Research on Comprehensive Evaluation of Digital Construction of Cultural Venues in Chaozhou City Based on AHP-Entropy Method

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Abstract

Under the digitalization trend, the protection and dissemination methods of cultural heritage are undergoing profound transformation. As an important component of Lingnan culture, the digitalization of numerous cultural heritage sites and historical landmarks in Chaozhou has become a significant research sample. Through evaluating Chaozhou’ s cultural venues using the Analytic Hierarchy Process (AHP) and entropy method, it was found that its digitalization construction suffers from weak foundations, low penetration rates of digital technology, and that both the construction level and digital interaction effects urgently need improvement. Finally, based on the evaluation data results, this paper proposes recommendations from the perspective of the established criterion layer, targeting the results displayed at the indicator layer, to provide scientific basis and strategic suggestions for accelerating the digitalization construction process of Chaozhou’ s cultural venues.

Full Text

Preamble

A Comprehensive Evaluation Study on the Digital Construction of Cultural Venues in Chaozhou City Based on the Analytic Hierarchy Process-Entropy Method

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Abstract

Under the digital transformation trend, the preservation and dissemination methods of cultural heritage are undergoing profound changes. As an important component of Lingnan culture, the digitization of numerous cultural heritages and historical sites in Chaozhou has become a significant research subject. Through evaluation using the Analytic Hierarchy Process (AHP) and the Entropy Method, this study reveals that Chaozhou' s cultural venues face issues such as weak foundational infrastructure, low penetration of digital technologies, and urgent need for improvement in construction standards and digital interaction effectiveness. Based on the evaluation results, this paper proposes targeted recommendations from the established criterion layers, addressing the findings at the indicator layer to provide scientific evidence and strategic suggestions for accelerating the digital construction process of Chaozhou' s cultural venues.

Keywords: Chaozhou City; Cultural Venues; Digitalization; Comprehensive Evaluation; Recommendations
Classification Number: G250.7

1 Introduction

With the rapid development of information technology, digital technology has become a crucial force driving transformation across various social domains. The application of digital technology provides new means and opportunities for the preservation and dissemination of cultural heritage. In recent years, China has attached great importance to the deep integration of cultural industries and technology, promoting cultural digital transformation through a series of policies. For instance, the *China Digital Cultural Industry Development Report (2018-2021)* proposed specific measures for building digital cultural public service platforms, including breakthroughs in key technical areas such as data collection, storage, analysis, and copyright protection. Additionally, the *Guiding Opinions on Promoting the Co-construction and Sharing of National Cultural Information Resources* clarified the construction goals for digital venues and platforms, providing a policy foundation for the digitalization of cultural venues.

As an essential component of China' s traditional cultural treasury, Lingnan culture is renowned for its unique regional characteristics, profound historical heritage, and rich intangible cultural heritage. Chaozhou, a famous historical and cultural city abundant in cultural resources and deep historical legacy, holds particular significance for the digital transformation of its cultural venues. However, literature review indicates that research on the digital construction of Chaozhou' s cultural venues under an evaluation framework remains scarce. Therefore, this study references the methodologies of Zhang Zhicheng et al. [**?**] and Zhang Yang et al. [**?**], employing a combined AHP and Entropy Method for comprehensive evaluation. This approach enriches the evaluation system for Chaozhou' s cultural venues and aims to provide scientific evidence and theoretical reference for their digital upgrading, thereby helping traditional culture gain new vitality in the new era.

2 Overview of Cultural Venues in Chaozhou City

Chaozhou is a prefecture-level city in Guangdong Province, located in the eastern part of the province along the middle and lower reaches of the Han River. It is not only a city in the Shantou-Chaozhou-Jieyang metropolitan area but also a gateway city in eastern Guangdong, boasting a long history and rich cultural heritage. Chaozhou covers a total area of 3,613.9 square kilometers, governing two districts (Xiangqiao District and Chao' an District), one county (Raoping County), and the Fengxi District as a county-level administrative zone. With over 2,000 years of administrative history, Chaozhou has been an important administrative center since the Sui Dynasty. It is one of the birthplaces of Chaoshan culture and preserves numerous historical sites and intangible cultural heritage items.

In recent years, Chaozhou has formulated a series of policies in line with national directives, such as the *Chaozhou Smart City Five-Year Plan (2021-2025)* and the *Work Plan for Strengthening the Overall Protection of Chaozhou Historical and Cultural City (2024-2025)*. The city has actively taken action, achieving remarkable progress in cultural venue infrastructure construction and public services, accelerating efforts to address shortcomings in public cultural, tourism, and sports facilities, and comprehensively building a modern public cultural, tourism, and sports service system. These developments have not only enriched citizens' spiritual and cultural lives but also become an important factor in attracting tourists.

3.1.1 Research Scope

This study focuses on cultural venues in Chaozhou City as the research subject. Referencing the digital construction content of the Palace Museum, literature review findings, and field survey data, this research examines nine cultural venues in Chaozhou, including the Chaozhou Museum, Library, Intangible Cultural Heritage Museum, and Chen Weinan Cultural Center. The evaluation is conducted from perspectives such as equipment penetration rate, venue intelligence, digital service quality, and user experience to assess the digital construction level of Chaozhou' s cultural venues [**?**].

3.1.2 Method Selection

This paper employs a combined weighting method integrating the Analytic Hierarchy Process (AHP) and Entropy Method to analyze the digitalization degree of various cultural venues in Chaozhou. This approach ensures that the weights reflect both the evaluator' s subjective judgments and the influence of objective data [**?**], providing a comprehensive assessment of the digital construction of Chaozhou' s cultural venues. The comprehensive evaluation method is suitable for multi-attribute decision-making problems, particularly when both subjective judgment and objective data must be considered, thereby enhancing the scientific rigor and objectivity of weight determination in the decision-making process.

The Analytic Hierarchy Process, first proposed by American operations researcher Thomas L. Saaty in the 1970s, is a multi-criteria decision-making method. It is a systematic and hierarchical analytical approach combining qualitative and quantitative analysis, applicable to priority ranking and resource allocation in complex problems. The specific operation involves decomposing systematic issues into different hierarchical dimensions for scientific evaluation, demonstrating good operability [?].

The Entropy Method is based on the concept of entropy from information theory, measuring system uncertainty and information volume. It finds extensive application in multi-criteria decision analysis (MCDM), performance evaluation, and weight determination. Its core principle involves calculating the information entropy of each evaluation indicator to reflect the effective information provided by these indicators, thereby assigning reasonable weights to each indicator. This constitutes an objective analytical method.

However, AHP relies on expert experience and judgment, potentially introducing subjectivity, while the Entropy Method, though effective at extracting weights from data itself, cannot fully replace expert opinions, particularly when historical data is lacking or data quality is poor. Following the research flowchart (Figure 1), this paper combines AHP with the Entropy Method to comprehensively consider subjective judgment and objective data, thereby improving the scientific reliability of decision-making.

3.2.1 Establish and Optimize Indicator System

Given the current research gap regarding evaluation studies on the digital construction of Chaozhou's cultural venues, this paper references evaluation methodologies from multiple literature sources to establish the foundation for its evaluation framework [?]. Zhang Yang et al. used the AHP-Entropy Method to evaluate DC-DC converters [?]; Zhang Zhicheng et al. assessed the quality of Gaoyi Ancient Village using AHP and Entropy Method [?]; Sun Jie et al. employed fuzzy AHP to determine weights for railway ecological impact evaluation indicators [?]; and Gan Langxiong et al. analyzed water traffic safety factors based on the entropy weight method [?]. These studies provide methodological references for the comprehensive evaluation of digital development of Chaozhou' s cultural venues and play an important role in constructing a scientific evaluation system.

This study collected relevant materials and literature, initially selecting and determining seven criterion layers and nineteen indicator layers based on the target layer (digital construction level of Chaozhou' s cultural venues) (Figure

2), and subsequently optimized the indicator system according to specific field survey findings.

[Figure 1: see original paper]

Figure 1 Flowchart of Digitalization Construction Research for Cultural Venues in Chaozhou

The evaluation indicator system adopts a three-level structure: the first level is the target layer, representing the evaluation of the digital construction level of Chaozhou' s cultural venues; the second level is the criterion layer, comprising seven evaluation factors; and the third level is the indicator layer, consisting of nineteen evaluation factors.

3.2.2 Obtain Expert Weighting and Weight Calculation

To minimize the impact of expert subjectivity on decision results, this study collected pairwise comparisons of importance degrees for indicators in the indicator layer from individuals knowledgeable about Chaozhou' s cultural venues. Importance was scored using a scale of 9, 7, 5, 3, 1, 9/1, 7/1, 5/1, 3/1.

After normalizing each matrix to calculate weights, consistency tests were conducted for each matrix and weights were optimized. The maximum eigenvalue of the matrix was calculated as:

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(PW)_i}{w_i}$$

Judgment matrices involve pairwise comparisons of multiple indicators, which may lead to contradictory situations and deteriorate consistency. Therefore, the consistency index CI is introduced [?], defined as:

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

When CI = 0, the judgment matrix has complete consistency. As $\lambda_{\max} - n$ increases, CI increases, indicating poorer consistency of the judgment matrix. To test whether the judgment matrix has satisfactory consistency, CI must be compared with the average random consistency index RI. RI values are as follows:

When the judgment matrix' s CR = CI/RI < 0.10, the matrix has satisfactory consistency; otherwise, the judgment matrix requires adjustment until it passes the consistency test.

To further enhance the robustness and accuracy of weight calculation results, after confirming that matrices meet consistency standards, this study innovatively combines two different weight calculation methods: the arithmetic mean method and the eigenvalue method, taking the average of their summed results as the final calculated weight. The arithmetic mean method calculates weights by directly averaging column values, effectively reflecting overall trends of evaluation indicators, while the eigenvalue method determines weights by solving for the maximum eigenvalue and its corresponding eigenvector of the judgment matrix. The final weights obtained through AHP (rounded) are as follows:

3.3.1 Indicator and Weight Calculation

In the Entropy Method, smaller entropy values indicate that an indicator carries more information, while larger entropy values indicate less information. Based on the dispersion degree of each indicator, the Entropy Method uses information entropy to calculate the entropy of each indicator, yielding relatively objective weights. This study first classifies indicators for calculation and standardizes the data. Indicators are distinguished as positive or negative, with different operations applied to each type. For i sample observations with maximum value n and j evaluation indicators with maximum value m, positive indicators are standardized as:

$$X'_{ij} = \frac{X_{ij} - \min X_{ij}}{\max X_{ij} - \min X_{ij}}$$

Negative indicators are standardized as:

$$X'_{ij} = \frac{\max X_{ij} - X_{ij}}{\max X_{ij} - \min X_{ij}}$$

This study assigns values to surveyed Chaozhou cultural venues according to the indicator system, calculating the ratio of the ith cultural venue' s value to the total sample value under the jth indicator:

$$p_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{n} X'_{ij}}$$

3.3.2 Calculate Information Entropy

The k value and information entropy of each indicator are calculated as:

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

where $k = \frac{1}{\ln(n)}$. The redundancy of information entropy is then calculated:

$$d_j = 1 - e_j$$

3.3.3 Calculate Weights

Using information entropy to determine evaluation indicator weights, greater information entropy redundancy corresponds to larger indicator weights. To ensure indicator weights sum to 1, data were imported into SPSSPRO to obtain the weight table for each indicator:

3.4.1 Combination Weighting Method

In multi-criteria decision analysis, combining different methods to determine weights is a common strategy for improving model accuracy and reliability. After independently calculating weights through AHP and the Entropy Method, this study employs arithmetic averaging to integrate the two methods' weights. The weights obtained through this combined approach consider both subjective judgment (AHP) and objective data information content (Entropy Method). The combined weights (rounded) are as follows:

4 Results Analysis and Recommendations

In the weight table, larger weights indicate more important evaluation indicators. According to the indicator weights shown in Table 4, the indicator layer weight is largest for offline promotion rate, followed by relatively large weights for equipment penetration rate, venue protection degree, user satisfaction, and user feedback collection.

4.1 Equipment Penetration Rate

Equipment penetration rate reflects the foundational hardware coverage of cultural venues in achieving comprehensive digital transformation, ensuring that cultural venues possess basic digital infrastructure—a prerequisite for implementing other advanced functions. Based on offline field investigations of Chaozhou's cultural venues' digital construction, this criterion layer determined one indicator considering both the actual situation of Chaozhou's cultural venues and model simplification. This indicator holds a relatively high weight of 0.09 in the weight table, demonstrating that equipment coverage significantly impacts the digital construction of Chaozhou's cultural venues. Currently, equipment penetration rates vary considerably across Chaozhou's cultural venues. Therefore, these venues should prioritize improving digital equipment coverage across all locations and appropriately enhance basic digital construction in venues with weak digital infrastructure.

4.2 Venue Intelligence

Venue intelligence reflects the service level and technological sophistication of digital equipment in cultural venues and can effectively protect cultural heritage. This criterion layer has the largest weight of 0.24 and comprises four indicators: AR/VR technology application rate, venue protection degree, and equipment comprehensiveness. Weights in descending order are venue protection degree, AR/VR technology application rate, guided tour system application rate, and equipment comprehensiveness. Venue protection degree reflects the level of ensuring safety for cultural relics and venue facilities, as protective measures can extend the lifespan of cultural artifacts. AR/VR technology can create immersive experiences through augmented reality (AR) and virtual reality (VR) applications, making cultural heritage more vivid and engaging, thereby enhancing visitor interest and understanding. Guided tour systems provide intelligent navigation services, helping visitors more conveniently understand exhibition content and improving the visiting experience. Equipment comprehensiveness ensures that venues have a complete range of smart devices to support diverse service needs. Chaozhou' s cultural venues currently employ relatively traditional cultural protection measures and should increase protection equipment for cultural relics and venues to enhance preservation safety, such as establishing new early warning systems. Simultaneously, they should emphasize the role of modern technologies (like AR/VR) in attracting visitors.

4.3 Digital Service Quality

Digital service quality refers to the performance of digital equipment in serving visitors. This criterion layer has a weight of 0.11, with its three indicator weights in descending order being service responsiveness, service accuracy, and service portability, representing the response speed of digital equipment to visitor services, the accuracy of information services, and the availability of corresponding mobile applications. When enhancing digital construction, Chaozhou' s cultural venues should pay attention to equipment responsiveness and accuracy.

4.4 User Experience

User experience focuses on visitors' experience with cultural venues' digital equipment, differing from digital service quality. This criterion layer has a weight of 0.21, with its three indicator weights in descending order being user satisfaction, user feedback collection, and user participation, representing visitors' overall satisfaction with digital equipment services, usage rates of digital equipment, and staff emphasis on collecting user feedback. Chaozhou' s cultural venues can establish suggestion boxes, place self-service satisfaction surveys at exit points, and regularly collect user feedback questionnaires through online platforms and near venues to deeply understand user needs, continuously improve services, enhance user recognition and support for cultural venues, and promote long-term development.

4.5 Online Function Completeness

Online function completeness helps expand cultural dissemination channels, attract more online users, break geographical limitations, and achieve broader cultural sharing. This criterion layer has a weight of 0.16. Chaozhou' s cultural venues should emphasize the role of online websites and official accounts in cultural dissemination and tourism promotion. The five indicator weights in descending order are: content completeness (whether pushed content comprehensively covers actual venue conditions such as future plans and opening/maintenance hours), video usage rate (utilizing high-quality videos to showcase cultural content), service completeness (ensuring online platform services comprehensively cover user needs such as online ticketing and virtual tours), 3D technology usage rate (providing virtual visit experiences through 3D modeling and other technologies), and activity promotion rate (effectively promoting various cultural activities through online channels). To better disseminate Chaozhou' s cultural artifacts, venues should operate social media accounts as much as possible while ensuring content coverage and quality, hiring operators to publish high-quality videos.

4.6 Online Penetration Rate

Online penetration rate signifies that digital resources and services of cultural venues are widely accepted and used. Given Chaozhou' s fame for local culture and its large tourist population, the online penetration rate of Chaozhou' s cultural venues cannot be separated from offline promotion. In subsequent online account promotion, Chaozhou's cultural venues should employ novel and diverse methods to attract visitor attention and increase revisit rates.

4.7 Operational Simplicity

The operational simplicity of digital equipment ensures that all users can conveniently and safely enjoy the benefits of digitalization. This criterion layer has a weight of 0.08, with its two indicator weights in descending order being operational security and operational simplicity. While existing digital construction in Chaozhou' s cultural venues is relatively simple to operate, data importation of cultural artifact data into digital systems may pose risks of data leakage due to inadequate cybersecurity measures or insufficient rigor. Chaozhou' s cultural venues should recruit cybersecurity talent or establish data management organizations to focus on new data security trends while maintaining existing cultural relic protection methods, employing cutting-edge technologies to ensure data security.

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Author Contribution Statement

Xinyu Liu: Designed research framework, established model and analysis, conducted practical research, wrote paper;
Yan Zhang: Refined research ideas, organized practical research, revised paper;
Xin Hong: Conducted practical research, recorded results, collected information, wrote paper.

Note: Figure translations are in progress. See original paper for figures.