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ASSESSMENT OF CHINESE CITIES' INTERNATIONAL TOURISM COMPETITIVENESS USING AN INTEGRATED ENTROPY-TOPSIS AND GRA MODEL

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Abstract: Amid fierce competition in the international tourism market, enhancing the tourism competitiveness of Chinese cities has become a pressing issue. However, existing studies often face limitations in evaluation methodologies and indicator selection. This study proposes an integrated evaluation model combining the Entropy Weight Method, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Grey Relational Analysis (GRA) to assess and rank the attractiveness of Chinese cities to foreign tourists. Using data from 352 cities, the analysis incorporates six critical factors: city scale, environmental protection, cultural heritage, transportation accessibility, climate, and cuisine. The data underwent preprocessing through linear regression and Kaiser-Meyer-Olkin (KMO) tests, with Principal Component Analysis (PCA) and Locally Linear Embedding (LLE) employed as dimensionality reduction techniques for different data categories based on R^2 values. To ensure consistency across variables, normalization was applied, and indicator weights were objectively calculated using the Entropy Weight Method. The integrated TOPSIS and GRA approach was then utilized to evaluate and rank the 352 cities, ultimately deriving their composite scores. The findings reveal that the top 37 towns exhibit relatively concentrated scores, while scores for subsequent cities show a gradual downward trend. This study provides a systematic evaluation framework and decision-making support for Chinese cities to develop differentiated strategies in the global tourism market.
Keywords: Tourism competitiveness; Entropy Weight Method; TOPSIS; GRA; PCA; LLE

1 INTRODUCTION

In recent years, with the rapid advancement of economic globalization and the continuous improvement in living standards, the international tourism industry has witnessed unprecedented growth. As the world's largest developing country, China has seen its tourism sector evolve into a crucial component of its national economy, playing an increasingly vital role in fostering economic growth and driving social development. Notably, with the deepening implementation of the Belt and Road Initiative, the level of internationalization in Chinese cities has significantly increased, fully unleashing the potential of the tourism industry. However, in the face of intensifying competition in the global tourism market, a critical challenge remains: how can Chinese cities effectively enhance their tourism competitiveness and attract more international tourists.

Traditional methods for evaluating urban tourism competitiveness often focus on single-dimensional analyses [1],such as the Analytic Hierarchy Process (AHP) or Factor Analysis (FA), which fail to capture the multidimensional characteristics of urban tourism competitiveness. Furthermore, existing research tends to over-rely on objective data, overlooking the significance of tourists' subjective experiences in their decision-making processes. Consequently, current evaluation systems struggle to provide accurate insights for decision-making or formulate effective competitive strategies.

To address these gaps, this study introduces an integrated evaluation approach aimed at overcoming the limitations of traditional methods and providing a comprehensive, objective assessment of Chinese cities' competitiveness in the international tourism market. Drawing on web-scraped data from 352 cities, the study examines six critical dimensions: city scale, environmental protection, cultural heritage, transportation accessibility, climate, and cuisine. The data was preprocessed using linear regression [2] and the Kaiser-Meyer-Olkin (KMO) test, followed by appropriate dimensionality reduction techniques.

To ensure the objectivity of the assessment, this research employs a combined Entropy-TOPSIS [3] and Grey Relational Analysis (GRA) model [4], constructing a robust weighting mechanism and standardizing the data to ensure consistency and comparability. Ultimately, the study identifies the "50 most desirable cities for international tourists" and provides quantitative analyses and decision-making support for enhancing the competitiveness of Chinese cities in the global tourism market.

2 DATA COLLECTION AND PREPROCESSING

This study takes cities as the primary unit of analysis, integrating multiple dimensions such as city scale, environmental protection, cultural heritage, transportation accessibility, climate, and cuisine. Relevant data were systematically collected and organized to ensure a comprehensive evaluation of urban characteristics. The data was sourced primarily from various publicly accessible platforms, providing a robust foundation for analysis. Details of the data sources and their respective contributions are outlined in Table 1:

Table 1 Data Source Website

Website	URL
China National Environmental Monitoring Center	http://www.cnemc.cn/
National Bureau of Statistics of China	http://www.stats.gov.cn/
Ministry of Culture and Tourism	http://www.mct.gov.cn/
Ministry of Transport	http://www.mot.gov.cn/
China Meteorological Administration	http://www.cma.gov.cn/
Dianping	https://www.dianping.com/

The data for this study were sourced from various platforms, covering key indicators related to city scale, environmental protection, cultural heritage, transportation accessibility, climate characteristics, and cuisine. Specifically, the data includes metrics such as Air Quality Index (AQI), green coverage rate, and wastewater treatment rate under environmental protection; line density and the number of airport flights for city scale; the number of historical landmarks and museums for cultural heritage; public transportation coverage and highway mileage for transportation accessibility; annual average temperature and precipitation for climate; and the number of restaurants and signature dishes for cuisine.

To facilitate subsequent analysis, the 20 collected indicators were systematically categorized. Based on their attributes and functional significance, the indicators were grouped into six primary categories: city scale, environmental protection, cultural heritage, transportation accessibility, climate, and cuisine. The detailed classification results are presented in Table 2:

Table 2 Indicator Classification

Category	Indicator
City Size	Line Density (km/km²)
	Number of Airport Flights
Environmental Protection	Air Quality Index (AQI)
	Green Coverage Rate (%)
	Wastewater Treatment Rate (%)
	Exhaust Gas Treatment Rate (%)
	Waste Sorting and Treatment Rate (%)
Cultural Heritage	Number of Historical Sites
	Number of Museums
	Frequency of Cultural Events
	Number of Cultural Facilities
Transportation Convenience	Public Transportation Coverage Rate (%)
	Highway Mileage (km)
Climate	Average Annual Temperature (°C)
	Annual Precipitation (mm)
	Number of Days Suitable for Tourism
	Air Humidity (%)
Gastronomy	Number of Restaurants
	Number of Specialty Dishes
	Frequency of Gastronomy Events

During the data preprocessing stage, the raw data were systematically cleaned to remove missing and outlier values, ensuring the accuracy and completeness of the dataset. This critical step enhanced the reliability of the data, laying a robust foundation for the subsequent evaluation of urban tourism competitiveness. By integrating data collection with meticulous preprocessing, this study provides a solid basis for assessing the tourism competitiveness of cities. Furthermore, it offers reliable data support for comparative analyses of various aspects of competitiveness across different cities.

3 DATA DIMENSIONALITY REDUCTION AND STANDARDIZATION

To facilitate a comprehensive analysis of urban tourism competitiveness, the collected indicators across six categories were subjected to dimensionality reduction and standardization. The primary objective of dimensionality reduction was to minimize redundant information and extract the most representative features, thereby improving the accuracy and efficiency of subsequent analyses. Different dimensionality reduction techniques were applied based on the correlation among indicators within each category [5].

Initially, a linear relationship analysis was conducted for the indicators in all six categories to evaluate their inter-correlations. Through linear regression analysis, the coefficient of determination (R^2) was calculated for each category, providing insights into the strength of the relationships among the indicators. The results of this analysis are presented in Table 3.

Table 3 R-squared Values for Linear Relationship Detection

Category	R-squared Value
City Size	0.8856
Environmental Protection	0.1250
Cultural Heritage	0.9483
Transportation Convenience	0.8412
Climate	0.7125
Gastronomy	0.9432

As shown in Table 3, the R^2 values for the Cultural Heritage and Gastronomy exceed 0.9, indicating a significant linear correlation among the indicators within these categories. This makes them well-suited for dimensionality reduction using Principal Component Analysis (PCA) [6]. In contrast, the R^2 values for the City Size, Transportation Convenience, and Climate categories are all above 0.7, suggesting a strong linear correlation. For these categories, further evaluation through the Kaiser-Meyer-Olkin (KMO) test was conducted to determine the appropriate dimensionality reduction method.

On the other hand, the Environmental Protection category has an R^2 value of only 0.1250, indicating almost no linear correlation among its indicators. Therefore, the Locally Linear Embedding (LLE) method was selected for dimensionality reduction for this category [7].

Subsequently, the KMO test results for the City Size, Transportation Convenience, and Climate categories were assessed. The detailed KMO values are presented in Table 4.

Table 4 City Size, Transport, Climate (KOM) Values

Category	KMO Value
City Size	0.5000
Transportation Convenience	0.5000
Climate	0.5091

Based on the results of the KMO test, the KMO values for the City Size, Transportation Convenience, and Climate categories were all below 0.6, indicating that these datasets are more suitable for dimensionality reduction using the Locally Linear Embedding (LLE) method. Consequently, this study employed LLE to reduce the dimensions of the indicators in the City Size, Transportation Convenience, Climate, and Environmental Protection categories. This approach allowed for the effective extraction of the primary features within each category.

During the dimensionality reduction process, the LLE method successfully captured the key components of each category. The results were visualized using contour maps, providing an intuitive representation of the extracted features. The visualization of the dimensionality reduction outcomes is presented in Figure 1.

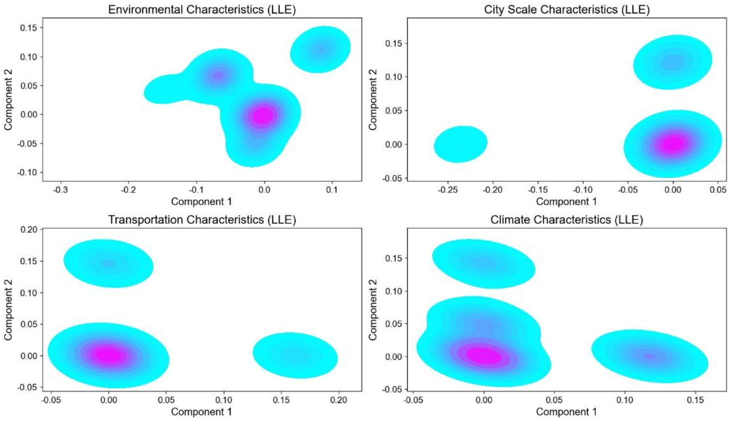

Figure 1 Contour map processed by LEE

After completing the dimensionality reduction process, a further step of standardization was undertaken to eliminate the impact of dimensional differences among indicators on the analysis results. All indicators were normalized, converting the raw data of varying scales into unit-free standardized evaluation values. By applying standardization formulas, each indicator's values were adjusted to a uniform evaluation basis, ensuring consistency and comparability across all metrics. This standardization process provided robust data support for subsequent comprehensive evaluations and ensured comparability between indicators from different categories.

Through the combination of dimensionality reduction and standardization, this study established a solid foundation for an in-depth analysis of urban tourism competitiveness. The dimensionality reduction methods effectively simplified the data structure, while the standardization process eliminated dimensional disparities. Together, these steps offer a more accurate and scientifically grounded basis for evaluating and comparing the tourism competitiveness of cities.

4 CONSTRUCTING A COMPREHENSIVE EVALUATION MODEL

To comprehensively assess the overall performance of cities across six key indicator categories, a hybrid evaluation model was developed, integrating the Entropy Weight Method, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [8], and Grey Relational Analysis (GRA). This approach enhances both the scientific rigor and reliability of the evaluation results.

First, the Entropy Weight Method was employed to objectively determine the weight of each indicator. By analyzing the contribution of each indicator, the entropy value was calculated to reflect its discriminative capacity. Lower entropy values indicate greater importance in distinguishing among samples. Based on the normalized data, an evaluation matrix was constructed, and corresponding weights were assigned to each indicator, resulting in a weighted evaluation matrix.

Building on this foundation, the TOPSIS method was applied to perform a comprehensive evaluation. This method calculates the Euclidean distance of each city from the positive and negative ideal points, which represent the optimal and least favorable values of each indicator, respectively. Specifically, for indicators classified as “larger-is-better,” the positive ideal point is the maximum value, and the negative ideal point is the minimum value. The proximity of each city to the ideal points was calculated to derive its composite score.

To further enhance the robustness and comprehensiveness of the evaluation, Grey Relational Analysis (GRA) was introduced. GRA evaluates the similarity in trends among indicators by calculating the correlation coefficients and degrees of association. Through the construction of a reference sequence and a different matrix, correlation coefficients, indicator weights, and final scores were sequentially computed. The degree of correlation reflects the similarity and variation in cities’ overall performance.

Finally, the results from the Entropy-TOPSIS and GRA methods were combined to construct an integrated evaluation model. Equal weights of 0.5 were assigned to each method, ensuring a balanced and comprehensive evaluation of urban competitiveness. The combined scores provide a reliable basis for comparison across cities. A visualization of the scores for selected cities is presented in Figure 2.

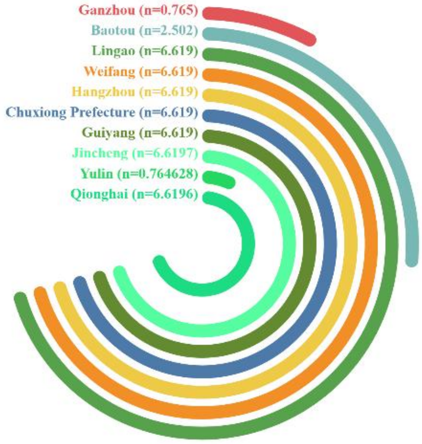

Figure 2 Rating Scores of Selected Cities

This integrated evaluation model effectively incorporates the heterogeneity and correlations of multidimensional data, overcoming the subjectivity and limitations of traditional weight assignment methods. By providing a scientific foundation for the quantitative analysis of cities' overall performance, the study results offer both theoretical support for enhancing tourism competitiveness and empirical evidence for policy formulation.

5 CONCLUSIONS

This research offers a novel framework and methodology that can be applied to tourism management and urban planning. The feasibility of the proposed approach is validated through its integration of entropy weighting, dimensionality reduction techniques (PCA and LLE), and multi-method evaluation, ensuring the objectivity and scientific rigor of the analysis. The framework not only enables stakeholders to devise differentiated development strategies based on objective data but also provides strong support for enhancing the global competitiveness of Chinese cities in the tourism market. Moreover, the methods and framework presented in this study demonstrate their potential applicability in broader fields of tourism and urban planning, offering valuable references for decision-making and research in these domains. This work contributes significantly to advancing the evaluation and strategic development of urban tourism competitiveness.

Future research can further advance the innovation and practicality of the proposed framework and methodology, emphasizing the progressive development of models and their applications. For instance, integrating artificial intelligence and big data technologies with dynamic scenario modeling and real-time data analysis could enhance predictive and decision-making capabilities in complex scenarios related to tourism management and urban planning.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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