Case Report

Exploring the Spatio-Temporal Evolutionary Characteristics of Paomo Restaurants in Xi'an's Central Urban Area Through POI Data Analysis

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Exploring the Spatio-Temporal Evolutionary Characteristics of Paomo Restaurants in Xi'an's Central Urban Area Through POI Data Analysis

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Abstract: This study investigates the spatial and temporal dynamics of Paomo restaurants in Xi'an's central urban area from 2012 to 2023, leveraging Point of Interest (POI) data through a series of sophisticated analytical techniques. Methods including nearest neighbor distance, kernel density estimation, and band set statistical analysis were employed to thoroughly examine the evolutionary patterns and key drivers influencing the spatial distribution of these eateries. Our results highlight a notable trend of expansion from the central city to the periphery, characterized by significant spatial agglomeration. Initially concentrated in the city center, the distribution of Paomo restaurants has progressively shifted towards multiple distinct cores, reflecting the dual influence of urban policy initiatives and the dynamics of market competition. Furthermore, the research identifies several pivotal factors shaping this spatial distribution, particularly transportation access, residential quality of life, and the availability of commercial services. These findings demonstrate the profound effects of urban spatial reconfiguration and socioeconomic development on the specialized catering industry. The insights gleaned from this analysis offer valuable guidance for urban planners and policymakers, providing strategic recommendations for the spatial planning of specialty catering services to optimize urban layouts and foster sustainable economic progress.

Keywords: POI data; Paomo restaurants; spatio-temporal evolution characteristics; Xi'an

1. Introduction

Xi'an, a city of crucial significance in the contemporary expansion of China's Western development strategy and the 'Belt and Road' initiative, has emerged as a vital hub in the inland 'dual circulation' strategy [1]. As a central urban node in the Western region and the core of the Guanzhong Plain urban agglomeration, Xi'an leverages its rich historical and cultural heritage alongside its robust and steady capacity for innovation [2]. This unique blend has enabled the city to evolve into a sophisticated spatial entity that seamlessly integrates historical elements with modernity. The city's development is characterized by a harmonious balance between self-organization and external collaboration, contributing significantly to its sustainable growth [3]. Through these dynamics, Xi'an exemplifies a model of urban development that respects its past while embracing the demands and opportunities of the future, thus serving as a key player in regional and global economic frameworks.

The catering industry plays an integral role in the interplay between urban economics and social dynamics, making the spatial distribution and locational attributes of dining establishments a focal point of interdisciplinary research spanning economics, sociology, statistics, architecture, and urban-rural planning [4–8]. These investigations are designed to elucidate the characteristics of urban spatial structures, summarize the underlying laws governing these structures, analyze the mechanisms that

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shape them, and propose strategies to optimize urban spatial layouts[9]. Within the broader spectrum of the catering industry, specialty dining venues characterized by their strategic neighborhood locations, immediate service capabilities, and distinct service attributes hold particular significance. These establishments not only cater to the needs of local residents and tourists alike, thereby satisfying immediate consumption demands, but they also play a crucial role in expanding domestic market demand, facilitating economic circulation, and propelling urban development forward. This study explores how specialty dining contributes to urban vitality and serves as a catalyst for broader economic and social advancements.

In Xi'an, Paomo is not merely a local specialty but also embodies a living fossil of the city's rich historical and cultural heritage, marking itself as a significant attraction in urban tourism since the dawn of the 21st century [10]. This dish boasts an extensive lineage, tracing its roots back to the "Yangrou Gan" from the Western Zhou period [11]. The renowned poetof the Song Dynasty in China, Su Shi encapsulated the cultural resonance of Xi'an's Paomo in his verse, 'In Qin cuisine, only lamb Paomo is featured,' underscoring its enduring cultural significance [12]. Traditional Paomo restaurants often feature a distinct ambiance that reflects the cultural richness of the region [13]. These restaurants are typically adorned with elements of classical Chinese architecture, such as wooden lattice windows, antique furniture, and calligraphy decorations that emphasize their historic heritage. The atmosphere in these establishments is warm and inviting, providing a setting that enhances the dining experience of enjoying Paomo, which is a staple dish from Shaanxi cuisine made from steamed bread soaked in a savory mutton stew (Figure 1).

Figure 1. The picture of a traditional Paomo restaurant in Xi'an.

As for the dish itself, Paomo is visually appealing and rustic. The presentation typically includes a large, steaming bowl filled with a rich, clear broth, pieces of tender mutton or lamb, and bits of unleavened bread torn into the soup by the diner themselves. The dish is often garnished with fresh coriander and slices of garlic, adding vibrant color and enhancing the flavor. Additional accompaniments might include pickled garlic and chili sauce on the side, allowing diners to adjust the taste to their liking.Paomo is not just a meal; it's an experience that involves interaction with the

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food, making it a unique culinary adventure that attracts both locals and tourists. The process of tearing the bread into small pieces and watching it soak up the flavorful broth creates a connection with the food that is both tactile and satisfying. This engaging eating process, combined with the historical setting of the restaurants, offers a deep dive into Xi'an's culinary culture.

Recent studies have highlighted that Paomo restaurants, serving as spatial manifestations of this traditional dish, have experienced substantial transformations and self-driven innovations in the digital age. These establishments have achieved notable enhancements in service quality, profitability, labor efficiency, and public perception, positioning themselves as quintessential models of traditional dining formats adapting to modern demands. Amid escalating market competition, the spatial distribution of Paomo restaurants has continuously evolved, reflecting both the inherent logistical considerations of catering business location selection and the everyday consumption capabilities and high-quality lifestyle expectations of local residents. Consequently, understanding the developmental dynamics of the catering industry and directing the strategic spatial planning of Paomo restaurants have emerged as issues of significant theoretical and practical importance.

2. literature Review

International scholars began to apply spatial theory to the analysis of the catering industry in the mid-20th century, employing a combination of traditional and innovative methodologies [14–20]. Building upon the foundational central place theory and a model describing the gravitational characteristics of the catering sector, I. Pirozhnik utilized both statistical data and real-time survey responses to delve into the developmental structure and regional traits of the tourism market in major Polish cities. His work illuminated the distinct spatial distribution characteristics of culinary and hotel services, as well as overall tourism development across 16 cities [21]. Han Ze and colleagues employed methods such as contour mapping and location entropy calculations, using POI data from significant domestic and international city tourism markets. Their research identified the spatial distribution traits of the urban catering industry and scrutinized the aggregation patterns and determining factors through the lens of industrial spatial differentiation [22]. Wang Weiwu and associates chose London, New York, Beijing, and Shanghai as their study areas, utilizing POI data to conduct kernel density estimations, spatial autocorrelation analysis, and Geographically Weighted Regression (GWR) methods. Their research aimed to characterize the overall spatial dynamics of the catering industry in these global cities, exploring the key influencing factors driving these patterns [23]. Ma Dongling and his team, analyzing POI data from 106 Chinese cities across the years 2016 and 2022, introduced the Natural Nearest Single Branch Model (NNSBM). Through adaptive clustering, they successfully identified clusters within the catering industry, significantly enhancing the efficiency of recognizing such clusters. They further utilized population density grid data alongside a binary spatial autocorrelation model to dissect the complex interplay between urban catering industry cluster distribution and population density, revealing notable evolution patterns in urban catering industry clusters. This body of work not only enriches our understanding of the spatial dynamics of the catering industry but also contributes valuable insights into urban economic development and planning [24].

In chinese, scholars research into China's catering industry began in the 1990s, initially anchored in empirical investigations concerning the location, level, and structural dynamics of the industry, drawing upon both domestic and international theoretical frameworks. In recent years, Chinese scholars have significantly expanded the scope of research findings through the integration of diverse data sources, exploration of multifaceted analytical models, and application to multi-dimensional urban contexts [25–30]. Zhai Qing and colleagues utilized data from prominent platforms such as Dianping and Ele.me to study the spatial distribution characteristics related to location and reputation. They collected extensive reviews from both catering merchants and consumers, distinguishing both offline core aggregation and online network structural characteristics in their analysis [31]. Meanwhile, Chen Yueying and her team leveraged road network data and POI information, focusing on Qingdao's urban landscape to apply global regression models. Their research examined the influence of road network centrality on the distribution patterns of the catering

 doi:10.20944/preprints202404.1910.v1

industry, revealing that eigenvector centrality exhibits a multi-core spatial structure significantly shaped by road centrality within Qingdao's catering sector [32]. Zhang Haiping and collaborators refined POI data and GIS field models for an enhanced visual analysis of the catering services in Jinan's urban area. They developed a density field hotspot detection model to map the spatial hotspot distribution and delineate scale structure characteristics effectively [33]. Additionally, Tang Jinyue and his team, using Shanghai as a case study and employing POI data coupled with kernel density analysis, meticulously described the spatial pattern of the catering industry in the urban three-dimensional context. By establishing Ordinary Least Squares (OLS), spatial lag, and spatial error models, they explored the multifaceted factors influencing Shanghai's catering industry spatial structure, revealing that it is shaped by an amalgamation of demographic, economic, transportation, and spatial elements, distributed in a ring-shaped pattern around the city [34]. Li Yunyun and associates assessed the spatial distribution traits of the catering industry in the urban area of Lhasa, a prominent highland tourism city. Utilizing nearest neighbor analysis, standard deviation ellipse, kernel density, and buffer zone methodologies, their findings indicated that the catering industry in Lhasa's urban area generally exhibits significant clustering characteristics, which are highly correlated with the city's transportation and tourism resources [35].

Through rigorous and comprehensive analyses, both domestic and international researchers have increasingly adopted sophisticated spatial econometric methods, seamlessly integrated with Geographic Information Systems (GIS) and other cutting-edge analytical tools [36–41]. This integrative approach has significantly enhanced the capacity for big data analytics to conduct intricate spatial analyses across various urban components, establishing this method as the foremost and central focus in the realm of contemporary urban studies. Predominantly, the spatial distribution of urban catering industries is characterized by patterns of central aggregation and peripheral dispersion.The key factors influencing these spatial dynamics include proximity to urban centers, the accessibility of transportation networks, the purchasing power of consumers, residential population density, urban land values, and the varied models of commercial operations [42–44]. In addition, the primary driving mechanisms shaping these distribution patterns cover a broad spectrum of elements [45–47]. These elements include the efficiency and reach of transportation networks, the availability and supply chain dynamics of goods, the fluidity and competitiveness of local labor markets, the pace and impact of technological innovations, and the level of trust and reliability perceived in products and services by consumers [48–50]. Together, these factors are instrumental in defining the spatial organization and operational dynamics of the catering industry within diverse urban landscapes, crucially impacting their efficiency and growth in today's rapidly urbanizing world [51–53].

In summary, a comprehensive array of existing research from international scholars has profoundly enhanced our understanding of the spatial organization and influencing dynamics of the catering industry. These studies have spanned diverse research methodologies, subject areas, and technological innovations, introducing significant theoretical frameworks such as the correlation effects between catering and information technology, spatial diffusion models for catering services, and efficiency hypotheses related to the sector. Despite these considerable advances, there persists a distinct lack of in-depth, detailed explorations specifically targeting the spatio-temporal evolution characteristics and the prospective spatial prediction simulations of distinct segments within the catering industry [54–56].

As the socio-economic landscape continues to undergo significant transformations, particularly in an era marked by increased uncertainties, the catering industry, recognized for its distinctive service attributes, inherent stability, social relevance, and spatial importance, has emerged as a fundamental pillar for socio-economic stability and a vital agent for spatial identification [57]. This is particularly evident in the context of Paomo restaurants, which not only carry potent regional cultural symbols but also act as barometers for shifts in consumer behavior towards higher quality consumption and serve as catalysts for enhancing urban tourism services. These establishments are pivotal in the study of the spatio-temporal evolution characteristics of Xi'an's specialty catering industry and warrant further scholarly attention and research.

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This call for expanded scholarly inquiry underscores the urgent need to delve deeper into how these establishments can adapt and flourish amidst evolving economic conditions and how their changing spatial patterns can potentially serve as benchmarks for the broader catering industry [58]. Furthermore, a more thorough investigation into Paomo restaurants could yield invaluable insights into the broader cultural and economic ramifications of specialty cuisines within urban environments. Such research could significantly contribute to the formulation of more effective urban planning and development strategies, aimed at fostering socio-economic growth and cultural preservation in rapidly urbanizing settings. This enhanced understanding could also facilitate the development of policies that support sustainable urban development and cultural heritage conservation, ensuring that the catering industry continues to thrive and positively impact urban communities.

3. Data Sources and Research Methods

3.1. Research Area and Data Sources

Based on the "Xi'an City National Land Space Master Plan (2020-2035)" (hereinafter referred to as "The Plan"), this study selected the central urban area of Xi'an as its focal research zone [59]. The central urban area is pivotal, serving as the heart and central hub of Xi'an. It functions as the core area for the city's spatial expansion, population aggregation, commercial activities, and tourism development [60]. "The Plan" specifies its spatial boundaries extending from the Wei River to the north, to the S107 provincial road to the south, and includes Hongqing Street and Dawang Town to the east and west, respectively. This delineated area encompasses all six urban districts—BEILI, XINCHENG, LIANHU, YANTA, WEIYANG, and BAQIAO—along with parts of Chang'an District and Xixian New Area, covering a total area of 1641.11 square kilometers. By the end of 2023, it is projected to host a permanent population of approximately 11 million and generate a GDP of about 1 trillion yuan(Figure 2).

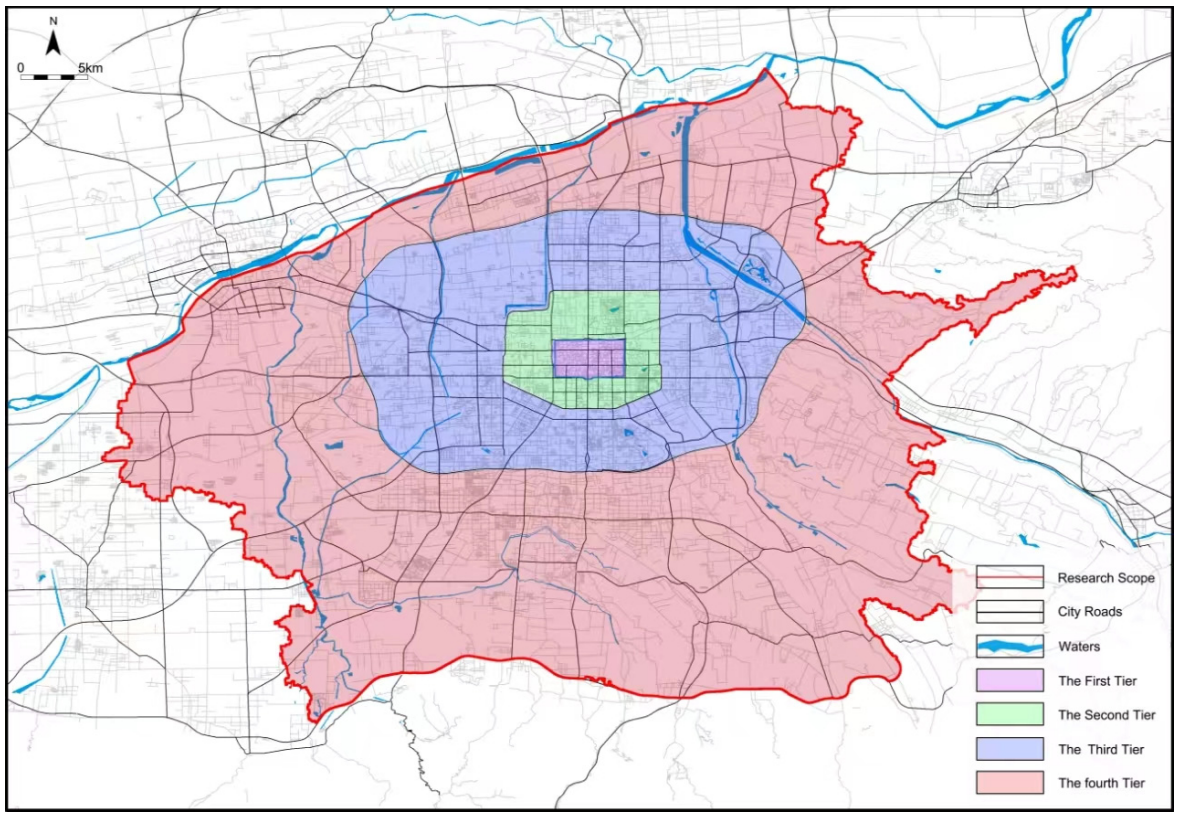

Figure 2. Study Area of Xi'an City Center.

"The Plan" categorizes the central urban area into four distinct tiers: the Old City, which lies within the Ming Dynasty city walls and serves as the primary area for Xi'an's historical, cultural, and

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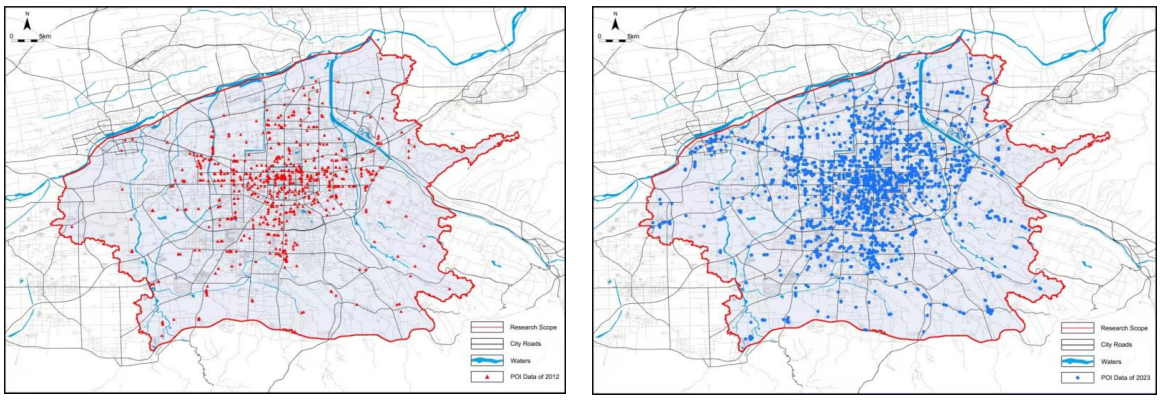
tourism activities; the Second Ring-Ming City Wall Tier, which acts as the traditional population center and a focal point for science and education; the Encircling City-Second Ring Tier, designated as the zone for commercial trade and industrial activities; and the area outside the Encircling City, identified as the future urban expansion carrying area. This tiered structure not only reflects the historical and cultural stratification of the city but also outlines the urban development strategies aimed at enhancing socio-economic growth, improving infrastructure, and fostering sustainable urban expansion as guided by the latest planning initiatives.

The decision to select Xi'an's central urban area as the primary research area was based on several compelling factors that underscore its relevance for a comprehensive spatial and socio-economic study. This area is characterized by its typical spatial distribution patterns, a well-developed socio-economic framework, a robust and extensive transportation network, and prominent commercial service offerings. Additionally, it exhibits a high level of urbanization, a rapid pace of lifestyle, and elevated demands for quality of life, making it an exemplary urban center for in-depth analysis. Moreover, the central urban area of Xi'an holds considerable promise for predictable development trajectories, especially given the momentum of the "Belt and Road" initiative, which further enhances its strategic importance. The availability of diverse data sets and the feasibility of material acquisition also played a crucial role in its selection as the study location. Base map data was meticulously sourced from the National Geographic Information Resources Catalogue Service System (www.webmap.cn), ensuring a reliable geographic framework for analysis. The acquisition of Point of Interest (POI) data was executed through advanced Python scripts utilizing the requests and json libraries, which enabled the dynamic collection of data from Amap's location service APIs for the periods of December 2012 and December 2023. This data was meticulously converted to the WGS1984 coordinate system to ensure accuracy and compatibility with global data standards. Furthermore, detailed information on the distribution of roads, rivers, and subway lines was extracted from the OSM open-source website (www.openstreetmap.com), providing a comprehensive understanding of the infrastructural elements that shape the urban landscape. Additional socio-economic development data were rigorously compiled from the "Xi'an Statistical Yearbook," offering a robust basis for analyzing trends and projections within the central urban area. This methodological rigor in data collection and analysis positions this research to contribute significantly to the understanding of urban dynamics in Xi'an(Figure 3).



(a) 2012 POI data (b) 2023 POI data

Figure 3. POI Distribution of Xi'an City Center Paomo Restaurants.

3.2. Research Methods

(1)Nearest Neighbor Distance Method

The nearest neighbor analysis is a quantitative method utilized to assess the spatial distribution characteristics of points within a given area [61–63]. This approach involves comparing the actual minimum distance between each point to the expected distance that would occur under a theoretical nearest neighbor model. The essence of this method is encapsulated in the construction of a standardized nearest neighbor index.

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$$E = \frac{\widetilde{\gamma_a}}{\widetilde{\gamma_e}} = \frac{(\sum_i r_i)/n}{\frac{\sqrt{n/A}}{2}} = \frac{2\sqrt{\rho}}{n}\sum_i \gamma_i \quad (1)$$

To elaborate, this index E is calculated by first determining the average nearest neighbor distance among points, represented as $\bar{d}$. This average is obtained by averaging the nearest neighbor distances d_i for each point i. Additionally, A represents the area under consideration, n denotes the total number of points within this area, and $\rho$is the density of the points, calculated as n/A. The expected average nearest neighbor distance under random distribution conditions is denoted as $\bar{D}$ and is inversely proportional to the square root of ρ.

The standard nearest neighbor index E is then computed by dividing the observed average nearest neighbor distance $\bar{d}$ by the expected distance $\bar{D}$. The value of E is indicative of the type of distribution of the points: a value of $E=1$ suggests a random distribution, reflecting no significant spatial clustering or dispersion; $E=0$ indicates a completely clustered distribution, where points are significantly closer than expected; and $E=2.1491$ characterizes an even distribution, implying that the points are dispersed in a uniform manner throughout the area.

This methodological framework not only facilitates the understanding of the spatial patterns observed in the data but also provides insights into the underlying spatial processes affecting these patterns. By applying the nearest neighbor analysis, researchers and analysts can evaluate the degree of clustering or dispersion in geographic phenomena, making it a vital tool in the fields of geography, ecology, and urban planning.

(2)Kernel Density Estimation Method

Kernel density estimation (KDE) is a sophisticated, non-parametric statistical technique that aligns closely with Tobler's First Law of Geography. This fundamental geographic principle asserts that while all entities are interconnected, those in closer proximity exhibit a greater degree of correlation than those further apart [64,65]. KDE excels in detecting and illustrating the spatial clustering of elements that are situated near one another by quantitatively assessing the intensity of events across a defined space through detailed density analysis.

This method effectively models a density function where the influence of a kernel element, representing a point or feature in space, gradually diminishes from its peak value to zero as the distance from the point extends beyond a specific threshold. This decay is controlled by a function that ensures the diminishing influence is smooth and gradual, reflecting the natural decrease in interaction intensity with increasing distance.

The strength and utility of KDE lie in its ability to provide a clear, visual representation of spatial data, illustrating areas of high density and potential clusters. By employing this method, researchers can gain valuable insights into the geographic distribution of phenomena, making KDE an indispensable tool in fields such as ecology, epidemiology, crime analysis, and urban planning. Through the application of KDE, spatial patterns that might not be evident through other analytical approaches become visible, offering a deeper understanding of spatial relationships and dynamics.

The formula for kernel density estimation is expressed as follows:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x-X_i}{h}\right) \quad (2)$$

Here, $f(x)$ represents the kernel density function estimated at spatial location x, h denotes the bandwidth or distance decay threshold, n is the number of elements within or equal to distance hh from the element at location x, and $K(x)$ is the spatial weight function, which in this study adopts a normal kernel function. The bandwidth h is critical as it determines the smoothing parameter of the kernel estimation, influencing the extent of the spread of the kernel function around each point.

The choice of h, or the distance decay threshold, is determined based on the Smooth Model principle, which ensures that the density estimate is neither too smooth nor too detailed, thereby optimizing the balance between variance and bias in the estimation. By carefully selecting hh, the KDE can effectively highlight areas of high element concentration, providing visual insights into the spatial distribution and density of the features being studied. This technique is widely applied in

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various fields such as environmental science, epidemiology, urban planning, and crime mapping, offering a powerful tool for spatial analysis and decision-making based on geographic phenomena.

(3) Other Analytical Methods

ArcGIS, a comprehensive geographic information system, offers specialized toolsx that facilitate detailed analyses on the directionality and correlation of spatial elements within a given dataset. To examine the directional patterns of spatial data, the Directional Distribution tool, part of the Spatial Statistics Tools in ArcGIS, is employed [66]. This tool is designed to analyze the spatial orientation and trends of geographic features, helping to identify prevailing directions or alignments in the data, which is crucial for understanding spatial dynamics in fields such as meteorology, hydrology, and urban planning.

For analyzing the correlation between spatial elements, particularly when dealing with multi-band raster data, the Band Collection Statistics tool from the Spatial Analyst Tools suite is used. This tool is instrumental in computing statistical relationships across different spectral bands, aiding in the identification of patterns and correlations that are not immediately apparent [67]. By utilizing this tool, researchers can effectively dissect complex interactions between multiple layers of data, enhancing their understanding of ecological dynamics, land use changes, or environmental monitoring.

These tools in ArcGIS provide robust capabilities for advanced spatial analysis, allowing researchers and professionals to derive meaningful insights from their geographic data. The integration of these analytical tools into spatial studies promotes a more nuanced interpretation of spatial phenomena, supporting more informed decision-making and strategic planning in various scientific and professional applications.

4. Spatiotemporal Evolution Characteristics

4.1. Generally Stable Spatial Development Trend

The application of the standard deviation ellipse calculation method provided insightful revelations into the spatial dynamics of Paomo restaurants within Xi'an's central urban area. This methodological approach highlighted a pronounced trend of outward spatial expansion in these establishments. Despite a varied rate of development across different sectors of the area, the overall growth pattern maintained a level of stability, as illustrated in Figure 4. The analysis indicated that the area encompassed by the ellipse in 2012 was considerably more compact, demonstrating a higher degree of aggregation. However, by 2023, the ellipse had expanded by 32.21%, signifying a significant outward shift in both population and land use within the central urban area. This expansion substantially exceeded the rate of construction land growth, which was about 20% over the same period, thereby underscoring a dynamic and vigorous development in the local catering sector.

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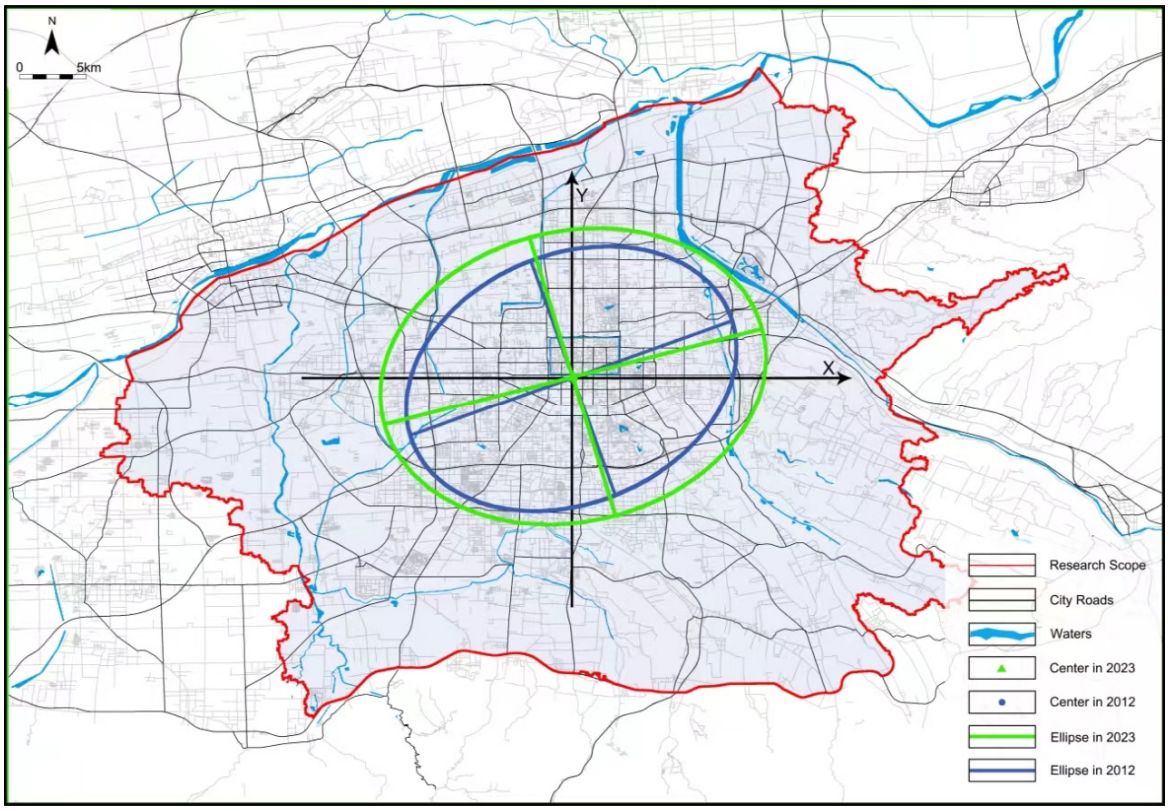

Figure 4. POI Standard Deviation Ellipse Analysis for Xi'an City Center Paomo Restaurants.

Additionally, the coordinates of the ellipse's center revealed subtle shifts in the spatial distribution center of Paomo restaurants during the research period. These establishments remained predominantly clustered around Xi'an's historic city wall, with only a minor northward movement of approximately 287 meters, as detailed in Table 1. The area of the ellipse increased from 312.43 km² in 2012 to 413.03 km² in 2023, showing a substantial growth of 100.6 km², or approximately 32.2%. This expansion indicates a notable outward spread of Paomo restaurants, suggesting a growing influence of this culinary type in the urban landscape. The slight shifts in the X and Y center points (from 108.93437° to 108.93615° and from 34.248831° to 34.251326°, respectively) represent a minor northward movement. This northward shift of roughly 287 meters suggests a gradual relocation of the density center of Paomo restaurants within the city, potentially reflecting new urban developments or shifts in the population center. The lengths of both the X-axis and Y-axis increased over the period, with the X-axis growing by 139.25 meters and the Y-axis by 159.19 meters. These changes underscore an increase in the spatial footprint of Paomo restaurants both in width and depth, indicative of a robust expansion in their geographic distribution.The rotation angle of the ellipse increased from 67.34° in 2012 to 77.22° in 2023, adjusting by 9.88°. This rotation suggests a change in the orientation of the spatial distribution, possibly aligning more closely with changes in urban infrastructure such as road development or shifts in commercial and residential layouts. The observed changes in the spatial characteristics of the Paomo restaurants not only reflect the industry's growth but also have implications for urban planning and development. The increased area and altered orientation could influence urban transportation planning, zoning decisions, and resource allocation to better accommodate and leverage the growth of the Paomo restaurant industry. Overall, this analysis reveals that the Paomo restaurants are not only increasing their reach within Xi'an's central urban area but also possibly adapting to or influencing new urban development patterns. This evolution in spatial distribution might also reflect broader socio-economic trends, such as shifts in consumer behavior, population movement, and urban expansion policies.

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Table 1. Statistics of POI Standard Deviation Ellipse for Xi'an City Center Paomo Restaurants.

Year	Standard Deviation Ellipse	Area (km²)	X Center (°)	Y Center (°)	X-axis Length (m)	Y-axis Length (m)	Rotation Angle (°)
2012	Standard Deviation Ellipse	312.43	108.93437	34.248831	852.18	1167.12	67.34
2023	Standard Deviation Ellipse	413.03	108.93615	34.251326	991.43	1326.31	77.22
Change	--	+100.6	+0.00178	+0.002495	+139.25	+159.19	+9.88

4.2. Significant Spatial Agglomeration Characteristics

This detailed analysis delves into the spatial distribution and temporal evolution of Paomo restaurants across different urban tiers in Xi'an from 2012 to 2023, as illustrated in Table 2. The data is categorized into four distinct urban tiers: Old City, Second Ring, Encircling City, and Suburbs, each presenting specific metrics such as average observed distances, expected average distances, E values, Z-scores, and distribution trends over the specified years.

Table 2. Statistical of Average Nearest Neighbor Analysis Results of POI Subcircle for Xi'an City Center Paomo Restaurants.

Index	Old City Tier		Second Ring Tier		Encircling City Tier		Suburbs Tier	
Year	**2012**	**2023**	**2012**	**2023**	**2012**	**2023**	**2012**	**2023**
Average Observed Distance (m)	16.22	11.17	36.29	23.55	33.66	26.24	80.77	38.28
Expected Observed Distance (m)	20.01	15.31	42.18	32.27	60.01	42.89	167.53	89.14
E Value	0.814	0.704	0.851	0.715	0.554	0.621	0.477	0.401
z-Score	-3.07	-6.57	-2.94	-7.57	-15.50	-19.24	-12.52	-25.78
Tend	**Aggregationg**		**Aggregationg**		**Diffusion**		**Aggregationg**	

Significantly, the average observed distances across all tiers show marked decreases, with the most notable reductions recorded in the Old City and Suburbs. This trend indicates a more concentrated clustering of Paomo restaurants in these areas, which suggests an enhancement of core commercial zones and possibly an intensification of consumer traffic within these regions. Furthermore, the expected distances exhibit a general decline, which likely reflects a rise in the number of Paomo restaurants coupled with denser urban development, thereby reducing the spatial separation between these establishments.

Regarding spatial clustering, the E values, which evaluate the degree of spatial clustering relative to a random distribution, have decreased in all tiers except for the Encircling City, where a slight increase is observed from 2012 to 2023. Observations of E values below 1 across all tiers suggest a prevailing clustered distribution, with the Suburbs exhibiting the most pronounced clustering effect. Additionally, the increasingly negative Z-scores in 2023 across all tiers highlight a statistically significant deviation from a random spatial pattern, further emphasizing the ongoing trend of clustering, which has become more distinct over time.

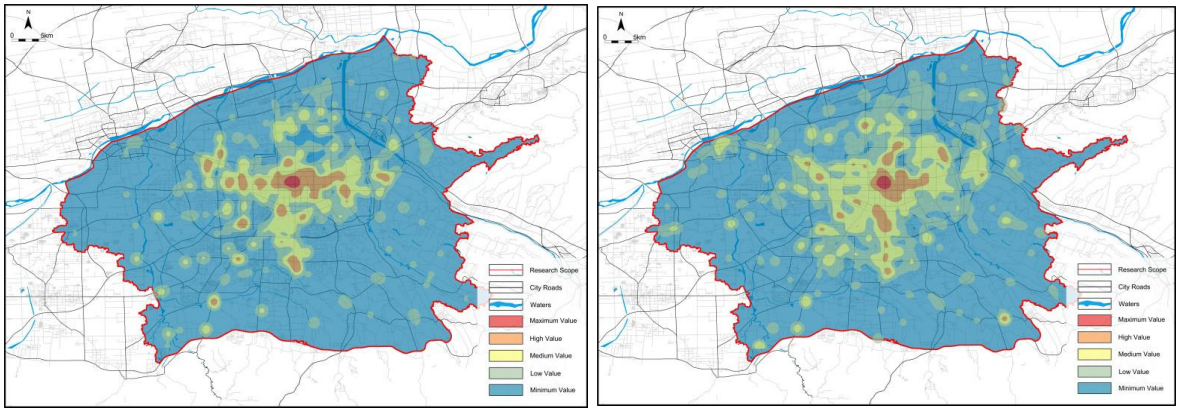
 doi:10.20944/preprints202404.1910.v1

The Old City and Suburbs display a clear trend of augmented clustering from 2012 to 2023. This pattern may be attributed to various factors, including historical centrality in the Old City and expanding suburban development which attracts additional establishments. Conversely, the Second Ring and Encircling City demonstrate varied trends. The Second Ring experiences a marked shift towards more intense clustering, likely driven by urban densification and commercial consolidation. Meanwhile, the Encircling City, although still exhibiting clustered tendencies, shows a moderate increase in the E value, possibly reflecting newer urban expansions and reduced density relative to more central areas.

This differentiation in spatial structure across tiers has profound social implications for the urban center. For example, the increasing strain on the supply of public resources and the reduced spatial environmental carrying capacity pose significant challenges, necessitating meticulous urban planning and policy intervention. Moreover, the rapid expansion and spatial diffusion in the Encircling City tier contribute to an outward flow of population and essential elements into suburban areas. This outward migration exacerbates the depletion of residential and educational resources, potentially undermining the balanced development of the city and highlighting the critical need for strategic urban management to foster equitable growth and resource distribution.

4.3. Change in Spatial Core Distribution Structure

The Kernel Density Estimation (KDE) analysis depicted in Figure 5 offers an in-depth examination of the spatial organization of Paomo restaurants within Xi'an's central urban area over the study period, revealing a prominent "center-periphery" spatial structure. This analysis highlighted significant high-density zones and areas of aggregation primarily centered around the Bell Tower, encapsulated within a high-value cluster surrounding the Xidajie Huifang. However, the secondary cores showed considerable dynamism.



(a) 2012 Kernel Density (b) 2023 Kernel Density

Figure 5. Kernel Density Estimation Analysis of POI for Xi'an City Center Paomo Restaurants.

In 2012, the spatial distribution exhibited an "east-west + scattered" pattern with notable sub-core distributions extending along the East-West Avenue, reaching into areas such as the High-tech Zone, Weiqu, Sanqiao, Zhangba, and Textile City. This pattern suggested a strong linkage to the local residential areas, indicating that the spatial placement of Paomo restaurants was closely aligned with the living quarters of local inhabitants.

By 2023, the spatial dynamics within Xi'an's central urban area displayed an increased trend towards multipolarization. While the primary core around the Bell Tower remained intact, it appeared slightly reduced in scale. Concurrently, there was a significant shift in the sub-core configurations: the core along the East Avenue extension line not only strengthened but also expanded towards Nan Dajie, reflecting a geographic widening of culinary hotspots. Conversely, the cores along West Avenue and in Textile City saw a notable decline. Noteworthy is the emergence of new sub-centers at strategic locations such as Longshouyuan-Daming Palace, Gaoxin Road-TV

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Tower, and Chanba Peach Blossom Dam, alongside the persistence of Weiqu, Sanqiao, and Zhangba sub-centers, albeit with trends indicating dispersion and contraction.

These transformations are likely influenced by the evolution of the city's north-south axis as the predominant spatial conduit for population flow, with significant construction developments around areas like the TV Tower, Chanba Ecological District, and Daming Palace Site Park catalyzing the intensification and clustering of POI facilities into defined "cores." These changes have substantially impacted the spatial distribution patterns of Paomo restaurants, reshaping the urban culinary landscape.

Interestingly, despite its status as a major tourist draw, the Qujiang Dayan Pagoda area did not evolve into a third-level or higher agglomeration. This observation raises pertinent questions regarding the effectiveness of planning guidance and the dynamics of market competition within this locale, suggesting a potential misalignment between tourist attraction and local commercial development. This scenario underscores the necessity for further focused research and nuanced understanding of the planning strategies and market forces that influence such crucial urban development outcomes.

4.4. Diverse Changes in Spatial Influencing Factors

Considering the inherent characteristics of the study subjects, and after conducting multiple comprehensive field surveys, it was determined that the most pertinent explanatory variables for the study encompass the spheres of transportation, workplace, residential living, and commerce. These broader categories were broken down into a total of 14 detailed secondary indicators to provide a nuanced understanding of the factors influencing the spatial distribution of the entities being studied. These indicators include the proximity to main roads and subway stations, which represent the transportation aspect; the density of corporate, financial, government, and social institutions, capturing the workplace dynamics; and the density of residential facilities, which reflects the living conditions in the area.

Additionally, the study examined the density of catering, scientific and educational, medical, leisure, and shopping facilities, which are integral to understanding the residential and commercial quality of life. For a more comprehensive view of the commercial environment, the density of tourism, hotel, and service facilities was also included. All these indicators (as detailed in Table 3) were selected based on their relevance and potential impact on the study's focus, ensuring a robust framework for analyzing the complex interactions between urban development and the spatial distribution of the study objects. This methodological approach allows for an in-depth exploration of the urban fabric and provides insights into how different urban factors contribute to shaping the dynamics of city spaces and the behavior of its inhabitants.

Table 3. Statistical Analysis of POI Band Set Statistics for Xi'an City Center Paomo Restaurants.

Primary Indicator (Weight)	**Secondary Indicator**	**Correlation Statistics**		**Change Rate**
		2012	**2023**	(%)
Traffic Factors (0.172)	Distance to main roads	0.53936	0.63574	+17.87
	Distance to subway stations	0.52692	0.46789	-11.20
	Weighted Average	0.533762	0.5602075	+4.95
Workplace Factors (0.309)	Density of company facilities	0.34709	0.56404	+62.51
	Density of financial facilities	0.69659	0.72737	+4.42
	Density of government and social institutions	0.75311	0.77281	+2.61
	Weighted Average	0.59687	0.68838	+15.33
Living Factors	Density of residential facilities	0.69168	0.79187	+14.49

 doi:10.20944/preprints202404.1910.v1

(0.382)	Density of dining facilities	0.82755	0.88691	+7.17
	Density of educational facilities	0.70940	0.73561	+3.69
	Density of medical facilities	0.85434	0.83116	-2.71
	Density of leisure facilities	0.56287	0.70431	+25.13
	Density of shopping facilities	0.77154	0.76472	-0.88
	Weighted Average	0.73634	0.79672	+8.21
	Density of tourist facilities	0.65296	0.37868	-42.01
Trade Factors	Density of hotel facilities	0.68924	0.76438	+10.90
(0.137)	Density of service facilities	0.78694	0.82866	+5.30
	Weighted Average	0.70403	0.62938	-10.59
Weighted Total		0.65926	0.70364	+6.73

The analysis is structured around several key urban factors—Traffic, Workplace, Living, and Trade—each assigned a specific weight reflecting its relative importance. The table provides a nuanced view into how each factor's sub-indicators have changed over the study period, and here we break down and interpret these changes. There was a significant improvement (17.87% increase) in the proximity of Paomo restaurants to main roads by 2023, suggesting enhanced accessibility. Conversely, the increase in distance to subway stations (11.20% decrease) could indicate a shift in restaurant locations away from immediate subway vicinity, possibly due to rising property costs in these areas.Despite mixed results in individual indicators, the overall traffic factor shows a modest improvement (4.95% increase), indicating better general accessibility for customers relying on road transport.

There was a substantial increase in the density of company facilities (62.51% increase), which may reflect a strategic move to locate Paomo restaurants near business centers to attract office workers. Slight increases in financial and government facilities densities suggest a steady growth in these areas.A significant rise (15.33% increase) in the overall workplace factor indicates a strengthening relationship between workplace density and restaurant placement, aligning with a growing lunchtime business market.

Marked increases in the density of residential facilities (14.49% increase) and dining facilities (7.17% increase) point to an expanding urban population and growing food service industry. These changes suggest Paomo restaurants are becoming more integrated into residential zones.The living factor shows a healthy increase (8.21%), reflecting an overall improvement in life service accessibility around these restaurants.

The stark decrease in the density of tourist facilities (-42.01% decrease) contrasts with the increase in hotel facilities density (10.90% increase), possibly indicating a shift in tourism dynamics or changes in tourist preferences.The decline in the overall trade factor (-10.59% decrease) could be concerning as it might reflect reduced commercial vitality in areas typically frequented by tourists.

Overall ImplicationsThe overall weighted total indicates a positive change (6.73% increase), suggesting that, on balance, the factors influencing the placement and success of Paomo restaurants have improved from 2012 to 2023. The varying performance across different categories highlights the complex interplay between urban development, market dynamics, and consumer behavior that influences the spatial distribution of culinary services.

Band set statistics results demonstrated a notable overall upward trend in correlation, with primary indicator correlations being ranked as living > commerce > work > transportation in 2012 and transitioning to living > work > commerce > transportation by 2023. This shift underscores a dynamic temporal evolution and change rates of secondary indicators, which generally indicated an increase in correlations across the board, except for the commerce sector. This suggests that Paomo restaurants initially developed in a somewhat chaotic and spontaneous manner. Over time, however,

 doi:10.20944/preprints202404.1910.v1

the uniformity of commercial behaviors has emerged as an endogenous driving force for social development, establishing a robust foundation for the optimization of urban spatial structures.

Traffic indicators revealed a strong and intensifying connection with main roads, yet there was a noticeable decline in the relationship to subway stations. This trend points to potential areas for improvement in making Paomo restaurants more accessible and appealing to younger demographics who frequently utilize public transit. Work-related indicators displayed a consistent upward trend across all secondary indicators, affirming the role of Paomo restaurants as a crucial dining option within primary work environments as urbanization advances.

Living factors consistently rose to prominence, underlining the sustained popularity of Paomo restaurants and emphasizing the significant role that specialty catering plays in the layout of urban spatial structures. However, commercial factors presented a more complex scenario; while relationships with hotels and service facilities consistently rose, indicating high appreciation by both tourists and locals, the correlation with tourism facilities significantly decreased. This decline suggests a notable mismatch between this specialty cuisine and tourist destinations, which hinders tourists from directly engaging with Xi'an's authentic culinary culture. This discrepancy highlights a gap when compared to domestic first-tier cities and calls for enhanced focus from relevant authorities.

Looking forward, urban planners and policymakers should carefully consider the spatial needs and evolving trends of specialty catering industries like Paomo restaurants. By guiding their sustainable development, it is possible to optimize urban commercial space structures and promote ongoing social and economic advancement. This strategic approach will not only cater to the immediate needs of local and visiting patrons but also contribute to the broader goal of urban renewal and cultural integration.

5. Conclusion

In this study, a comprehensive analysis was performed to explore the spatial attributes and significant research value of Paomo restaurants in Xi'an, highlighting their role as exemplars of the city's specialty catering sector. The spatial structure characteristics of these establishments align closely with the broader patterns observed in urban retail and commercial space development. Utilizing foundational documents such as the "Xi'an National Land and Space Master Plan (2023-2023)" alongside Point of Interest (POI) data collected from the central urban area, a variety of analytical methods were applied. These included nearest neighbor distance, kernel density estimation, standard deviation ellipse, and band set statistics, which facilitated a detailed examination of the spatiotemporal evolution characteristics of Paomo restaurants within this urban context.

The findings from this research elucidated several critical aspects: the evolving trends in urban spatial distribution, pronounced agglomeration tendencies, and the dynamic shifts in factors influencing the distribution and growth of Paomo restaurants. These elements together provide a deeper understanding of how these specialty restaurants not only adapt to but also influence the shifting dynamics of urban spaces in Xi'an. This analysis contributes to the body of knowledge necessary for urban planners and policymakers who aim to enhance the integration of cultural heritage within modern urban development, ensuring that traditional culinary practices continue to thrive and shape the city's cultural and economic landscape.

Our study results indicate several key findings related to the spatial distribution and developmental dynamics of Paomo restaurants in Xi'an's central urban area.

First, The study revealed a notable stability in the spatial development trends of Paomo restaurants in Xi'an's central urban area between 2012 and 2023. The spatial distribution of these restaurants exhibited a gradual outward expansion, characterized by an uneven pace of development but maintaining overall stability. Throughout the period, the primary focal point of spatial distribution has consistently centered in the city core, yet there has been a discernible trend of expansion towards the northern and peripheral areas. This movement aligns with shifts in urban population flows and reflects the broader impact of demographic changes on the spatial distribution of Paomo restaurants. This expansion into less central areas may be influenced by several factors,

 doi:10.20944/preprints202404.1910.v1

including urban sprawl, the development of new residential and commercial zones, and possibly the saturation of the market in the city center, which typically leads businesses to seek less competitive locations. Moreover, the northern expansion trend could be attributed to specific urban development policies, infrastructural enhancements, or a natural growth pattern as the city evolves. Understanding these dynamics is crucial for urban planners and business strategists. It allows them to anticipate changes in consumer behavior and to strategize effectively for the sustainable growth of the catering industry. Moreover, these insights can aid in the planning of infrastructure and services to support the burgeoning areas, ensuring balanced urban growth and the integration of cultural and commercial activities across the cityscape.

Secondly, The analysis highlights the significant spatial agglomeration features of Paomo restaurants in Xi'an's central urban area, underscoring the ongoing concentration of these establishments within specific urban locales. During the period between 2012 and 2023, despite the observable outward expansion and the somewhat weakened agglomeration within the Second Ring-Encircling City tier due to factors such as urban expansion and population shifts, Paomo restaurants have maintained a strong presence in the traditional city center and its immediate surroundings. This enduring concentration in the city center and adjacent areas illustrates the strong appeal of specialty catering to both urban residents and tourists. The city center typically offers greater visibility, higher foot traffic, and easier accessibility, factors that are crucial for the success of culinary establishments. Furthermore, these areas often serve as cultural and social hubs, making them particularly attractive for dining experiences that offer a unique taste of local heritage, such as Paomo. The sustained popularity and concentration of Paomo restaurants in these areas also reflect the role of culinary culture in enhancing the attractiveness of urban spaces. It indicates how specialty catering not only caters to the gastronomic preferences of the population but also contributes to the cultural and economic vitality of urban centers. This spatial concentration can stimulate local economies through increased employment, preservation of local culinary practices, and attraction of tourist revenue. For urban planners and policymakers, understanding the dynamics behind the spatial distribution and agglomeration of such specialty restaurants is essential. It provides insights into consumer behavior and urban attractiveness, aiding in the formulation of strategies to bolster urban development while preserving cultural heritage. This could include planning for adequate infrastructure, creating supportive policies for local businesses, and promoting cultural tourism that leverages the unique culinary landscape of Xi'an.

Additionally, The evolution of the spatial distribution of Paomo restaurants in Xi'an's central urban area from 2012 to 2023 showcases a significant structural change, moving from a predominantly single central aggregation to a more dispersed multi-core structure. Initially, these restaurants were highly concentrated in a central area, reflecting traditional consumer patterns and urban layouts. However, over the study period, this pattern diversified, forming multiple cores and centers. This shift indicates a transition in core directions from east-west to a more pronounced north-south orientation, underscoring the influence of dynamic urban development and competitive market forces on the spatial arrangement of these establishments. This structural shift in the core distribution of Paomo restaurants aligns with broader urban development policies that have encouraged the growth of emerging commercial and residential districts. As new areas develop and attract residents and businesses, they create viable new markets for Paomo restaurants, facilitating their spread beyond traditional boundaries. This dispersal is likely driven by the need to capture emerging market segments, reduce dependency on saturated central areas, and exploit new areas with potentially lower competition and overhead costs. Furthermore, the rapid population growth in these new urban sectors not only increases the potential customer base but also influences the types of services and products in demand, including food services. As Paomo restaurants expand into these areas, they adapt to changing consumer preferences and demographics, which are increasingly influenced by newer, younger populations looking for convenience and diversity in dining options. The strategic response of Paomo restaurants to these urban dynamics highlights their adaptability and the critical role of spatial planning in their success. It also reflects the ongoing impact of urban planning and development strategies that seek to balance growth and sustainability. For urban

 doi:10.20944/preprints202404.1910.v1

planners, this observation emphasizes the importance of considering how food service businesses, particularly those offering culturally significant fare, can serve as anchors in new urban developments, contributing to the vibrancy and attractiveness of these areas. By understanding these structural changes in spatial distribution, policymakers can better align urban development plans with market needs, ensuring that infrastructure, zoning, and regulatory frameworks support the sustainable growth of both new and traditional business districts. This alignment is crucial for fostering economic diversity and enhancing the overall quality of urban life, as it supports a mix of commercial activities that cater to a broad range of residents and visitors.

Lastly, The analysis of the main spatial factors influencing the distribution of Paomo restaurants in Xi'an's central urban area from 2012 to 2023 highlights three critical areas: transportation accessibility, residential living standards, and commercial service functions. As the city has evolved and society has progressed, the placement of Paomo restaurants has become increasingly intertwined with residential neighborhoods, commercial hubs, and key transportation nodes. This integration suggests that as urban areas develop, the demand for such restaurants grows not only due to the local population but also due to their accessibility to commuters and shoppers. However, a notable trend is the weakening correlation between Paomo restaurants and subway and tourism facilities. This divergence indicates a potential mismatch between the location of these restaurants and key tourist destinations, which is a significant gap when compared to the integration seen in chinese first-tier cities. This discrepancy may be due to several factors, such as the strategic choices in restaurant locations being primarily driven by local demand rather than tourist traffic or possibly the nature of the cuisine, which may not align with the dining preferences of tourists. This situation underscores a critical area for urban planning and policy intervention. To bridge this gap, relevant departments need to reassess and realign the strategic positioning of Paomo restaurants to better integrate them with tourist pathways and transportation hubs. Enhancing this alignment could not only increase tourist engagement with the local cuisine, contributing to a richer cultural experience but also bolster economic benefits from increased spending in the sector. Looking forward, it is essential for urban planners and policymakers to undertake a holistic consideration of the spatial needs and development trends of specialty catering industries like Paomo restaurants. There is a need to guide their sustainable growth through strategic planning that optimizes urban commercial space structures. This approach should aim to balance the enhancement of local cultural identity with economic objectives, ensuring that these culinary landmarks are accessible and appealing to both residents and tourists. By fostering a conducive environment for the growth of specialty catering, cities can enhance their cultural landscape and promote continuous socio-economic progress. This will not only cater to the gastronomic needs of the urban population but also position the city as an attractive destination for cultural tourism, thereby driving broader urban revitalization and sustainable development.

In the comprehensive study of urban development, the differentiation of commercial spaces plays a crucial role in shaping the evolution of urban spatial structure patterns. This process is driven by an aggregation-diffusion mechanism within polarized centers, where urbanization not only fosters commercialization but also, reciprocally, commercialization reinforces urbanization. This dynamic interplay culminates in a multi-core-networked development model for urban spaces, which is evident in the ongoing transformation within cities. The observation of the spatial evolution of Xi'an's central urban area from 2012 to 2023 indicates that the city is currently in a critical phase of commercial space reorganization and integrated development extending from the urban center to the periphery. This pivotal transition necessitates the acceleration of urban infrastructure development, particularly in transportation networks, tourism facilities, residential facilities, and public service amenities. These enhancements are essential for supporting and sustaining the urban expansion and intensification efforts. To effectively leverage the hub-and-spoke model, it is imperative to cultivate multiple regional secondary and tertiary centers. Such a strategy will enhance the industrial, social, economic, and cultural influence of the urban core areas, extending their reach and benefits more broadly throughout the urban environment. This approach will facilitate a shift from the traditional single-center sprawl development model to a more sustainable, clustered, and ecologically friendly

 doi:10.20944/preprints202404.1910.v1

development paradigm. Furthermore, efforts should focus on bridging the disparities between the urban center and its periphery. By transforming suburban areas into hinterlands that not only support but also contribute to the prosperity of the central areas, these regions can become active receivers of industries and populations. Such a strategy is vital for propelling the region towards a more integrated and balanced developmental trajectory. These strategic initiatives are crucial for fostering a cohesive and resilient urban framework that supports sustainable growth and development, ensuring that cities like Xi'an can meet the challenges of modern urbanization and evolve into more livable, efficient, and dynamic spaces.

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