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The Chinese-style modernization of cultural heritage protection and the cultural tourism industry under the new productive forces enabled by AI

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Abstract In the context of AI-enabled new productive forces, clarifying the relationship between cultural heritage protection and the cultural tourism industry through scientific methods is of great significance for promoting the tourism development of cultural heritage and advancing the transformation of cultural tourism toward Chinese-style modernization. This study takes Hunan Province as its research object. Subsequently, using geographic detectors and the Moran index, it analyzes the spatio-temporal differentiation characteristics and driving factors of the coupling coordination degree between cultural heritage protection and the cultural tourism industry in Hunan Province. The results indicate that the coupled and coordinated development of cultural heritage protection and the cultural tourism industry is the result of multiple factors, including economic, social, and ecological factors. Within Hunan Province, the cities and prefectures are primarily concentrated in three zones: “low-high,” “low-low,” and “high-low.” Additionally, cities and prefectures in high-value zones have a limited radiating effect on surrounding areas.

Index Terms coupling evaluation method, geographic detector, Moran's index, cultural heritage protection, cultural tourism industry

I. Introduction

National rejuvenation, cultural security, national soft power, and the community of shared future for mankind have become the central themes of China's development. Each of these themes is closely intertwined with China's outstanding traditional culture. “Bringing cultural heritage to life” has provided a clear direction for the protection, inheritance, and development of outstanding historical and cultural heritage. However, in today's rapidly developing tourism industry, the protection faces unprecedented opportunities and challenges. On the one hand, tourism development provides cultural heritage with financial support and opportunities for cross-regional cultural dissemination [1], [2]. On the other hand, issues such as excessive commercialization, inadequate management mechanisms, and limitations in technological application pose threats to the authenticity and integrity of cultural heritage [3], [4]. Ensure the proper protection and inheritance of cultural heritage has become an urgent and important issue to address.

As cultural and tourism integration enters a period of accelerated digital transformation, digital technology is reshaping the boundaries and forms of cultural and tourism integration [5]. The digital transformation of cultural heritage's cultural accessibility and inclusivity can overcome barriers to the integration, while also requiring the exploration of the historical and memory dimensions underlying digital culture [6], [7]. The application of digital art, the digital economy, and digital platforms in fields such as cultural heritage tourism can promote partnerships and knowledge acquisition among cultural capital, digital capital, and stakeholders [8]-[10]. Additionally, the integration of digital elements, support for innovative transformation, and corporate management decisions are both the driving force behind the integration and the primary production model for the integration of cultural heritage and tourism [11]-[13]. Therefore, innovative digital cultural heritage management approaches will drive the relationship between cultural heritage and tourism from conflict toward symbiosis [14].

Currently, the tourism-oriented protection and inheritance of cultural heritage should become the mainstream model for digital empowerment of cultural and tourism integration. Literature [15] indicates that with the support of digital technology tools, cultural heritage management is undergoing digital transformation oriented toward the tourism industry, meaning that scientifically reasonable tourism development is an effective pathway to promote cultural heritage protection and sustainable development. Literature [16] designed an application centered on cultural heritage tourism itineraries, which serves as a powerful tool for online marketing and research, enabling the

promotion of cultural heritage dissemination and protection without increasing environmental and ecological risks. Literature [17] introduces new forms of digital heritage tourism in the cultural tourism market, providing innovative pathways for the dissemination of items and knowledge preserved by museum institutions. Literature [18] created a virtual reality (VR) application for multimodal purposes, enabling users to access immersive experiences in a heritage tourism context through high-precision reconstruction of cultural heritage. Literature [19] explores cultural heritage protection strategies for immersive digital tourism experiences, combining history with immersive technologies such as augmented reality and virtual reality to enhance users' experiences during heritage tourism while promoting the protection and management. It is evident that vigorously promoting the upgrading of digital tourism assets will facilitate the digital transformation and development of the cultural tourism industry, leveraging technological empowerment to provide intelligent safeguards for the protection and transmission of cultural heritage.

The article first establishes evaluation indicator systems for cultural heritage protection and the cultural tourism industry, respectively. Using data from 14 prefectures in Hunan Province from 2012 to 2024, it employs coupling analysis to measure the degree of coupling and coordination between cultural heritage protection and the cultural tourism industry in Hunan Province. Subsequently, methods such as the geographic detector and Moran's index are employed to analyze the spatiotemporal changes in the comprehensive development level of cultural heritage protection and the cultural tourism industry in Hunan Province. Finally, it proposes a Chinese-style modernization transformation mechanism for cultural heritage protection and the cultural tourism industry.

II. Evaluation model for cultural heritage protection and cultural tourism industry development

II. A.Principles for constructing the indicator system

(1) Principle of scientificity

Scientificity is a prerequisite for constructing an evaluation indicator system. Before designing indicators, it is first necessary to define the concepts of cultural heritage protection and cultural tourism industry development. Second, through analysis of existing relevant literature and combined with field research, summarize and categorize indicators at all levels. The selected indicators should be verified, and erroneous indicators should be eliminated to make sure the accuracy and comprehensiveness. Finally, calculations must be scientifically reasonable, with all data indicators further standardized, and appropriate methods selected for weighting and calculation.

(2) Systemic Principle

The evaluation indicator systems are complex systems with diverse indicators. Therefore, a systemic principle must be applied to their calculation. When selecting indicators, it is necessary to adopt a holistic mindset and fully consider the interconnections between indicators. The construction of the evaluation indicator system must also ensure applicability, ensuring it can be applied across different regions while also capturing regional differences. Additionally, the evaluation indicator system must be operational, ensuring that indicator data can be obtained within the scope of available capabilities.

(3) Hierarchical principle

The components of cultural heritage protection and cultural tourism industry development are diverse, and not all indicators are at the same level. Therefore, when designing the indicator system, it is essential to consider hierarchical structure, selecting indicators that are representative and comprehensive while eliminating redundant indicators. Indicators at different levels should be categorized, summarized, and classified, with different indicators assigned to different hierarchical levels. Indicators at the same level may vary in importance within the system. The influence of an indicator on cultural heritage or the cultural tourism industry should be considered, and weights should be determined based on the degree of influence.

II. B.Construction of an evaluation indicator system

Currently, there are numerous qualitative analyses and case studies on the integration and development of cultural heritage and the cultural tourism industry, but quantitative analyses are relatively scarce. As a result, there is a lack of a comprehensive and scientific evaluation indicator system for measuring the transformation of both toward Chinese-style modernization. Existing research on cultural heritage evaluation is relatively scarce, with most studies focusing on evaluating the abundance of cultural resources within a specific region and designing a series of evaluation indicator systems. As an important component of cultural resources, cultural heritage naturally shares intrinsic connections with cultural resources in terms of evaluation content, but there are also certain differences. This study draws on regional cultural resource evaluation indicator systems, combines the unique characteristics of cultural heritage, and evaluates cultural heritage from three aspects: resource base protection, living heritage transmission effectiveness, and environmental synergy capacity, to design a cultural heritage protection evaluation indicator system. A relatively scientific and comprehensive evaluation indicator system has been established,

primarily including industry integration depth, product innovation level, smartization degree, economic benefits, and cultural security and identity. The evaluation indicator system for the Chinese-style modernization transformation is shown in Table 1.

Table 1: Evaluation index system for the protection

Target layer	Subsystem	First-level indicator	Secondary indicators
The Chinese style of cultural heritage protection and cultural tourism industry is transformed	Cultural heritage protection(A)	Resource background protection(A1)	Digital construction rate of cultural heritage(A11)
			The risk of an endangered heritage repair rate(A12)
			Safety monitoring coverage of cultural relics(A13)
		Dynamic inheritance efficiency(A2)	Carry on the ladder(A14)
			Penetration of non-legacy community practices(A15)
			Youth education participation(A16)
		Environmental synergy(A3)	Ecological quality index of heritage sites(A31)
			Completeness of historical space(A32)
			Protect the compliance rate of regulations(A33)
	Cultural tourism industry development level(B)	Depth of industrial integration(B1)	Cultural heritage conversion utilization(B11)
			The richness of the investment in the investment(B12)
			Industrial chain driving coefficient(B13)
		Product innovation level(B2)	Technology is a product of product(B21)
			The derivative value of cultural ips(B22)
			Tourist Satisfaction Index(B23)
		Degree of intelligence(B3)	The coverage of smart navigation(B31)
			Online dissemination influence(B32)
			Data platform integration degree(B33)
		Economic benefits(B4)	The contribution of wen brigade industry GDP(B41)
			Community population income growth rate(B42)
			Export volume of cultural trade(B43)
		Cultural Security and identity(B5)	Local cultural identity(B51)
			Correct usage of cultural symbols(B52)
			International cultural influence(B53)

II. C.Determining the weighting of measurement indicators

The entropy weight method has high reliability, can avoid excessive subjectivity in calculations, and can eliminate analysis errors caused by inconsistent indicator units. This paper will use it to determine the weights of the indicators and perform dimensionless processing on the data [20].

(1) Dimensionless processing of the original indicator data

① The number of evaluation indicators is n with $i = 1,2,3,4\ldots\ldots n$. Then:

$$x_i = \frac{X_i - \min(X_i)}{\max(X_i) - \min(X_i)} \tag{1}$$

In Equation (1), x_i represents the dimensionless value of the i th indicator in the evaluation indicator system, x_i denotes the raw data corresponding to the indicator, $\min(X_i)$ and $\max(X_i)$ denotes the mininum and maximum value of the corresponding item in the evaluation indicator system.

② The number of evaluation indicators is m and $j = 1,2,3,4\ldots\ldots n$. Then:

$$y_i = \frac{Y_i - \min(Y_i)}{\max(Y_i) - \min(Y_i)} \tag{2}$$

In Equation (2), y_i represents the standardized value after processing. Y_i denotes the original data, $\min(Y_i)$ denotes the minimum value of the corresponding item in the evaluation indicator system.

(2) Calculate the entropy values of each indicator in the two evaluation systems.

① Calculate the weight of the j th indicator under the i th scheme:

$$P_{ij} = \frac{x_{ij}}{\sum_{j}^{m} x_{ij}} \left(i = 1,2,3\cdots\cdots m, j = 1,2,3\cdots\cdots n\right) \tag{3}$$

② Calculate the entropy value of the indicator:

$$e_j = -K\sum_{i=1}^{m} p_{ij} \ln p_{ij} \left(0 \le e_j \le 1\right) \quad \left(i = 1,2,3\cdots\cdots m, j = 1,2,3\cdots\cdots n\right) \tag{4}$$

③ Calculate the coefficient of variation of the indicator:

$$h_j = 1 - e_j \tag{5}$$

④ Calculate the weight of the jth indicator:

$$W_j = \frac{h_j}{\sum_{j=1}^{n} h_j} \tag{6}$$

⑤ Calculate the evaluation index:

$$F_i^k = \sum w_i^k \times x_{ij}^k \tag{7}$$

II. D.Coupling evaluation method

The coefficient of variation is the primary method for measuring coupling coordination, enabling comparisons of variance between different research subjects [21].

$$Cv = \frac{\sqrt{\frac{1}{N}\sum_{t=1}^{N}\left(x_t - \bar{x}\right)^2}}{\bar{x}} = \sqrt{\frac{\left(x - \frac{x+y}{2}\right)^2 + \left(y - \frac{x+y}{2}\right)^2}{\frac{x+y}{2}}} = 2\sqrt{1 - \frac{xy}{\left(\frac{x+y}{2}\right)^2}} \tag{8}$$

In equation (8), the necessary and sufficient condition for Cv to take its minimum value is that $\frac{xy}{\left(\frac{x+y}{2}\right)^2}$ takes its maximum value. Thus, the coupling degree formula can be derived as follows:

$$C = \left\{ \frac{xy}{\left(\frac{x+y}{2}\right)^2} \right\} k \tag{9}$$

In equation (9), k is the adjustment coefficient, and in most cases, the value range is $0 \le k \le 2$. To distinguish the degree of differentiation, the value of k is taken as 1, x is the standardized value of the intangible cultural heritage abundance index, where $0 \le x \le 1$, and y is the standardized value of the cultural tourism industry index, where $0 \le y \le 1$.

Enabling a more intuitive understanding of the current state of integration between intangible cultural heritage and the tourism industry. The coupling coordination degree formula is constructed as follows:

$$R = \sqrt{C * P} \quad P = \alpha x + \beta y \tag{10}$$

The coordination coupling degree model integrates cultural heritage protection and the cultural tourism industry and compares their relative levels.

III. Analysis of the level of coupled development

III. A. Comprehensive Development Level Evaluation

III. A. 1) Selection of Time Points and Explanation of Data Sources

This study utilizes time-series data from 2012 to 2024 for 24 indicators in Hunan Province, primarily sourced from the following three channels: (1) Statistical Yearbooks and Bulletins. (2) Research Reports. (3) Government websites. Additionally, due to the extensive time span, in cases where statistical methodologies have changed or data has been recalculated subsequently, the latest version of the data is used. For certain missing annual data indicators, values were calculated using regression analysis based on data from other years. The administrative boundary vector data for Hunan Province used in this study was obtained from the National Basic Geographic Information Center website.

III. A. 2) Evaluation Indicator System Weighting

The range method was used to standardize the 13 years of data collected for the 24 indicators. The weights of the 24 indicators for agricultural cultural heritage and the tourism industry were calculated using the formula. As shown in Table 2:

Table 2: Index weight

Target layer	Subsystem	First-level indicator	Weight	Secondary indicators	Positive and reverse	Weight
The Chinese style of cultural heritage protection and cultural tourism industry is transformed	(A)	(A1)	0.326	(A11)	Positive	0.147
				(A12)	Positive	0.157
				(A13)	Positive	0.022
		(A2)	0.463	(A14)	Positive	0.158
				(A15)	Positive	0.139
				(A16)	Positive	0.166
		(A3)	0.211	(A31)	Positive	0.059
				(A32)	Positive	0.053
				(A33)	Positive	0.099
	(B)	(B1)	0.202	(B11)	Positive	0.055
				(B12)	Positive	0.041
				(B13)	Positive	0.106
		(B2)	0.194	(B21)	Positive	0.099
				(B22)	Positive	0.043
				(B23)	Positive	0.052
		(B3)	0.297	(B31)	Positive	0.074
				(B32)	Positive	0.137
				(B33)	Positive	0.086
		(B4)	0.194	(B41)	Positive	0.096
				(B42)	Positive	0.061
				(B43)	Positive	0.037
		(B5)	0.113	(B51)	Positive	0.029
				(B52)	Positive	0.023
				(B53)	Positive	0.061

III. A. 3) Analysis of the Comprehensive Development Level of Cultural Heritage Protection

As shown in Table 3, the numerical value of Hunan Province's comprehensive development level of cultural heritage protection shows a clear upward trend, increasing by an average of 0.08 annually. The minimum value is derived from the starting year of the study, 2012, after which it exhibits a continuous growth trend. Additionally, the comprehensive development index increased from 0.0228 in 2012 to 0.9833 in 2024. This indicates that the overall situation of cultural heritage protection in Hunan Province is relatively good, which aligns with the actual circumstances. Based on the research and evaluation results, the comprehensive development level can be divided into three stages. The first stage spans from 2012 to 2015, during which the comprehensive development level index was below 0.2. The comprehensive development level index for cultural heritage protection in Hunan Province was at a relatively low level during this period, primarily due to insufficient promotional efforts for cultural heritage protection in the early stages. The second stage spans from 2016 to 2019, with the comprehensive development

level index ranging between 0.2 and 0.7. The positive trend in Hunan Province's cultural heritage protection index after 2016 is closely tied to policy guidance and encouragement. The third stage covers the period from 2020 to 2024, with the comprehensive development level index ranging between 0.7 and 1.0.

Table 3: The comprehensive development level index

Year	Development level
2012	0.0228
2013	0.0267
2014	0.1427
2015	0.1806
2016	0.2876
2017	0.3765
2018	0.5506
2019	0.6397
2020	0.7137
2021	0.7742
2022	0.8658
2023	0.9227
2024	0.9833

III. A. 4) Analysis of the Comprehensive Development Level of the Cultural Tourism Industry

Similar to the calculation process of chapter 3.1.3, the index value of the comprehensive development level of cultural tourism industry in Hunan Province and cities in 2012~2024 is calculated, as shown in Table 4. On the whole, the comprehensive development level score of the cultural tourism industry in Hunan Province showed a steady upward trend, with an average annual increase of 0.075. The comprehensive development level index of the tourism industry increased from 0.0319 in 2012 to 0.9313 in 2024, indicating that the overall development has been moving forward steadily and uninterrupted, showing a trend of sustainable development. The reason for the rapid development and overall upward trend of the tourism industry is not only that it bears the title and halo of "China's famous historical and cultural city", but also to a certain extent, the integrated three-dimensional transportation network built by the development of Hunan Province and cities over the years also provides strong support for the development. In recent years, the development orientation and image positioning of Hunan Province and cities are becoming more and more clear and refined, and we have begun to promote the construction of five important systems with project-driven and industrial integration as the core, so as to build Hunan Province into an important tourism destination for global tourists.

Table 4: The comprehensive development level of the cultural tourism industry

Year	Development level
2012	0.0319
2013	0.0758
2014	0.0942
2015	0.1488
2016	0.2449
2017	0.2851
2018	0.3625
2019	0.4258
2020	0.5076
2021	0.5885
2022	0.7038
2023	0.8401
2024	0.9313

III. B. Calculation results

To better observe the changes and distribution of coupling coordination levels in the sample regions from different dimensions, this paper calculates the coupling degree and coupling coordination level of the sample population from

2012 to 2024. As shown in Table 5, the coupling coordination degree of the two subsystems in the sample region has shown a continuously rising trend, transitioning from severe imbalance to high-quality coordination over more than a decade of development. Hunan Province's cultural heritage protection and cultural tourism industry have effectively achieved a Chinese-style modernization transformation and continue to develop in a positive direction. Among these, from 2023 to 2024, Hunan Province's agricultural cultural heritage and cultural tourism industry consistently exhibited extremely high coupling levels, but the initial coupling coordination level was relatively low. This indicates that while the degree of mutual association and influence between cultural heritage and the cultural tourism industry during their development was profound, the overall development level was relatively low. This indirectly corroborates that, from the perspective of subsystems, these two indeed exhibit a mutually reinforcing relationship of balanced coordination.

Table 5: The calculation result of the overall coupling coordination degree of the sample

Year	Coupling degree E value	Coordination index T value	Coupling coordination degree F value	Coupling coordination level
2012	0.9839	0.0211	0.2001	Severe Disorder
2013	0.9853	0.0373	0.2002	Severe Disorder
2014	0.9936	0.1241	0.3561	Mild Disorder
2015	0.9939	0.2236	0.4753	Risk Disorder
2016	0.9961	0.248	0.4939	Grudgingly Coordination
2017	0.9832	0.3347	0.5832	Grudgingly Coordination
2018	0.9767	0.45	0.6638	Primary Coordination
2019	0.9839	0.537	0.7313	Intermediate Coordination
2020	0.9906	0.6183	0.784	Intermediate Coordination
2021	0.995	0.6888	0.8282	Good Coordination
2022	0.997	0.7497	0.863	Good Coordination
2023	0.998	0.8453	0.9169	Excellent Coordination
2024	0.999	0.9172	0.9531	Excellent Coordination

IV. Spatio-temporal evolution measurement method

IV. A. Geodetic detector

Compared to traditional spatial statistical methods, geographic detectors have unique advantages, namely, they do not require any prior assumptions during analysis and can overcome the limitations of traditional statistical methods in handling variables.

This paper employs the factor detector within geographic detectors to assess the explanatory power of influencing factors. The formula is as follows:

$$q = 1 - \frac{1}{N\sigma^2}\sum_{h=1}^{L} N_h \sigma_h^2 \tag{11}$$

IV. B. Spatial Weight Matrix

Based on the principle of the geographical law that “the closer two things are to each other, the more closely they are connected,” this article uses the administrative divisions and geographical data of Hunan Province to construct a spatial weight matrix W using Queen's adjacency [22]. The specific construction method is shown in Equations (12) and (13):

$$W = \begin{bmatrix} w_{11} & \cdots & w_{1n} \\ \vdots & \vdots & \vdots \\ w_{n1} & \cdots & w_{nn} \end{bmatrix} \tag{12}$$

$$w_{ij} = f(x) = \begin{cases} 1, & \text{When city } i \text{ and city } j \text{ are adjacent} \\ 0, & \text{When city } i \text{ and city } j \text{ are not adjacent} \end{cases} \tag{13}$$

Among them, when $i = j$, $w_{ij} = 0$.

IV. C. Moran Index

The Moran's I index is an important indicator used to determine whether spatial autocorrelation exists. When larger values cluster with smaller values, it indicates the presence of negative spatial correlation. If the distribution is relatively random, there is no spatial autocorrelation, and the spatial factor does not need to be included in the econometric model.

Global spatial autocorrelation analysis describes attribute values across the entire spatial region, reflecting the degree of interconnection between attributes in adjacent areas. It focuses on analyzing the spatial distribution and trend of a specific characteristic of spatial attributes. Its value range is between $(-1,1)$.

This paper employs exploratory spatial data analysis methods to study the spatial characteristics, primarily using the global Moran's I index for calculation, as shown in Equation (14):

$$Global\ Moran'\ I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{s^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{14}$$

In the equation, x_i and x_j represent the values of a certain indicator for regions i and j respectively, s^2 represents the variance of the indicator within the region, represents the mean value of the indicator, and w_{ij} is an element of the bivariate spatial weight matrix.

Global Moran's I can classify four different types of spatial differences: high-high clustering (HH), low-high clustering (LH), high-low clustering (HL), and low-low clustering (LL). High-high clustering indicates that both the region itself and its surrounding areas have relatively high average attribute levels, with minimal spatial differences between them. The remaining types follow this pattern. Based on whether the High-High or Low-Low types are most prevalent, one can determine whether a particular attribute in a region exhibits obvious spatial clustering characteristics.

V. Spatio-temporal evolution analysis

V. A. Analysis of Driving Factors for the Coupling and Coordination of Cultural Heritage Protection and the Cultural Tourism Industry

V. A. 1) Analysis of single-factor detection results

The indicator system for the driving factors of the coordinated development of cultural heritage protection and the cultural tourism industry is shown in Table 6. All seven influencing factors passed the 99.9% confidence level test ($P < 0.001$). Economic development, social culture, and ecological environment have different impacts on the coordinated development, and they have varying degrees of explanatory power for spatial differentiation. In terms of overall explanatory strength, economic development > ecological environment > social culture, reflecting that the economic development levels and government support levels of various cities are major factors influencing the coordinated development of the two industries. Based on the ranking of q values, in 2023, the order of explanatory power was: a2 > a7 > a1 > a3 > a4 > a5 > a6. First, these factors explain the spatial variation in the coupling coordination degree between cultural heritage protection and the cultural tourism industry to the extent of 31.92%, 31.31%, 19.06%, 16.82%, 14.98%, 10.98%, and 9.47%, respectively. Secondly, this result also indicates that both industrial economic development and ecological protection have a significant impact on the integration of Hunan Province's cultural tourism industry. However, the q-values for per capita paved road area and per capita park green space area tend toward 0.1, indicating that these two indicators have relatively weak explanatory power. By 2024, the ranking of explanatory power has changed: a7 > a1 > a2 > a6 > a3 > a4 > a5, explaining 58.74%, 33.77%, 30.2%, 29.08%, 21.02%, 17.72%, 15.95%, respectively. By comparing the q-values from 2023, it is observed that the indicators under the ecological dimension have undergone significant changes. This suggests that ecological factors exert a significant influence and possess strong explanatory power among the driving factors affecting the coupling and coordination of cultural heritage protection and the cultural tourism industry in Hunan Province. However, when examining individual indicators, the proportion of the tertiary sector in GDP shows a declining trend. Based on the results, ecological and economic factors are the key elements influencing the development of coupling coordination.

Table 6: The indicator system of driving factors

Driving factors	Driving factors	q value	
		2023	2024
Economic development	Total retail sales of consumer goods (in ten thousand yuan)/a1	0.1906	0.3377
	The proportion of the tertiary industry in GDP (%) /a2	0.3192	0.302

	General public budget expenditure (in ten thousand yuan) /a3	0.1682	0.2102
Social culture	Population density (people per square kilometer) /a4	0.1498	0.1772
	Per capita paved road area (square meters) /a5	0.1098	0.1595
Ecological environment	Per capita park green space area (square meters) /a6	0.0947	0.2908
	Annual average concentration of inhalable fine particulate matter (micrograms per cubic meter) /a7	0.3131	0.5874

V. A. 2) Analysis of factor interaction detection results

The results of the interaction analysis reveal the driving role of cultural heritage protection and tourism industry in promoting coordinated development under two scenarios: single-factor analysis and two-factor interaction. Through factor interaction analysis, we can more clearly understand whether the influence of driving factors is independent or synergistic. As can be seen from the Table 7, the q-values of the interaction results between the seven influencing factors are all greater than the q-values of the individual indicators, indicating that factor interaction has a more significant impact on the coupling degree between cultural heritage protection and the cultural tourism industry. The results fall into two major categories: nonlinear enhancement and dual-factor enhancement, with nonlinear enhancement significantly outnumbering dual-factor enhancement. This indicates that the coordinated development of cultural heritage protection and the cultural tourism industry in various cities is a complex phenomenon driven by multiple factors, with a significantly higher explanatory strength than single-factor effects. Overall, the interaction between economic development and ecological environment is significantly higher than that of social and cultural factors. From the individual indicators, we can see that in 2023, the interaction values between the annual average concentration of inhalable fine particulate matter (a7) and any other indicator were all above 0.85, with most exceeding 0.95, indicating that ecological environment protection must be integrated into all levels. Similarly, the trend in 2024 is also comparable, but the interaction in the economic dimension in 2024 is significantly higher than that in 2011. Based on the results of the interaction factor analysis, it can be concluded that for the coordinated development of cultural heritage protection and the cultural tourism industry in Hunan Province, economic and ecological factors are the two major driving forces, playing a dominant role among multiple influencing factors.

Table 7: The coupling force interaction detection situation

2023			2024		
Two interactions	Interaction value	Interaction result	Two interactions	Interaction value	Interaction result
A1∩a2	0.5515	Double factor enhancement	A1∩a2	0.7247	Double factor enhancement
A1∩a3	0.9203	Nonlinear enhancement	A1∩a3	0.8352	Nonlinear enhancement
A1∩a4	0.4038	Double factor enhancement	A1∩a4	0.5059	Double factor enhancement
A1∩a5	0.4034	Double factor enhancement	A1∩a5	0.8653	Nonlinear enhancement
A1∩a6	0.8415	Nonlinear enhancement	A1∩a6	0.7805	Nonlinear enhancement
A1∩a7	0.9909	Nonlinear enhancement	A1∩a7	0.8794	Double factor enhancement
A2∩a3	0.7595	Nonlinear enhancement	A2∩a3	0.8935	Nonlinear enhancement
A2∩a4	0.6017	Double factor enhancement	A2∩a4	0.8304	Nonlinear enhancement
A2∩a5	0.474	Double factor enhancement	A2∩a5	0.6745	Nonlinear enhancement
A2∩a6	0.7951	Nonlinear enhancement	A2∩a6	0.8243	Nonlinear enhancement
A2∩a7	0.9813	Nonlinear enhancement	A2∩a7	0.8859	Double factor enhancement
A3∩a4	0.5833	Nonlinear enhancement	A3∩a4	0.5946	Nonlinear enhancement
A3∩a5	0.3739	Double factor enhancement	A3∩a5	0.4144	Double factor enhancement
A3∩a6	0.4474	Nonlinear enhancement	A3∩a6	0.4636	Double factor enhancement
A3∩a7	0.4328	Double factor enhancement	A3∩a7	0.9508	Nonlinear enhancement

A4∩a5	0.3027	Double factor enhancement	A4∩a5	0.5462	Nonlinear enhancement
A4∩a6	0.5286	Nonlinear enhancement	A4∩a6	0.8594	Nonlinear enhancement
A4∩a7	0.9883	Nonlinear enhancement	A4∩a7	0.7596	Double factor enhancement
A5∩a6	0.5192	Nonlinear enhancement	A5∩a6	0.5221	Double factor enhancement
A5∩a7	0.4411	Double factor enhancement	A5∩a7	0.9767	Nonlinear enhancement
A6∩a7	0.8831	Nonlinear enhancement	A6∩a7	0.8363	Double factor enhancement

V. B. Spatial correlation analysis

V. B. 1) Global spatial autocorrelation analysis of coupling coordination degree

Global Spatial Autocorrelation Analysis of Coupling Coordination Degree Previous studies have shown that there is a certain degree of spatial correlation between the coordination degree of cultural heritage protection and the comprehensive development level of the tourism industry in Hunan Province. To further explore the spatial pattern characteristics of the overall coupling coordination degree between the two, the global autocorrelation Moran's I test results for the coupling coordination degree between cultural heritage protection and the cultural tourism industry in Hunan Province from 2012 to 2024 were calculated. The results of the global Moran's I test are shown in Table 8. The p-value is greater than 0.05, indicating that the significance of the Moran index is weak, and the spatial correlation of the coupling coordination degree between cultural heritage protection and the cultural tourism industry is weak, without showing obvious agglomeration characteristics. Starting from 2020, the global Moran index began to shift from negative values less than 0 to positive values, with the overall global Moran index showing an upward trend. Before 2020, the coupling coordination degree of the comprehensive development level of cultural heritage protection and the cultural tourism industry in Hunan Province exhibited a negative correlation, with the regional distribution showing a dispersed pattern. However, the absolute values continued to decline, indicating that the overall gap in the coupling coordination degree of the comprehensive development level between the two industries gradually narrowed.

Table 8: The global self-correlation moran index test results

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Moran Index	-0.176	-0.219	-0.142	-0.075	-0.066	-0.044	-0.088	-0.041	0.068	0.095	0.046	0.085	0.043
P value	0.27	0.169	0.348	0.489	0.482	0.467	0.462	0.461	0.27	0.206	0.24	0.206	0.255

V. B. 2) Local spatial autocorrelation analysis of coupling coordination degree

To further explore the spatial relationships between adjacent prefectures within Hunan Province, the local Moran's I index was calculated for each prefecture at three time points: 2020, 2022, and 2024. The results were visualized, and the Moran's I scatter plots for the coupling coordination degree of cultural heritage protection and cultural tourism industry comprehensive development levels in Hunan Province for 2020, 2022, and 2024 are shown in Figures 1, Figure 2, and Figure 3, respectively. As shown in the figures, the spatial evolution pattern of the coupling coordination degree of cultural heritage protection and the comprehensive development level of the cultural tourism industry in the 14 prefectures of Hunan Province changes over time, primarily clustering in three zones: “low-high,” “low-low,” and “high-low.” The “high-high” zone is located in the eastern cities and prefectures of Hunan Province, indicating that the cities and prefectures in the high-value zone have a small radiating effect on surrounding cities and prefectures, with low levels of coordinated development and a tendency toward polarization. The specific details are as follows.

1) High-high zone (H-H zone).

The cultural tourism industry in this region has a high level of coupling coordination, and the surrounding cities and prefectures also have high levels of coordination between cultural heritage protection and the cultural tourism industry, with small spatial differences. Yueyang City was located in this zone in 2020, 2022, and 2024, Zhuzhou City entered this zone in 2020 and 2022, and Changsha City entered this zone in 2022 and 2024. These three cities have relatively developed economies, abundant tourism resources, and deep cultural heritage, with relatively good comprehensive development levels of both industries. The expansion of the high-high zone from 2020 to 2024 indicates that the coordinated development status of neighboring cities and prefectures in this region is generally

good, with significant radiation effects, and cultural heritage protection and cultural tourism industries exhibit mutually reinforcing regional characteristics.

2) Low-High Zone (L-H Zone).

The cultural tourism industry in this region has not developed well on its own, while neighboring prefectures and cities have developed better. However, the radiation effect of cultural heritage protection and cultural tourism industry development in neighboring prefectures and cities on this region is relatively small. In 2020 and 2022, this region included Shaoyang City, Xiangtan City, Yiyang City, Zhangjiajie City, and Yongzhou City, with Zhuzhou City added in 2024. This indicates that the cities and prefectures in this region should actively learn from surrounding cities and prefectures, strengthen cultural and tourism integration, and enhance the level of coordinated development in cultural and tourism sectors.

3) Low-Low Zone (L-L Zone).

The cities and prefectures in this region have relatively low levels of economic development both internally and in relation to surrounding areas. From 2020 to 2024, Loudi City and Xiangxi Prefecture were located in this region. By 2024, the region included Yiyang City, Loudi City, Zhangjiajie City, Changde City, and Xiangxi Prefecture. This indicates that these cities and prefectures have limited connections with surrounding areas in terms of the two industries, and their coordination between cultural heritage protection and cultural tourism industry development is suboptimal.

4) High-Low Zone (H-L Zone). In this zone, cultural heritage protection and the cultural tourism industry have developed relatively well, such as in Hengyang City and Chenzhou City. However, due to the low level of coordination in cultural tourism development among surrounding prefectures and cities, they are unable to fully leverage their own advantages and lack the capacity to radiate and drive development.

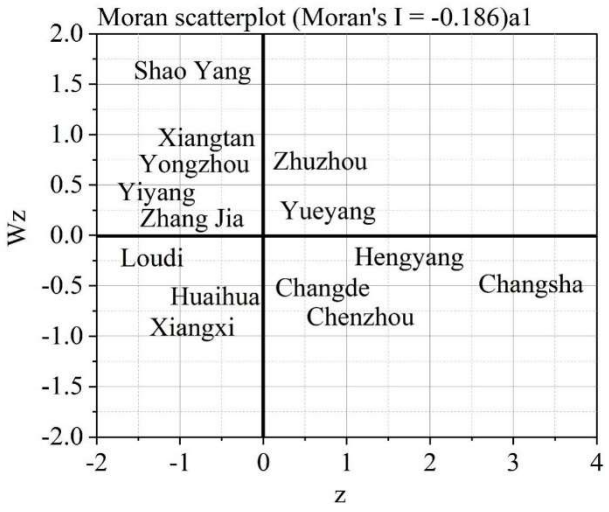

Figure 1: 2020 coupling coordination

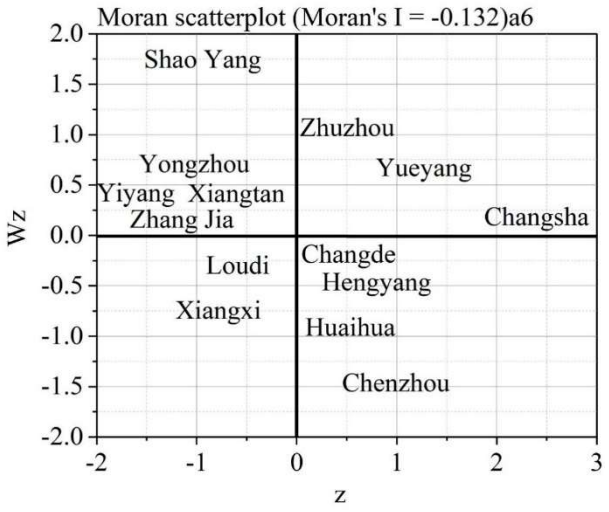

Figure 2: 2022 coupling coordination

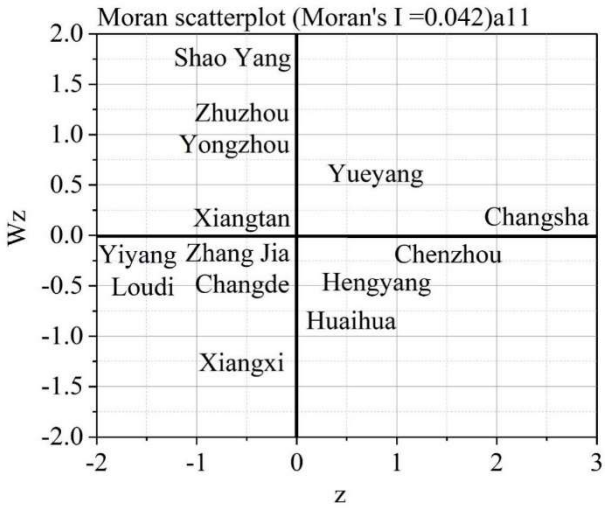

Figure 3: 2024 coupling coordination

VI. Mechanisms for the integration of cultural heritage protection and cultural tourism industry development

In response to the above research conclusions, this paper proposes a mechanism for the integrated development of cultural heritage and the cultural tourism industry: a cultural ecological compensation mechanism, a profit-sharing mechanism, and a symbiotic mechanism.

VI. A. Cultural ecological compensation mechanism

Ecological compensation is an important principle applied in the development of tourism in natural resource heritage sites. The ecological compensation mechanism focuses on the cultural foundation, public foundation, inheritors, and other audiences of cultural heritage. The cultural tourism industry's utilization of cultural heritage primarily involves packaging and planning it as a tourism resource, with the aim of meeting consumer needs. Such involvement by the cultural tourism industry inevitably has a certain impact on the inheritance, development, and protection of cultural heritage itself. When tourism intervenes in the inheritance and protection of cultural heritage, it inevitably affects the production or lifestyle of residents in the area where the cultural heritage is located, and it affects the local cultural ecology. The tourism development of cultural heritage can have negative impacts on the local cultural ecology, posing a potential risk. To better avoid adverse effects on the local area, it is essential to comprehensively assess the negative impacts of tourism development on the local cultural ecology and evaluate their severity. The cultural ecology compensation mechanism aims to reconcile the contradictions between cultural heritage transmission and tourism development, avoiding negative impacts on cultural heritage transmission, particularly preventing tourism from undermining the cultural authenticity of heritage sites. Tourism development of cultural heritage involves selecting aspects of cultural heritage that are of interest to tourists, and then materializing, conceptualizing, and landscape-izing the culture. However, the aspects that are filtered out often result in the destruction of their ecological environment.

VI. B. Benefit-sharing mechanisms

Benefit-sharing refers to the cultural heritage and cultural tourism industries, which can allocate the benefits derived from their cooperation in a reasonable manner based on their respective interests, taking into account the extent of their contributions and investments during the development process. The benefit-sharing mechanism is a set of mechanisms that ensure the smooth operation of all parties by focusing on their core interests. In cultural heritage and cultural tourism industries, the interests of stakeholders in cultural heritage and cultural tourism are determined through systems, standards, and regulations, and a specific distribution method is proposed. All parties involved in interest distribution should collaborate, communicate, and negotiate to maximize their input-output ratios, ultimately achieving a win-win situation. Tourism development provides financial support for the inheritance and protection of cultural heritage, enhances its visibility and influence, expands its audience, and strengthens the public foundation for its inheritance and development. The two mutually promote and drive each other. To sustain this positive, coordinated relationship, it is essential to establish a mechanism that unifies industrial development with interest

sharing. The core of the interest-sharing mechanism lies in the distribution of interests among different stakeholders, which must be evaluated and measured based on their contributions to the development of the cultural tourism industry. The construction of such a mechanism requires identifying its stakeholders and establishing criteria to evaluate their contribution ratios in tourism development.

VI. C. Symbiotic Mechanisms

Symbiosis is a concept in biology that describes the interdependent survival strategies of different organisms based on their need to survive. This interdependent relationship is also referred to as the symbiosis theory. Cultural heritage and the cultural tourism industry, as two distinct themes, can also form a symbiotic system and symbiotic relationship. This symbiotic model can be categorized into four types based on behavioral patterns: parasitism, one-sided mutualism, asymmetric mutualism, and symmetric mutualism. Cultural heritage and the cultural tourism industry can adopt the symmetric mutualism model. The relationship between cultural heritage and the cultural tourism industry can be categorized into two modes—asymmetric mutualistic symbiosis and antagonistic mutualistic symbiosis—based on the specific development status of the cultural tourism industry and the preservation and protection status of cultural heritage in a particular region. Cultural heritage and the cultural tourism industry exhibit good symbiotic potential, as they possess the general conditions for symbiosis, including symbiotic units, symbiotic modes, and symbiotic relationships. The symbiotic units between cultural heritage and the cultural tourism industry are formed by the interconnection of tourism resources, with the cultural tourism industry as the core, and the cross-fertilization of different cultures. The symbiotic interface between cultural heritage and tourism can be a specific tourist destination or heritage site, the tourism needs of visitors, or the infrastructure of a tourist destination, a technological platform, etc.

VII. Conclusion

The main research conclusions are as follows.

From the perspective of the driving factors influencing the coupling coordination degree between Hunan Province's cultural industry and tourism industry, the explanatory power of spatial differentiation in the coordinated development of the cultural tourism industry is as follows: economic development > ecological environment > social culture. The levels of industrial development, government support, and environmental conditions play a dominant role. Moreover, the explanatory power of factor interaction detection is higher than that of individual factors, exhibiting a dual-factor enhancement or nonlinear enhancement, reflecting the combined driving effect of multiple factors. Among these, the interaction between economic development and ecological environment is significantly higher than that of social culture.

The study proposes three mechanisms for the transformation of cultural heritage protection and cultural tourism industry toward Chinese-style modernization in Hunan Province: the cultural ecological compensation mechanism, the interest-sharing mechanism, and the symbiotic mechanism.

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