Research on the Coupled and Coordinated Development of Tourism and Transport in Chengdu City

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Abstract: Based on a total of 16 indicators selected from the tourism and transport industries, an evaluation index system of the coupling and coordination development level of tourism and transport is constructed. The entropy value method and the coupling coordination degree model are used to conduct an empirical study on the development level and coupling coordination level of the transport and tourism industries in Chengdu City from 2011 to 2020. The results show that, on the whole, the coupling coordination degree of transport and tourism in Chengdu is poor and has been in a state of mild to moderate dysfunction. The development level of tourism lagged behind the development of transport from 2011 to 2012, and the two were in a state of mild dysfunction. However, from 2013 onwards, the development level of tourism was prioritized over the development level of transport. This shift caused the coupling coordination degree of the two industries to decline sharply to 0.23305 in 2013. The development level of the tourism industry increased again, reaching 0.34206 in 2019, which marked an improvement. Consequently, the coordination degree of the transport and tourism industries evolved from moderate dislocation to mild dislocation. Finally, the results of the empirical research are analyzed, and corresponding suggestions are put forward to promote the sustainable growth of the transport and tourism industries in Chengdu City. These suggestions aim to improve the coupled and coordinated development level of the two industries.

Keywords: Coupling coordination; Chengdu city; Transport industry; Tourism industry; Entropy value method; Coupling coordination degree model

1. Introduction

With the deepening of China's market economic system, the importance of tourism has become increasingly prominent, and transport, as a key foundation for tourism development, is directly related to the sustainable development of tourism [1,2]. Tourists' requirements for transport are constantly improving, and advancements in transport technology significantly promote the development of tourism [3,4]. Numerous policies issued by the state emphasize the integrated development of transport and tourism [5]. In the context of Chengdu's rapid development, promoting the synergistic development between the two has become an urgent problem to be solved.

Developed countries were the earliest to pay attention to the relationship between tourism and transport [6]. Foreign scholars primarily focus on the correlation between tourism and transport [7], the impact of transport on the development of tourism [8-10], the mutual demand between transport and tourism, and tourists' choices of travel modes [11]. There are fewer foreign studies on the coupled and coordinated development of tourism and transport [12,13]. Domestic studies mostly use coupled coordination models, fuzzy comprehensive evaluation, and other methods to explore the coordination relationship between tourism and transport [14,15]. Some scholars also study the coordinated development of tourism, traffic conditions, and the ecological environment from the perspective of a ternary relationship [16,17]. Many studies reveal that the coupled coordination of tourism and transport has gradually increased, showing a spatio-temporal correlation [18,19]. Research on different regions, provinces, and cities in China shows differences in the coupling coordination between transport and tourism, but the overall trend is toward coordination [20,21]. Studies specific to highways or high-speed railways and the tourism economy show a positive trend [22]. Additionally, the understanding of the relationship between transport and tourism has been further deepened through the analysis of the spatio-temporal evolution of transport [23].

This paper addresses the insufficient research on the coupled synergistic development of tourism and transport in Chengdu and the lack of comprehensiveness in the evaluation system. It aims to construct a multi-indicator evaluation system to empirically analyze the coupled and coordinated relationship in Chengdu City, supported by data from 2011–2020. Through qualitative and quantitative research, it identifies problems and puts forward countermeasures to promote the coordinated development of the two industries. This study provides new perspectives and ideas for Chengdu City and other regions, which is of great theoretical and practical significance.

2. Research design

2.1. Case site selection

Chengdu is the capital of Sichuan Province, a sub-provincial city with a history of more than 2,000 years. It ranks among China's top ten ancient capitals and famous historical and cultural cities. Located in the western part of the Sichuan Basin, it neighbors several cities and autonomous regions. In 2016, the total area of Chengdu reached 14,335 km², with an urban area of 4,241.81 km^2, of which the built-up area is 931.58 km^2 [24]. Chengdu has risen significantly in international tourism rankings, winning numerous honors, such as "World's Best Tourism Destination," "China's Tourism and Leisure Demonstration City," and "National Cultural and Tourism Consumption Demonstration City" [25]. As an important city in Southwest China, Chengdu is rich in tourism resources and has convenient transport, making it an ideal case site for this study.

2.2. Data sources and research methods

2.2.1. Data sources

Based on relevant literature, this paper selects Chengdu City as the study object. Using data availability and the referability of the index system, relevant data from 2011 to 2020 are adopted to study the overall transport situation in Chengdu City and its coupling and coordination with tourism. All index data on the development of tourism and transport are obtained from the "Chengdu Statistical Yearbook."

2.2.2. Research methods

(1) Literature analysis method: The literature on the coupled and coordinated development of tourism and transport, both domestic and international, was collected through the China Knowledge Network. The coordinated development of the two was qualitatively analyzed by combining data from the Statistical

Yearbook. The research trend was systematically sorted to provide a theoretical reference for this paper.

(2) Quantitative and qualitative combination method: A multi-indicator evaluation system was established, and the coupling model was used to quantitatively analyze the degree of synergistic development of tourism and transport in Chengdu. Combining qualitative and quantitative methods makes the research more rigorous and scientific, with conclusions qualitatively summarized after quantitative research.

2.3. Research process

2.3.1. Construct evaluation index system

Drawing on the indicator evaluation system of relevant scholars [18,19,26] and the actual situation of tourism and transport development in Chengdu, we construct the indicator evaluation system representing the transport capacity of Chengdu and the indicator evaluation system representing the development of Chengdu's tourism industry. These systems were developed according to the principles of scientificity, reasonableness, easy access to data, and comprehensiveness. The evaluation system for transport includes three primary indicators and nine secondary indicators, while the evaluation system for tourism includes two primary indicators and seven secondary indicators. All indicators are positive indicators, selected to be representative and combined with statistical data from the Chengdu Statistical Yearbook. The construction of specific indicators is shown in **Table 1**.

Table 1. Indicator system of tourism and transport industry in Chengdu City

	Primary indicator	Secondary indicators	Unit	Characteristic
Traffic transport sector (J)	Scale of transport network	Road mileage	km	+
		All motor vehicle types	10,000 vehicles	+
		Number of civil aviation routes		+
	Transport capacity	Road passenger traffic	million	+
		Railway passenger traffic	million	+
		Civil aviation passenger traffic	million people	+
	Transport benefits	Road passenger turnover	million km	+
		Railway passenger turnover	million km	+
		Civil air passenger turnover	million km	+
Travel trade (L)	Tourism economic benefits	Gross tourism income	billion Chinese yuan	+
		Domestic tourism revenue	billion Chinese yuan	+
		International tourism income	million US dollars	+
		Per capita spending on tourism	Chinese yuan	+
	Tourism attraction capacity	Domestic and foreign tourists received	10,000 person trips	+
		Domestic tourist arrivals	10,000 person trips	+
		Road passenger traffic	10,000 person trips	+

2.3.2. Measurement of indicator weights: entropy value method

Measuring the degree of coupling between the transport industry and tourism requires first assigning weights to the indicators. The entropy value method is widely used because of its high accuracy and objectivity [27]. In this paper, the entropy value method is used to assign weights to the evaluation indexes of the tourism and transport industry in Chengdu, calculate the comprehensive score, and then conduct a comprehensive evaluation of the two. The steps are as follows: assignment, calculation of comprehensive score, and comprehensive evaluation.

First of all, this paper selects the panel data about the transport and tourism industry in Chengdu City from 2011 to 2020, so the data of the Chengdu City Statistical Yearbook needs to be standardized after the data collection and organization, assuming that X_{ij} and Y_{ij} represent the original value of a certain indicator in transport and tourism industry in a certain year respectively, where $i(i = 1, 2, ..., n)$ represents a certain year, $j(j = 1, 2, ..., m)$ denotes a certain indicator, X_{max}, Y_{max} denotes the maximum value of a certain indicator in all the years in transport and tourism respectively, X_{min}, Y_{min}, denotes the minimum value of a certain indicator in all the years, then X'_{ij}, Y'_{ij} represent the original data of transport and tourism respectively. The standardized values are calculated as follows:

$$\begin{cases} X'_{ij} = (X_{ij} - X_{min})/(X_{max} - X_{min}) \\ Y'_{ij} = (Y_{ij} - Y_{min})/(Y_{max} - Y_{min}) \end{cases} \quad (1)$$

Since the values after performing the normalization process may have zero values, to avoid the meaningless state of calculating ln 0 afterward, 0.0001 is added to each normalized value [23]. At this point, the equation reads:

$$\begin{cases} X'_{ij} = (X_{ij} - X_{min})/(X_{max} - X_{min}) + 0.0001 \\ Y'_{ij} = (Y_{ij} - Y_{min})/(Y_{max} - Y_{min}) + 0.0001 \end{cases} \quad (2)$$

Then it is to find the proportion of each indicator in the two systems in different years, P_{1j}, P_{2j} denotes the $j(j = 1, 2, ..., m)$ indicators in the $i(i = 1, 2, ..., n)$ in the year the weight formula is:

$$\begin{cases} P_{1j} = X'_{ij}/\sum_{i=1}^{n} X'_{ij} \\ P_{2j} = Y'_{ij}/\sum_{i=1}^{n} Y'_{ij} \end{cases} \quad (3)$$

Once again, the entropy value e_j is sought for the j-th $j(j = 1, 2, ..., m)$ entropy value e_j of the indicator, the entropy value e_j is calculated by the formula:

$$e_j = -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij} \ln p_{ij} \quad (4)$$

The value h_j is used to measure the size of the indicator variability and directly determines the size of the weight that the indicator occupies in the whole system [27]. The greater the data variability h_j, the smaller the entropy value e_j, the greater the weight of the indicator, then the greater the impact of the indicator on the comprehensive evaluation; on the contrary, the smaller the data variability h_j, the greater the entropy value e_j, the smaller the weight of the indicator, the smaller the impact of the indicator on the comprehensive evaluation. To find the coefficient of variation h_j of j an indicator, the formula is:

$$h_j = 1 - e_j \quad (5)$$

Then find the total weight of the j-th indicator in all the years, the formula is:

$$W_j = \frac{h_j}{\sum_{j=1}^{m} h_j} = \frac{1-e_j}{\sum_{j=1}^{m}(1-e_j)} \quad (6)$$

Finally, the linear weighting method is used to find the development-level indices H_{1i} and H_{2i} of transport and tourism, which are calculated as follows:

$$\begin{cases} H_{1i} = \sum_{j=1}^{m} W_j X'_{ij} \\ H_{2i} = \sum_{j=1}^{m} W_j Y'_{ij} \end{cases} \quad (7)$$

From the above calculation, the index system of Chengdu's transport and tourism industry is derived, in which the larger the index of the development level of the transport and tourism industry, H_{1i} and H_{2i}, the higher the score value of the evaluation object, indicating that the comprehensive effect of the evaluation results is better.

2.3.3. Coupling coordination model

This paper draws on the capacity coupling coefficient model in physics to establish the coupling coordination degree model between the two systems of transport and tourism [28]. Since transport is one of the six elements of tourism, and the relationship between transport and tourism is mutually reinforcing, the coupling coordination development level between transport and tourism in Chengdu is calculated by drawing on the relevant coupling model, and the specific calculation formula is as follows.

The coupling formula:

$$C = 2\sqrt{H_{1i} \times H_{2i}/(H_{1i} + H_{2i})^2} \qquad (8)$$

Integrated coordination formula:

$$T = \alpha H_{1i} + \alpha H_{2i} \qquad (9)$$

Coupled coordination degree equation:

$$D\ (H_{1i}, H_{2i})\ = \sqrt{C \times T} \qquad (10)$$

Here, C is the coupling degree of transport and tourism, $C \in [0, 0.5]$, the higher the coupling degree C, the stronger the interaction between the systems; T is the comprehensive coordination index of transport and tourism; D is the coupling coordination degree of tourism and transport. At the same time, according to related research [29,30], tourism and transport industries in the process of coordinated development, both are very important, so take $\alpha = \beta = 0.5$ and the coordinated development of the transport industry and tourism for the coupling degree of coordination level division [31], the specific division criteria as shown in **Table 2**.

Table 2. Coupling coordination degree classification level table

D	Coordination level	D	Coordination level
$0.0 < D \le 0.1$	Extreme disorder development	$0.5 < D \le 0.6$	Barely coordinated development
$0.1 < D \le 0.2$	Severe disorder development	$0.6 < D \le 0.7$	Elementary coordinated development
$0.2 < D \le 0.3$	Moderate disorder development	$0.7 < D \le 0.8$	Intermediate co-ordinated development
$0.3 < D \le 0.4$	Mild dysregulation development	$0.8 < D \le 0.9$	Good coordinated development
$0.4 < D \le 0.5$	Threatened dysregulation development	$0.9 < D \le 1.0$	Quality co-ordinated development

3. Empirical research and analysis of results

3.1. Empirical research

This paper adopts the panel data of relevant indicators about the transport industry and tourism in Chengdu City from 2011 to 2020, processes the data through the above, calculates the development level of the transport industry and tourism industry with the formula of the weight of the indicators, and then calculates the degree of coordination of the coupling between the development level of the transport industry and tourism industry in Chengdu City according to the coupling coordination model, and finally retains the calculated results to five decimals, and finally reserves five decimals, and the results of the calculation. The specific empirical results are shown in **Table 3**.
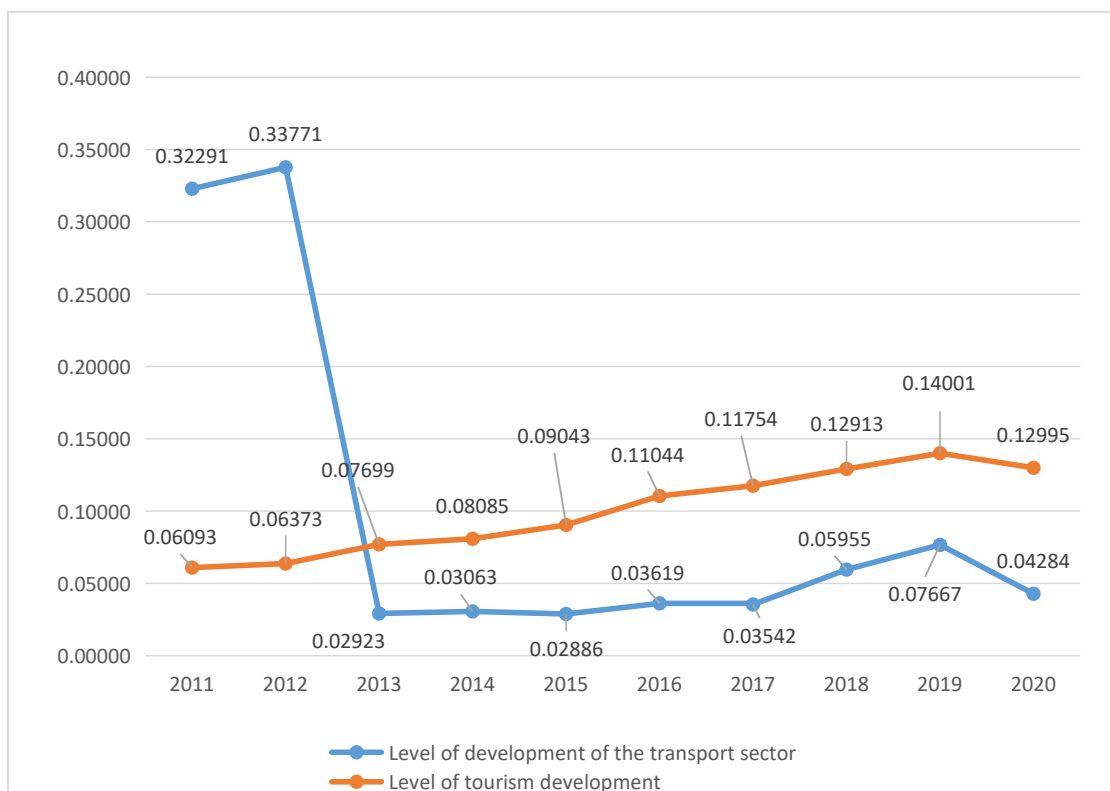
Table 3. Empirical results of the coupling coordination degree of transport industry and tourism development level

Year	Level of development of the transport industry (H_{1i})	Level of tourism development (H_{2i})	Degree of coupling coordination (D)	Coordination level
2011	0.32291	0.06093	0.38041	Mild disorder development
2012	0.33771	0.06373	0.38905	Mild disorder development
2013	0.02923	0.07699	0.23305	Moderate disorder development
2014	0.03063	0.08085	0.23870	Moderate disorder development
2015	0.02886	0.09043	0.24255	Moderate disorder development
2016	0.03619	0.11044	0.26971	Moderate disorder development
2017	0.03542	0.11754	0.27284	Moderate disorder development
2018	0.05955	0.12913	0.31575	Mild disorder development
2019	0.07667	0.14001	0.34206	Mild disorder development
2020	0.04284	0.12995	0.29297	Moderate disorder development

3.2. Result analysis

3.2.1. Development level result analysis

Figure 1 shows the development level of transport and tourism in Chengdu from 2011 to 2020. Before 2013, the transport industry leads; after that, tourism rises rapidly and surpasses. The transport industry fluctuates and rises, and changes from quantity to quality after 2013, but declines in 2020 due to the impact of the epidemic. Tourism has grown significantly after 2015, largely due to Chengdu's focus on and support for tourism. both decline in 2020 due to the Xinguan epidemic. Overall, both markets develop positively, but the epidemic hits both.

Figure 1. Trend of the development level of transport and tourism in Chengdu City

3.2.2. Analysis of coupling coordination degree results

Figure 2 shows that the overall coupling coordination degree of transport and tourism in Chengdu is low. 2011–2012 is mildly out of tune, and 2013–2018 is moderately out of tune. The reason is that the development of tourism lagged behind the transport industry until 2013, and then the tourism industry overtook the transport industry, resulting in a sudden drop in the degree of coupling coordination. In 2018, the development of the tourism industry was improved, narrowing the gap with the transport industry, and returning to a mild dislocation. However, in 2020, due to the impact of the new crown epidemic, the coupling degree of coordination between the two is again back to the level of moderate dislocation.
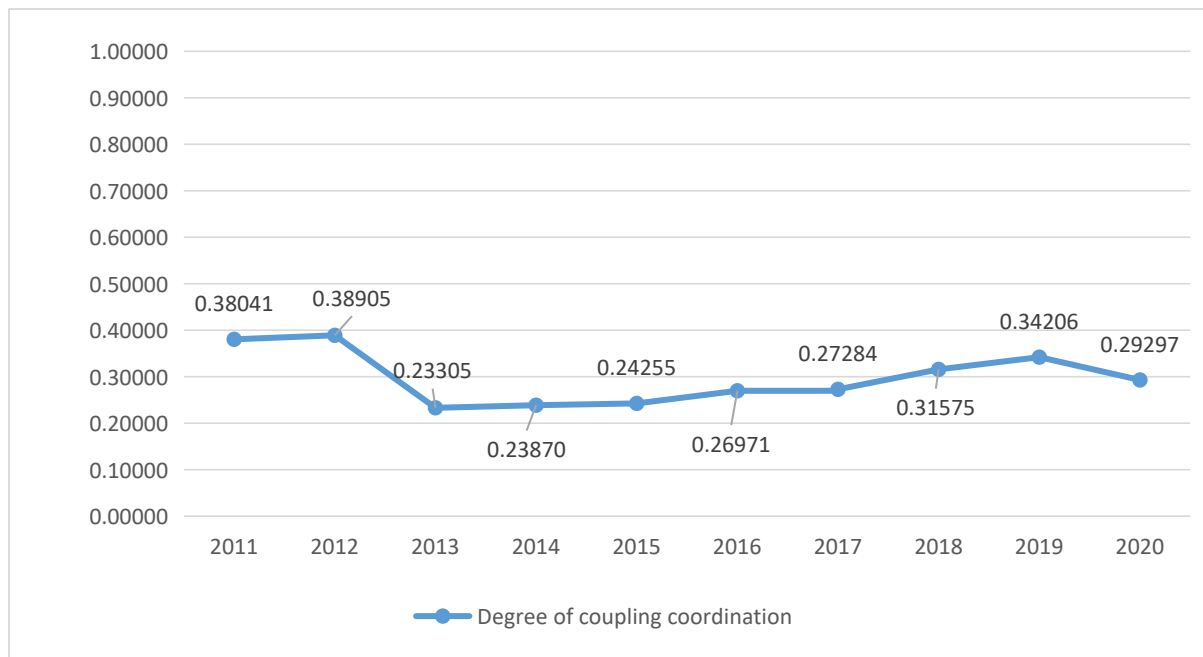

Figure 2. Trend of coupling coordination degree of transport and tourism in Chengdu city

By analyzing the results of the above coupling coordination degree, the coupling and coordinated development of the tourism and transport industry in Chengdu is currently in a state of disorder, which is very unfavorable for the long-term development of Chengdu, but the results also show that there is much room for the improvement of the integration degree of the transport industry and the tourism industry in Chengdu and that there is an urgent need for the coordinated development of the two industries. Therefore, relevant departments should take initiatives and countermeasures to solve the detailed problems of the coupled and coordinated development of tourism and transport in Chengdu.

4. Conclusions and recommendations

4.1. Conclusion

This paper analyzes the level of coupled and coordinated development of transport and tourism in Chengdu by constructing an evaluation index system for the synergistic development of transport and tourism in Chengdu. Using the entropy value method and coupled coordination model, the study draws the following conclusions:

    (1) Overall, the coupling coordination degree of the transport and tourism industries in Chengdu from 2011 to 2020 is poor and has been at the level of mild or moderate dislocation.

    (2) The comprehensive development of the tourism industry in Chengdu after 2013 has been higher than

the development level of the transport industry in the same period. This indicates that the level of transport development in Chengdu cannot fully meet the needs of the rapidly developing tourism industry, and the shortcomings of the transport industry constrain the development of the tourism industry to a certain extent.

(3) From the trend chart of the overall development level, it can be seen that both industries are rising, and the coupling coordination degree is also developing towards coordination. Therefore, for the tourism and transport industries in Chengdu to achieve a more high-quality and coordinated state in the future, it is necessary to formulate relevant measures to continue supporting the coordinated development of both industries and maintain their synergistic relationship.

4.2. Recommendations

To promote the synergistic development of tourism and transport in Chengdu, improve and optimize the efficiency and quality of tourism development, and provide an efficient, safe, comfortable, and convenient transport environment for the tourism industry, the following recommendations are proposed:

(1) Deepen research and data collection: Enhance data collection through questionnaires and expert interviews to improve the credibility of the study. Provide more comprehensive and accurate data support for the synergistic development of tourism and transport in Chengdu.

(2) Optimization and upgrading of transport infrastructure: Build a modern transport network with high-speed rail and expressways as the core to improve the coverage and accessibility of the transport network. Focus on the development of urban rail transport to ease intra-city traffic pressure and improve travel efficiency. Increase investment in transport facilities in rural tourist attractions and improve rural transport conditions. Create an efficient and convenient transport environment to support tourism development.

(3) Tourism and transport service innovation: Encourage cooperation between tourism and transport enterprises to develop new promotional models and promote special attractions. The government should improve support policies, optimize route planning around scenic spots, and build a "fast-forward slow-travel" transport network. Promote the application of tourism big data and Internet technology in smart tourism. Provide personalized transport services such as customized tourism routes and chartered bus services. This will improve tourists' experiences and enhance the ability to convert "passenger flow" into "passenger retention."

(4) Branding and integrated development: Highlight Chengdu's urban characteristics and cultural heritage, strengthen the city's branding, and showcase Chengdu's natural scenery and cultural landscape through city promotional films, tourism festivals, and other activities. Strengthen cooperation and exchange between the transport and tourism industries, and explore new modes of integrated development. Enhance the visibility and reputation of Chengdu and promote the deep integration of tourism and transport.

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Disclosure statement

The authors declare no conflict of interest.

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