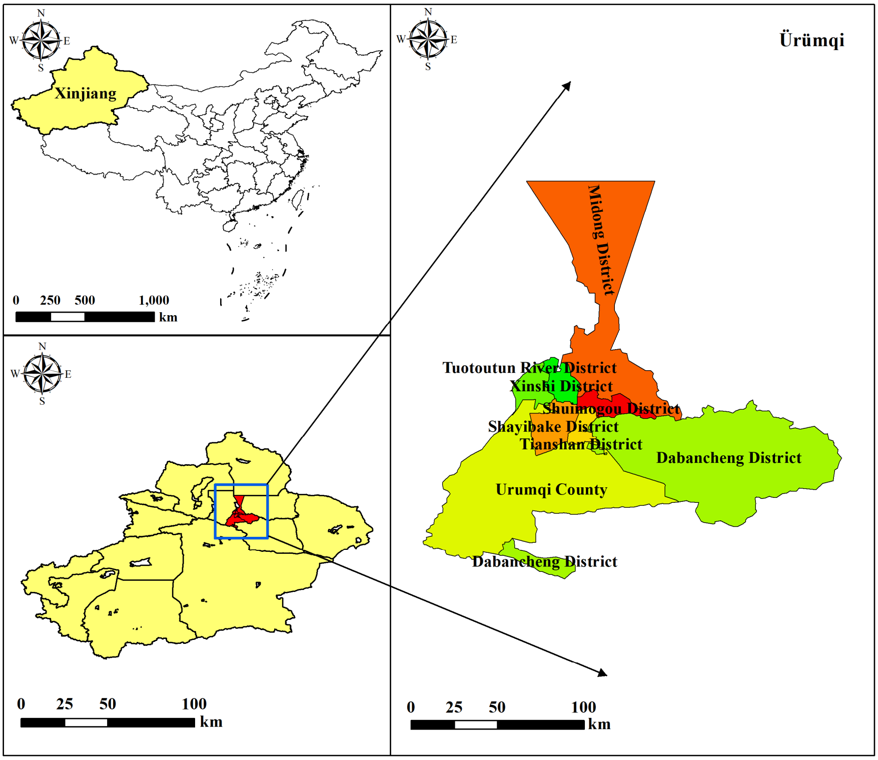

Fig. 1. Location of Ürümqi in China

Meanwhile, the rapid growth of tourism in Ürümqi is mainly due to the rapid development of transportation. Convenient transportation greatly improves travel convenience and comfort, promotes point-to-point transportation efficiency in tourist destinations, and shortens the spatial and temporal distance between tourist attractions [1]. Transportation development and tourism are interlinked and inseparable, and there is a close coupling and coordinated development relationship. Transportation is not only the foundation and guarantee of tourism development, but also the link between tourism demand and supply, relying on a perfect transportation system, can continuously promote the coordinated development of tourism in high quality. The development of tourism will in turn affect the development of transportation, not only affecting the future planning and layout of transportation, overall development and operation, as well as promoting the construction of transportation and tourism infrastructure, the development of high-quality highway tourism routes and the upgrading of related means of transportation.

Therefore, this paper explores the coordinated development relationship between transportation and tourism based on the coupling theory, and adopts the gray correlation analysis method to deeply analyze the influence of different indicators on the degree of coupled and coordinated development of the transportation system and tourism system in Ürümqi, so as to determine the key factors affecting the coupling of the two systems; The degree of influence of key factors on system coupling coordination is further verified by sensitivity analysis, aiming to provide a theoretical basis for improving system coupling coordination. Finally, this paper provides management insights to promote the sustainable and coordinated development of Ürümqi's transportation system and tourism system, with a view to providing relevant references for the sustainable and coordinated development of the transportation industry and tourism industry in the core area of the Silk Road Economic Belt.

2 Literature Review

Research on the issue of coordinated development of transportation and tourism has been a hot topic in international research. The earliest by foreign developed countries first attention, after decades of development has been rich in research results [2]. Prideaux [3] studied the impact of transportation on the coordinated development of tourism destinations and proposed a transportation cost model (Resort Development Spectrum) using relevant economic principles. Crouch [4] used the elasticity of demand model as a tool to study the coordinated development relationship between transportation and tourism and concluded that there is a sensitivity difference in tourism demand. Hayes [5] emphasized the importance of developing transportation systems and sustainable tourism to meet the needs of tourists and local communities. Fernandez et al. [6] utilized the SFA analysis method and concluded that there is a high correlation between tourism and air transportation. While from a tourism transportation perspective, Can [7] studied the coupling coordination relationship between transportation and tourism development for the first time and pointed out the relevant factors affecting tourists' choice of transportation mode. Xu et al. [8] used the coupling coordination degree to quantitatively analyze the relationship between the coordinated development of tourism and transportation, and the results showed that the slopes of the trend functions of the two were similar and in the same direction. Zhang and Wen [9] studied the factors of coupled and coordinated development of tourism economy and transportation in Shaanxi province, China, and concluded that the transportation system and epidemic impacts have a significant impact on the coupled and coordinated development of tourism economy. In recent years, the results of using coupling coordination model to study the coupling coordination development relationship between transportation and tourism have gradually increased. Lu et al. [10] with the help of coupling model, integrated geographic detector and other research methods, China's transportation and tourism coupling and coordinated development of related analysis, for the results of the relevant countermeasures proposed. Ye et al. [11] concluded that the development of the degree of coordination between the two is mainly limited by the degree of comprehensive co-ordination through a comparative study of the level of coupled synergy between tourism and transportation in the western region of Xiangxi, China. Liu [12] studied the degree of coordination between tourism and urban transport coupling in Nanjing, China, and finally concluded that tourism resources must be optimized in order to improve tourism attractiveness. Yu et al. [13], Chen et al. [14] and Wang et al. [15] conducted a study in Chizhou, Dalian and Xi'an, respectively, and concluded that there is a strong coupling and coordination between urban transportation and tourism development. Zhang et al. [16] and Bi et al. [17] conducted a study on tourism economy and transportation system in Hebei and Yunnan provinces using the coupled coordination degree model, and concluded that there is also a strong coupled coordination between different regional transportation optimization and transportation accessibility and tourism industry and tourism economic development.

Through the above literature analysis, it can be seen that the coupled and coordinated development of transportation and tourism has become the hot direction of the research on the coordinated development of transportation and tourism at home and abroad, and the related scholars present a diversified trend in the research on transportation and tourism. However, most of the literature on the coupling of the two interactive development of the relationship between the two research on the coupling of the two only macro-analysis, not able to further analyze the factors that cause the coupling of the system to coordinate the degree of increase or decrease in the analysis of the factors, in particular the lack of specific regions or destinations of transportation and tourism development coupling and coordination of the factors affecting the empirical research, the number of related literature is not a lot, is still in the initial stage, the relevant research results are insufficient. Therefore, this paper considers the unique location advantage that Ürümqi has and conducts more related research to promote the sustainable and coordinated development of transportation and tourism in the core area of the Silk Road Economic Belt.

3 Data and Methodology

3.1 Data Sources and Evaluation Index System Construction

After sorting out the studies related to transportation and tourism, frequency statistics method, expert consultation method, and theoretical analysis method were used, combining with the statistical indicators of the National Bureau of Statistics, the Ministry of Transportation and the Ministry of Culture and Tourism related to transportation and tourism and the specific situation of Ürümqi. On the basis of existing research results [13,18-21], the evaluation index system of Ürümqi transportation system and tourism system is constructed separately as shown in Table 1.

Table 1. Evaluation index system and weights for transportation and tourism systems

Subsystem	Evaluation indicator	Unit	Indicator attributes
Transportation system	Highway mileage	10,000 km	+
	Road passenger capacity	10,000 passengers	+
	Road passenger turnover	100 million passengers/km	+
	Railroad passenger capacity	10,000 passengers	+
	Railroad passenger turnover	100 million passengers/km	+
	Air passenger capacity	10,000 passengers	+
	Air passenger turnover	100 million passengers/km	+
	Urban public transportation vehicles	count	+
	Road area	10,000 m^2	+
Tourism system	Domestic tourist arrivals	10,000 passengers	+
	Inbound tourist arrivals	10,000 passengers	+
	International tourism (foreign exchange) income	100 million yuan	+
	Domestic tourism income	100 million yuan	+
	Total tourism revenue as% of GDP	%	+

The evaluation indicators of the transportation system include nine indicators: road mileage (X1), road passenger traffic (X2), road passenger turnover (X3), railroad passenger traffic (X4), railroad passenger turnover (X5), air passenger traffic (X6), air passenger turnover (X7), urban public transportation operating vehicles (X8) and road area (X9). The evaluation indicators of the tourism system are five indicators: domestic tourism numbers (Y1), inbound tourism numbers (Y2), international tourism (foreign exchange) revenues (Y3), domestic tourism revenues (Y4), and total tourism revenues as a share of GDP (Y5). The attributes of the above 14 evaluation indicators are all positive ("+"), indicating that the larger the value of their indicators, the greater the positive contribution to the system.

The research period of this paper is 10 years, i.e., 2013-2022 (in order to be able to truly reflect the status of coupled and coordinated development of the transportation system and tourism system in Ürümqi, and to consider the reasonableness and dynamics of the data, the raw data during the epidemic of 2020-2022 is included). The raw data are derived from Ürümqi Statistical Yearbook and Ürümqi National Economic and Social Development Statistical Bulletin for 2014-2019.

3.2 Research Methods

1.Entropy weighting method

The entropy weight method has the advantage of being more objective and can overcome the defects of cognitive one-sidedness and subjective arbitrariness of subjective determination of weights [22], and thus is widely used in empirical research. The main calculation steps of the method are as follows:

(1) Quasi-processing of raw data labels

To reduce the effects of differences created by different units of measurement, as well as in number and size, the raw data were standardized using the range method [23].

Positive indicators were standardized as follows:

$$X_{ij}^{'} = \frac{X_{ij}-X_{ij\min}}{X_{ij\max}-X_{ij\min}}+0.01 \quad (1)$$

Negative indicators are standardized as follows:

$$X_{ij}^{'} = \frac{X_{ij\max}-X_{ij}}{X_{ij\max}-X_{ij\min}}+0.01 \quad (2)$$

In equations (1) and (2), i is the i-th (i=1, 2) system, j is the j-th (j=1, 2, ⋯, n) indicator, X_{ij} represents the original value of the data, $X_{ij}^{'}$ represents the standardized value, $X_{ij\max}$ represents the maximum value in the indicator system, and $X_{ij\min}$ represents the minimum value in the indicator system. When standardizing the data, it is necessary to translate data to prevent zero-value indicators, which would affect subsequent calculations, by adding 0.01 to the end of equations (1) and (2) [24].

(2) Calculate information entropy, information utility value and indicator weights

The information entropy value for each indicator variable in the evaluation index system (transportation and tourism) is calculated using the entropy weighting method according to the following equations:

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m}\frac{X_{ij}^{'}}{\sum_{i=1}^{m}X_{ij}^{'}}\ln\frac{X_{ij}^{'}}{\sum_{i=1}^{m}X_{ij}^{'}} \quad (3)$$

$$h_j = 1 - e_j \quad (4)$$

$$w_j = \frac{h_j}{\sum_{j=1}^{n}h_j} \quad (5)$$

In Equation (3), m is the m-th evaluation year (m=1,2,⋯,n), e_j is the entropy value of the j-th indicator, and 0 means $0<e_j\leq 1$; $\frac{1}{\ln m}$ is the coefficient of information entropy; in Equation (4), h_j is the coefficient of variation of the j-th indicator; in Equation (5), w_j is the weight of the j-th indicator, and 0 means $w_j\leq 1$ and $\sum_{j=1}^{m} w_j=1$.

(3) Calculation of comprehensive appraisal value of transportation system and tourism system

The comprehensive evaluation of the development level of the transportation and tourism systems was carried out through a linear weighting method with the following equations:

$$P(X)=\sum_{j=1}^{t} X_j^{'1} w_{ij}^{1} \quad (6)$$

$$Q(Y)=\sum_{j=1}^{r} Y_j^{'2} w_{ij}^{2} \quad (7)$$

In Equation (6), $P(X)$ denotes the evaluation value of the comprehensive development level of the transportation system, t (t=1, 2, ⋯, n) denotes the number of evaluation indicators, w_{ij}^{1} denotes the weight of the j-th indicator, and $X_j^{'1}$ denotes the standardized value of its evaluation indicators. In Equation (7), $Q(Y)$ denotes the evaluation value of the comprehensive development level of the tourism system, r (r=1, 2, ⋯, n) denotes the number of evaluation indicators, w_{ij}^{2} denotes the weight of the j-th indicator, and $Y_j^{'2}$ denotes the standardized value of its evaluation indicators.

2.Coupling coordination model

Coupling coordination degree is an important indicator to assess the ability of coordination degree on the basis of the existence of coupling relationship between systems or elements. It integrates the information of both coupling degree and coordination degree between systems or elements. The coupling coordination degree specific model is as follows [25-27]:

$$C=\frac{2\times\sqrt{P(X)\times Q(Y)}}{P(X)+Q(Y)} \tag{8}$$

$$T=\alpha P(X)+\beta Q(Y) \tag{9}$$

$$D=\sqrt{C\times T} \tag{10}$$

In Equation (8), C is the degree of coupling between the transportation system and the tourism system. Its value range is $0 \le C \le 1$. A larger value of C means a greater degree of coupling, and vice versa. When $C = 1$, it means that the two major systems are in the best state of coupling. When $C = 0$, it means that the worst possible coupling exists between the two systems, or that the system is in a state of disordered development.

In Equation (9), T is the comprehensive coordination index of the transportation and tourism systems; α and β, which are coefficients to be determined, indicate the importance of the transportation system and tourism system, respectively: $\alpha + \beta = 1$. Because the two systems have the same importance in the national economy and social development system, α and β take the value of 0.5 each.

In Equation (10), D is the degree of coupling coordination between transportation system and tourism system. The value range is $0 \le D \le 1$; a larger value of D indicates better coupling of the transportation and tourism systems.

The degree of coupling only reflects the degree of mutual influence between systems or elements; it cannot, however, reflect the level of coordination between them [20]. In order to more intuitively reflect the coordination between the development of the transportation system and the tourism system and the coupling coordination degree level and other related conditions, reference to related scholars [28-30] and other research results to determine the coupling coordination degree level of the development of the transportation system and the tourism system and the assessment criteria as shown in Table 2.

Table 2. Criteria for categorizing the degree of coupling coordination

Coupling coordination *D*-value Interval	Coordination level	Degree of coupling coordination	Coordination phase
(0.0~0.1)	1	Extreme dysfunction	Recessionary phase
[0.1~0.2)	2	Severe dysfunction	
[0.2~0.3)	3	Moderate dysfunction	
[0.3~0.4)	4	Mild dysfunction	Harmonization of the transition phase
[0.4~0.5)	5	On the verge of dys-function	
[0.5~0.6)	6	Bare coordination	
[0.6~0.7)	7	Primary coordination	Harmonized development phase
[0.7~0.8)	8	Moderate coordination	
[0.8~0.9)	9	Good coordination	
[0.9~1.0)	10	Excellent coordination	

3.Gray correlation model

The coupling coordination evaluation model can effectively measure the coupling degree and the coupling coordination degree between the transportation system and the tourism system in Ürümqi. The coupling coordination development of the transportation system and tourism system is a complex development process in which many internal and external factors influence each other, and the coupling coordination degree model is only an overall assessment of the strength of the interactive coupling relationship between the two systems and the degree of coupling coordination from the overall comprehensive development level of the two systems. However, the inquiry into the coupling coordination relationships between systems is ultimately about examining the extent to which different indicators influence the association of systems.

Gray correlation analysis is a multifactorial statistical analysis method, which is based on the sample data of the factors of the system using gray correlation to describe the strength, size and order of the relationship between the factors [31-32]. The application of gray correlation model analysis can further analyze the influence of the development indicators related to the transportation system and tourism system on the coupling coordination development. The calculation steps of the model are as follows:

(1) Determine the evaluation object and the reference series matrix and derive the normalization matrix A

Assuming that there are m evaluation objects and n evaluation indicators, the reference columns are $x_0=\{x_0(k)|k=1, 2, \cdots, n\}$ the comparison columns are $x_i=x_i(k)|k=1, 2, \cdots, n, i=1, 2, \cdots, m$, and normalize the raw data to produce the normalization matrix A.

$$A=\begin{bmatrix} x_0(1) & x_1(1) & \cdots & x_1(n) \\ x_0(2) & x_2(1) & \cdots & x_2(n) \\ \vdots & \vdots & \vdots & \vdots \\ x_0(n) & x_m(1) & \cdots & x_m(n) \end{bmatrix} \tag{11}$$

(2) Calculate the gray correlation coefficient

$$\xi_i(k)=\frac{\min_i \min_k |x_0(k)-x_i(k)|+\rho \max_i \max_k |x_0(k)-x_i(k)|}{|x_0(k)-x_i(k)|+\rho \max_i \max_k |x_0(k)-x_i(k)|} \tag{12}$$

In equation (12), $\xi_i(k)$ is the correlation coefficient of the comparison series x_i to the reference series x_0 in the k-th index, where $\rho \in [0,1]$ is the resolution coefficient, commonly used value is 0.5, generally speaking, the larger the resolution coefficient ρ is, the larger the resolution is, the smaller ρ is, the smaller the resolution is, $|x_0(k)-x_i(k)|$ is the difference sequence, $\min_i \min_k |x_0(k)-x_i(k)|$ is the minimum difference of the two levels, $\max_i \max_k |x_0(k)-x_i(k)|$ is the maximum difference of the two levels.

This yields that the judgment matrix H.

$$H=\begin{bmatrix} \xi_1(1) & \xi_1(2) & \cdots & \xi_1(k) \\ \xi_2(1) & x_2(2) & \cdots & \xi_1(k) \\ \vdots & \vdots & \vdots & \vdots \\ \xi_i(1) & \xi_i(2) & \cdots & \xi_i(k) \end{bmatrix} \tag{13}$$

(3) Calculate the degree of relevance

$$R_i=\frac{\sum_{k=1}^{n} \xi_i(k)}{n} \tag{14}$$

In Equation (14): R is the gray correlation of the i-th evaluation object to the ideal object. the value range of R is (0, 1], and its specific type and rank [33] are shown in Table 3.

Table 3. Gray correlation types and ranking criteria

Gray correlation	Style	Level
（0.00, 0.35]	Lower correlation	Extremely weak coupling
（0.35, 0.45]	Low correlation	Weak coupling
（0.45, 0.65]	Medium level of association	Moderate coupling
（0.65, 0.85]	High correlation	Stronger coupling
（0.85, 1.00]	Extremely high correlation	Extremely strong coupling

(4) Evaluation analysis

According to the size of the gray correlation, each evaluation object is sorted, and the correlation order of the evaluation object can be established, and the larger the correlation, the better its evaluation results.

4.Sensitivity analysis methods

Sensitivity analysis is an analytical method used to study and analyze how sensitive a system's indicator state changes are to system changes. Sensitivity analysis is used to determine the greatest impact of changes in each evaluation index of the transportation system and tourism system in Ürümqi on the coupling coordination degree between the transportation system and the tourism system. The results of the sensitivity analysis can be used to identify the key factors influencing the coupling coordination degree between transportation system and the tourism system, and provide suggestions for management strategies to address these factors.

4 Results and Analysis

4.1 Data Weight Calculation

The entropy weight method is used to calculate the weights of the indicators of the evaluation index system of Ürümqi transportation and tourism system as shown in Table 4, in which Y4 has the largest weight of 0.2461 and X8 has the smallest weight of 0.0542. The calculation results are used for the subsequent calculation of the comprehensive evaluation value and the coupling coordination degree of Ürümqi transportation system and tourism system.

Table 4. Summary of the results of the entropy method for calculating weights

Variable	Evaluation indicator	Information entropy value e	Information utility value h	Weighting factor w
X1	Highway mileage	0.9066	0.0934	7.40%
X2	Road passenger capacity	0.8613	0.1387	10.99%
X3	Road passenger turnover	0.8257	0.1743	13.81%
X4	Railroad passenger capacity	0.8711	0.1289	10.21%
X5	Railroad passenger turnover	0.8914	0.1086	8.60%
X6	Air passenger capacity	0.7753	0.2247	17.81%
X7	Air passenger turnover	0.9088	0.0912	7.23%
X8	Urban public transportation vehicles	0.9316	0.0684	5.42%
X9	Road area	0.7662	0.2338	18.53%
Y1	Domestic tourist arrivals	0.8034	0.1966	22.29%
Y2	Inbound tourist arrivals	0.8600	0.1400	15.88%
Y3	International tourism (foreign exchange) income	0.8571	0.1429	16.20%
Y4	Domestic tourism income	0.7695	0.2305	26.14%
Y5	Total tourism revenue as% of GDP	0.8281	0.1719	19.49%

4.2 Index Analysis of the Comprehensive Development Level of the Transportation System and Tourism System

As can be seen from Figure 2, the comprehensive development level of the transportation system and tourism system in Ürümqi from 2013 to 2022 can be divided into two stages, with the overall basically rising stage from 2013 to 2019 before the epidemic and the overall sharp decline from 2020 to 2022 after the epidemic Stage.

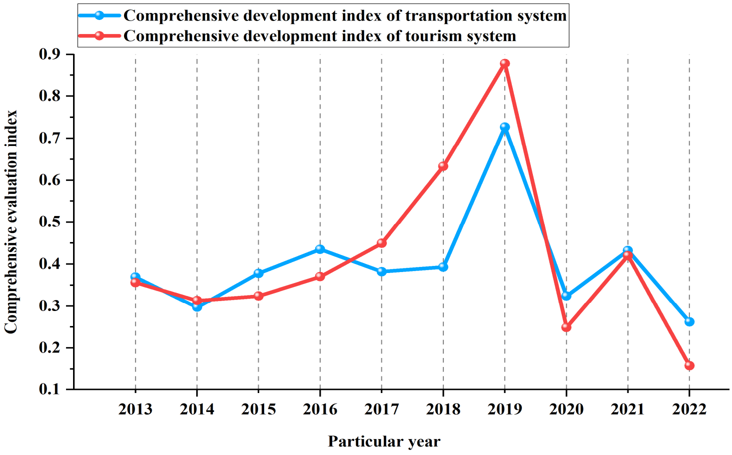

Fig. 2. Comprehensive index of the development level of the transportation and tourism systems in Ürümqi, 2013–2022

From the point of view of the development of the transportation system, the evaluation index of the development of the transportation system increased from 0.369 in 2013 to 0.727 in 2019, indicating that the condition of the transportation system has been significantly improved and the supporting role of the transportation system for the development of the tourism system has been rapidly enhanced. Also in terms of overall trends in transportation system development, the 2013-2019 transportation system development is also uneven, with ups and downs. Specifically, the main performance is that the Comprehensive Development Index decreased from 0.369 in 2013 to 0.297 in 2014, mainly because Ürümqi was affected by the riot incident, which affected the development of the transportation system to a certain extent. The Ürümqi Transportation System Development Composite Index rose from 0.378 to 0.435 in 2015-2016, an increase of 46.5%, demonstrating the momentum of rapid development. The main reason is that transportation has been greatly developed, Xinjiang Railway stepped into the era of high-speed rail in 2014, so that the degree of modernization of railroad transportation has developed by leaps and bounds, and the capacity of railroad transportation has been improved unprecedentedly; at the same time, the passenger throughput of Xinjiang Ürümqi International Airport exceeded the 20 million mark for the first time in 2016, and the positioning of Ürümqi Diwopu International Airport has been upgraded from a "Gateway Hub" to an "International Aviation Hub" at the same level that can be comparable to that of Beijing, Shanghai, and Guangzhou. All of the above have contributed to the development of the Ürümqi transportation system. The sharp increase in the comprehensive index of the development of the transportation system in Ürümqi in 2017-2019 indicates the rapid development of the transportation system in Ürümqi, mainly due to the accelerated construction of the international transportation hub in Ürümqi on the basis of continuous investment in the continuous construction of the transportation infrastructure in the previous period, and the increasing prominence of the international transportation hub status.2020-2022, due to the impact of the epidemic, the overall trend of the index of the comprehensive development level of the transportation system is declining.

From the development status of tourism system, the comprehensive evaluation value of tourism system increases from 0.356 in 2013 to 0.878 in 2019, with an increase of nearly 146.63%, indicating that the tourism system of Ürümqi city has been developed rapidly. From Figure 2 development trend, the overall trend of Ürümqi tourism system development from 2013-2019 is an upward phase, but two distinct development phases can be seen. Among them, the Comprehensive Development Index decreased from 0.356 to 0.313 in 2013-2014, which was mainly due to the impact of the riot incident in Ürümqi, which partially affected the healthy development of the tourism system. However, after 2015, the tourism system in Ürümqi has shown a rapid upward trend, which is mainly due to the main construction results of the development strategy of Xinjiang Tourism "One Heart, One Place" put forward by the Second Central Xinjiang Work Symposium in 2015, which has greatly facilitated the rapid development of the tourism system in Ürümqi by improving the tourism infrastructure across the territory, increasing the strength of tourism promotion, developing new tourism products, launching new routes for tourism, and fostering new business models, among other measures. In 2020-2022, also affected by the epidemic, the overall trend of the Tourism System Composite Development Index is a significant decrease.

Comparison of the relationship between the development index of Ürümqi transportation system and tourism system concludes that: from 2013 to 2016, the comprehensive development level of the transportation system is higher than the comprehensive development level of the tourism system in the same period, and the type of comparison is shown as $P(X) > Q(Y)$, i.e., presenting a lagging type of development status of tourism. However, the comprehensive development level of the transportation system in 2017-2019 began to be lower than the comprehensive development level of the tourism system in the same period, and the type of comparison is again manifested as: $P(X) < Q(Y)$, i.e., presenting a transportation lagging-type development state. The above illustrates that before 2016, the transportation system in Ürümqi played a certain supporting role in the development of the tourism system, and the trend of the transportation system's leading role in the tourism system in 2017-2019 appears to be gradually weakening. Therefore, transportation construction should be accelerated to meet the needs of rapid tourism development. However, in the period of 2020-2022, both systems are affected by the epidemic, and it shows that the comprehensive development level of the transportation system is higher than the comprehensive development level of the tourism system in the same period, and the comparison type is: $P(X) > Q(Y)$, and it shows the tourism lagging development state, which indicates that the development of the tourism system is heavily reliant on the development state of the transportation system. Therefore, in the long run, in order to adapt to the sustainable development of the tourism industry, it is still appropriate to further accelerate the construction of the integrated transportation system, while strengthening the coordinated development of the two after the epidemic.

4.3 Analysis of Degree of Coupling Coordination Between Systems

The coupling coordination degree of Ürümqi transportation system and tourism system is shown in Figure 3 and Table 5.

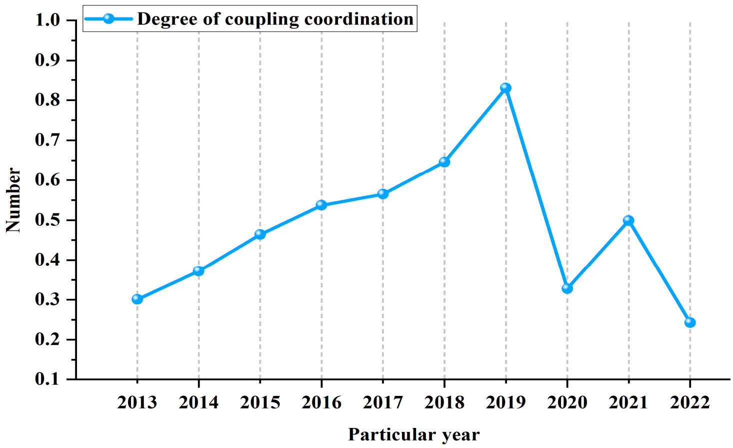

Fig. 3. Development trend for the degree of coupling coordination between the transportation and tourism systems in Ürümqi, 2013–2022

Table 5. Calculation results of coupling coordination degree

Year	Coupling degree *C* value	Coordination index *T*-value	Coupling coordination *D*-value	Degree of coupling coordination	Coordination level	Coordination phase
2013	0.255	0.356	0.301	Mild dysfunction	4	Recessionary phase
2014	0.463	0.299	0.372	Mild dysfunction	4	
2015	0.625	0.344	0.464	On the verge of dysfunction	5	Harmonization of the transition phase
2016	0.731	0.395	0.537	Bare coordination	6	
2017	0.783	0.408	0.565	Bare coordination	6	
2018	0.831	0.503	0.646	Primary coordination	7	Harmonized development phase
2019	0.877	0.787	0.830	Good coordination	9	
2020	0.382	0.281	0.328	Mild dysfunction	4	Recessionary phase
2021	0.596	0.418	0.499	On the verge of dysfunction	5	Harmonization of the transition phase
2022	0.286	0.206	0.243	Moderate dysfunction	3	Recessionary phase

The coupling coordination degree D of the transportation system and tourism system in Ürümqi increased from 0.301 to 0.830 from 2013 to 2019, which indicates that the coupling coordination degree of the transportation system and tourism system is improving year by year, the coupling interaction effect is gradually strengthened, and the coupling coordination degree grade is gradually transformed from mildly dysfunctional development to well-coordinated development, and keeps moving to a better direction of development. However, after peaking in 2019 the overall trend decreases in 2020-2022 due to the impact of the epidemic. The development of system coupling and coordination has gone through 3 different stages:

Coordination transition stage (2013-2015): During this period, the coupling coordination degree increased from 0.301 in 2013 to 0.464, with an average annual growth rate of 16.1%, indicating that the level of coupling coordination between the two systems gradually increased, from mildly dysfunctional to on the verge of dysfunctional transformation.

Coordinated development stage (2016-2019): during this period the coupling coordination degree rises from 0.537 in 2016 to 0.830 in 2019, with an average annual growth rate of 12.01%, and the coupling coordination degree of the two crosses directly from barely coordinated to well-coordinated coupling state, which indicates that the coupling coordination degree of Ürümqi's transportation and tourism systems growth rate is faster, the development potential is huge, and the interaction between the two is further enhanced.

Epidemic impact stage (2020-2022): as 2020-2022 is affected by the epidemic, the coupling coordination degree of the transportation system and tourism system also goes up and down with the bumps of the epidemic, and the value of the coupling coordination degree decreases from 0.830 to 0.328, then rises to 0.499, and finally plunges down to 0.243, and the coupling coordination degree grade is specifically shown from good coordination status to mildly dysfunctional status, then to near dysfunctional status, and finally directly plummeted to moderate dysfunctional status. The development stage, although it declines from coordinated development to dysfunctional decline, then rises to coordinated transition, and finally declines to dysfunctional decline stage, are caused by the impact of the epidemic. It shows that the two systems will have coupled and coordinated fluctuation phenomenon under the influence of external disturbances and uncontrollable factors.

The above analysis proves once again that there is a close coupling and coordinated development relationship between the Ürümqi transportation system and the tourism system. Therefore, in the future, attention should be paid to strengthening the development status of the coupling coordination between the Ürümqi transportation system and the tourism system after the end of the epidemic, and measures should be taken to promote the coordinated development of the two systems.

4.4 Gray Correlation Analysis of the Transportation System and Tourism System

On the basis of constructing the evaluation index system of Ürümqi transportation system and tourism system, the gray correlation model is applied to take the coupling coordination degree of Ürümqi transportation system and tourism system as a reference sequence. The indexes of transportation system and tourism system is taken as a comparative sequence, and by calculating the degree of coupling and coordination and the gray correlation of indexes of the evaluation index system of transportation system and tourism system, and the results of the calculation are shown in Table 6. We analyze the influence of evaluation indicators of Ürümqi transportation system and tourism system on the development of system coupling coordination degree.

Table 6. Gray correlation and ranking of evaluation indicators and system coupling coordination degree of transportation system and tourism system

Evaluation indicators	Evaluation content	Relatedness value	Ranking
Y5	Total tourism revenue as% of GDP	0.827	1
X6	Air passenger capacity	0.806	2
X4	Railroad passenger capacity	0.783	3
X7	Air passenger turnover	0.782	4
X8	Urban public transportation vehicles	0.756	5
X1	Highway mileage	0.743	6
Y4	Domestic tourism income	0.739	7
X9	Road area	0.717	8
X5	Railroad passenger turnover	0.709	9
Y1	Domestic tourist arrivals	0.684	10
Y2	Inbound tourist arrivals	0.630	11
Y3	International tourism (foreign exchange) income	0.626	12
X2	Road passenger capacity	0.585	13
X3	Road passenger turnover	0.565	14

From the calculation results in Table 6, it can be seen that the gray correlation value of Y5 is 0.827, ranked 1st, belonging to the very high level of correlation, and the coupling coordination degree of transportation system and tourism system plays an extremely strong role and has the greatest influence. X6 has a gray correlation value of 0.806, ranking 2nd, which is a high level of association and has a strong role in coupling coordinating of the transportation system with the tourism system; X4 has a gray correlation value of 0.783, ranking 3rd, which is a high level of association and has a strong role in coupling coordinating of the transportation system with the tourism system; whereas X2 has a gray correlation value of 0.585, ranking 13th, which belongs to the medium level of association and has a medium level of coupling coordinating effect on the transportation system and tourism system. The above analysis shows that domestic tourism revenue in Ürümqi will increase with the increase in the number of tourists. most of the increase in the number of tourists is mainly the tourists who prefer choosing to take airplanes and trains, while the number of tourists choosing to travel by road transportation is decreasing year by year, which basically coincides with the above analysis.

4.5 Sensitivity Analysis

Based on the results of gray correlation calculation, sensitivity analysis of evaluation indexes of transportation system and tourism system is carried out to find out the key factors affecting the coupling coordination degree of transportation system and tourism system in Ürümqi. Considering that Ürümqi transportation system and tourism system are affected by the epidemic in 2020-2023, the coupling coordination degree is in a fluctuating and undulating state. In order to ensure that the data are in line with the actual situation, based on the data of the transportation system and the tourism system in 2019, the X4 and X6 indexes with the top ranking of the degree of correlation are selected for sensitivity analysis. Two parallel adjustments are carried out respectively, that is when adjust the X6 indicator, the Y1 and Y4 indicators are changed; when adjust the X4 indicator, the Y1 and Y4 indicators are changed. Ultimately, based on the changes in the degree of coordination of system coupling produced by the two adjustments, we derive the most important influencing factors affecting the degree of coordination of system coupling. The adjusted system coupling coordination degree comparison is shown in Figure 4.

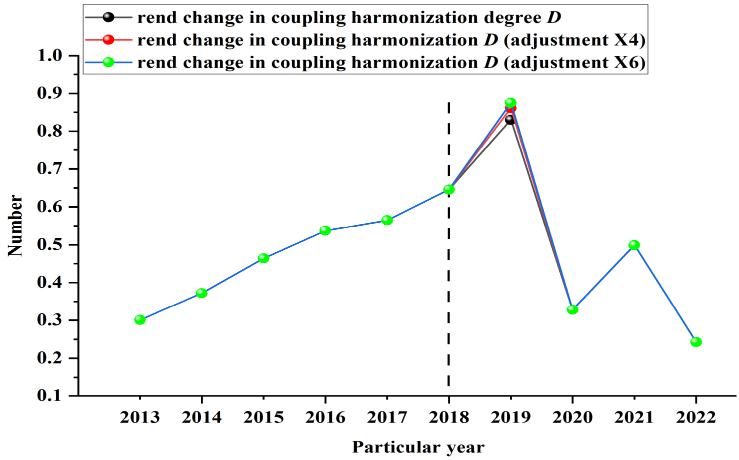

Fig. 4. Comparison of the development trend of system coupling coordination degree

It is calculated that adjusting for an average growth rate of 23.37% for indicator X6 would result in an average increase of 88% for indicator Y1 and 3 per cent for indicator Y4. Adjusting the X4 indicator by an average growth rate of 9.7% would result in an average growth of 25% for the Y1 indicator and 3% for the Y4 indicator. As can be seen from Figure 3, adjusting the X6 indicator will raise the coupling coordination degree of the transportation system and tourism system from the original 0.830 to 0.875; adjusting the X4 indicator will raise the coupling coordination degree of the transportation system and tourism system from the original 0.830 to 0.861.

Through the above analysis, it can be seen that the factor that has the greatest influence on the improvement of the coupling coordination degree of Ürümqi's transportation system and tourism system is the X6 indicator, followed by the X4 indicator. Mainly because of Ürümqi's special geographic location is determined, Ürümqi is the world's farthest city from the ocean, is the geographic center of the Asian continent, is located in the northwestern part of China, the distance from the central and eastern cities in mainland China average distance of more than 2,000 kilometers. In order to save the cost of travel time, the majority of tourists are willing to choose to take a plane to travel, and taking into account the economic costs and comfort requirements, there are still some tourists choose to Railroad travel. It can be seen that with the development of the economy and the increase of people's income, people pay more attention to the comfort, safety and convenience of travel, which ultimately causes the tourists who choose to travel by road to decrease year by year, which is consistent with the decline in the development trend of the X2 indicator over the years.

5 Conclusions

In order to improve the coupling coordination degree of Ürümqi transportation system and tourism system, the entropy weight method, coupling coordination degree model and gray correlation analysis method are used. The computational study found that air passenger traffic in the transportation system has the greatest impact on the tourism system; railroad passenger traffic has the second greatest impact on the tourism system; and road passenger traffic has the least impact on the tourism system. By adjusting the air passenger volume indicator and the rail passenger volume indicator, it will increase the coupling coordination of the system, and the main conclusions of this paper are as follows:

(1) In terms of the time evolution of the study, the time series of this study is 10 years, which is reference value. The coupling coordination degree of Ürümqi transportation system and tourism system has been in a steady upward trend from 2013-2019 and peaked in 2019, but with a low growth rate. By adjusting both air passenger traffic and rail passenger traffic indicators in the transportation system in 2019 will improve the coupling coordination of the system, which means that air passenger traffic and rail passenger traffic are the key factors affecting the coupling coordination of the system.

(2) In terms of key influencing factors, the transportation system has the greatest impact on the coupling coordination development of transportation and tourism systems in Ürümqi. Moreover, the indicators of air and railroad traffic passenger volume are the key factors affecting the development of system coupling coordination. It is mainly because through the increase of air and railroad traffic passenger volume, it will cause a significant increase in the number of tourists and tourism income in Ürümqi, which will eventually cause changes in the transportation system and tourism system, thus promoting the increase of the coupling coordination of the system.

(3) From the sensitivity analysis of the system coupling coordination degree, it can be seen from the adjustment changes in 2019 that adjusting the air passenger traffic indicator causes the change in the system coupling coordination degree to be greater than the change caused by adjusting the rail passenger traffic indicator, indicating that the air passenger traffic indicator is more sensitive than the rail passenger traffic

indicator. Therefore, in the future, to improve the coupling and coordination of Ürümqi's transportation system and tourism system, it is suggested that firstly improve the index of air passenger traffic, increase the turnover of air passengers, improve the air capacity, increase the construction of civil aviation and other three-dimensional transportation, continuously improve the function of the hub, improve the level of interconnection and improve the efficiency of transferring travelers inside and outside of the country, strengthen the movement of people, promote the development of tourism, and continuously improve the tourism revenue brought by the function of the hub. Secondly, to improve the coupling coordination of Ürümqi's transportation system and tourism system by increasing the indicator of railroad passenger traffic, we should vigorously develop the infrastructure of high-speed railroad to realize high-speed railway network to save the time cost of tourists. At the same time, we should increase the frequency of ordinary trains to improve the turnover of railroad passengers in order to increase the number of tourists, and ultimately to promote the coupling coordination development of the transportation system and the tourism system.

References

1. Ge, J., Ding, K. (2022) Analysis of the evolution characteristics of aviation network driven by tourism in Xinjiang. J. Gansu Sci., 34(05): 136-145. http://doi.org/10.16468/j.cnki.issn 1004-0366.2022.05.022.
2. Martin, C. A., Witt, S. F. (1988) Substitute prices in models of tourism demand. Ann. Tourism Res., 15(2):255-268. http://doi.org/10.1016/0160-7383(88)90086-2.
3. Prideaux, B. (2000) The role of the transport system in destination development. Tourism Manage., 21(1):53-63. http://doi.org/10.1016/s0261-5177(99)00079-5.
4. Crouch, G. I. (1994) Demand elasticities for short-haul versus long-haul tourism. J. Travel Res., 33(2):2-7. http://doi.org/10.1177/004728759403300201.
5. Hayes, C. J. (2023) Placemaking in the periphery: leveraging liminoid spaces for host promotions and experience creation at the Japan 2019 Rugby World Cup. Tourism Hospitality, 4(2):1-19. http://doi.org/10.3390/tourhosp4020013.
6. Fernandez, X. L., Coto-Millan, P., Diaz-Medina, B. (2018) The impact of tourism on airport efficiency: the Spanish case. Util. Policy, 55(0):52-58. http://doi.org/10.1016/j.jup.2018.09.002.
7. Can, V. V. (2013) Estimation of travel mode choice for domestic tourists to Nha Trang using the multinomial probit model. Transp. Res. Part A: Policy Pract., 49:149-159. http://doi.org/10.1016/j.tra.2013.01.025.
8. Xu, Y., Qin, J., Wu, T., Liu, B., Xia, Y. (2022) Research on spatiotemporal association between tourism and transportation based on CGS model. Comput. Intell. Neurosci., 2022:9559170. http://doi.org/10.1155/2022/9559170.
9. Zhang, W., Wen, L. (2023) Analysis of the coordination effects and influencing factors of transportation and tourism development in Shaanxi region. Sustainability, 15(12):9496. http://doi.org/10.3390/su15129496.
10. Lu, B., Liu, M., Ming, Q., Liu, A., Li, T. (2020) Coupling and coordination of tourism and transportation in China and its dynamic mechanism. World Reg. Stud., 29(01): 148-158.
11. Ye, M., Wang, Z., Tan, Y. (2020) Characteristics and effects of coupled coordination between transportation and tourism development in western Hunan region. Econ. Geogr., 40(08): 138-144. http://doi.org/10.15957/j.cnki.jjdl.2020.08.017.

12. Liu, J. (2020) Empirical analysis of the coupled and coordinated development of tourism economy and urban transportation in Nanjing. China Econ. Trade Her., (12): 81-83.
13. Yu, F., Hu, W., Rong, H. (2015) Coordinated development about tourism economy and transportation in medium and small cities: Chizhou as example. Sci. Geogr. Sin., 35(09): 1116-1122. http://doi.org/10.13249/j.cnki.sgs.2015.09.007.
14. Chen, X., Li, Y. (2008) Quantitative evaluation of coordinated development of urban traffic and tourism−taking Dalian as an example. Tourism Tribune, (02): 60-64.
15. Wang, Y., Ma, Y. (2011) Analysis of coupling coordination between urban tourism economy and transport system development−a case study of Xi'an city. J. Shaanxi Normal Univ. (Nat. Sci. Ed.), 39(01): 86-90. http://doi.org/10.15983/j.cnki.jsnu.2011.01.024.
16. Zhang, S., Wei, F. (2012) Study on the optimized interaction between tourism economy and transportation based on the coupling degree model-taking Hebei province as an example. J. Shaanxi Agric. Sci., 58(04): 163-166.
17. Bi, L., Ma, Y. (2013) Analysis of coupling coordination between traffic system development and province tourism economy−a case study of Yunnan province. J. Univ. Finance Econ., 26(01): 124-128. http://doi.org/10.19331/j.cnki.jxufe.2013.01.023.
18. Chen, Q., Jin, X. (2019) Spatial and temporal analysis on the coupling and coordination between highway transportation and tourism economy in Anhui province. J. Chizhou Univ., 34(11): 31-36.
19. Chen, X., Xiong, H. (2009) The quantitative evaluation and time series analysis on the coordinated development between Xinjiang's transport and tourism. Areal Res. Dev., 28(06): 118-121.
20. Sheng, Y., Zhong, Z. (2009) Study on the coupling coordinative degree between tourism industry and regional economy−a case study of Hunan province. Tourism Tribune, 24(08): 23-29.
21. He, S. (2013) Quantitative evaluation research on the coordinated development of transportation and tourism in Urumqi. Spec. Zone Econ., (02): 93-95.
22. You, D., Xu, F. (2005) The comparative analysis on economic benefit of regional tourism based on information entropy. J. Appl. Stat. Manage., (03): 82-85. http://doi.org/10.13860/j.cnki.sltj.2005.03.015.
23. Qi, Y. The method of determining index weight and its application research. Northeast. Univ., 2010. http://doi.org/10.7666/d. J0105079.
24. Feng, Y., Wu, X., Zhang, H., Jiang, Z. (2021) Spatial and temporal evolution of coupled and coordinated development of high-speed transportation and tourism in Jiangsu province. Mod. Urban Res., (01): 59-65+108.
25. Deng, F., Fang, Y., Xu, L., Li, Z. (2020) Tourism, transportation and low-carbon city system coupling coordination degree: a case study in Chongqing municipality, China. Int. J. Environ. Res. Public Health, 17(3):792. http://doi.org/10.3390/ijerph17030792.
26. Li, S., Du, S. (2021) An empirical study on the coupling coordination relationship between cultural tourism industry competitiveness and tourism flow. Sustainability, 13(5525):5525. http://doi.org/10.3390/su13105525.
27. Chen, Q., Bi, Y., Li, J. (2021) Spatial disparity and influencing factors of coupling coordination development of economy-environment-tourism-traffic: a case study in the middle reaches of Yangtze River urban agglomerations. Int. J. Environ. Res. Public Health, 18(15):7947. http://doi.org/10.3390/ijerph18157947.
28. Gao, N., Ma, Y., Li, T., Bai, K. (2013) Study on the coordinative development between tourism Industry and urbanization based on coupling model: a case study of Xi'an. Tourism Tribune, 28(01): 62-68.

29. Liao, Z. (1999) Quantitative judgement and classification system for coordinated development of environment and economy–a case study of the city group in the Pearl River Delta. Trop. Geogr., (02): 76-82.
30. Wang, J., Han, Z., Xia, X. (2014) Research on coordination between Bohai city tourism and urban development. Resource Dev. Mark., 30(11): 1377-1381.
31. Li, Q., Zhao, Y., Li, S., Li, X. (2020) Analysis of the spatial-temporal characteristics and driving force of the coupling between social security and economic development in China. Geogr. Res., 39(06): 1401-1417.
32. Zhang, J., Zhang, Y. (2020) Measurement and analysis of coupling coordination degree of eco-agriculture and eco-tourism based on gray system theory: Hunan province as an example. Ecol. Econ., 36(02): 122-126+144.
33. Zhang, C. Coupling of tourism flows and destinations: a study on modeling and factor contributions. Shaanxi Normal Univ., 2015.