ISSN 2616-5902 Vol. 7, Issue 11: 141-148, DOI: 10.25236/AJBM.2025.071119

Analysis on the Coupling and Coordinated Development of Aviation Culture and Tourism Industry in Shandong Province

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Abstract: *In recent years, with the rapid development of the aviation industry in Shandong Province, aviation cultural industries such as aviation-themed parks and aviation technology exhibitions have become emerging hotspots in mass tourism. A development trend of "Bidirectional Empowerment, Synergistic Coexistence" has also emerged between the two. Based on statistical data from 2014 to 2023, this paper calculates the coupling coordination degree of the development of aviation culture and tourism industry in Shandong Province using the entropy method and coupling coordination degree model, and analyzes the evolution characteristics of the coupling coordination development between the two systems. The results show that the comprehensive development level index of Shandong's aviation cultural industry shows an overall annual upward trend; the comprehensive development level index of the tourism industry continued to grow from 2014 to 2019, and showed a "W"-shaped fluctuation from 2019 to 2023. The coupling coordination degree between the two systems shows an overall upward trend, with continuous growth from 2014 to 2019 and fluctuating growth from 2019 to 2023. The coupling coordination type has gradually changed from an aviation cultural industry lag type to a tourism industry lag type, evolving from imbalance to coordination.*

Keywords: *Aviation Culture; Tourism Industry; Entropy Method; Coupling Coordination Degree*

1. Introduction

In recent years, with the rapid development of civil aviation transportation, aviation-themed cultural industries such as aviation science education, aviation theme parks, and aviation technology exhibitions have gradually emerged and evolved into a new business model, becoming fresh tourism experiences for the public. The aviation cultural industry plays a positive role in promoting tourism development by providing abundant materials, innovative ideas, and diversified integration approaches for tourism product development. This drives tourism products to transition from traditional sightseeing to immersive experiences and from single formats to composite business models. Meanwhile, the sustained growth of tourism also creates vast market opportunities, diverse communication channels, and sustainable profit models for the aviation cultural industry's market expansion. The "Bidirectional Empowerment, Synergistic Coexistence" virtuous cycle between these two sectors lays a solid foundation for their coordinated development. At this critical stage where Shandong Province is vigorously promoting the integration of culture and tourism and building a "Welcoming Shandong" cultural tourism brand system, it is essential to analyze the interaction mechanisms between aviation culture and tourism industries within the province, further examine their interaction levels, and explore their spatiotemporal evolution characteristics. To this end, this paper employs a coupling coordination model [1,2] to measure the coupling coordination degree between Shandong's aviation cultural industry and tourism sector, investigate their interaction types, and analyze their spatiotemporal evolution features. The findings aim to provide decision-making references and theoretical guidance for achieving comprehensive coordination and stable development of aviation cultural industries and tourism in the province.

2. Research Methods

To accurately assess the coupling coordination between the aviation cultural industry and tourism, this study utilizes key metrics including the number of aviation-specialized universities in Shandong

ISSN 2616-5902 Vol. 7, Issue 11: 141-148, DOI: 10.25236/AJBM.2025.071119

Province, the quantity of aviation-themed pavilions, total tourist numbers, tourism revenue, and average tourist stay duration. These indicators are comprehensively analyzed to evaluate the synergy between the two subsystems.

2.1 Calculate indicator weights

The entropy method, an objective weighting approach based on information entropy theory, converts indicator values into entropy values and determines weights by calculating data dispersion [3]. Widely applied in economic [4], resource [5], and engineering [6] research, this method helps avoid subjectivity in weighting indicators for aviation cultural industries and tourism. To address this, the paper employs the entropy weighting method with the following steps:

(1) Indicator standardization

$$x'_{ij} = \frac{x_{ij} - X_{\min}}{X_{\max} - X_{\min}} \text{ (Forward indicator)} \tag{1}$$

$$x'_{ij} = \frac{X_{\max} - x_{ij}}{X_{\max} - X_{\min}} \text{ (Reverse indicator)} \tag{2}$$

(2) In order to ensure that all indicators can maintain a reasonable numerical range after standardization, non-negative processing of standardized data is required, which is usually completed by numerical translation.

$$x''_{ij} = H + x'_{ij} \quad x''_{ij} = H + x'_{ij} \tag{3}$$

Here H is the amplitude of the indicator movement, usually taken as 0.0001.

(3) Indicator contribution

$$p_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{n} x'_{ij}} \tag{4}$$

(4) Index entropy

$$E_j = -\ln(m) \cdot p_{ij} \cdot \ln\left(p_{ij}\right) \tag{5}$$

(5) Index difference coefficient

$$d_j = 1 - E_j \tag{6}$$

(6) Indicator weights

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{7}$$

Among the above, i represents the year; j represents the value of each selected indicator; x'_{ij} represents the value after standardization; x_{ij} represents the initial value of indicator j in year i; $x_j^{\max}$ represents the maximum value of indicator j; $x_j^{\min}$ represents the minimum value of indicator j; P_{ij} represents the contribution degree of indicator j in year i; E_j represents the entropy value of indicator j; g_j represents the difference coefficient of indicator j; ω_j represents the weight value of indicator j.

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2.2 Calculation of the comprehensive development index

$$S_k = \sum_{j=1}^{m} w_{ij} \cdot x'_{ij} \tag{8}$$

Among the above, S_k represents the comprehensive development level index of the -th subsystem.

2.3 Coupling Coordination Model

Coupling degree serves as a metric to quantify the intensity of interactions between systems. This concept originated from research on interaction phenomena in complex physical systems. As coupling intensity increases, the system's evolution becomes more orderly, with interactions between components stabilizing. Conversely, reduced coupling leads to disorderly evolution and heightened interaction instability [7,8]. To analyze the interrelationships between aviation cultural industries and tourism development, a coupling coordination model between subsystems was introduced.

Table 1 Evaluation criteria for the coupling coordination model

Coupling level	D price	Coordination type	S1 and S2 relationship	Type Classification
Low coupling level	0<D≤0.1	Extremes	S1>S2	Extreme imbalance tourism lagging type
			S1=S2	Extreme aviation culture-tourism synchronization
			S1<S2	The aviation cultural industry with extreme imbalance is lagging behind
	0.1<D≤0.2	Severe Distress	S1>S2	Severely distressed category tourism lagging type
			S1=S2	Severely disturbed aviation culture-tourism synchronization type
			S1<S2	Severely distressed category: lagging aviation cultural industry
	0.2<D≤0.3	Moderate Dissonance	S1>S2	Moderate dislocation type tourism lagging type
			S1=S2	Moderate dissonance type aviation culture-tourism synchronization
			S1<S2	Intermediate coordination category aviation cultural industry laggard
rivalry	0.3<D≤0.4	Mild dysregulation	S1>S2	Mild dislocation type tourism lagging type
			S1=S2	A mild form of aviation culture-tourism synchro
			S1<S2	The aviation cultural industry with mild imbalance lags behind
	0.4<D≤0.5	Endangered	S1>S2	Tourism in the category of endangered species lags behind
			S1=S2	Aerial culture in the verge of extinction-synchronous tourism
			S1<S2	The aviation cultural industry in the category of endangered is lagging behind
burning-in	0.5<D≤0.6	Compromise	S1>S2	The tourism industry with a lagging coordination is barely coordinated
			S1=S2	A coordinated aviation culture with synchronized tourism
			S1<S2	The coordinated aviation cultural industry lags behind
	0.6<D≤0.7	Primary Coordination Category	S1>S2	Primary coordination category tourism lags behind
			S1=S2	Primary coordination of aviation culture and tourism
			S1<S2	The primary coordination category of aviation cultural industry lags behind
High coupling level	0.8<D≤0.9	Good coordination	S1>S2	Good coordination type tourism lags behind
			S1=S2	Good coordination of aviation culture and tourism
			S1<S2	Good coordination category aviation cultural industry lagging type
	0.9<D≤1.0	Quality Coordination	S1>S2	High-quality coordinated tourism lags behind
			S1=S2	High-quality coordinated aviation culture and tourism synchronization
			S1<S2	High-quality coordinated aviation cultural industry lags behind

$$C = 2\left(\frac{S_1 \cdot S_2}{(S_1+S_2)\cdot(S_1+S_2)}\right)^{\frac{1}{2}} \tag{9}$$

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$$D = (C \cdot T)^{\frac{1}{2}} \tag{10}$$

$$T = \alpha S_1 + \beta S_2 \tag{11}$$

Here, C represents the coupling degree between Shandong Province's aviation cultural industry and tourism sector; T denotes the overall benefit index, reflecting the system's contribution to coupling coordination; D indicates the coupling coordination degree between the aviation cultural industry and tourism sector in Shandong Province; αand βrepresent undetermined coefficients, where both subsystems are considered equally important (α=β=0.5). Based on domestic research literature and the current development of the aviation cultural industry and tourism, the coupling coordination relationship between Shandong's aviation culture and tourism industry is categorized into four levels and ten types [9,10], as detailed in Table 1.

3. Coupling, coordination and evolution analysis

The weights of each indicator were calculated using the entropy weighting method, as detailed in Table 2. The comprehensive development index of aviation cultural industry and tourism (which was omitted due to space constraints) was derived through formulas (1)-(8). By integrating the coupled coordination model, the coupling coordination degree of Shandong Province's aviation cultural industry and tourism from 2014 to 2023 was determined.

Table 2 Evaluation Index System for Synergy between Aviation Cultural Industry and Tourism

subsystem	metric	Entropy	coefficient of variation	weight
Aviation cultural industry	Number of aviation colleges	0.7285	0.2715	83%
	Number of aviation theme pavilions	0.9439	0.0561	17%
tourism	Total number of tourists	0.8360	0.1640	38%
	Total tourism revenue	0.8362	0.1638	38%
	Average stay per person	0.8982	0.1018	24%

3.1 Analysis of Evolutionary Characteristics of Shandong's Aviation Culture and Tourism Development

From the comprehensive development level index of aviation cultural industry and tourism in Shandong Province, as shown in Figure 1. The comprehensive development level index of aviation culture in Shandong Province showed an overall upward trend from 2014 to 2023, increasing from 0.001 in 2014 to 0.989 in 2023. The number of aviation-themed schools in Shandong Province increased from 5 in 2014 to 10 in 2023, and the number of aviation-themed pavilions in Shandong Province increased from 3 in 2014 to 9 in 2023, indicating a sustained positive trend in the aviation cultural industry. From 2014 to 2017, there was a slow growth trend, mainly due to the aviation cultural industry being in its initial stage at that time, with incomplete relevant policies. From 2017 to 2020, there was a sharp growth trend. During this period, aviation culture, as an important component of aviation industry development, played a significant role in promoting the aviation economy and expanding the radiation range of the aviation industry, facing rare development opportunities. In November 2016, Feng Zhenglin, then Director of the Civil Aviation Administration of China, pointed out at the 11th China International Aviation and Aerospace Exhibition that conditions should be created to ignite the enthusiasm of general aviation enthusiasts, with a focus on supporting local governments and social forces in promoting aviation cultural education and spreading aviation culture. From 2020 to 2023, the aviation cultural sector experienced fluctuating growth. While pandemic impacts affected its development, the industry maintained an overall upward trajectory. This momentum was primarily driven by the 2022 "Guidelines for Planning and Construction of Aviation Observation Facilities at Civil Airports," which outlined three core objectives: enhancing passenger experiences and public engagement through aviation facilities, promoting aviation knowledge and cultural awareness, and elevating airport service standards and brand image. These strategic initiatives have significantly propelled the growth of the aviation cultural industry.

The Comprehensive Development Index of Shandong Province's tourism industry exhibited a year-on-year upward trend from 2014 to 2019, followed by a W-shaped pattern from 2019 to 2023.

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During the 2014-2019 period, the index surged from 0.020 to 0.932, reflecting the industry's full integration into China's national strategic framework. Tourism became a strategic pillar industry in national economic development, particularly as the drive to build a moderately prosperous society in all respects progresses steadily, tourism has evolved into a key component of people's daily life, fueling the tourism industry's unprecedented robust growth. However, from 2020 to 2023, the index fluctuated between 0.090 and 0.790, marking a decline compared to pre-2019 levels. The pandemic's impact significantly hindered tourism development during this phase.

Overall, before 2019, Shandong Province's tourism industry had maintained a higher comprehensive development index than its aviation cultural industry, with the former growing at a faster pace. This was primarily due to tourism's solid foundation and strong growth potential, which outpaced the aviation cultural industry in scale during this period when the latter remained in its early exploratory phase. From 2020 to 2023, however, the aviation cultural industry's comprehensive development index surpassed tourism's, mainly due to pandemic impacts that slowed tourism growth. This manifested in a sharp decline in tourist numbers and severe contraction of related economic benefits, significantly affecting the tourism sector.

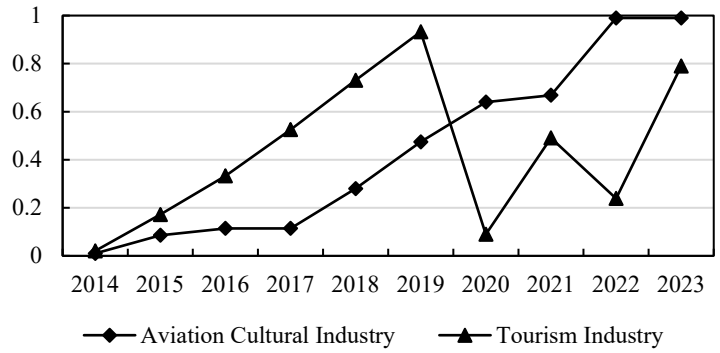

Figure 1 Evolution of the Comprehensive Development Index of Aviation Cultural Industry and Tourism in Shandong Province

3.2 Analysis of Evolutionary Characteristics of Synergy between Aviation Culture and Tourism in Shandong Province

Based on the comprehensive development level index of aviation cultural industry and tourism in Shandong Province, the coupling coordination degree of aviation cultural industry and tourism industry in Shandong Province can be calculated according to formulas (9) to (11), as shown in Figure 2.

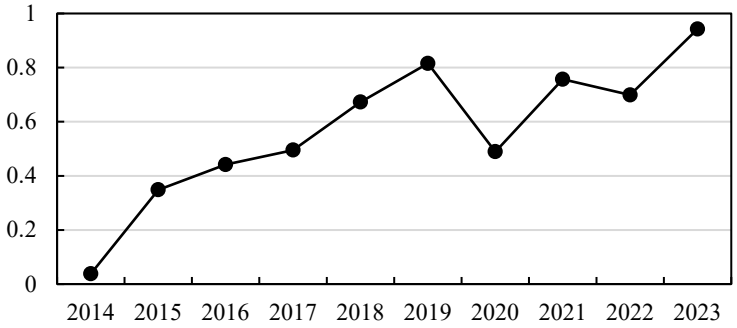

Figure 2 Evolution of coupling coordination between aviation cultural industry and tourism in Shandong Province

The data reveals that between 2014 and 2023, the coupling coordination degree between Shandong Province's aviation cultural industry and tourism sector showed a consistent upward trend, rising from 0.038 to 0.943. The most significant growth occurred between 2014 and 2019, when the coordination degree surged from 0.038 to 0.815. This remarkable progress was primarily driven by the government's vigorous promotion of aviation cultural development and tourism integration during this period. The "13th Five-Year Plan for Tourism Development" issued by the State Council in December 2016 emphasized integrating low-altitude airspace pilot programs with aviation experience activities and

ISSN 2616-5902 Vol. 7, Issue 11: 141-148, DOI: 10.25236/AJBM.2025.071119

sports. Subsequently, the Shandong Provincial Department of Culture and Tourism outlined in its January 2017 guidelines for tourism development that deep cultural-tourism integration would be prioritized, with special focus on innovative models like educational tours and low-altitude flight experiences. These coordinated efforts have laid a solid foundation for achieving high-level synergy between aviation cultural industries and tourism.

The period from 2019 to 2023 exhibited a W-shaped fluctuating upward trend, with the coupling coordination degree fluctuating between 0.489 and 0.943. Analysis of the comprehensive development index of the two industries reveals that this developmental pattern primarily resulted from the tourism sector's W-shaped growth trajectory during this timeframe. Specifically, the coupling coordination degree between the two systems significantly declined in 2019-2020 due to the sudden outbreak of the pandemic, which severely impacted the tourism industry. After 2022, the coupling coordination degree gradually increased. At the provincial cultural and tourism conference held in Shandong Province in January 2021, authorities emphasized the need to balance epidemic prevention and control with resumption of work and production, promote the creation and exhibition of artistic masterpieces, improve the public service system for culture and tourism, enhance the quality of cultural and tourism industry development, and strengthen the "Friendly Shandong" brand, which contributed to partial recovery of the tourism sector. Additionally, in February 2021, the Central Committee of the Communist Party of China and the State Council issued the "National Comprehensive Three-Dimensional Transport Network Plan Outline," proposing to develop the "low-altitude economy." This emerging economic model further boosted the aviation cultural industry and enhanced the coordinated development between the two systems.

By analyzing the comprehensive development index of aviation cultural industry and tourism in Shandong Province from 2014 to 2023, along with the coupling coordination degree between the two systems, and applying the classification framework and evaluation criteria for coordinated development of aviation culture and tourism, we can determine the coupling coordination types of aviation cultural industry and tourism in Shandong Province during this period. The specific results are presented in Table 3.

Table 3 Coupling and coordination types of aviation cultural industry and tourism in Shandong Province

a particular year	Coupling Coordination Degree D	S1 and S2 relationship	Type Classification
2014	0.038	S1<S2	The aviation cultural industry with extreme imbalance is lagging behind
2015	0.348	S1<S2	The aviation cultural industry with mild imbalance lags behind
2016	0.442	S1<S2	The aviation cultural industry in the category of endangered is lagging behind
2017	0.495	S1<S2	The aviation cultural industry in the endangered category lags behind
2018	0.673	S1<S2	The primary coordination category of aviation cultural industry lags behind
2019	0.815	S1<S2	Good coordination category aviation cultural industry lagging type
2020	0.489	S1>S2	Tourism in the category of endangered species lags behind
2021	0.757	S1>S2	Intermediate coordination category tourism laggard
2022	0.699	S1>S2	Primary coordination category tourism lags behind
2023	0.943	S1>S2	High-quality coordinated tourism lags behind

Overall, the coupling coordination between Shandong Province's aviation cultural industry and tourism sector has evolved from imbalance to harmony over time, with the coordination pattern shifting from aviation cultural industry lag to tourism lag. In 2014, the coupling coordination between the aviation cultural industry and tourism development in Shandong Province was classified as an extreme imbalance type characterized by aviation cultural industry lag. This was primarily due to the existing developmental disparities between the two subsystems at that time. Aviation cultural initiatives such as aviation science education and aviation-themed tourism were still in their infancy, with weak foundations and insufficient scale, resulting in significantly lagging development compared to tourism. Meanwhile, tourism development mainly focused on traditional natural landscapes and

ISSN 2616-5902 Vol. 7, Issue 11: 141-148, DOI: 10.25236/AJBM.2025.071119

historical-cultural tours. Under these circumstances, the aviation cultural industry and tourism sector lacked effective collaboration in resource integration and product convergence, leading to the lowest level of coupling coordination.

From 2015 to 2019, Shandong Province witnessed a coordinated evolution in aviation cultural industries and tourism development, transitioning from a mildly imbalanced lagging state to a well-coordinated lagging state. The synergistic relationship between these two sectors showed significant improvement during this period. The thriving development of aviation-themed museums, aviation schools, and integrated tourist attractions further optimized the growth environment for aviation cultural industries and tourism. Additionally, Shandong's "Cultural Industry Development Plan for the Provincial Capital Urban Agglomeration Economic Circle (2013-2020)" emphasized building a three-dimensional tourism system integrating water, land, and air resources. The plan prioritized accelerating aviation cultural industry development through establishing four cultural industry parks, including aviation industrial parks and cultural innovation parks. By leveraging market mechanisms and shared interests, the initiative achieved optimized integration of regional resources and cultural elements, effectively promoting the synergistic development of aviation cultural industries and tourism. However, when examining the development of their respective systems, the aviation cultural industry still lags behind the tourism sector, with tourism maintaining its dominant position. This disparity primarily stems from the aviation cultural industry's late start and the need to further consolidate its foundational development. Data from the comprehensive development index reveals that the gap between the two industries has been gradually narrowing during this period, indicating they have entered a phase of positive interaction. Aviation culture has infused tourism with technological and experiential elements, while tourism has provided aviation culture with dissemination channels and market opportunities. This synergy has elevated overall development levels, with increasingly evident characteristics of resource sharing and complementary advantages between the industries.

From 2020 to 2023, the pandemic significantly impacted the coupling coordination between the aviation and tourism industries. While the two systems transitioned from imbalance to coordination, their coupling pattern evolved into tourism's lagging development. The aviation cultural industry, however, surpassed tourism in growth. This shift primarily stemmed from pandemic impacts, with tourism being more vulnerable due to its inherent characteristics. In contrast, aviation cultural activities thrived through flexible industrial models. Overall, the aviation cultural industry and tourism sector demonstrated strong synergy, with their development increasingly converging into a coordinated relationship.

4. Conclusions and recommendations

Based on the calculation of the coupling coordination degree of aviation cultural industry and tourism in Shandong Province from 2014 to 2023, and the analysis of the evolution characteristics of the coupling coordination degree, the main conclusions are as follows:

(1) From 2014 to 2023, Shandong Province's Aviation Culture and Tourism Development Index exhibited distinct trends. The Aviation Culture Index showed consistent annual growth, while the Tourism Index initially rose steadily from 2014 to 2019 before entering a W-shaped pattern from 2019 to 2023. Prior to 2019, both sectors maintained strong momentum, though the Tourism Index outpaced the Aviation Culture Index, indicating the need for the aviation industry to strengthen its foundation and accelerate development. Between 2020 and 2023, the Aviation Culture Index surpassed Tourism's, as pandemic-related slowdowns hindered tourism growth while the aviation sector's unique characteristics and policy support enabled robust progress.

(2) From 2014 to 2023, the coupling coordination degree between aviation cultural industry and tourism in Shandong Province exhibited an overall upward trend. Specifically, the period from 2014 to 2019 saw a sustained growth momentum with significant expansion, while the 2019-2023 phase demonstrated a W-shaped fluctuating upward pattern. This developmental trajectory primarily stemmed from the tourism industry's W-shaped growth trend during this timeframe. Overall, the coupling coordination relationship between Shandong's aviation cultural industry and tourism has evolved from imbalance to harmony over time, with the coordination pattern transitioning from aviation cultural industry lagging to tourism lagging.

On the basis of the analysis, the following recommendations are made:

(1) Enhance the integration of aviation and cultural tourism resources. Building on the current

ISSN 2616-5902 Vol. 7, Issue 11: 141-148, DOI: 10.25236/AJBM.2025.071119

policy support for aviation tourism development, we will intensify efforts in developing aviation-themed cultural tourism projects and establishing aviation science education bases. By deeply exploring the integration of cultural tourism resources, we aim to create comprehensive aviation cultural tourism products that combine "aviation culture + natural landscapes + historical heritage." This initiative will incorporate the spirit of "Contribute to National Development through Aviation, Build a Powerful Aviation Nation" optimize the industrial structure of aviation cultural tourism, and focus on building a diversified product system. These efforts will enhance the industry's sustainable development capabilities and risk resilience.

(2) Innovative Promotion and Market Expansion. We will utilize diversified channels to promote aviation culture and integrated tourism products, leveraging social media platforms to showcase Shandong's aviation cultural charm and distinctive tourist attractions. By organizing aviation cultural tourism festivals and themed competitions, we aim to engage visitors, enhance brand recognition, and further expand market share. This will effectively drive the coordinated development of aviation cultural industries and tourism sectors.

Acknowledgements

This work was supported by Key Project of Art Science in Shandong Province (L2023Z04190726); Scientific Research Fund Project of the Young Talent Innovation Project of Binzhou University (BZXYQNLG202102); Key Project of Think Tank Decision Consulting Research, Shandong Association for Science and Technology (2025ZKZD008).

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