

Article

Scale Distribution of Retail Formats in the Central Districts of Chinese Cities: A Study Analysis of Ten Cities

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Abstract: Analyses of urban hierarchy and scale distribution are crucial in urban research, as they examine the laws of urban development and the functional layout of urban spatial systems. However, previous studies have focused on the macro-spatial distribution of the economy, businesses, and population at the regional level, whereas systematic research on the scale distribution of retail formats in central urban areas is lacking. Therefore, this study investigated the hierarchical scale distribution of retail formats in the top ten cities in China by GDP, using the Public Service Facilities Index Method to define central district boundaries, using scale as an epistemological framework of order and analyzing the spatial distribution patterns of retail formats. The results revealed that the spatial hierarchical scale follows a power law within a certain range; the spatial distribution exhibits stage characteristics, providing a quantitative method for defining retail centres; and the dominant functions, development directions, and morphological characteristics of central districts influence the hierarchical scale distribution of retail formats.

Keywords: retail formats; urban hierarchy system; scale distribution; central urban area; spatial distribution; power law distribution



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1. Introduction

Economic geography and spatial-scale research on retail formats actively reflect societal development and changes [1]. In 2023, China's total retail sales of consumer goods reached 47.15 trillion yuan, an increase of 7.5% from 2022, with final consumption expenditures contributing 82.5% to GDP growth [2]. Retail consumption has become a vital driver of national economic development. Moreover, the rational distribution of retail locations can influence the local economy through changes in the retail network and even urban culture, thereby promoting retail as a “temple of consumption” (Xavier, 2018 [3]). However, technological advancements, such as social media and the internet, along with increased customer spatial mobility, are gradually diminishing the impact of location factors on formats (Tobias Johansson [4]; Teller et al., 2016 [5]). Urban expansion has led to increased transportation costs in retail networks (Kowalski and Wiśniewski, 2017 [6]; Romanowska and Jamroz, 2015 [7]), as well as environmental and financial costs (M. Borowska-Stefańska et al. [8]). Furthermore, the uneven distribution of urban retail formats has significantly affected the stable development of urban economies. As iconic windows of urban economic and social development levels, the retail development situation in city centres is in poor condition [9]. Almost every town centre in England and Wales loses an average of 8% of its stores, which continues to be difficult to stop (Wrigley and Lambiri, 2015 [10]), affecting sustainable urban development. Therefore, under the new circumstances, analysing the characteristics of retail format scale distribution in urban centres and clarifying the objective mechanisms behind retail scale formation are crucial for promoting stable urban development [11].

Researchers in various fields have examined the scale distribution laws of urban retail formats to guide the rational layout of retail locations. Previous studies have mainly focused on the spatial position choice, spatial distribution patterns, and impact mechanisms of retail formats [12–14]. Moreover, scholars increasingly recognise that rapid urban growth and expansion cause polarisation and distortion of resources within urban systems [15], restricting balanced urban development. Although this phenomenon appears complex on the surface, it follows certain statistical laws. Many scholars used power-law relationships to explain the unequal distribution of resource elements [16], providing an interpretable basis for various irrational phenomena through power-law distributions that represent actual distribution situations for different types of complex data [17]. Therefore, to clarify the objective laws of urban retail format development scales, this study examined multiple city types, recognising the imbalanced spatial distribution of retail formats in different urban centres [18]. Furthermore, this study used a power-law distribution model to comprehensively analyse the spatial heterogeneity of retail distribution and promote sustainable urban development.

The heterogeneous distribution of retail formats in urban centres is unavoidable [19]. Due to differences in developmental factors, policies, and conditions across various regions and cities, heterogeneity exists in the scale of retail formats among cities, and different scales of retail development should provide distinct insights. This power-law phenomenon is not exclusive to retail but is also prevalent in demographics and social sciences, such as population size distribution and regional income levels [20–22]. Power-law distribution offers new perspectives and methods for analysing the scale characteristics of retail distribution, enabling a better understanding of the reasons behind retail scale distribution patterns.

In this context, understanding whether a power-law phenomenon exists in the spatial distribution of urban retail formats is crucial for accurately determining the scale distribution of retail formats in urban centres [23]. Therefore, this study examined the central districts of the top ten cities in China based on their GDP as case studies. These central districts have stable economies, relatively mature retail format development, and clear differences in spatial hierarchical distribution, thus offering strong universality. We analysed the retail formats of these diverse types of urban centres to identify their retail scale distribution characteristics and provide insights into the retail layouts of most cities.

It should be noted that urban scale is not just a static and somewhat rigid “scale distribution”, but rather has fluidity and contingency (Moore A, 2008 [24]; Simandan, D., 2018 [25]). Based on this, scholars such as Taylor P [26], Neil Smith [27–29], Brenner [30], and Swyngedouw E [31,32] have focused on the dynamic competitive relationship between economy and politics in geographic space, gradually advancing the establishment of scale theory research framework based on “social production”. This framework not only provides us with a vivid perspective to understand the changes in the scale of urban retail formats, but also emphasises the dynamic and accidental characteristics of their changes, providing a more detailed and dynamic analysis path for the deep understanding and research of urban retail formats. Different from the traditional research methods of regional geography, this study starts from the perspective of urban retail formats, deeply explores the specific manifestations of economic activities in the spatial dimension, and re-understands and elaborates on the spatial rank-scale of urban retail formats.

Based on the above research, this article incorporates and extends the views of Delaney, D. and Leitner, H. [33], emphasising that retail format scale is an important tool for analysing spatial order and is particularly crucial in the field of urban planning, to deepen our understanding of the distribution patterns of urban retail format scale. The main research question of this study is, what is the distribution pattern of retail format level scale in different types of urban centres? To answer this main question, we posed the following research questions:

1. What are the developmental characteristics of retail formats in urban centres with different attributes at the spatial scale level?
2. What are the laws governing the hierarchical scale distribution of retail formats in urban centres?

3. What are the spatial characteristics of the hierarchical scale distribution of retail formats in urban centres?

2. Materials and Methods

2.1. Scale and Validation Calculations

2.1.1. Scale Calculation for Retail Formats in Urban Centres

As shown in Figure 1 (created by the authors), we divide retail into four categories: shopping service, catering service, life service, and leisure service, and carry out kernel density analysis, respectively. After obtaining the kernel densities for these four formats, we applied the natural break method to reclassify the grid density into 20 groups. Subsequently, we overlaid the grid density results of the four formats to calculate the kernel density values for the retail formats in different areas. Subsequently, we reordered these values from the smallest to the largest to determine the hierarchical scale of retail formats in urban centres.

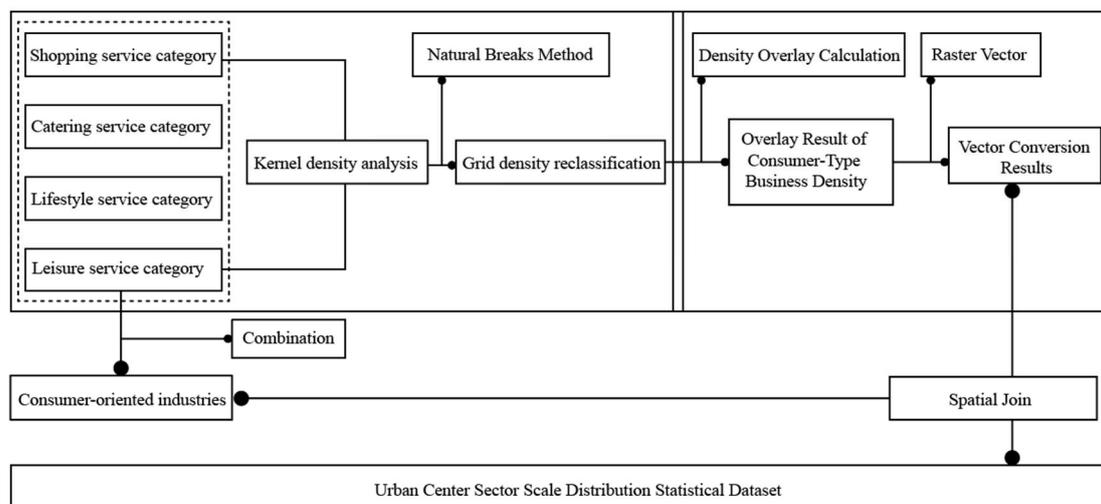


Figure 1. Technical framework of the distribution dataset for the business type scale in urban central areas.

The overlay results of the grid density for retail formats in urban centres were then vectorised. After spatially combining these results with all retail formats, we calculated the number of formats in different hierarchical scale areas. Finally, we summarise the scale distribution dataset of retail formats in urban centres for further analysis and calculations.

2.1.2. Fitting and Verification Calculation

The power-law distribution, also known as the heavy-tail distribution, is a common statistical law of probability distribution found in nature (Aaron Clauset et al., 2009 [34]). In addition, urban-scale distributions exhibit the characteristics of power-law distributions (Chao Li and John Gibson, 2015 [35]). Based on this, this study investigated the scale distribution characteristics of retail formats in urban centres to uncover the scale of economic features from a block perspective [36]. This provides an important research foundation for studying the scale distribution of consumer-oriented formats in urban centres.

The following formula was used:

$$p(x) = kx^{-\alpha}$$

where k is a constant, and α is known as the exponent or scaling parameter. To test for a power-law distribution, we used the logarithm of both sides to determine whether a straight line appears, which means that

$$\ln(y) = -\alpha \ln(x) + \ln(k)$$

In practice, all values rarely follow a power-law distribution. Due to the systematic errors introduced during the process of determining the power-law exponent, we must verify the power-law distribution (Friedman J. A., 2015 [37]). In general, the method for verifying the power-law distribution is divided into three parts (Newman 2005 [38]):

Step 1: Estimation of power-law parameters x_{\min} and α ;

Step 2: Goodness-of-fit test;

Step 3: Comparison of the power law with alternative hypotheses using likelihood ratio tests.

This study used the open-source R package developed by Gillespie (2015) [39] for power law distribution fitting and verification. The program was concluded with a goodness-of-fit test, resulting in a p -value. This p -value indicates the deviation between the empirical data and the hypothesised model. A p -value close to 1 suggests conformity with a power-law distribution. However, if the observed data are scarce, and the p -value is close to 1, the distribution law remains uncertain. Conversely, if the p -value is small, it does not conform to a power-law distribution. In this experiment, due to the limited observational data, we chose a certain standard to determine conformity with a power-law distribution.

2.2. Case Selection, Boundary Definition, and Retail Format Selection

2.2.1. Case Selection and Boundary Definition of Urban Centres

This study analysed the central districts of the top ten cities in China by GDP for the year 2020 (listed in order): Shanghai, Beijing, Shenzhen, Guangzhou, Chongqing, Suzhou, Chengdu, Wuhan, Hangzhou, and Nanjing, as presented in Table 1 (National Bureau of Statistics of China, Department of Urban Socio-Economic Survey, 2020). From a macro perspective, a higher GDP reflects a city's economic maturity and relative stability from a macro perspective [40]. Compared to other cities, these ten cities have more stable characteristics in terms of business distribution, which can effectively represent their economic development and level of retail formats.

Table 1. Top 10 cities ranked by GDP.

Serial Number	City	Gross Domestic Product (Billion Yuan)
1	Shanghai	38,701
2	Beijing	36,103
3	Shenzhen	28,000
4	Guangzhou	25,019
5	Chongqing	25,003
6	Suzhou	20,171
7	Chengdu	17,717
8	Wuhan	16,106
9	Hangzhou	15,623
10	Nanjing	14,718

Furthermore, this study utilised the Public Service Facilities Index Method to define the boundaries of urban centre districts (JunYan Yang, 2018 [41]), followed by field surveys of these districts for further boundary delineation. As shown in Figure 2 (created by the authors), The Public Service Facilities Index Method determines the extent of urban centre districts based on the density and height indices of urban commercial facilities, aligning with the characteristics of the central district scale distribution from a density perspective. Moreover, it defines the scope of economic development in urban centre districts in terms of height and density, thus meeting the requirements for the truncation range of urban centre sizes. We identified the boundaries and areas of the central districts of the ten cities using the Public Service Facilities Index Method, as shown in Figure 3 (created by the authors).

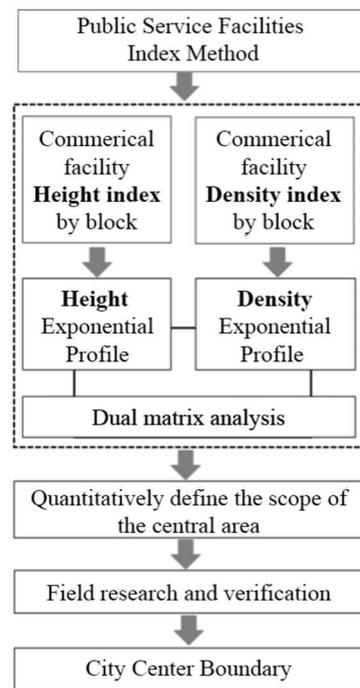


Figure 2. Index method for public service facilities.

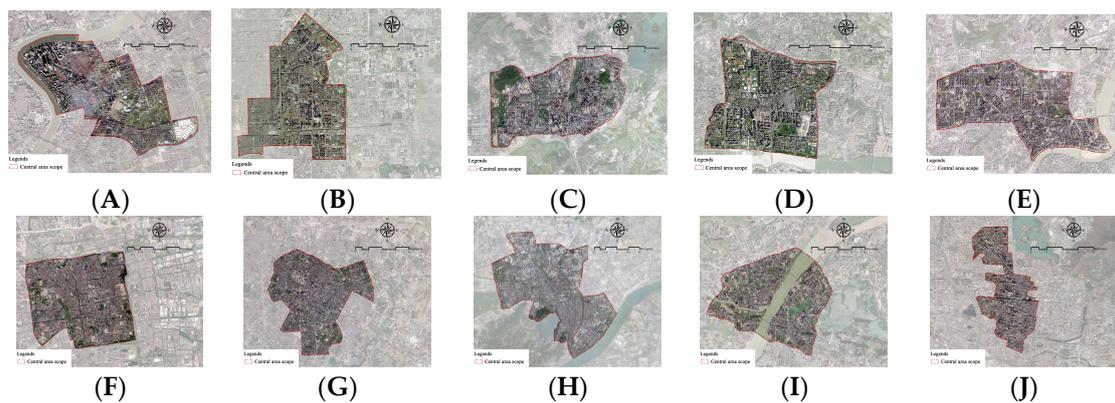


Figure 3. Research areas and the corresponding information. (A) Shanghai Lujiazui, area: 27.17 km²; (B) Beijing Chaoyangmen, area: 88.35 km²; (C) Shenzhen Futian, area: 32.79 km²; (D) Guangzhou Tianhe, area: 20.73 km²; (E) Chongqing Jiangbei, area: 40.95 km²; (F) Suzhou Pingjiang, area: 28.11 km²; (G) Chengdu Tianfu, area: 35.94 km²; (H) Hangzhou Gongshu, area: 143.34 km²; (I) Wuhan Gongshu, area: 186.90 km²; (J) Nanjing Xinjiekou, area: 17.37 km².

2.2.2. Selection of Retail Formats

Retail formats are diverse. Based on the service characteristics and the classification standards of the “National Economic Industry Classification” (GB/T 4754-2017 [42]), the collected format data were reclassified according to the service features of the retail formats. Finally, they were divided into four categories: shopping, catering, lifestyle, and leisure (Table 2 (created by the authors)).

Point of Interest (POI) data encompass geographical and business attribute information, accurately reflecting the spatial distribution characteristics of different functional formats, offering a new perspective for urban spatial structure research. In this research, we utilised the Amap API to methodically extract Points of Interest (POI) data from the maps of ten major cities, a tool that grants access to intricate geographic details. We crafted specialised scripts using advanced web scraping techniques to selectively query the API for POI categories indicative of retail formats in these cities’ central districts [43]. The process

entailed submitting API requests with specific parameters to guarantee the collected data's relevance and precision.

Table 2. Classification of retail business types.

Business Categories	Classification of Service Industry Sectors	POI Types
Shopping Services	Commercial Centres, Shopping Malls, etc.	Convenience Stores, Clothing Stores, etc.
Catering Services	Catering Industry	Snack Shops, Restaurants, etc.
Lifestyle Services	Residential Services, Daily Product Repair, etc.	Auto Repair Shops, Hardware Stores, Hair Salons, etc.
Leisure Services	Entertainment Industry, Sports and Fitness	Cinemas, KTV (Karaoke), Gyms, etc.

Subsequent to data retrieval, we applied stringent data cleansing protocols, employing algorithms to detect and eliminate duplicates, thereby preserving the uniqueness of each POI. We also harmonised the data formats to enable consistent analysis, transforming disparate data types into a uniform format. This detailed approach allowed us to delineate and classify four unique retail format types within the central districts of the selected cities, offering an in-depth perspective on the urban retail environment.

3. Characteristics and Analysis of Retail Format Hierarchical Scale

3.1. Spatial Distribution Characteristics of Retail Formats

To gain a more intuitive understanding of the spatial characteristics of retail formats in various urban centres, we used ArcGIS to calculate their kernel density values [44]. We then classified the hierarchy of retail formats using the natural breaks method and visualised the results to obtain the spatial distribution of the retail format hierarchies in urban centres.

As shown in Figure 4 (created by the authors), the retail formats in the central districts of the ten cities exhibited common spatial distribution characteristics, displaying both agglomeration and dispersion trends. This duality highlighted the spatial features of the urban retail formats. First, retail formats showed a clear tendency towards agglomeration, forming clustered centres in specific areas. Moreover, we observed a trend towards outwards diffusion, creating spatial dispersion. Retail formats expanded outwards from clustered centres along roads, with their spatial hierarchy gradually decreasing.

Furthermore, differences were observed in the spatial distribution of retail formats among various urban centres. First, the number of retail format agglomeration centres varied. Some urban centres had a single agglomeration centre, whereas others have multiple centres. For instance, Shanghai's Lujiazui had a single agglomeration centre, forming a unique core area, whereas Suzhou's Pingjiang urban centre showed a more dispersed pattern, with two retail format agglomeration centres.

Second, the spatial location of the retail format agglomeration areas showed significant differences. In some areas, the retail format agglomeration centres were located at the centre of urban centres, whereas in others, they were distributed around urban centres. Chengdu's Tianfu urban centre chooses to place its retail format agglomeration centre in its central area, focusing on retail formats to provide consumers with convenient access and concentrated shopping venues. Conversely, because Shenzhen's Futian centre is in a city with low hills and significant topographical variations, and considering factors such as urban planning and land availability, retail-format agglomeration centres were distributed around the urban centre. This layout resulted in multiple dispersed agglomeration points of retail formats on the edges of the urban centre, offering a broader service range covering communities and surrounding areas.

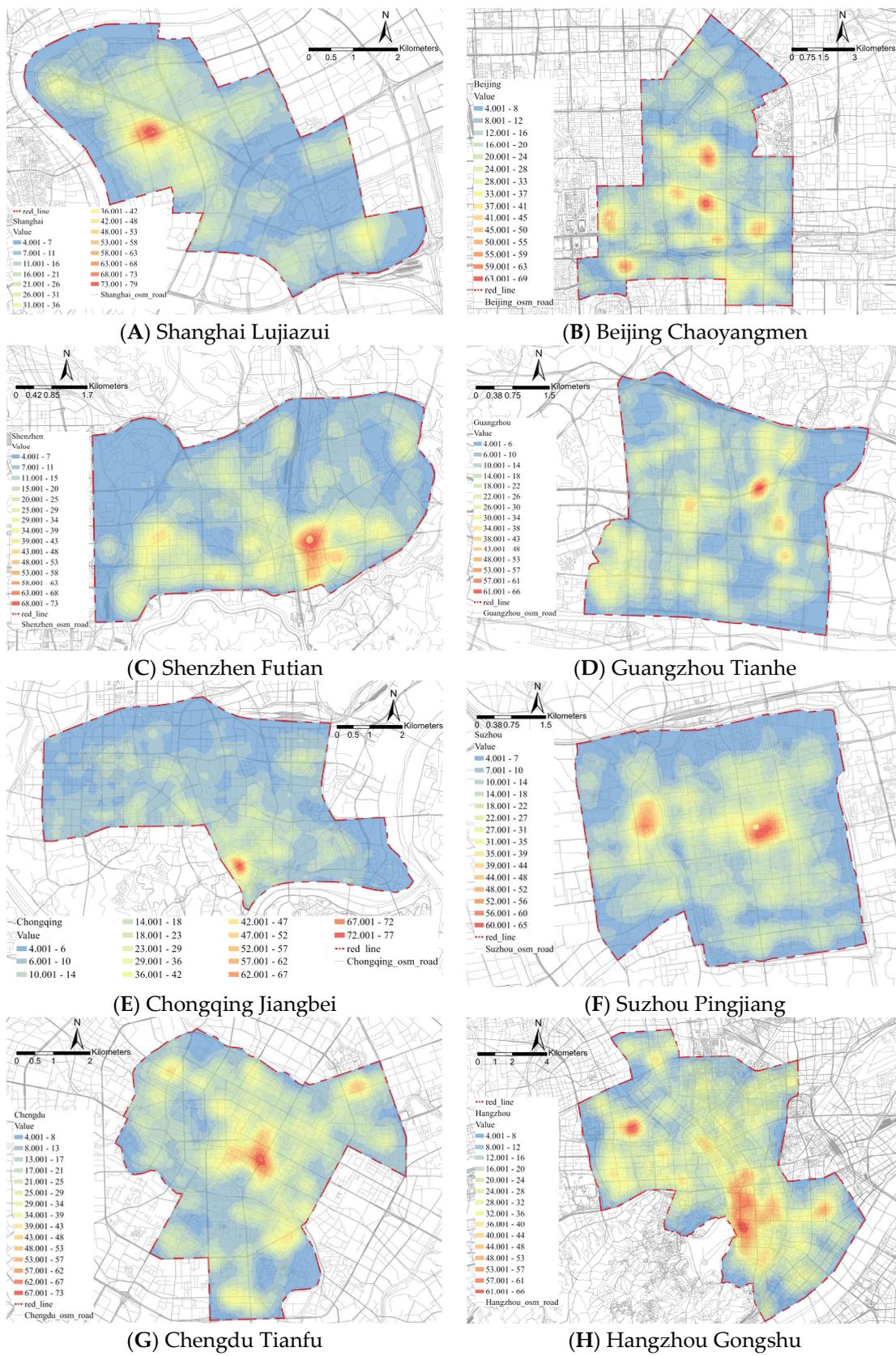


Figure 4. Cont.

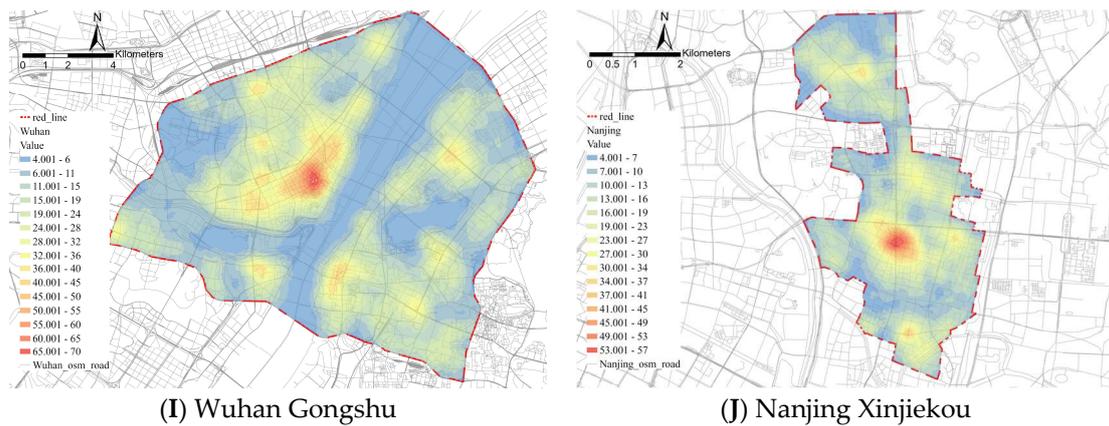


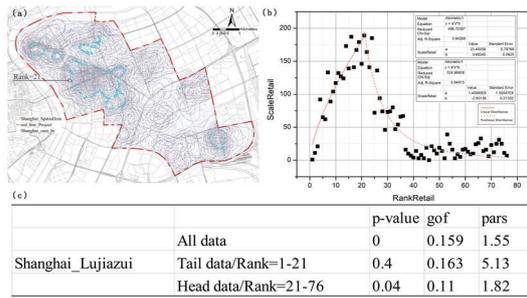
Figure 4. Spatial distribution of retail business levels in urban central areas.

3.2. Power-Law Distribution Characteristics of Retail Formats

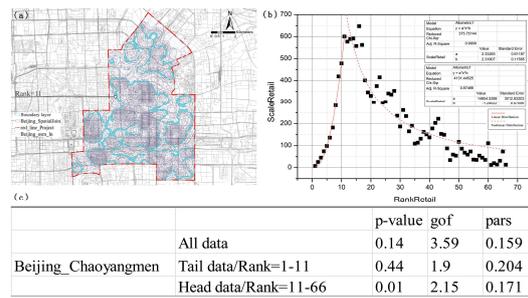
Utilising the aforementioned R-package for power-law modelling, we fitted the power-law distribution to the retail formats in the central districts of the cities, thereby unveiling the characteristics of the scale distribution of retail formats.

In spatial terms, Figure 5(a) (created by the author) shows the spatial distribution of the hierarchical structure of retail formats in the central urban area, the hierarchy of retail formats exhibited a spatial distribution pattern similar to that of the contour lines. This reflected the spatial stratification of different retail format hierarchies within urban centres, forming retail format layers of varying levels. Furthermore, Figure 5(b) (created by the author) presents the power law fitting results of the number of retail formats and the level of retail formats. Figure 5(c) (created by the author) shows the results of power-law fitting values for retail formats. We observed two distinct scenarios in the retail data format: those conforming to and those deviating from the power-law phenomenon. The boundary layer delineated these two scenarios, identified through observation of the power-law phenomenon, allowing us to classify retail formats by hierarchy. This resulted in the formation of a high-tier retail format dataset as the head dataset and a low-tier retail format dataset as the tail dataset. As shown in Figure 6 (created by the authors), the head dataset in this spatial structure appeared as the head layer close to the urban centre, representing the agglomeration of high-tier retail formats. Conversely, the tail dataset formed a peripheral tail layer in space, representing the agglomeration of low-tier retail formats. This approach aided in a more detailed understanding of the power-law phenomenon across different tiers of retail format sizes in urban centres, offering a more comprehensive spatial perspective.

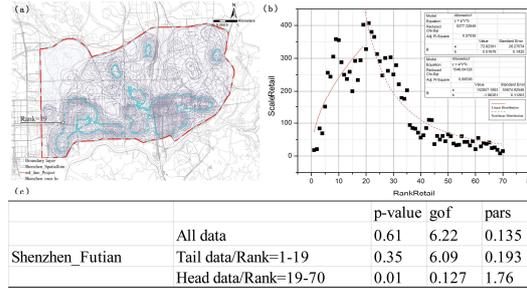
In the central districts of the cities, the scale of retail formats exhibited consistent spatial distribution characteristics. Initially, the retail formats in these urban centres demonstrated significant initial growth in scale, which, after reaching a peak, began to decrease gradually. Second, as shown in Figure 7 (created by the authors), the scale and number of formats in the ten urban centres displayed a clear segmented distribution, which could be divided into linear and nonlinear parts. The boundary between linear and nonlinear distributions corresponded to the scale of the format with the maximum number of formats. Finally, except for the Guangzhou urban centre, retail formats in other urban centres exhibited a power-law phenomenon across different scales.



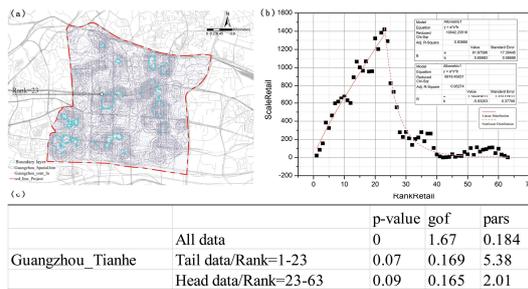
(A) Shanghai Lujiazui



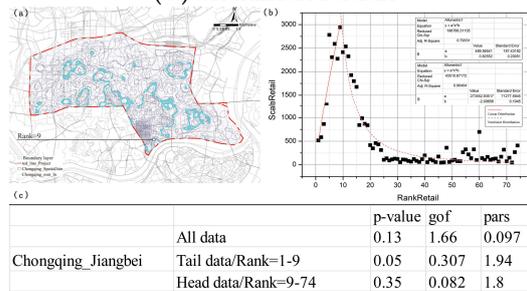
(B) Beijing Chaoyangmen



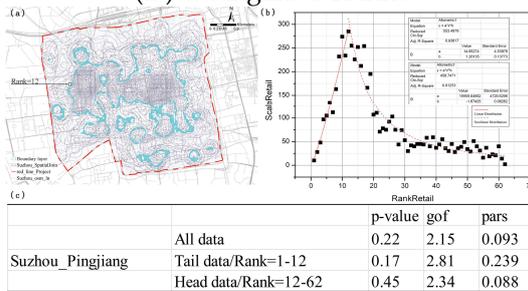
(C) Shenzhen Futian



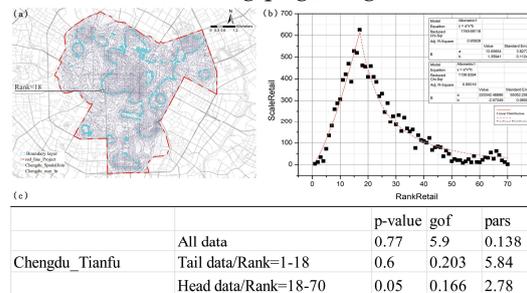
(D) Guangzhou Tianhe



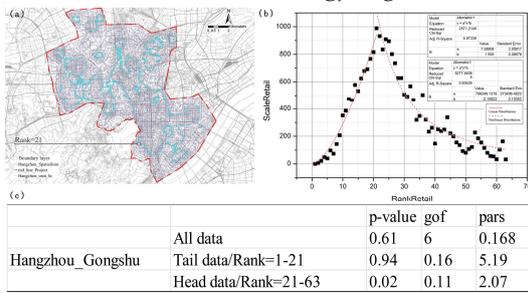
(E) Chongqing Jiangbei



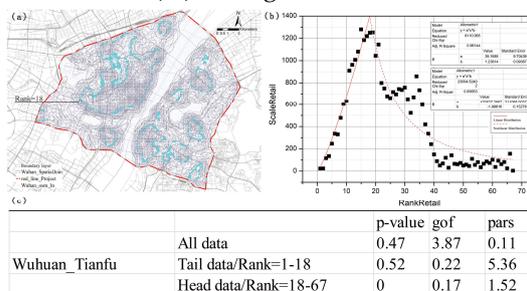
(F) Suzhou Pingjiang



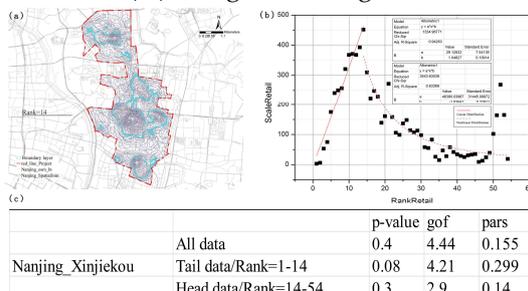
(G) Chengdu Tianfu



(H) Hangzhou Gongshu



(I) Wuhan Gongshu



(J) Nanjing Xinjiekou

Figure 5. Fitting results of power-law distribution for retail business types in urban central areas.

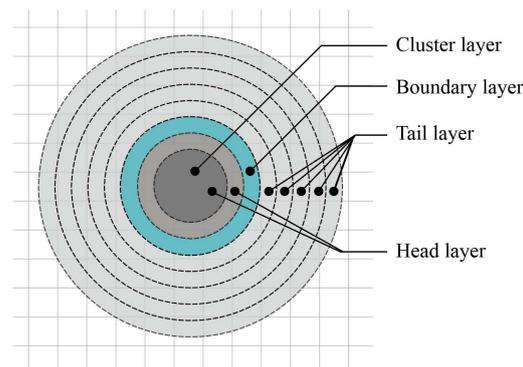


Figure 6. Schematic diagram of power-law layer.

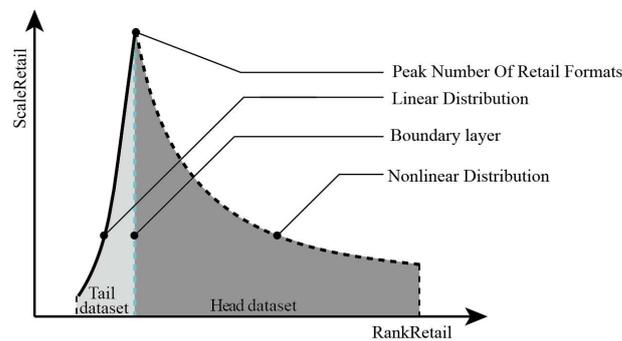


Figure 7. Schematic diagram of power-law dataset.

Differences existed among the ten urban centres in both the overall and local power-law fitting results. As shown in Figure 5 (created by the authors), in terms of overall power-law fitting, the retail formats in the urban centres of Shenzhen, Chengdu, Wuhan, Hangzhou, and Nanjing conformed to the power-law distribution, whereas the other five cities did not. Second, only the retail formats in the urban centres of Chongqing, Suzhou, and Nanjing showed a power-law phenomenon in the head dataset. Specifically, the scale of retail formats remained relatively stable near the high-tier spatial layers, followed by a gradual increase. In the tail dataset, the retail formats in the urban centres of Shanghai, Beijing, Shenzhen, Chengdu, Wuhan, and Hangzhou exhibited a power-law phenomenon, characterised by stable fluctuations as the scale approached the high-tier spatial layers. Finally, the retail formats in Guangzhou did not conform to the power-law distribution in either the retail agglomeration centre or surrounding areas, with the head dataset showing a distinct discontinuity, demonstrating different scale development characteristics. The similarities and differences in the scale characteristics of retail formats in these urban centres, influenced by variations in urban spatial morphology, provide valuable insights for a deeper understanding of the spatial distribution of retail formats in urban centres.

3.3. Analysis of Power-Law Distribution Characteristics of Retail Formats

Summarising the power-law fitting results for the central districts of the ten cities, we identified a pattern in retail formats within urban centres. This pattern exhibited both commonalities and differences across cities and was influenced by various factors.

The power-law phenomenon in urban retail formats demonstrated certain commonalities. First, as shown in Figure 8 (created by the authors), the head and tail datasets of the ten urban centres exhibited fluctuations in the boundary layer positions, with the tail dataset constituting approximately 25% of the entire retail format dataset. This observation indicated a general trend of fluctuation in the distribution of retail formats within urban centres. Furthermore, in specific dataset analyses, we observed that the highest scale of retail formats in urban centres was generally located at approximately one quarter of the layer radius. This suggested that relative to the entire area, the quarter mark was where

the retail format density was the highest in different urban centres. This commonality provides technical support for future spatial location choices in retail format. Such consistent phenomena highlight a common development law in the distribution of retail formats at specific locations within urban centres.

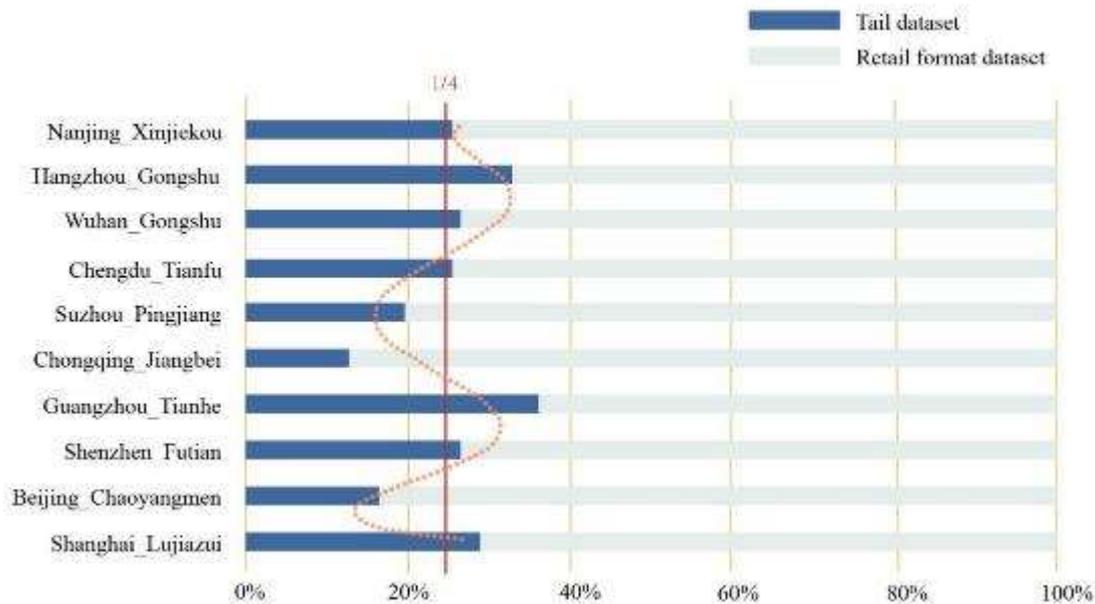


Figure 8. Location of boundary circles in ten city centres.

Differences in the power-law phenomenon in urban centres were influenced by urban morphology. First, regarding the boundary layer, the tail dataset of Chongqing's centre constituted only 12% of the entire dataset, deviating from the general trend. Upon further analysis, considering Chongqing's mountainous terrain with significant topographical variations, various formats were distributed among the mountains. This unique geography led to anomalies in the power-law phenomenon of retail formats. A simple density method may not provide accurate judgments, suggesting that Chongqing requires alternative methods to assess the hierarchical structure of consumer formats. Therefore, the specificity of a geographical environment may cause the distribution of retail formats to exhibit patterns that differ from those in other cities.

Second, in terms of power-law distribution verification, the central districts of the ten cities exhibited different power-law phenomena based on urban morphology. As shown in Table 3 (created by the authors), based on the overall retail format datasets of the ten urban centres, the central districts of Shenzhen, Chengdu, Wuhan, Hangzhou, and Nanjing conformed to the power-law distribution. Compared with other urban centres, these five cities displayed diverse economic characteristics in their urban forms. Economic activities in these urban centres varied, exhibiting a broad and rich industrial distribution. In addition, these five urban centres had large population sizes but were relatively dispersed, creating a more relaxed urban layout. This dispersed urban form provided flexible spatial arrangements for various industries and formats, thereby facilitating the power-law phenomena. Thus, the power-law phenomenon was closely related to the diversity and dispersion of urban forms.

Finally, from the perspective of the tail dataset, the central districts of Shanghai, Beijing, Shenzhen, Chengdu, Wuhan, and Hangzhou conformed to a power-law distribution. These urban centres are among the major cities in the country with high urban density and a mature stage of economic development and modernisation. Therefore, they formed a relatively complete urban system, where retail-format agglomeration centres were large and fully developed, exhibiting a power-law phenomenon. Conversely, from the perspective of the head dataset, Chongqing, Suzhou, and Nanjing conformed to a power-law

distribution. These urban centres had a relatively lower scale and density and were influenced by historical building conservation and topographical constraints, leading to limited diffusion of retail format agglomeration centres. The development of retail formats outside agglomeration centres was relatively balanced, conforming to the power-law phenomenon. Hence, the differences in the layer power law phenomenon were closely related to the stages of urban development and geographical characteristics.

Table 3. Verification of power law distribution in ten city centres.

City	Power Law Distribution Verification		
	Overall Dataset	Tail Dataset	Head Dataset
Shanghai Lujiazui	×	○	×
Beijing Chaoyangmen	×	○	×
Shenzhen Futian	○	○	×
Guangzhou Tianhe	×	×	×
Chongqing Jiangbei	×	×	○
Suzhou Pingjiang	×	×	○
Chengdu Tianfu	○	○	×
Wuhan Gongshu	○	×	×
Hangzhou Gongshu	○	○	×
Nanjing Xinjiekou	○	×	○

Notes: ○ represents conformity; × represents non-conformity.

4. Conclusions

4.1. Limitations

Employing the power-law phenomenon to fit the scale distribution dataset of retail formats is a novel exploration of the distribution laws of formats in urban centres; however, it has certain limitations.

Considering the difficulty in obtaining relevant urban data and current absence of a definitive quantitative analysis method to summarise the factors influencing the urban power-law phenomenon, accurately quantifying the factors affecting this phenomenon in urban retail formats is challenging. Subsequent research should delve further into the factors influencing the urban retail format power-law phenomenon.

Moreover, the formats selected in this study were mainly obtained from Amap API. Thus, incomplete data may be present in some formats. However, as the final results across the ten cities did not significantly differ, we believe that these such discrepancies were negligible.

The scale distribution of retail formats obtained in this study started primarily from the morphological level, preliminarily demonstrating its conformity to power-law distribution characteristics. However, we did not conduct an in-depth analysis of this structure's impact on the economy, including its potential impact on market mechanisms, competitive landscapes, and economic benefits. Therefore, we did not have a clear judgment of the economic significance of the scale distribution of this retail format before conducting a thorough analysis of the economic level. Furthermore, this study had certain limitations in terms of economic theory. Nonetheless, this research provides a new perspective on applying power-law distribution laws to the study of the spatial distribution of retail formats in urban centres and supplements the research methods for investigating spatial scale distribution in urban centres.

In this research context, the discussion on the universality and research value of power-law phenomena in cities in the fields of human geography and social sciences has become particularly important (Marston, S.A. [45]). Although some scholars hold the view that the widespread existence of power-law phenomena in multiple cities may weaken their value as research objects (MacKinnon, D., 2011 [46]). However, other scholars emphasize from the opposite perspective that the study of the scale of urban retail formats not only reveals the spatial layout patterns of urban retail formats in a fiercely competitive

urban environment, but also deepens our understanding of urban spatial relationships [47]. Therefore, despite the universality of power law phenomena, exploring the inherent logic of urban scale through power law analysis still constitutes a research topic of profound academic value. Furthermore, from the perspective of urban planning, this analysis path not only helps to demonstrate the distribution patterns of urban retail formats, but also provides important strategic insights on how to effectively plan urban resources and spatial layout to promote economic growth and social equity. In all, using power law analysis to study the scale of urban retail formats can provide a key theoretical basis and practical guidance for urban planning and development strategy formulation, thereby enhancing our understanding of the development and adaptation mechanisms of cities in complex socio-economic backgrounds.

4.2. Conclusions

Retail format data harbours significant implications for the sustainable development of the national economy [48], reflecting not only the economic level and consumption structure of a city at a given stage but also exhibiting dynamic characteristics [49]. Additionally, the inherent presence of power-law phenomena contributes to the uneven development of retail formats, thereby affecting the stable economic growth of urban centres. Therefore, analysing the hierarchical scale distribution of retail formats and validating the power-law phenomena in urban centres can offer deep insights into the characteristics of these phenomena, providing a basis for balanced urban development [50].

In this context, numerous scholars have conducted in-depth studies on the power-law characteristics of urban retail formats. Ahjond S. Garmestani [51] focused on the scale of 310 cities in the southeastern United States, using total population to categorize city scales and explore the impact of urban markets and industries on urban development. Similarly, Wu Guangzhou [52] examined the population and primacy ratio of provincial capital cities in China to investigate the presence of power-law characteristics, thereby assessing the balance of urban economic development. These studies, while thoroughly exploring the overall power-law characteristics of cities, emphasize the importance of enhancing the comprehensive carrying capacity and optimising resource allocation in central cities, contributing to sustainable urban development.

However, these studies primarily based on overall urban data, do not delve into the fundamental causes of power-law phenomena. From a holistic perspective, this approach limits the depth of investigation into the factors dividing urban retail formats, leading to a somewhat superficial understanding of the mechanisms behind power-law phenomena. Despite providing valuable insights into the power-law characteristics of urban retail formats, these studies face limitations in exploring the mechanisms of power-law phenomena in depth.

To address these limitations, our study focuses on multiple urban centres and employs a method to categorize retail format scales, aiming to explore the commonalities in the power-law characteristics of retail formats and move beyond the overly generalised scope of previous research. By concentrating on urban centres, we can more intricately examine the spatial distribution of urban retail formats, enhancing our understanding of the mechanisms behind power-law phenomena. This approach also aids in evaluating the future urban management and business decision-making directions of urban centre retail formats from a sustainable development perspective.

Our study highlights two innovative points, offering new research perspectives on the power-law phenomenon in urban retail formats. Firstly, this study innovates in the selection of research perspectives. Unlike traditional power-law studies that focus on population and urban size, we focus our research on urban retail formats. This unique perspective enables us to gain a deeper understanding of the spatial distribution characteristics of urban retail formats. Second, in the selection of research objects, considering that urban retail formats are usually concentrated in urban centres, this study adopts the Public Service Facilities Index Method to define urban centres. This method not only improves the precision of

identifying the power law phenomenon of retail business in urban centre area, but also provides us with more detailed and accurate data support.

Our findings deepened our understanding of the retail format scale in urban centres and its correlation with the power-law phenomenon. First, our study of the spatial scale of retail formats revealed a typical pattern of substantial initial growth, followed by a gradual decrease within urban centres. The transition from the growth phase to the declining phase is often observed around the one quarter layer of the urban centre, where the scale of retail formats reaches its peak. This suggests that businesses may prefer locations within this layer in the future. Overall, the urban centres of the five cities (Shenzhen, Chengdu, Wuhan, Hangzhou, and Nanjing) exhibited characteristics consistent with a power-law distribution.

Furthermore, an analysis of the power-law phenomena in the retail formats of ten urban centres showed that urban centres with high levels of modernisation and clear agglomeration features generally exhibited power-law phenomena in their head datasets, whereas their tail datasets do not conform. Specifically, urban centres such as Shenzhen, Chengdu, Wuhan, and Hangzhou fell into this category, indicating a relative concentration of retail formats in the head dataset areas that align with the power-law distribution rules. Conversely, the tail datasets of urban centres in Chongqing, Suzhou, and Nanjing did not exhibit power-law phenomena, whereas their head datasets do, suggesting that these urban centres tend to maintain their developmental urban patterns, thereby limiting the expansion of retail formats. Moreover, neither the head nor tail datasets of the retail formats in Guangzhou's Tianhe District conformed to the power-law distribution, showing clear differences in retail formats across different areas and reflecting a certain spatial heterogeneity in Guangzhou Tianhe's retail layout.

Finally, this study comprehensively explores and summarises the power law phenomenon in 10 cities by analysing the spatial distribution commonalities of urban retail formats in depth. We found that the power-law phenomenon of retail formats in urban centres was influenced by a complex interplay of factors, such as the geographical environment, urban morphology, and economic characteristics. Together, these factors offer a multilayered explanation of the spatial distribution of retail formats in urban centres. Geographical features, such as mountainous terrain, may lead to anomalous distribution patterns, whereas dispersed urban layouts and flexible spatial arrangements foster conformity with the power-law phenomenon. The stages of urban development and economic activities are closely associated with variations in the power-law phenomenon of retail formats in urban centres. These insights have valuable implications for urban planning and retail development.

In summary, the distribution laws of the hierarchical scales elucidate the spatial dependency of retail formats within the scale of urban centres, offering effective technical methods and theoretical support for examining the spatial characteristics and statistical laws of retail formats. This will contribute to the sustainable development of spatial distribution and location choices for future consumer types and formats.

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