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Assessment of Coupling Coordination of Tourism Urbanization System in Jiangsu Province, China

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ABSTRACT

As a developed coastal province in China, Jiangsu's tourism urbanization process holds significant demonstrative value for regional sustainable development. This study constructs a novel evaluation system integrating tourism industry, urbanization, and ecological environment subsystems. Employing the Analytic Hierarchy Process (AHP) for initial weighting and entropy method optimization for scientific parameter weighting, it calculates coupling and coordination degrees among subsystems. The median segmentation method identifies developmental stages. Applying this AHP-entropy-coupling coordination model quantitatively assessed 13 prefecture-level cities. Key findings reveal: All cities achieved intermediate coupling (>0.4), confirming high subsystem interrelation; Spatial coupling displayed a distinct bimodal pattern with peaks in northern/southern regions flanking a central trough; Overall coordination levels remained low, with most cities in low-to-intermediate ranges; Six coordination combinations emerged: Southern Jiangsu achieved coordinated development, while Northern and Central cities exhibited disorder. The study proposes differentiated strategies: Regions undergoing rapid urbanization must prioritize infrastructure development and ecological conservation to prevent low-level subsystem constraints. Conversely, areas with stabilized urbanization rates should leverage tourism's driving effects on urbanization and ecology to foster high-level synergy. This integrated approach provides a methodological framework for optimizing regional sustainable development through balanced tourism-urbanization-ecology interactions.

Keywords: : *tourism urbanization, coupling, coordination, ecological environment, subsystem, Jiangsu*

INTRODUCTION

In the late 20th Century, China had sprouted tourism urbanization (*Qian et al. 2012; Li et al. 2021*), directly improving the urbanization level and transforming and upgrading industrial sectors. Regional service sector including, tourism industry, rode the wave (*Wang and Wu 2018*), and created jobs (*Ma and Lv 2020*), which in turn improved the urban ecological environment (*Ma and Lv 2020; Chen and Zhao 2018*). *Luo et al.* (*2016*) had studied China's decades-long urbanization and believed that domestic urbanization would make tourism common for people from all walks of life. Meanwhile, the development of the tourism industry also shapes urbanization in social and cultural dimensions, including population, employment, economy and geographical environment.

Mullins (*1991*) proposed the concept of "tourism urbanization" and believed that tourism urbanization first emerged in western developed countries in the 20th century. It is a form of city built for urban pleasure based on the postmodern consumerist idea. Later, *Gladstone* (*1998*) proposed the concept of "location entropy" and divided the tourist city into tourist metropolises and leisure cities (*Lu and Ge 2006*). Lu and Ge from China believed that tourism urbanization is a product of development at a certain social and economic stage, and a natural urban form that emerges during the development of tourism and urbanization (*Lu and Ge 2006*).

With the deepening of research on tourism urbanization, the interrelationship between tourism and urbanization has become headlines. Some scholars argued that tourism, urbanization, and industrialization play an important influencing role in balancing economic growth and environmental protection in Southeast Asia (*Brahmasrene and Lee 2017*). *Du et al.* (*2021*), *Chen and Zhao* (*2018*) and *Hu et al.* (*2015*) noted that the tourist economy, industrial development, and urbanization level have a coupling-coordination relationship as observed through their empirical studies on China's regional urbanization. The scholars all agreed that coupling refers to the phenomenon in which two or more systems interact and mutually influence each other mutually. The coupling degree quantifies the intensity of these interactions among multiple systems. Typically, the quality and magnitude of coupling effects are assessed through coordination, which represents the beneficial manifestation of coupling interactions. The coordination degree measures the extent to which multiple systems achieve harmonious alignment during the coupling process. While interrelated, these two concepts are distinct: the coupling degree reflects the strength of interactions between systems, whereas the coordination degree evaluates the qualitative harmony of these interactions (*Xie 2020; Fang et al. 2021; Zhao and Zhang 2020*).

In related studies, subsystems are defined as the core components constituting the composite system of tourism urbanization, typically encompassing the tourism industry subsystem, urbanization subsystem, and ecological environment subsystem. Scholars posit that the tourism industry drives urbanization development, Scholars posit that the tourism industry drives urbanization development and urbanization underpins the upgrading of tourism infrastructure and services. while the ecological environment simultaneously sustains and constrains both subsystems. The delineation of these subsystems and the analysis of their coupling coordination provide theoretical analytical tools and practical research perspectives for optimizing regional tourism urbanization strategies (*Xiong et al. 2020; Fang et al. 2021*). However, these studies mostly focused on the interaction of a single or two subsystems, but the coupling-coordination relationship among the three subsystems of the tourism industry, urbanization and ecological environment have not yet been studied. From the perspective of viewing tourism urbanization as a complex system, constructing a multi-subsystem index system suitable for the development evaluation of tourism urbanization and carrying out empirical research on specific regions is an important way to enrich the analysis of the mechanism of tourism urbanization.

In studies on the coupling coordination degree of tourism urbanization, evaluation index systems generally adhere to multi-dimensional and hierarchical construction principles to comprehensively reflect the interactions among the tourism industry, urbanization, and ecologicalenvironment subsystems. Existing research frameworks (*Xiong et al. 2020; Ma 2020; Hu et al. 2015*) typically encompass three core dimensions: tourism industry (market scale, economic benefits, and structural elements), urbanization (economic, demographic, and social urbanization), and ecological environment (pressure, state, and response mechanisms). These systems integrate 20–30 indicators to balance scientific rigor and operational feasibility. The complexity of such systems lies in addressing data heterogeneity through normalization techniques (e.g., range standardization) and optimizing weight allocation via methods, such as Analytic Hierarchy Process (AHP) or entropy weighting to mitigate subjective biases. Regional adaptability is further ensured by adjusting subsystem weights.

By constructing a comprehensive evaluation index system for tourism urbanization and using the cross-sectional data of each district and city in 2021, the action mechanism of each subsystem in the interaction wass explored. This study will follow this idea and take Jiangsu Province as an example to specifically investigates the coupling coordination relationships among the three subsystems- tourism industry, urbanization, and ecological environment-within the process of regional tourism urbanization. Leveraging relevant statistical data for quantitative characterization and hierarchical classification of interaction intensity and synergistic alignment, this framework aims to achieve the identification and comparative analysis of the developmental stages of tourism urbanization across cities.

MATERIALS AND METHODS

Overview of the Research Area

Jiangsu is a coastal province in the Yangtze River Delta, facing the Yellow China Sea. It is south to Shandong Province, north to Zhejiang Province, and east to Anhui Province (**Figure 1**). Covering an area of 10,720,000 ha, Jiangsu is one of the best-developed and prosperous regions in China with a hospitable climate, a good natural environment, and rich vegetation types. Under Jiangsu, there are 13 cities grouped into three regions of Northern Jiangsu, Central Jiangsu and Southern Jiangsu. Northern Jiangsu consists of five cities, including Xuzhou, Lianyungang, Suqian, Huai'an and Yancheng; Central Jiangsu includes three cities of Yangzhou, Taizhou and Nantong; and Southern Jiangsu comprises five cities of Nanjing, Zhenjiang, Changzhou, Wuxi and Suzhou.

The tripartite regional classification of Jiangsu Province into Southern, Central, and Northern Jiangsu arises from comprehensive geographical,socio-economic,

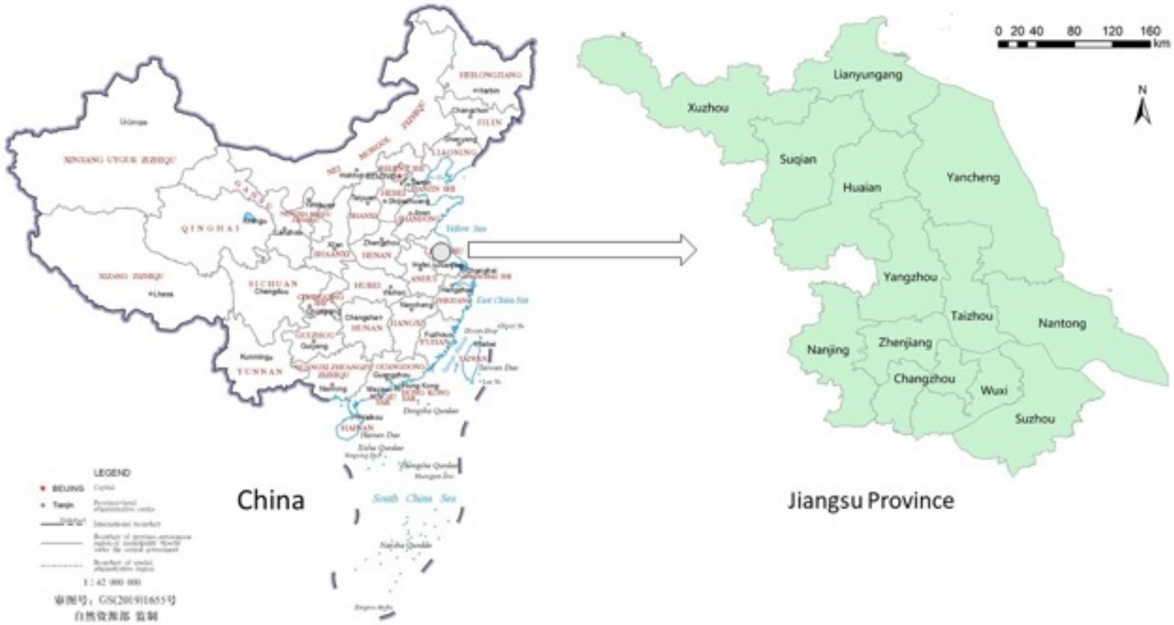

Figure 1. The location of Jiangsu Province in China.

Figure 2. Regional classification of Jiangsu Province, China.

and historical-cultural heterogeneity. Administrative demarcations delineate these regions as follows: Southern Jiangsu comprises Nanjing, Zhenjiang, Changzhou, Wuxi, and Suzhou; Central Jiangsu incorporates Yangzhou, Taizhou, and Nantong; while Northern Jiangsu encompasses Xuzhou, Huai'an, Yancheng, Lianyungang, and Suqian (**Figure 2**).

This regional differentiation has been substantially influenced by developmental disparities rooted in spatial economics. Southern Jiangsu's strategic adjacency to Shanghai, a global economic hub, has facilitated superior transportation infrastructure and industrial agglomeration, enabling early-stage economic primacy. Central Jiangsu demonstrates transitional characteristics, exhibiting moderated development patterns intermediate between its northern and southern counterparts. Conversely, Northern Jiangsu's geographically peripheral location has constrained transportation connectivity and industrial modernization, resulting in comparatively delayed economic advancement.

The persistent regional disparities stem from compounded historical path dependencies, includingdifferential access to coastal economic spillover effects, variations in human capital accumulation since China's reform era, and heterogeneous institutional support for industrial upgrading. These multidimensional factors have engendered self-reinforcing developmental trajectories that sustain the tri-regional structure.

The outbreak and spread of COVID-19 have had a great impact on the operation and development of tourism, and will also change the mechanism of tourism urbanization to some extent. In 2019, 2,954 travel agencies and 482 star-hotels in Jiangsu served a total of 876.117 million domestic tourists and 3.995 million foreign tourists, recording revenue of RMB1,390.221 billion (average exchange rate in 2019 is 1 US$ to 6.8985 RMB) from domestic tourism and foreign exchange earnings of US $4,743.56 million from international tourism. Jiangsu is leading the tourism development across China (*Statistical Bulletin on National Economic and Social Development of Jiangsu Province 2019*).

In 2019, Jiangsu's urbanization rate was up to 60%~85%, exceeding the national average level (60.6%)

(*Xin 2020*). The capital of Nanjing has the highest urbanization rate of 83.2%, while Suqian is the lowest at 61.1%). In general, Southern Jiangsu has a significantly higher urbanization rate than Northern and Central Jiangsu.

The Working Mechanism of Coupling Coordination

According to relevant research, tourism urbanization is an open and complex giant system formed in the interaction of tourism, urbanization and ecological environment (**Figure 3**). As numerous materials exchange and information are transported between the subsystems,development or transformation in any subsystem is bound to change the other two subsystems. Therefore, the three subsystems couple with each other, forming an entirety (*Du et al. 2021; Hu et al. 2015; Xie 2020*). The ecological environment serves as the material basis of urbanization and urbanization guarantees the evolution of tourism urbanization. Last but not the least, urbanization guarantees the evolution of tourism urbanization (*Ma et al. 2012; Xiong et al. 2020; Han et al. 2018; Liu and Yang 2011; Rong et al. 2019*).

The key man-land relationship lies in resource carrying capacity, the restrictive factor for urbanization. The required demands made by city residents for well-developed urbanization can only be met by scientific and effective planning and governance of the ecological environment (*Ma et al. 2012; Xiong et al. 2020; Han et al. 2018*).

The ecological environment is also the precondition and the basis for the operation of the tourism industry. Good ecological environment and rich natural resources give areas an advantage in developing the tourism industry while the rapidly growing tourism will in turn demand better regional ecology and environments (*Hu et al. 2015; Xiong et al. 2020; Han et al. 2018*).

The regional urbanization process will be restricted by the layout of tourist attractions and the characteristics of high integration and close associations. Urban space will be more likely built towards tourism industry agglomerations. Transportation and other urban infrastructures provide services to the tourism industry. Moreover, the clustered urban residents will constantly enhance the potential consumption capacity of these tourist cities, thereby attracting more industries to settle in. Therefore, tourism industry clusters will have the chance to develop soundly and better, catalyzing the emergence of “Tourism +” industry chain (*Brahmasrene and Lee 2017; Fang et al. 2021; Li 2020*).

Du et al. (*2021*) have constructed the evaluation index system of tourism economy and urbanization, and have verified the rationality of nine indices measuring the development of the tourism industry, including domestic tourism income, international tourism income, the proportion of tourism income in GDP, total tourism income, etc. The reliability of nine indexes including per capita GDP, urban density, the proportion of industrial GDP in GDP total, and the proportion of tertiary industry

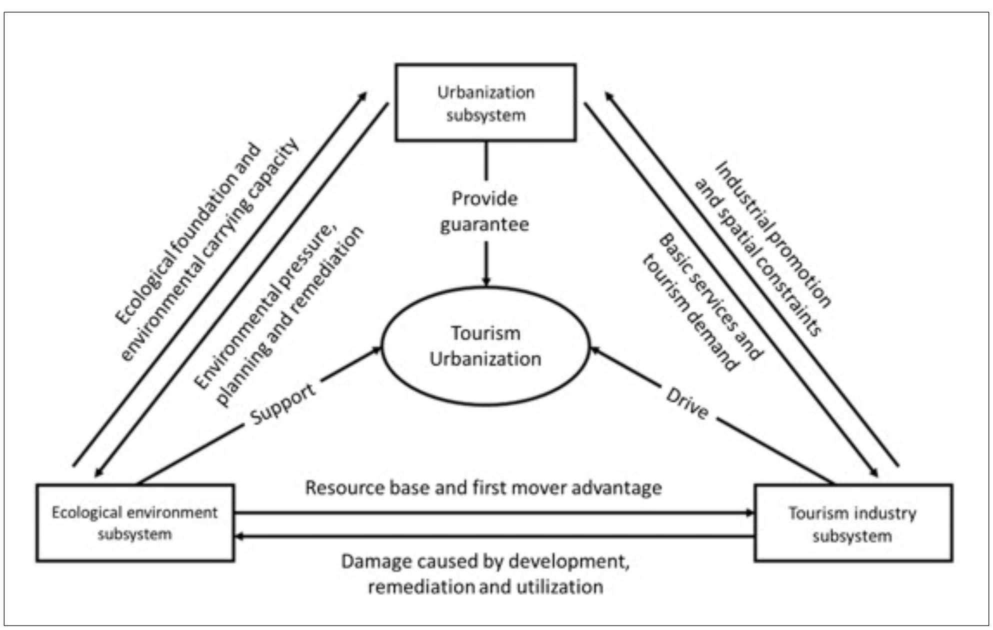

Figure 3. Coupling and coordinating mechanism of tourism urbanization (According to *Xiong 2020*, revised)

output value in GDP, in measuring the development of tourism industry is verified by *Hu et al.* (*2015*). Some studies have successfully used 10 specific indicators, including per capita industrial wastewater discharge, sewage treatment rate, comprehensive utilization rate of solid waste and per capita park green space area, to measure the quality of urban ecological environment (*Xie 2020; Ma et al. 2012; Xiong et al. 2020*). The above indicators also show obvious reliability in measuring the tourism economy- urbanization and urbanization-ecological environment relationships (*Han et al. 2018; Liu and Yang 2011; Rong et al. 2019*). This study selected thirty indices for quantitative analysis to describe the three systems based on the above action mechanism of coupling coordination and literature research (*Du et al. 2021; Hu et al. 2015; Xie et al. 2020; Fang et al. 2021; Zhao and Zhang 2020; Xiong et al. 2020; Han et al. 2018; Liu and Yang 2011; Rong et al. 2019*).

Evaluation indices of urbanization include per capita GDP, investment in fixed assets and the per capita disposable income of urban residents. Those indicators reflect the economic level of tourism urbanization, as well as the proportions of gross industrial production and tertiary industry output value in GDP. The tertiary industry payroll represents the industrial structure of tourism urbanization. The population density, per capita urban road area, registered urban unemployment rate at the end of the year and the Engel coefficient (aneconomic metric calculated as the percentage of household expenditure on food relative to total disposable income. It serves as an indicator of living standards, where a lower coefficient reflects higher socioeconomic development and greater discretionary spending capacity, while higher values typically characterize developing economies with constrained consumption patterns). The consumption patterns of urban residents reflect the infrastructure construction in tourism-urbanized regions and local living standards (*Fang 2022*).

Evaluation indices of the tourism industry include the number of inbound and domestic tourists, which reflect the tourist attractiveness of target areas. Foreign exchange earnings from international tourism, revenue from domestic tourism and the total tourism revenue reflect the profitability of the regional tourism industry and the level of tourist consumption. The proportion of tourism revenue in GDP and the tertiary industry reflects the tourism development degree in each region and the contribution made by the tourism industry to the local economy. The number of A-grade tourist attraction (the A-grade tourist attraction classification in China refers to a hierarchical rating system (ranging from 1A to 5A) administered by the Ministry of Culture and Tourism, which evaluates scenic areas based on standardized criteria including resource significance, infrastructure adequacy, service quality, environmental sustainability, and visitor experience, with 5A representing the highest national benchmark for tourism excellence), star-hotel and travel agency reflects the quality of tourism resources and infrastructure in these regions (*Xie 2020*).

Evaluation indices of ecological environment included per capita industrial waste water discharge, per capita solid waste production and sulfur dioxide (SO_2) emissions, which reflect how the regional ecology has been polluted by production and construction. Sewage treatment rate, the comprehensive utilization rate of solid waste and gas popularity rate reflect regional environmental pollution control. The green coverage of the built-up area, per capita park and green area, the days of good air quality in the urban area and total water resources reflect the regional ecology and resource consumption (*Xie 2020*).

Based on the reliability of indicators proven by previous studies, considering the needs of comparison among cities and the convenience of obtaining indicators, the indicators selected in this study were from the statistical yearbooks. The research data were extracted from the Jiangsu Statistical Yearbook 2022 and the Statistical Yearbook 2022 of the thirteen cities in Jiangsu.

Calculation Method of Index Weight (AHP)

The entropy weight method was used to determine the index weight according to the information load of each index, which can eliminate the deviation caused by subjective factors. Range standardization was applied to the selected indicators to eliminate scale differences caused by varying units of measurement and make them comparable. This processing yielded standardized indicator values for each subsystem, which were then utilized to determine the corresponding indicator weights. The initial weights (*Zi*) of each index in the evaluation system were calculated using Yaahp 0.6.0 software based on the Analytic Hierarchy Process (AHP). To ensure the rationality of the obtained weights, a consistency check was performed on the judgment matrices. If the consistency ration (CR) was less than 0.1, the judgment matrix was deemed to exhibit satisfactory consistency. Subsequently, the weight vectors of the indicator layer relative to the target layer were computed, yielding reasonably justified weights (Z_i).

The Entropy Method was adopted to correct the weight coefficient and calculate the entropy value and entropy weight of the three subsystems.

Step 1: Performs dimensionless treatment of raw data. Suppose the optimal value for each column in the matrix X was *Xj**, then calculate the index value proportion of evaluated object No. i under No. j index through the equation:

$$P_{ij} = r_{ij} / \sum_{i=1}^{m} r_{ij}.$$

Step 2: Calculated the entropy value of No. j index, which was:

$$e_j = -k \sum_{i=1}^{m} p_{ij} LnPu$$

where k=1/lnm.

Step 3: Calculated the entropy weight of No. j index in:

$$w_j = \left(1 - e_j\right) / \sum_{j=1}^{n} \left(1 - e_j\right)$$

Step 4: Calculate the modified weight of the No. j index in: $W_j = ½Z_j + ½w_j$

Calculation Method of Coupling Coordination Degree

(1) Calculation of coupling degree

Coupling degree, an index expressing the degree of interaction among multiple systems, was first used in physics and later widely used in humanities and social sciences. The two calculation formulas of coupling degree are as follows (*Cong 2019*):

$$C_1\left(X_1, X_2, X_3 \ldots\ldots X_n\right) = n \times \left[\mathrm{X_1X_2X_3 \ldots X_n} / \left(\mathrm{X_1 + X_2 + \ldots X_n}\right)\right]^{\frac{1}{n}} \quad (1)$$

$$C_2\left(X_1, X_2, X_3 \ldots\ldots X_n\right) = 2 \times \left[\mathrm{X_1X_2X_3 \ldots X_n} / \prod_{i>j}\left(X_i + X_j\right)^{\frac{2}{n-1}}\right]^{\frac{1}{n}} \quad (2)$$

Where *n* is the number of subsystems *(n≥2), Xi(Xi≥0)* is the comprehensive evaluation function of subsystems.

(2) Calculation of coordination degree

Coordination degree refers to the degree of synergistic coupling in the interaction, reflecting the coordination status. The indicator describes whether the functions promote each other at a high level or restrict each other at a low level. The calculation formula of coordination degree is as follows:

$$D = \left(C \times T\right)^{\frac{1}{2}} \mathrm{T} = \lambda_1 \mathrm{X_1} + \lambda_2 \mathrm{X_2} + \lambda_3 \mathrm{X_3} + \ldots\ldots + \lambda_n \mathrm{X_n} \quad (3)$$

$$D = \left(C \times T\right)^{\frac{1}{2}} \quad (4)$$

Where C is the coupling degree, T is the evaluation index of subsystems, *λi* is the undetermined coefficient, and *Xi* (*Xi ≥0*) the comprehensive evaluation function of subsystems.

(3) Evaluation function

In the evaluation functions constructed for the three subsystems, we input the calculation results into the coupling degree model and coordination degree model for calculation. The calculation formula of evaluation function is as follows:

$$f\left(x\right) = \sum_{i=1}^{m} a_i x_i, \quad g\left(y\right) = \sum_{j=1}^{n} b_j y_j, \quad h\left(z\right) = \sum_{k=1}^{t} c_k z_k \quad (5)$$

$$C = 2 \times \sqrt[3]{\frac{f\left(x\right) \times g\left(y\right) \times h\left(z\right)}{\left[f\left(x\right) + g\left(y\right)\right]\left[f\left(x\right) + h\left(z\right)\right]\left[g\left(y\right) + h\left(z\right)\right]}} \quad (6)$$

$$D = \left(C \times T\right)^{\frac{1}{2}}, T = \alpha f\left(x\right) + \beta g\left(y\right) + \gamma h\left(z\right) \quad (7)$$

Where *f(x), g(y), h(z)* are the evaluation functions of the three subsystems, a_i, b_j, c_k are the weights of elements *i, j, k* of the three subsystems, x_i, y_j, z_k are the normalized values, *m, n, t* are the numbers of elements. *T* represents the evaluation index, and *α, β, γ* are the undetermined coefficients.

This study believed that the three subsystems are equally important for tourism urbanization, so *α=β=γ*=0.333.

The measured coupling degree and coordination degree fall in the range of [0,1] through dimensionless normalization and model-based computation. The median segmentation method divides the range into four states of (0, 0.3], (0.3, 0.5], (0.5, 0.8], (0.8, 1] by, representing the different states of the system from low coupling, intermediate coupling, high coupling, dipolar coupling, low coordination, intermediate coordination, high coordination and dipolar coordination (*Xiong et al. 2020*).

RESULTS AND DISCUSSION

Index System

According to the index weight calculation method, combined with the index data in the 2022 statistical yearbook, the indices and weights of the three subsystems (**Tables 1 to 3**) along with its comparative discriminant matrix passed the consistency test (**Table 4)**.

The entropy value and entropy weight of the three subsystems were also calculated after normalization (**Tables 5 to 7**).

The AHP and Entropy Method calculated the weights which are synthesized to generate the modified weight of each indices (**Table 8**).

Coupling Coordination Degree of the System

According to the calculation method of Coupling Coordination Degree (2.4.2), combined with the index data in 2021, the coupling coordination degree is divided into ten cells, and the classification standard is formulated. The coupling coordination degree was divided by the calculated C value and D value (*Rong et al. 2019*). The City of Suzhou had demonstrated a high quality of coordination, as indicated by the calculation results of the coupling degree, coordination degree, and evaluation function of tourism urbanization compared to other cities in Jiangsu (**Table 9**).

Spatial Mapping of Coupling Coordination Degree

According to the calculation results of the coupling degree and coordination degree of tourism urbanization in Jiangsu, the corresponding spatial differentiation maps with 0.1 as the basic differentiation range were illustrated (**Figures 4 and 5**).

According to the calculation results of the coupling degree and coordination degree, the coordination level of tourism urbanization of each city was divided into different types (**Figure 6**).

Spatial Difference of Coupling Degree

The coupling degree of tourism urbanization in Jiangsu was relatively high, ranging from the lowest of 0.413 (Taizhou) and the highest of 1 (Suzhou), suggesting the three subsystems were highly interrelated.

The spatial distribution of the tourism urbanization coupling degree in Jiangsu showed a bimodal distribution pattern emerges with dual peaks in northern/southern

Table 1. Analytic Hierarchy Process analysis results of urbanization subsystem.

Indices	Eigenvector	Weights	Maximum eigenvalue	Consistency Index
Per capita GDP	1.9969	0.1536	11.2204	0.1356
Population density	0.3415	0.0263		
Proportion of industrial output in GDP	0.6704	0.0516		
Proportion of tertiary industry output in GDP	1.4963	0.1151		
Investment in fixed assets	0.5255	0.0404		
Proportion of employed population in tertiary industry	1.8745	0.1441		
Per capita disposable income of city residents	3.3118	0.2547		
Per capita road area in city	0.3162	0.0243		
Registered unemployment rate in city	0.9043	0.0695		
Engel coefficient of city residents	1.5666	0.1205		

Table 2. Analytic Hierarchy Process analysis results of tourism industry subsystem.

Indices	Eigenvector	Weights	Maximum eigenvalue	Consistency Index
Inbound tourist arrivals	1.0814	0.0814	10.9748	0.1083
Domestic tourist arrivals	0.6892	0.0519		
International tourism foreign exchange earning	1.0305	0.0775		
Domestic tourism revenue	1.5219	0.1145		
Proportion of tourism revenue in GDP	1.9512	0.1468		
Proportion of tourism revenue in the tertiary industry	1.9512	0.1468		
Amount of grade tourist attractions	0.4340	0.0327		
Total tourism income	3.8981	0.2934		
Amount of star rated hotels	0.3906	0.0294		
Amount of travel agencies	0.3400	0.0256		

Table 3. Analytic Hierarchy Process analysis results of ecological environment subsystem.

Indices	Eigenvector	Weights	Maximum eigenvalue	Consistency Index
Per capita industrial wastewater discharge	2.2679	0.1894	10.6632	0.0737
Per capita solid waste production	1.5274	0.1276		
Sewage treatment rate	1.8228	0.1522		
Comprehensive utilization rate of solid waste	1.7617	0.1471		
SO_2 emissions	0.5012	0.0419		
Greening coverage rate of built-up area	0.6988	0.0584		
Per capita park & green space area	0.5830	0.0487		
Proportion of days with good air quality in city	1.8280	0.1527		
Total water resources	0.4640	0.0388		
Gas penetration rate	0.5190	0.0433		

Table 4. Summary of consistency test results.

Subsystem	Maximum eigenvalue	CI (*Consistency Index*)	RI (*Random Index*)	CR (*Consistency Ratio*)	Consistency Test Results
Urbanization	11.2204	0.1356	1.49	0.0910	passed
Tourism industry	10.9748	0.1083	1.49	0.0727	passed
Ecological environment	10.6632	0.0737	1.49	0.0495	passed

Table 5. Entropy weight method result of urbanization subsystem.

Indices	Entropy value	Entropy weight
Per capita GDP	0.8505	0.1529
Population density	0.9482	0.053
Proportion of industrial output in GDP	0.5977	0.4113
Proportion of tertiary industry output in GDP	0.9098	0.0922
Investment in fixed assets	0.9759	0.0246
Proportion of employed population in tertiary industry	0.9776	0.0229
Per capita disposable income of city residents	0.9917	0.0085
Per capita road area in city	0.908	0.0941
Registered unemployment rate in city	0.9526	0.0485
Engel coefficient of city residents	0.91	0.092

Table 6. Entropy weight method result of tourism industry subsystem.

Indices	Entropy value	Entropy weight
Inbound tourist arrivals	0.8505	0.1529
Domestic tourist arrivals	0.9482	0.053
International tourism foreign exchange earning	0.5977	0.4113
Domestic tourism revenue	0.9098	0.0922
Proportion of tourism revenue in GDP	0.9759	0.0246
Proportion of tourism revenue in the tertiary industry	0.9776	0.0229
Amount of grade tourist attractions	0.9917	0.0085
Total tourism income	0.908	0.0941
Amount of star rated hotels	0.9526	0.0485
Amount of travel agencies	0.91	0.092

sectors flanking a central trough. Southern Jiangsu has the highest coupling degree, while the lowest data are found in Central Jiangsu, especially in Yangzhou and Taizhou (0.4-0.5), but still are within the intermediate coupling range.

Spatial Difference of Coordination Degree

The coordination degree of tourism urbanization in Jiangsu was relatively low and spatially different, ranging from the lowest of 0.066 (Suqian) to the highest 0.99 (Suzhou), suggesting non-benign interactions between the three subsystems, such as coupling at low

Table 7. Entropy weight method result of ecological environment subsystem.

Indices	Entropy value	Entropy weight
Per capita industrial wastewater discharge	0.9691	0.1148
Per capita solid waste production	0.9005	0.3696
Sewage treatment rate	1	0
Comprehensive utilization rate of solid waste	0.9995	0.0019
SO_2 emissions	0.9247	0.2797
Greening coverage rate of built-up area	0.9999	0.0004
Per capita park and green space area	0.9969	0.0115
Proportion of days with good air quality in city	0.9995	0.0019
Total water resources	0.9407	0.2203
Gas penetration rate	1	0

Table 8. Comprehensive evaluation index system of tourism urbanization.

Subsystem	Evaluation indices	Attribute	Modified Weight
Urbanization	Per capita GDP	positive	0.19915
	Population density	positive	0.0341
	Proportion of industrial output in GDP	positive	0.0648
	Proportion of tertiary industry output in GDP	positive	0.0933
	Investment in fixed assets	positive	0.14345
	Proportion of employed population in tertiary industry	positive	0.02458
	Per capita disposable income of city residents	positive	0.15415
	Per capita road area in city	negative	0.0349
	Registered unemployment rate in city	positive	0.1856
	Engel coefficient of city residents	negative	0.06585
Tourism industry	Inbound tourist arrivals	positive	0.11715
	Domestic tourist arrivals	positive	0.0524
	International tourism foreign exchange earning	positive	0.24445
	Domestic tourism revenue	positive	0.10335
	Proportion of tourism revenue in GDP	positive	0.0857
	Proportion of tourism revenue in the tertiary industry	positive	0.08485
	Amount of grade tourist attractions	positive	0.0206
	Total tourism income	positive	0.1937
	Amount of star rated hotels	positive	0.0389
	Amount of travel agencies	positive	0.05885
Ecological environment	Per capita industrial wastewater discharge	negative	0.1521
	Per capita solid waste production	negative	0.2485
	Sewage treatment rate	positive	0.0762
	Comprehensive utilization rate of solid waste	positive	0.07445
	SO_2 emission	negative	0.16075
	Greening coverage rate of built-up area	positive	0.0294
	Per capita park & green space area	positive	0.0301
	Proportion of days with good air quality in city	positive	0.07725
	Total water resources	positive	0.1296
	Gas penetration rate	positive	0.02165

levels or being restrictive at low levels.

The coordination degree of tourism urbanization differed across Jiangsu. The coordination degree in Southern Jiangsu is significantly higher than that in Central Jiangsu and Northern Jiangsu. To be specific, the intermediate coordination range covered Xuzhou in Northern Jiangsu, Nantong in Central Jiangsu, Zhenjiang, Changzhou and Wuxi. Suzhou in Southern Jiangsu falls in the dipolar coordination range, while Nanjing in Southern Jiangsu was in the high coordination range.

Combination of Coupling Coordination Degree There were six combinations of coupling coordination degrees of tourism urbanization in Jiangsu (refer to the summary of the range of values for judging the degree of coupling coordination as shown in **Table 10**): intermediate coupling-low coordination

Table 9. Results of coupling coordination level of tourism urbanization in all cities in Jiangsu, China.

City	Coupling C Value	Coordination D Value	Evaluation function T Value	Coordination Level	Degree of Coordination
Suzhou	1	0.995	0.992	10	High quality coordination
Nanjing	0.759	0.724	0.692	8	Intermediate coordination
Wuxi	0.739	0.634	0.543	7	Primary coordination
Nantong	0.928	0.613	0.406	7	Primary coordination
Zhenjiang	0.968	0.61	0.384	7	Primary coordination
Xuzhou	0.988	0.565	0.323	6	Reluctantly coordination
Changzhou	0.73	0.539	0.399	6	Reluctantly coordination
Yancheng	0.789	0.437	0.242	5	Verge of disorder
Lianyungang	0.775	0.377	0.183	4	Mild disorder
Huai'an	0.622	0.334	0.179	4	Mild disorder
Yangzhou	0.434	0.338	0.263	4	Mild disorder
Taizhou	0.413	0.341	0.281	4	Mild disorder
Suqian	0.602	0.2	0.066	2	Serious disorder

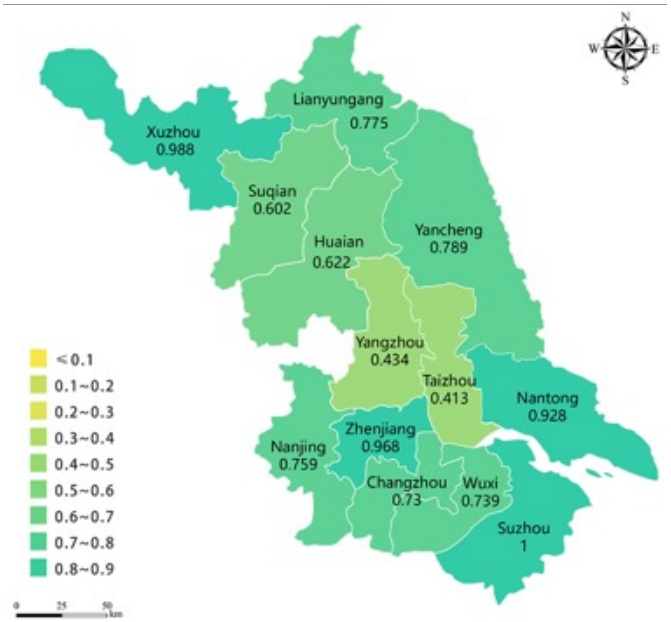

Figure 4: Spatial differentiation of tourism urbanization coupling degree (2021) in Jiangsu Province, China.

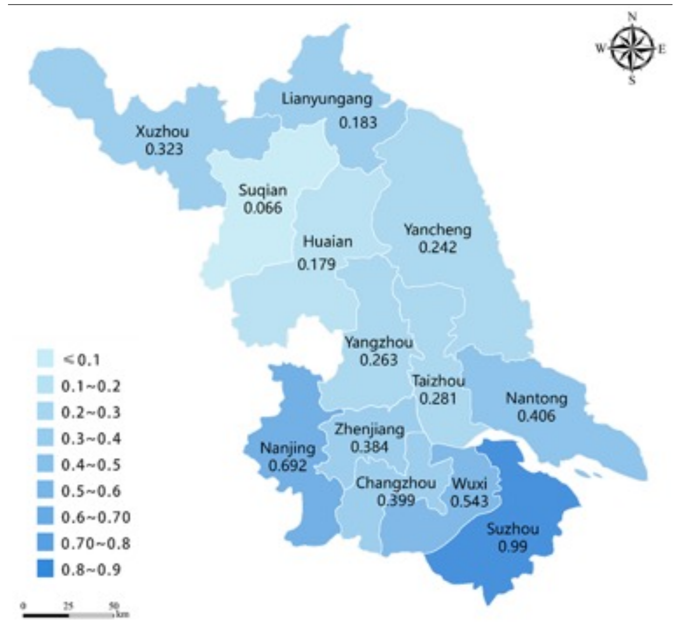

Figure 5: Spatial differentiation of tourism urbanization coordination degree (2021) in Jiangsu Province, China.

(Yangzhou, Taizhou), high coupling-low coordination (Lianyungang, Huai'an, Suqian, Yancheng), high coupling-intermediate coordination (Changzhou), high coupling-high coordination (Nanjing, Wuxi), dipolar coupling-intermediate coordination (Xuzhou, Zhenjiang, Nantong), dipolar coupling-dipolar coordination (Suzhou). Most of the cities had "high coupling degree and low coordination degree", suggesting that the three closely linked subsystems had a low benign coupling degree and non-benign interactions in the process of tourism urbanization.

From the perspective of coupling coordination degree, cities in Northern Jiangsu and Central Jiangsu suffered disorder, but in different degrees. Suqian suffered the most severe disorder, Lianyungang, Huai'an, Yangzhou and Taizhou experienced a mild disorder, and Yancheng was on the verge of disorder. In contrast, only Xuzhou achieved a slightly coordinated state. Over the past years, such disorders were caused by excessive urbanization without proper infrastructure construction and urban planning in Northern Jiangsu and Central Jiangsu. In addition, over-pursuit of economic development at the expense of the ecological environment also led the subsystems to restrict each other with low coordination levels. Southern Jiangsu enjoyed coordinated development despite the spatial differences. To be specific, Changzhou was only slightly coordinated; Zhenjiang, Wuxi and

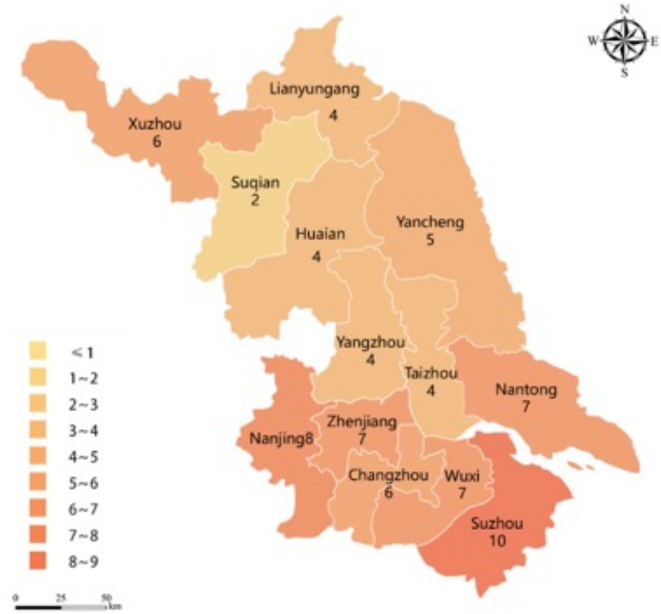

Figure 6: Spatial differentiation of tourism urbanization coordination level (2021) in Jiangsu Province, China.

Table 10. Range of Coupling and Coordination values defined to varying degrees.

Degree Definition	Coupling C Value Range	Coordination D Value Range
Dipolar	(0.8, 1]	(0.8, 1]
High	(0.5, 0.8]	(0.5, 0.8]
Intermediate	(0.3, 0.5]	(0.3, 0.5]
Low	(0, 0.3]	(0, 0.3]

Nantong had a primarily coordinated state; Nanjing had been intermediately coordinated while Suzhou had achieved high-quality coordination with the highest degree. A generally coordinated Southern Jiangsu was due to the mature economic development and early industrial structure transformation. The region is devoted to gathering talent and technology, which will result in high urbanization level, thus leading a high promotion level between the subsystems.

CONCLUSIONS AND RECOMMENDATIONS

Through the processing and calculation of 2021 cross-sectional data, this paper analyzes the interaction of subsystems in the development of tourism urbanization in Jiangsu. This paper established a coupling coordination degree evaluation index system for the tourism urbanization in Jiangsu from three aspects, including tourism industry, urbanization and ecological environment. The coupling coordination degree of tourism urbanization in thirteen Jiangsu cities were measured and analyzed with the model. The main research conclusions are as follows:

The tourism urbanization in all Jiangsu cities reached the intermediate coupling degree of > 0.4, suggesting the three subsystems were highly interrelated. The findings of this study diverge from analogous research conducted in the Silk Road Economic Belt, Dongting Lake region, Poyang Lake Rim region, and Shandong Province (*Han et al. 2018; Hu et al. 2015; Xiong et al. 2020; Du et al. 2021*). This discrepancy suggests that spatial heterogeneity in socioeconomic foundations, ecological conditions, and resource endowments across different regions directly influences the tourism urbanization system within a given area. Furthermore, the interrelationships among subsystems are significantly affected by natural and social spatial heterogeneity. The strong interconnections observed among these three dimensions may be attributed to the coordinated development of regional socioeconomic and ecological systems, where no apparent "weak-link" effect substantially constrains other subsystems.

The spatial distribution of the tourism urbanization coupling degree in Jiangsu exhibits an internal regional imbalance in coupling coordination degree, with relatively favorable coupling levels observed in Southern Jiangsu and Northern Jiangsu, while Central Jiangsu demonstrates generally lower coupling intensity. However, this spatial pattern contradicts the D-value measurements, further confirming that under specific circumstances, the C-value may fail to accurately reflect interaction efficacy between subsystems or align with their individual developmental stages (*Han et al. 2018*). Specifically, paradoxically higher coupling patterns emerge when urbanization, ecological conservation, and tourism industrialization maintain relatively low baseline levels, a phenomenon inconsistent with practical developmental realities. Northern Jiangsu cities including Lianyungang and Suqian, remain in nascent and developmental stages of tourism economic advancement despite experiencing relatively rapid economic growth as reflected in their suboptimal provincial rankings that inadequately correspond to their socioeconomic progression.

The tourism urbanization coordination degree in Jiangsu was at a low level, only two cities demonstrated coordination grades reaching intermediate-level thresholds or higher, while most cities fall in the low and intermediate coordination ranges. The coordinated development index reveals significant regional disparities across Jiangsu Province. Among the five cities in Northern Jiangsu, only Xuzhou attained a "marginally coordinated" status, while the remaining municipalities persisted in low-level synergy configurations. All three Central Jiangsu cities exhibited disequilibrium states, and within Southern Jiangsu's five urban centers, merely Nanjing and Suzhou achieved optimal coordination grades. The principal constraining factors across most cities stem from suboptimal urbanization rates and underdeveloped tourism industrialization, which collectively impede the tripartite coordination of tourism-urbanization-ecological environment systems (*Hu et al. 2015; Du et al. 2021*). Overall, the development of the tourism industry in Northern and Central Jiangsu lags behind urbanization. In the coming years, it is necessary to strengthen tourism cooperation, complement tourism resource advantages, avoid homogeneous competition, deeply explore the potential of eco - tourism resources, increase tourism development efforts, and enhance the competitiveness of the tourism industry. The Southern Jiangsu area should better leverage the dual-core advantages of Nanjing and Suzhou to further radiate to surrounding cities. This will accelerate urbanization regional and tourism cooperation in these cities. While continuously optimizing the ecological environment, high - quality urbanization should be used to improve and support tourism development. At the same time, tourism development should lead and promote urbanization, enhancing its quality level and, so that the two can improve and develop synergistically.

There were six combinations of tourism urbanization coupling coordination degrees in Jiangsu, where Southern Jiangsu realized coordinated development, but Northern and Central Jiangsu cities were in disorder. In terms of spatial distribution, low-level combination types were mainly found in central and northern Jiangsu, while high-level ones were concentrated in southern Jiangsu. Their spatio-temporal layouts showed similar differentiation in coordination degrees but differed in coupling degrees. Across different spatio-temporal scales, the symbiotic coupling of the three subsystems-tourism industry, urbanization, and ecological environment-leads to spatio-temporal differences in coupling coordination. Previous analysis shows that the coordination degree is highly correlated with factors like tourism development, urbanization levels, and ecological governance (*Xiong 2020*). These factors are the main drivers of the observed spatio - temporal differentiation.

Previous research shows that the coupling relationship between tourism economy and urbanization is moving towards benign coordination, but there are obvious spatial differences. The coupling coordination of central cities is obviously better than that of other cities, and the relative development level is transformed from tourism lag type to synchronous type (*Du et al. 2021*). Some studies suggested the contradiction between urbanization, tourism development and ecological environment is the main factor restricting the coordinated development of regions, In the future, on the basis of persisting in repairing and improving the ecological environment, the development of tourism and the process of urbanization should be accelerated so as to realize the comprehensive coordination and rapid improvement of regional tourism industry, urbanization and ecological environment (*Hu et al. 2015; Xie 2020*). Some studies believe that the coordinated development mechanism of regional tourism, urbanization, and ecological environment should be further optimized, the driving role of tourism enhanced, guarantee foundation of urbanization consolidated, the supporting role of ecological environment enhanced, the overall improvement of internal coordination level promoted, and the synchronous development of coupling and coordination realized (*Xiong et al. 2020*). At the same time, enhancing the complementary advantages of tourism resources, building differentiated tourism brands, accelerating urbanization and regional tourism cooperation, improving and supporting tourism development with urbanization, and leading and promoting the process of urbanization with tourism are also considered to be feasible measures to improve the development level of tourism urbanization (*Han et al. 2018*).

Based on the suggestions of previous literature and the findings of this empirical study, this study recommends further enhancement of the benign coordination among tourism industry, ecological environment and urbanization for better tourism urbanization in Jiangsu. All cities in Southern Jiangsu should actively promote the three subsystems for benign coupling and enhanced coordination. Central Jiangsu should enhance the connection between the subsystems and translate the tourism industry development into the driving force of urban industrial structure transformation and upgrading based on urbanization and the ecological environment, thus achieving higher coupling and coordination degrees. Northern Jiangsu should further optimize the subsystem structure of economy and environment, and effectively promote the evolution of subsystem coupling and coordination to a higher level.

Although the results measured using panel data will improve the accuracy of research, the main purpose of this study is to build an evaluation model of multi subsystems, and conduct an empirical analysis of the development performance and subsystem interaction mechanism of tourism urbanization in Jiangsu. The relevant research results cannot only help managers more intuitively understand the development status of tourism urbanization in various districts and cities in the province, but also facilitate the horizontal comparison of major regions in the country in the same period. Further improving the applicability of this index system and using panel data to study the temporal and spatial mechanism of tourism urbanization could be the main purpose of the next study.

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Data Availability Statement

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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