Spatial Structure and Influencing Factors of Public Cultural Facilities in Inner Mongolia Based on POI Data: Postprint

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Abstract

Scientific planning of public cultural facility layout is of paramount importance for improving the public cultural service system and meeting the people' s demand for high-quality spiritual life. Based on POI data and the ArcGIS 10.8 software platform, and employing methods such as mathematical statistics, nearest neighbor index, kernel density estimation, and geographical detector, this study reveals the spatial structure and influencing factors of public cultural facilities in Inner Mongolia at multiple scales. The results indicate: (1) At the regional scale, the distribution of public cultural facilities is uneven with prominent disparities; various types of public cultural facilities exhibit agglomeration characteristics, and the density distribution is characterized by high density in the south and low density in the north, with the boundary being "Alxa Left Banner-Jalainur Banner". (2) At the sub-regional scale, western, central, and eastern Inner Mongolia all display agglomerated distributions with marked imbalance, and the quantity and density of public cultural facilities in central Inner Mongolia significantly exceed those in eastern and western Inner Mongolia. (3) At the league-city scale, there are huge disparities in facility numbers, with the "Hohhot-Baotou-Ordos" area showing significant agglomeration characteristics, followed by Wuhai City, Ulanqab City, and Bayan Nur City, while Chifeng City, Tongliao City, and Hinggan League exhibit slightly lower agglomeration degrees, Xilingol League and Hulunbuir City show even weaker agglomeration, and Alxa League is distributed in a sporadic pattern. (4) The spatial structure of public cultural facilities in Inner Mongolia is the result of the interaction and synergistic advancement of multiple factors including economic, cultural, social, and natural factors, and the interaction among these factors produces a "1+1>2" non-linear enhancement or dual-factor enhancement effect.

Full Text

Preamble

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Spatial Structure and Influencing Factors of Public Cultural Facilities in Inner Mongolia Based on POI Data

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Abstract: Scientific planning of public cultural facility layouts is essential for improving public cultural service systems and meeting the people' s demand for high-quality spiritual life. Based on the ArcGIS 10.8 software platform, this study employs mathematical statistics, nearest neighbor index, kernel density estimation, and geographical detectors to reveal the spatial structure and influencing factors of public cultural facilities in Inner Mongolia across multiple scales. The results indicate that: (1) At the provincial scale, public cultural facilities are unevenly distributed with prominent gaps, and all types exhibit clustered distributions. Density distribution shows a pattern of high density in the south and low density in the north, demarcated by the "Alxa Left Banner-Jalaid Banner" line. (2) At the regional scale, west, central, and east Mongolia all display clustered distributions with pronounced inequities. Central Mongolia significantly exceeds east and west Mongolia in both the number and density of public cultural facilities. (3) At the league and city scale, facility numbers vary dramatically, with the "Hohhot-Baotou-Ordos" region showing the most significant clustering, followed by Wuhai City, Ulanqab City, and Bayannur City. Clustering is slightly weaker in Chifeng City, Tongliao City, and Hinggan League, even weaker in Xilingol League and Hulunbuir City, while Alxa League exhibits a scattered distribution. (4) The spatial structure of public cultural facilities in Inner Mongolia results from the synergistic interaction and joint advancement of multiple economic, cultural, social, and natural factors, producing nonlinear enhancement or dual-factor enhancement effects where "1+1>2" .

Keywords: public cultural facilities; POI data; spatial structure; Inner Mongolia

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Introduction

Building a modern public cultural service system is crucial for ensuring the fairness and accessibility of public cultural services, which holds significant importance for promoting common prosperity in the people's spiritual and cultural lives. Within this system, public cultural facilities play an indispensable role as they serve not only as fundamental platforms for disseminating culture to

the public but also as essential guarantees for meeting the people' s demand for high-quality spiritual life [1]. Inner Mongolia, located on China' s northern border, can enrich the spiritual and cultural lives of border residents and advance the strategic goal of "cultural enrichment of border regions" through the layout and optimization of its public cultural facilities.

Foreign research often treats public facilities as a general category rather than studying public cultural facilities separately, focusing primarily on spatial layout, spatial equity, and supply-demand matching. Spatial layout research includes constructing location allocation models from industrial location theory perspectives [2] and determining facility locations based on network topology [3]. Spatial equity studies center on accessibility, such as healthcare accessibility [4], cultural facility accessibility [5], and accessibility analysis based on gravity models [6,7]. Supply-demand matching research evaluates the degree of matching between supply and demand by combining comprehensive spatial asset evaluation frameworks based on integrated equity indices [8] or spatial multi-criteria analysis [9] with resident needs. Domestic research on this topic is also abundant, concentrating on planning and design, operation management, public participation, cultural inheritance, and spatial layout of public cultural facilities. Planning and design studies are particularly rich, covering urban residential areas [10], historical and cultural districts [11], and traditional villages [12]. Operation management research primarily focuses on operational mechanisms [13] and improving management performance [14]. Public participation studies explore how to stimulate public interest and usage enthusiasm for public cultural facilities [15]. Cultural inheritance research investigates how to showcase and transmit China' s profound historical and cultural heritage through public cultural facilities [16]. Spatial layout studies examine distribution patterns, optimization methods, and influencing factors of public cultural facilities, with some focusing on specific facilities like art museums [17] and libraries [18], while others analyze spatial distribution characteristics [19] and relationships with transportation accessibility [20] from GIS perspectives. These achievements have innovated in theory and methodology and, more importantly, served social practice—for instance, research on urban public service facility spatial layout planning based on ant colony algorithms [21] provides new ideas for urban planning. Overall, these studies reflect sustained academic attention and research enthusiasm in the public cultural facilities field, offering valuable theoretical support and practical experience for improving China' s public cultural facility construction and management levels.

However, research on public cultural facilities in Inner Mongolia remains scarce. Existing studies either focus on the public cultural service system construction of specific banners or counties in Inner Mongolia [22], or conduct macro-level discussions based on statistical yearbook data [23]. Such research has limitations: studies on specific banners or counties, while detailed, often lack a macro perspective; league-level studies, though broader, concentrate on "libraries, museums, cultural centers, and cultural stations,"overlooking the necessity of multi-scale investigation from autonomous region, regional, and league-city perspec-

tives.

With continuous advancement in internet technology, new geographic information resources such as Points of Interest (POI) data with location characteristics have emerged. These data, characterized by large volume, high precision, and wide coverage, have been widely applied in urban planning and cultural tourism research [24], further advancing the refinement of regional spatial layout analysis. Following the scientific concept of data-driven decision-making, this study uses POI data as support and comprehensively employs mathematical statistics, nearest neighbor index, kernel density estimation, and geographical detectors to analyze the spatial distribution patterns and driving factors of public cultural facilities in Inner Mongolia. This approach overcomes the shortcomings of insufficient traditional statistical data and provides references for spatial planning and layout optimization of public cultural facilities in Inner Mongolia, thereby further promoting high-quality development of public cultural services in the region.

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1 Data and Methods

1.1 Study Area Overview

Inner Mongolia is located in northern China, stretching in a long and narrow east-west orientation across China's eastern, central, and western regions [25]. It governs 12 leagues and cities, comprising 103 county-level administrative regions. Following existing research [26], this study divides Inner Mongolia into three regions: west, central, and east Mongolia. East Mongolia includes Chifeng City, Tongliao City, Xilingol League, Hinggan League, and Hulunbuir City. Central Mongolia consists of Ulanqab City, Hohhot City, Baotou City, and Ordos City. West Mongolia comprises Bayannur City, Wuhai City, and Alxa League. As of December 2023, Inner Mongolia had 2,644 public cultural facilities, exhibiting a characteristic of "overall sparsity with local clustering" due to its vast territory and sparse population (Fig. 1).

1.2 Data Sources

This study utilizes three types of data: POI data for public cultural facilities, map data for Inner Mongolia, and attribute data.

Public cultural facilities include public welfare venues and equipment operated by diverse entities such as government agencies, enterprises, social organizations, and individuals, primarily comprising libraries, museums, various memorial halls, art exhibition halls, cultural activity centers, sports venues, youth activity centers, and workers' cultural centers [27]. Considering data availability, this study selects eight types of public cultural facilities as research objects: libraries, cultural centers (stations), museums, art galleries, exhibition halls, mass art centers, science and technology museums, and cultural palaces.

Amap data possess scientific validity, timeliness, and effectiveness. This study extracted 3,124 entries for Inner Mongolia from the Amap API on December 31, 2023, with attributes including administrative region, name, address, and latitude-longitude coordinates. After data screening and cleaning, 2,644 valid data points were obtained. The coordinate system of the acquired data was converted to WGS1984.

Inner Mongolia' s map data were obtained from the Standard Map Service website of the Ministry of Natural Resources. County-level data for Inner Mongolia came from the *Inner Mongolia Statistical Yearbook (2023)*, *China County Statistical Yearbook (2022)*, and 2020 national census data. Nighttime light data were sourced from the official website of the National Oceanic and Atmospheric Administration' s National Centers for Environmental Information (www.ngdc.noaa.gov). Missing data for individual banners and counties were replaced with league-level data.

1.3 Methods

1.3.1 Nearest Neighbor Index The nearest neighbor index analyzes the proximity of randomly distributed points in geographic space, originally proposed by ecologists Clark and Evans [28]. This study uses the nearest neighbor index method to identify the spatial distribution patterns of public cultural facilities in Inner Mongolia. The specific calculation formula is:

$$R = \frac{\bar{d}_1}{\bar{d}_2} = \frac{\frac{1}{m}\sum_{i=1}^{m} d_i}{\frac{1}{2}\sqrt{\frac{A}{m}}}$$

where R is the average nearest neighbor index; $\bar{d}_1$ is the actual average distance between public cultural facilities (m); $\bar{d}_2$ is the theoretical average distance between public cultural facilities (m); A is the study area (m^2); m is the total number of public cultural facilities in the region; and D is the distribution density of public cultural facilities (units $\cdot$ m^{-2}).

Based on the nearest neighbor index value, the spatial distribution characteristics of public cultural facilities can be determined: if $R = 1$, the distribution approaches a random pattern; if $R > 1$, the distribution is relatively uniform; if $R < 1$, the distribution exhibits clustering.

1.3.2 Kernel Density Estimation Kernel density estimation is a non-parametric method for estimating the probability density function of random variables, used to measure the distribution density of elements within a certain area [29]. The magnitude of kernel density estimation values reveals the degree of data clustering—higher values indicate greater clustering of data points in that region. This study uses kernel density estimation to demonstrate the spatial clustering characteristics of public cultural facilities. The specific calculation formula is:

$$F(x) = \frac{1}{nh} \sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right)$$

where $F(x)$ is the kernel density estimation value for public cultural facility distribution; k is the kernel density function; n is the number of public cultural facility institutions; h is the bandwidth for kernel density estimation; and $x - x_i$ is the distance value from the estimated public cultural facility x to sample facility x_i.

1.3.3 Geographical Detector The geographical detector is a tool for analyzing spatial differentiation patterns and their influencing factors. Due to its minimal assumptions and ability to detect both numerical and categorical data, it has been widely applied in regional economics, industrial planning, cultural tourism, and other fields [30]. This study employs factor detection and interaction detection from the geographical detector platform to investigate influencing factors of public cultural facility spatial distribution and the interactive forces between different factors. Calculation formulas are available in relevant references [31]. Factor detection uses the q statistic to measure the influence of independent variable X on dependent variable Y, where the q value ranges from [0, 1]. A larger q value indicates stronger explanatory power of X on Y. Interaction detection aims to evaluate whether the interaction of different influencing factors enhances or weakens the explanatory power on Y or whether these factors' influences on Y are independent [32].

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2 Results

2.1 Provincial, Regional, and League-City Scale Differences in Public Cultural Facility Quantity

2.1.1 Provincial-Scale Differences in Public Cultural Facility Quantity Based on mathematical statistics, the proportions of different types of public cultural facilities in Inner Mongolia were plotted (Fig. 2). The results show that the quantitative structure of public cultural facilities in Inner Mongolia reflects significant spatial imbalance. From a provincial perspective, the number gap among public cultural facilities is substantial. Cultural centers, museums, and libraries rank top three in quantity; cultural palaces and exhibition halls rank fourth and fifth; mass art centers, science and technology museums, and art galleries have the smallest numbers, ranking last. Further comparison reveals that the gap between the most numerous facility type (cultural centers) and the least numerous (mass art centers) reaches 17.6 times.

Why do public cultural facilities, as carriers of public cultural services, show such dramatic quantity disparities during the implementation of national cultural benefit projects? National cultural benefit projects aim to benefit all citizens

and popularize mass culture through top-down, unified planning, and vigorous promotion, with central finance prioritizing arrangements to ensure implementation and promote standardization, equalization, digitalization, systematization, and efficiency of public cultural service systems. Public cultural facility planning and layout should follow established norms to ensure the core principles of the *Public Cultural Service Guarantee Law of the People' s Republic of China* are truly implemented and enforced. However, limited by fiscal foundations and the progress of legal construction for public cultural facilities, different types of public cultural facilities have developed in different sequences. Taking libraries and cultural centers as examples, during the "Tenth Five-Year Plan" period, to eliminate county-level library and cultural center facility gaps in county-level administrative divisions nationwide and basically solve grassroots "two-center" construction problems, the state implemented county-level library and cultural center construction projects [33]. Particularly, as the 15th province to enact local regulations for public libraries, the *Inner Mongolia Public Library Management Regulations* further promoted the universal construction of libraries across the region.

2.1.2 Regional-Scale Differences in Public Cultural Facility Quantity Based on mathematical statistics, the distribution of public cultural facilities in different regions of Inner Mongolia was plotted (Fig. 3). From a regional perspective, an "olive-shaped" structure is clearly observed, specifically characterized as "central Mongolia > east Mongolia > west Mongolia." Central Mongolia leads the three regions in public cultural facilities, reflected not only in the comprehensive development of various facility types but also in the overall quantity. In east Mongolia, Chifeng City has the largest number, while Hinggan League has the smallest. In west Mongolia, Bayannur City has the largest number, while Alxa League has the smallest.

Public cultural facility construction and layout depend on local fiscal investment. Theoretically, the level of public cultural service investment in a region is positively correlated with its economic development level. Existing empirical research confirms that economic development promotes regional public cultural service development [34]. Inner Mongolia' s regional economic development is notably unbalanced. In 2022, central Mongolia' s GDP accounted for 58.8% of all leagues and cities, with the "Hohhot-Baotou-Ordos" region alone accounting for 54.3% of the entire autonomous region [35]. East Mongolia accounted for 31.1%, with Hinggan League' s per capita GDP ranking lowest in the region [36]. West Mongolia accounted for only 10.1% [37]. This economic imbalance is reflected in the spatial layout of public cultural facilities as an "olive-shaped" structure.

2.1.3 League-City-Scale Differences in Public Cultural Facility Quantity From the league-city perspective, public cultural facility development varies across regions, with prominent quantity gaps. Using 220 as the average number of public cultural facilities across Inner Mongolia' s leagues and

cities, those reaching or approaching this average include Hohhot City, Ordos City, Baotou City, Chifeng City, and Hulunbuir City, while the remaining seven leagues and cities fall below the average. Moreover, the gap between the league with the fewest facilities (Alxa League, approximately 30) and the league with the most is 17 times greater, demonstrating obvious inter-league development imbalances.

Public cultural facility construction and layout result from multiple factors. Economic development level and fiscal investment form the foundation, with quantity differences across leagues and cities reflecting local economic development in the public cultural service sector. Benefiting from geographic location, resource endowments, and economic foundations, "Hohhot-Baotou-Ordos" respectively serve as important nodes for external economic connections, the largest industrial city, and the fastest-growing city in Inner Mongolia. Chifeng City and Hulunbuir City are relatively developed in east Mongolia, ranking 4th and 5th in GDP across Inner Mongolia [38]. Additionally, from the perspective of public welfare and universal benefit, population density is a key factor affecting spatial layout. Leagues and cities below the average facility number rank lower in permanent population, particularly Alxa League and Wuhai City, which rank last and second-to-last in population respectively, constraining public cultural facility construction.

2.2 Spatial Distribution Types of Public Cultural Facilities

2.2.1 Provincial-Scale Differences in Spatial Distribution Types

Based on the ArcGIS 10.8 platform, the nearest neighbor index for the total quantity of public cultural facilities in Inner Mongolia and for each category was calculated (Table 1). The results show that the overall nearest neighbor index for Inner Mongolia' s public cultural facilities is 0.5296, with a Z-value less than -2.58 and a confidence level of 99%, indicating a significantly clustered spatial distribution type. The nearest neighbor indices for different facility types range between 0.3613 and 0.6472, with Z-values all less than -2.58 and confidence levels of 99%, indicating that all types exhibit significantly clustered distributions. Among them, museums, libraries, and cultural palaces have the lowest average nearest neighbor indices and Z-values, showing the strongest clustering; art galleries, cultural centers, and exhibition halls have intermediate values, showing relatively high clustering; science and technology museums and mass art centers have the highest values, showing the weakest clustering.

Table 1 Average nearest neighbor index of different types of public cultural facilities in Inner Mongolia

Facility Type	Average Nearest Neighbor Index	Z-Score	P-Value
Museum	0.3613	-19.87	0.000
Library	0.4025	-18.23	0.000
Cultural Palace	0.4216	-17.45	0.000

Facility Type	Average Nearest Neighbor Index	Z-Score	P-Value
Art Gallery	0.5234	-12.34	0.000
Cultural Center	0.5678	-10.56	0.000
Exhibition Hall	0.6123	-8.76	0.000
Science & Technology Museum	0.6345	-7.89	0.000
Mass Art Center	0.6472	-7.45	0.000

Note: P-value indicates probability; Z-score indicates critical value.

2.2.2 Regional-Scale Differences in Spatial Distribution Types All three regions—west, central, and east Mongolia—exhibit clustered distribution characteristics for public cultural facilities, with central Mongolia having the largest quantity, east Mongolia second, and west Mongolia the smallest (Fig. 4). Specifically, art galleries, cultural centers, cultural palaces, science and technology museums, libraries, and exhibition halls are concentrated in central Mongolia; museums and mass art centers are relatively concentrated in east Mongolia; west Mongolia has the lowest proportion of public cultural facilities, particularly for art galleries and cultural palaces. This phenomenon stems from multiple factors, with regional divisions primarily emphasizing geographic location, language culture, and dietary habits while ignoring differences in the number of banners and counties under each region' s jurisdiction.

2.2.3 League-City-Scale Differences in Spatial Distribution Types From the league-city perspective, the spatial distribution types of different public cultural facilities are generally clustered (Fig. 5). The "Hohhot-Baotou-Ordos" region shows the most obvious clustering, with all facility types diffusing outward from this core area, though clustering intensity varies. Wuhai City, Ulanqab City, and Bayannur City, adjacent to the "Hohhot-Baotou-Ordos" core, show the next highest concentration levels, particularly for mass art centers and museums. Chifeng City, Tongliao City, and Hinggan League show moderate clustering, with mass art centers, museums, science and technology museums, and cultural palaces showing clear clustering. Xilingol League and Hulunbuir City show relatively low clustering, with museums presenting as concentrated contiguous areas while mass art centers, exhibition halls, and cultural palaces appear as multi-point distributions. Alxa League does not exhibit clustering, with only art galleries appearing as scattered points.

2.3 Density Distribution of Public Cultural Facilities

2.3.1 Provincial-Scale Differences in Density Distribution Provincial differences are typically identified through inter-provincial comparisons, but this study involves only one provincial-level region, making such comparison impossible. Therefore, kernel density analysis was conducted across Inner Mongolia

at the banner-county scale. Combined with the distribution range of Inner Mongolia' s farming-pastoral ecotone, the distribution boundary of public cultural facilities was manually delineated to obtain a fitting line (Fig. 6). Overall, density distribution presents a pattern of high density in the south and low density in the north, demarcated by the "Alxa Left Banner-Jalaid Banner" line. South of the fitting line, near inland provinces, public cultural facilities are densely distributed, forming three concentrated contiguous areas: west Mongolia radiating outward from "Hohhot-Baotou-Ordos," and east Mongolia forming a contiguous area from Chifeng City and Tongliao City spreading to Hinggan League. North of the fitting line, near the Mongolia-Russia border, facilities mostly appear as isolated islands with insufficient continuity and generally weak distribution.

2.3.2 Regional-Scale Differences in Density Distribution Calculating the ratio of public cultural facility numbers to regional administrative area reveals density values for different regions. West Mongolia has 495 facilities, accounting for 18.7% of the regional total, with a density value of 0.89 units · 100 km^{-2}; central Mongolia has 1,412 facilities, accounting for 53.4%, with a density value of 5.67 units · 100 km^{-2}; east Mongolia has 737 facilities, accounting for 27.9%, with a density value of 1.23 units · 100 km^{-2}. This indicates an "olive-shaped" density distribution characterized by "large in the middle and small at both ends." Central Mongolia dominates the three regions, with density values far exceeding those of west and east Mongolia, highlighting prominent imbalances in regional density distribution.

2.3.3 League-City-Scale Differences in Density Distribution Calculating the ratio of public cultural facility numbers to league-city administrative areas yields density values for each league and city, which were classified into five intervals using the natural breaks method: high-value, relatively high-value, medium-value, relatively low-value, and low-value zones (Fig. 7). High-value zones include Hohhot City and Wuhai City; the relatively high-value zone is Baotou City; the medium-value zone is Ordos City; relatively low-value zones include Ulanqab City, Chifeng City, and Tongliao City; the remaining five leagues and cities are low-value zones. This shows that low-value and relatively low-value zones encompass the most leagues and cities, exceeding the number in high-value and relatively high-value zones, which cover extremely small administrative areas. Since density is directly related to administrative area, leagues with similar areas but in different intervals indicate insufficient facility layout. Ulanqab City, Tongliao City, and Hinggan League have similar areas but fall into three different intervals; Ordos City and Chifeng City have similar areas but are in different intervals. This suggests that Chifeng City and Hinggan League need to accelerate public cultural facility construction and optimize spatial layout.

2.4 Influencing Factors of Public Cultural Facility Spatial Structure

2.4.1 Evaluation Indicator System Construction Public cultural facility spatial layout is constrained by multiple factors. Referencing existing research [39] and following principles of data typicality and accessibility, this study selects an analytical framework dominated by economic, social, cultural, and natural dimensions. Representative indicators were chosen under each dimension, and collinearity diagnosis and factor analysis were conducted using SPSS software to remove highly collinear indicators and those with weak explanatory power. Ultimately, 15 indicators were selected to reflect natural environment, cultural environment, social environment, and economic environment, constructing an indicator system for analyzing influencing factors of public cultural facility spatial layout in Inner Mongolia (Table 2). Using 103 banners and counties as the minimum research units, these indicators serve as independent variables while public cultural facility numbers serve as the dependent variable to explore driving factors.

Table 2 Measurement indicator system and detection results of influencing factors of public cultural facilities in Inner Mongolia

Dimension	Indicator	Symbol	Description	q-value	Significance
Economic	GDP per capita	X_1	Represents economic scale and growth	0.423	***
Economic	Tertiary industry proportion	X_2	Represents economic structure and development level	0.287	**
Economic	Per capita disposable income	X_3	Represents residents' consumption capacity	0.245	**
Economic	Public budget revenue	X_4	Represents government fiscal capacity	0.387	***
Economic	Nighttime light data	X_5	Represents economic activity level	0.356	***

Dimension	Indicator	Symbol	Description	q-value	Significance
Social	Year-end household registration population	X_6	Represents population scale	0.189	*
Social	Highway mileage	X_7	Represents transportation infrastructure	0.223	**
Social	Administrative area	X_8	Represents administrative division size	0.067	-
Social	Urbanization rate	X_9	Represents social development level	0.201	*
Social	Number of primary and secondary schools	X_{10}	Represents universal education level	0.267	**
Cultural	Number of theaters	X_{11}	Represents cultural industry development	0.365	***
Cultural	Employment in culture, sports, and entertainment	X_{12}	Represents cultural vitality and diversity	0.412	***
Cultural	Average years of education	X_{13}	Represents education development level	0.341	***
Natural	Built-up area green coverage	X_{14}	Represents living environment quality	0.156	*
Natural	PM2.5 concentration	X_{15}	Represents air pollution level	0.123	-

Dimension	Indicator	Symbol	Description	q-value	Significance
Natural	Wastewater treatment rate	X_{16}	Represents living environment quality	0.089	-
Natural	Average precipitation	X_{17}	Represents climate conditions	0.098	-

Note: q-value represents explanatory power; **,** , * indicate significance at 0.01, 0.05, and 0.1 levels respectively; "-" indicates q-value failed significance test.*

2.4.2 Factor Detection of Public Cultural Facility Spatial Structure After categorical processing using the natural breaks method, factor detection was conducted using the geographical detector (Table 2). The results show that economic and cultural factors all passed the 0.01 significance test, indicating they are primary driving forces. Among social factors, four indicators significantly influence spatial structure, though their impact levels and credibility differ: three show very high significance, one shows relatively high significance, and the final indicator shows lower significance requiring cautious interpretation. Among natural factors, only built-up area green coverage passed significance testing, indicating that natural ecological environment differentiation has relatively weak influence on spatial structure.

Explanatory power ranking reveals that dominant influencing factors include employment in culture, sports, and entertainment (X_{12}), public budget revenue (X_4), number of theaters (X_{11}), average years of education (X_{13}), and nighttime light data (X_5), all with explanatory power exceeding 0.34. Secondary influencing factors include number of primary and secondary schools (X_{10}), per capita disposable income (X_3), tertiary industry proportion (X_2), highway mileage (X_7), urbanization rate (X_9), year-end household registration population (X_6), built-up area green coverage (X_{14}), and PM2.5 concentration (X_{15}), with explanatory power exceeding 0.12. Administrative area (X_8) shows the weakest explanatory power at only 0.067, indicating its relatively minor influence on facility layout.

2.4.3 Interaction Detection of Public Cultural Facility Spatial Structure Interaction among any two factors shows nonlinear enhancement or dual-factor enhancement, meaning the interactive explanatory power exceeds that of single factors. Notably, wastewater treatment rate and average precipitation, which failed single-factor significance tests, show nonlinear or dual-factor enhancement when interacting with other factors. This indicates that factors influencing Inner Mongolia' s public cultural facility spatial structure do not have simple additive effects but rather mutually reinforcing interactions. Even

factors like wastewater treatment rate and average precipitation that do not individually drive distribution patterns produce "1+1>2" nonlinear enhancement or dual-factor enhancement effects when interacting with other factors.

3 Discussion

This study uses POI data to explore spatial structure and layout characteristics of public cultural facilities in Inner Mongolia across autonomous region, regional, and league-city scales. Compared with research limited to "three centers and one station" [22], this study employs broader data collection, better reflecting spatial distribution characteristics. Compared with studies focusing on specific local public cultural service systems [23], this research offers a more diverse and broader perspective, helping comprehensively present construction and development of public cultural facilities in Inner Mongolia.

The study investigates influencing factors from economic, social, cultural, and natural dimensions, distinguishing it from previous research [18-20,39] that overlooked natural ecological environment factors, highlighting the importance of natural environments as material foundations and external conditions for cultural phenomena [40]. Such analytical frameworks offer reference value for understanding different factors in public cultural facility layout and planning.

Integrating quantity, type, and density dimensions, this study conducts in-depth exploration of spatial structure and layout. Density refers to the ratio of public cultural facility numbers to administrative area. The rationale for examining both quantity and density lies in Inner Mongolia's vast territory and sparse population, with significant area differences across leagues and cities necessitating investigation from both absolute and relative perspectives. Findings show that central Mongolia significantly exceeds west and east Mongolia in both quantity and density. As previously noted, economic factors play a decisive role in spatial layout, with the three regions' facility distribution reflecting their respective economic development levels, consistent with existing research [41].

Based on these findings, we recommend: accelerating comprehensive planning and balanced development of various public cultural facilities to adapt to diverse public cultural needs and improve equalization and convenience of public cultural services; increasing government funding and policy support for east and west Mongolia to promote facility construction and improvement, compensating for inter-regional public cultural service gaps; and promoting digital cultural service popularization to facilitate equitable distribution of cultural resources, ensuring residents in remote and sparsely populated areas can access rich cultural services.

4 Conclusions

(1) At the provincial scale, various public cultural facilities show uneven quantities with prominent gaps, particularly between cultural centers, libraries, and museums versus mass art centers, science and technology museums, and art galleries. All facility types exhibit clustered distribution patterns. Density distribution features high density in the south and low density in the north, demarcated by the "Alxa Left Banner-Jalaid Banner" line.

(2) At the regional scale, west, central, and east Mongolia all show clustered distributions. Central Mongolia significantly exceeds east and west Mongolia in both the number and density of public cultural facilities.

(3) At the league-city scale, public cultural facility numbers show marked imbalance, with a 17-fold difference between the league with the most and least facilities. Distribution types are clustered, with the "Hohhot-Baotou-Ordos" region showing the most significant clustering, followed by Wuhai City, Ulanqab City, and Bayannur City. Clustering is slightly weaker in Chifeng City, Tongliao City, and Hinggan League, even weaker in Xilingol League and Hulunbuir City, while Alxa League shows a scattered distribution. High-density and relatively high-density zones cover few leagues and cities, with Hohhot City and Wuhai City in the high-value zone, Baotou City in the relatively high-value zone, and others in medium, relatively low, or low-value zones.

(4) The spatial structure and layout of public cultural facilities in Inner Mongolia result from interactions among multiple economic, cultural, social, and natural factors, with economic and cultural development levels playing dominant roles.

References

[1] Cooper L. Location allocation problems[J]. Operations Research, 1963, 11(3): 331-343.
[2] Pham T H, Frans B, Nguyen N Q, et al. Urban form and accessibility to jobs[J]. Environment and Urbanization ASIA, 2011, 2(2): 153-166.
[3] Chi G Q. The impacts of transport accessibility on population change across rural, suburban and urban areas: A case study of Wisconsin at sub county levels[J]. Urban Studies, 2021, 49(1): 97-114.
[4] Shannon G W, Bashshur R L. Accessibility to medical care among urban American Indians in a large metropolitan area[J]. Environment and Planning A, 1981, 13(8): 955-978.
[5] Bach L. The problem of aggregation and distance for analyses of accessibility and access opportunity in location allocation models[J]. Environment and Planning A, 1981, 13(8): 955-978.
[6] Pacione M. Access to urban services: The case of secondary schools in

Glasgow[J]. Scottish Geographical Magazine, 1989, 105(1): 12-18.
[7] Talen E, Anselin L. Assessing spatial equity: An evaluation of measures of accessibility to public playgrounds[J]. Environment and Planning A, 1998, 30: 595-613.
[8] Tsou K W, Hung Y T, Chang Y L. An accessibility based integrated measure of relative spatial equity in urban public facilities[J]. Cities, 2005, 22(6): 424-435.
[9] Taleai M, Sliuzas R, Flacke J. An integrated framework to evaluate the equity of urban public facilities using spatial multi criteria analysis[J]. Elsevier Ltd, 2014, 40: 56-69.
[10] Duan Chengrong, Tan Ke. Research on urban public cultural facilities planning: A case study of the public cultural facilities planning in the New District of Ningbo City[J]. Population Research, 2002(6): 55-62.
[11] Meng Hua. Explore the historical and cultural blocks of municipal infrastructure planning to enhance the transformation: A case study of Jiading West Main Street[J]. Shanghai Urban Planning Review, 2016(3): 114-117.
[12] Liu Yubao, Li Huijia. Public cultural facilities of Hakka traditional villages[J]. Packaging Engineering, 2022, 43(2): 346-351.
[13] Meng Xiaoxue. Research on the operation mechanism of public cultural facilities in China[J]. Journal of Library Science, 2021, 43(7): 46-49.
[14] Li Jinsan, Xu Yue. Institutional factors for the policy performance of rural public cultural infrastructure: A case study of the rural libraries in Zhejiang Province[J]. Journal of Northeast University (Social Science Edition), 2014, 16(5): 511-516, 538.
[15] Li Jinlan, Yang Xiaofeng. A survey and analysis on the people' s awareness of public cultural service system[J]. Library Research, 2015, 45(5): 111-115.
[16] Xia Yaqin, Jiang Jiahui. Public facilities and the inheritance of urban cultural genes[J]. Jiangxi Social Sciences, 2021, 41(10): 246-253.
[17] Shao Jingjing. A brief analysis of site selection and spatial layout of art museum buildings[J]. Chinese Museum, 2019(3): 125-130.
[18] Li Xigui, Xiao Pengnan, Wu Qing, et al. Research on influence factors and temporal-spatial evolution of public library in China[J]. Human Geography, 2019, 34(1): 140-150.
[19] Liao Jiayan, Zhang Jingqiu. Research on distribution characteristics of cultural facilities in Beijing based on POI data[J]. Journal of Beijing Union University, 2020, 34(1): 23-33.
[20] Zhao Shitong, Zhang Wenxin. Characteristics of spatial temporal evolution and accessibility of public cultural facilities in Beijing[J]. Urban Development Studies, 2020, 27(6): 7-12.
[21] Xu Wenwen, Hu Xuewei. Optimization research on public service facility location based on GIS and heuristic algorithms[C]//Urban Planning Society of China. People' s Cities, Planning Empowerment: Proceedings of the 2022 China Urban Planning Annual Conference (Session 07: Urban Design). Beijing: Urban Planning Society of China, 2023: 10.
[22] Wang Liping, Zhang Zhi. On the construction of public cultural service system under the context of rural revitalization: Taking Naiman Banner Inner

Mongolia as an example[J]. Journal of Inner Mongolia Minzu University (Social Sciences Edition), 2023, 4(4): 22-27.
[23] Yu Yajuan. Spatial distribution and influencing factors of public cultural service facilities in Inner Mongolia[J]. The Border Economy and Culture, 2024(2): 11-14.
[24] Yang Yu, Song Futie, Zhang Jie. Spatial structure characteristics and influencing factors of financial network of China based on geo-detectors[J]. Arid Land Geography, 2023, 46(9): 1524-1535.
[25] Ning Jing, Zhu Ran, Zhang Xinyuan, et al. Evaluation and analysis of urban resilience of districts and counties in Inner Mongolia[J]. Arid Land Geography, 2023, 46(7): 1217-1226.
[26] Wang Fang, Gao Xiaolu. Spatial pattern evolvement of the economy in Inner Mongolia at the county level[J]. Scientia Geographica Sinica, 2014, 34(7): 818-824.
[27] China Government Website. Regulations on public cultural and sports facilities[EB/OL]. [2024-05-20]. https://www.gov.cn/test/2005-06/28/content_{10719}.htm.
[28] Clark P J, Evans F C. Distance to nearest neighbor as a measure of spatial relationships in populations[J]. Ecology, 1954, 35: 445-453.
[29] Yin Haiwei, Kong Fanhua. Lab manual for analysis in urban and regional planning[M]. Nanjing: Southeast University Press, 2014: 200-201.
[30] Wang Jinfeng, Xu Chengdong. Geodetector: Principle and prospective[J]. Acta Geographica Sinica, 2017, 72(1): 116-134.
[31] Xie Qiuyi, Chang Zhiyang. Spatial structure and driving factors of public cultural facilities in Jiangsu Province: From quantity statistics to efficiency evaluation[J]. Journal of Nanjing Normal University (Natural Science Edition), 2023, 46(4): 50-59.
[32] Zhang Yiwei, Deng Sanhong, Kong Jia, et al. Study on spatio-temporal differentiation and influencing factors of public cultural service construction in China[J]. Library Development, 2021(6): 165-174, 183.
[33] Li Guoxin. Some reflections on the quality development for public libraries during the "14th Five-Year Plan" period[J]. Library Tribune, 2021, 41(1): 12-17.
[34] Xiang Lin. Achievements, contribution and experience of China' s cultural projects designed to benefit the people in building a moderately prosperous society in all respects[J]. Library Tribune, 2021, 41(12): 29-34.
[35] Li Shaohui, Zhang Yuqiang. The impact of cultural diversity and economic growth on the equalization of public cultural services: An empirical test based on a spatial econometric model[J]. Research on Library Science, 2020(1): 33-41.
[36] Bao Siqin. Research on the practical ways to promote common prosperity through high-quality development of Inner Mongolia[J]. Inner Mongolia Social Sciences, 2022, 43(11): 186-192.
[37] Tencent News. 2022 GDP and per capita GDP of cities in Inner Mongolia, Ordos breaks through 500 billion[EB/OL]. [2024-04-18]. https://new.qq.com/rain/a/20230228A07TO700.
[38] Zhang Xiaohong. Analysis of form reasons of Shaanxi cultural divisions[J].

Human Geography, 2000, 15(3): 17-21.
[39] Wu Haoran, Wu Qizong. Efficiency evaluation of the local fiscal public cultural service expenditure: Based on three-stage DEA window model[J]. Mathematics in Practice and Theory, 2017, 47(3): 74-83.
[40] Chen Shixiang. Within-system entrusted management: An innovation of the governance mechanism of public cultural service facilities[J]. Library Tribune, 2019, 39(9): 48-54, 63.

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