Research on the Distribution and Typological Characteristics of Urban Office Centres from a Fine-Grained Perspective: A Case Study of Yangpu District in Shanghai, China

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Abstract
IT maturity has transformed business operations and the preferences for office space, altering urban office distribution. This study uses geospatial data to map fine-scale office space patterns in Yangpu District, Shanghai, identifying office centres, exploring their typologies and relationships with nearby facilities. Key findings: (1) Offices are dispersing from central CBDs and re-aggregating spatially forming new centres. (2) These centres feature high-density, mixed-use surroundings, good subway access, and proximity to residences/universities. Five spatial types emerge: TOD Developments in Peripheral Location, University-linked Mini Industrial Clusters, Small-scale Creative Parks in urban renewal, We-work space based on Multiple-Functional Community Complexes, and CBD Zones. This study enhances understanding of internet-era office spaces and provide theoretical support for the refined organisation and optimisation of urban employment spaces.

Key words: urban office centres; facilities in the environment; clustering analysis; decentralisation

1. Introduction

Residence and work are considered two fundamental urban functions by Le Corbusier, and the jobs-housing relationship – the spatial layout relationship between employment and residential areas – has long been a classic and critical topic in urban planning. Since the late 19th century, shifts in policy thinking and advancements in transportation and communication technologies have continuously presented new opportunities and challenges for this relationship, giving rise to numerous urban theoretical models addressing it. In China, abundant job opportunities and higher wages continue to attract populations towards cities, with urban population size projected to grow further. By the end of 2023, China's permanent urbanisation rate reached 66.16%, and it is expected that the urban population will surpass one billion for the first time by 2030. Where to live and where to work are two core questions urban residents inevitably face. Over the past decade, rapid regional and urban economic development has driven continuous global industrial upgrading. Modern service industries, particularly producer services, have gradually become pillar industries in major cities. Office spaces, primarily comprised of commercial office buildings, provide urban residents with substantial employment opportunities and high-quality work environments, exerting a significant influence on the urban jobs-housing relationship. Optimizing the spatial organisation of office space is thus a major research focus in global geography and urban planning disciplines.

The maturity of information technology (IT) has seen information connectivity gradually replace traditional transportation connectivity, revolutionizing office models in the internet era. During the Third Industrial Revolution, the proliferation of digital infrastructure and remote collaboration tools enabled cross-spatiotemporal communication. Online office forms like video conferencing, web-based training, and mobile working became widely adopted, even partially replacing face-to-face interaction. By the end of 2021, the number of online office users in China reached 469 million (Sun Bindong, 2021). Devices like mobile workstations became new carriers for resources and information, diminishing the external gravitational pull and spatial effects of industrial clusters, thereby reducing the physical scale of industrial spatial agglomeration (Castells, 1989, 1996). Advances in communication technology and online interaction tools liberated people from geographical and physical office constraints, enabling work from virtually anywhere. Concurrently, digitisation and knowledge-intensive activities transformed the nature of work itself, making flexible employment models like remote work and freelancing increasingly important, leading to the virtualisation and decentralisation of workspaces (Long Ying, 2022). Many companies are transitioning towards networked, distributed management models. Progress in office organisation methods has greatly enhanced flexibility. Driven by factors such as rent, resource availability, and environmental quality, office functions are gradually detaching from traditional industrial cluster areas and dispersing spatially (Yang Dejin, 2012). Against this backdrop, office space is developing in a decentralised manner within cities, with significant emergence outside traditional urban cores, showcasing diverse urban office scenarios and vibrant economic activity.

Theoretically, academia widely agrees that breaking the “agglomerated yet separate” polarised development pattern of employment centres and residential centres, and enhancing urban functional mix, is one pathway to optimizing the jobs-housing relationship. Urban planning concepts like Smart Growth and New Urbanism also endorse this view. Building on the “Neighbourhood Unit” concept, China has further developed the “Community Life Circle” concept based on “15-Minute City” theory. This serves as a spatial carrier for residential life, aiming to meet residents’ diverse activity needs. Localizing employment opportunities is a key aspect of building 15-Minute Cities. Shanghai’s community renewal practices explicitly include “Suitable for Employment” as one of its “Five Amenity Goals” (Wu Yi), advocating for ample job opportunities within or near communities to reduce commute times and pressure. Current research on urban office spaces often focuses on the agglomeration patterns of high-level employment centres at a macro scale (e.g., CBDs, sub-centres, polycentric structures). Studies investigating finer-scale, decentralised yet re-agglomerating office centres are relatively scarce, and the pathways to achieve localised employment opportunities within the “15-Minute City” framework remain unclear. Therefore, addressing this gap, this paper focuses on fine-scale office centres. We propose the hypothesis: “Office space is dispersing from the urban CBD and re-agglomerating spatially on a smaller scale to form new office centres.” After validating this hypothesis, we explore the characteristics of these office centres to decipher the mechanisms behind employment decentralisation and localisation. This analysis may offer insights for optimizing urban spatial layouts under constrained land development conditions. The structure of this paper is as follows: Section 2 presents a literature review on office space research, establishing the necessity and innovation of this study. Section 3 details the methodology for hypothesis validation and subsequent analysis. Sections 4 and 5 present systematic empirical research. Conclusions are summarised in Section 6.

2. Literature Review

Reviewing research themes on office space structure both domestically and internationally, collecting relevant literature through searches in Science Direct and the CNKI helps establish a relatively comprehensive literature database system on office space research. Searches were conducted based on keywords such as “producer services,” “office space,” “office centres,” “urban spatial structure,” “influencing factors,” “evolutionary trends,” and “dispersed distribution.” encompassing research themes including CBDs, business offices, business districts, office buildings, urban design, layout characteristics, spatial structure, and evolutionary features.

Early research on office spaces in Western countries was not an independent topic but appeared within economic studies. Based on classical economic methods, core theories such as Thünen’s Agricultural Location Theory, Weber’s Industrial Location Theory, and the Market Location Theories of Scheffler, Christaller, and Lösch were formed, primarily focusing on economic activities in urban centres and their spatial carriers. In the 1920s, alongside the transition from secondary to tertiary industries, the Central Business District (CBD) emerged as a typical spatial carrier, prompting specialised research on office spaces in western planning academia. From the 1920s to 1940s, research focused on the characteristics and causes of the centripetal agglomeration of office activities. The classic urban spatial structure theories proposed by the Chicago School—Burgess’s Concentric Zone (1923), Hoyt’s Sector (1939), and Harris and Ullman’s Multiple Nuclei (1939)—all indicated that office space should be highly concentrated in urban centres. After the 1950s, the office industry became a pillar industry in major Western cities, and related research became increasingly systematic. Guided by Location Theory, Urban Spatial Structure Theory, Central Place Theory, theories of office decentralisation, and stage development models, academia conducted extensive theoretical and empirical research on office activities, the office industry, and office spaces, leading to a maturing theoretical system. Research subjects were concentrated in three main fields: urban economics, financial economics, and urban geography. Content covered office space location, spatial structure, types of agglomeration distribution, morphological structure, formation mechanisms, and increasingly, research on layout evolution under suburbanisation and informatisation.

Research on office spaces in China began in the 1990s, approximately 70 years later than in the West. Relying on theories such as Office Space Location Theory, Agglomeration-Diffusion Structure Theory, and Enterprise Behavioral Decision Theory, research mainly focused on the concept of the office industry, office location theory, headquarters economy space, urban CBDs, and the interaction between office space and urban development. In recent years, improved research capabilities and data informatisation have significantly expanded data coverage and reduced acquisition difficulty. Using GIS technology to analyse the agglomeration characteristics of urban functional spaces has become a trend. Concurrently, transformations in office models have spawned various new forms of office spaces such as co-working spaces, SOHO, and renovated industrial buildings, enriching the typology of office architecture.

2.1 Research on Factors Influencing Office Space Distribution

Western office location theory takes corporate autonomous site selection as its basic premise, viewing it as the intrinsic driver shaping office spatial patterns. Since the mature development of Central Business Districts (CBDs) in the 1980s, academia has gradually revealed the formation mechanisms and influencing factors of office space agglomeration structures through empirical case studies. As an emerging industrial space characterised by low land occupancy and low transportation costs, its site selection is primarily dominated by non-production cost factors, encompassing multidimensional influences such as agglomeration economies, face-to-face communication needs, information technology advancements, changes in corporate organisational structures, urban cultural environments, and market environments. These factors can be categorised into three levels: economic-market, technological-social, and organisational-institutional.

The spatial agglomeration distribution of office spaces at the urban scale can essentially be seen as a product of the co-evolution of the city's multifunctional systems, shaped by both the active force system (office districts, residential areas, commercial districts, transportation hubs, etc.) and the environmental constraint system (natural ecology, green spaces, built environment, etc.). Agglomeration scale reflects the level of development of urban functional spaces, agglomeration characteristics reveal endogenous development laws, and the uneven distribution of spatial elements leads to heterogeneous effects of the same influencing factor in different regions, exhibiting significant non-stationary characteristics. For instance, a specific factor might strengthen agglomeration in the centre while potentially triggering dispersion in the suburbs. This is the particularity of this complex mechanism within the Chinese context. The three-dimensional driving framework proposed by XUE Dongqian et al. (2011) for Xi'an's producer services confirms this: market orientation creates demand pull, locational factors trigger spatial competition, and government guidance implements policy intervention. Together, these three aspects explain the evolutionary logic of office spaces during the transition period.

2.2 Research on Trends of Concentration and Dispersion in Office Spaces

The agglomeration and dispersion, equilibrium and disequilibrium of office spaces within cities are core topics in geographical research. Agglomeration is considered a fundamental characteristic of office space. Studies show that regardless of changes in urban structure, the Central Business District (CBD), centreed on office functions, typically maintains its core position, with office buildings generally tending to locate in relatively central urban areas. This pattern has been confirmed in the urbanisation processes of Western countries (Kee Boim Nahm, 1999). However, although the agglomeration trend has not fundamentally changed, office space layouts in developed metropolitan areas in recent years have shown a tendency towards dispersion, gradually spreading to sub-regional urban centres. Large companies, in particular, are increasingly likely to relocate some operations to lower-cost peripheral areas, forming localised office functions. This dispersion pattern first appeared at the national urban system level, accompanying the shift from centralised to dispersed regional development models. Simultaneously, dispersion also occurs within cities. For example, research in Toronto shows that non-central urban areas can also become new office centres to reduce communication costs.

Accompanying the maturation of CBDs and the localisation of office space, academia has gradually identified typical layout patterns such as "Cluster" and "Net of mixed beads." Integrating the research of Erickson and Hart, Masu proposed a universal four-stage localisation evolution framework: 1) Spillover and Specialisation; 2) Dispersion and Diversification; 3) Polycentricity (Filling Nuclei / Diffusing Nuclei); 4) Three forms of suburban office space

(Loop Centres, Radial Road Centres, Unstructured Expansion). Castells argued that concentration and dispersion often coexist rather than being absolute, both at the regional and urban levels, categorizing office space distribution states into four types: Agglomeration, Dispersion, Concentrated Agglomeration, and Concentrated Dispersion. Similarly, ZHANG Jingqiu et al. (2011) quantitatively analysed Beijing's office building distribution, extracting three industry-specific agglomeration types: "Large Dispersion - Small Agglomeration," "Large Dispersion - Large Agglomeration," and "Small Dispersion - Large Agglomeration," noting their spatial coupling with major transportation arteries. Scholars such as WANG Yang (2016), WANG Junrong (2017), ZHANG Zhibin (2019), and YE Qiang (2022) subsequently conducted empirical studies in cities like Guangzhou, Zhengzhou, Lanzhou, and Changsha, further enriching regional case support. This stage saw the extensive application of mathematical statistical analysis methods.

The existing literature review indicates that international research has recognised the trend of office space decentralisation, theoretically explained the process, and dialectically analysed the two spatial organisation modes—agglomeration and dispersion—from macro perspectives of regions or cities. However, relevant research still exhibits relative gaps: First, the research objects mostly focus on traditional commercial office buildings, with less identification and differentiation of new office space types from spatial or industrial perspectives. Second, there is a scarcity of in-depth studies targeting dispersed office centre entities at the meso-micro scale and a lack of systematic exploration into the characteristic typologies of new office spaces.

3. Research Design

This study is divided into two main parts. The first part describes the evolving characteristics of office space distribution within the study area and verifies the hypothesis. The second part identifies office centres within the study area at a fine scale and conducts an exploratory analysis of their characteristic typologies. This research utilises Point of Interest (POI) data and Location-Based Service (LBS) data as the basis for identifying office spaces and office centres. Open geographic information data from OSM, Baidu Maps, and AMap are employed for spatial calculations to describe the fundamental characteristics of the office centres. The study adopts spatial analysis methods such as Standard Deviational Ellipse Analysis and Spatial Autocorrelation Analysis, alongside quantitative analytical methods like Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) for induction and interpretation.

3.1 Research Approach

To address the hypothesis proposed in this paper – "Office space is dispersing from the urban CBD and re-agglomerating spatially on a smaller scale to form new office centres" – this study primarily utilises multi-temporal POI data for the study area obtained from online sources. First, data pre-processing is performed in ArcGIS to filter business office POI point data exhibiting characteristics of producer services. Facilities within the jurisdiction capable of providing employment are treated as individual discrete points. The Standard Deviational Ellipse (SDE) method is used to determine the overall distribution characteristics of office space within the study area. Based on planning documents, the study area is divided into central urban areas and non-central areas. Spatial grid statistics are employed to count office spaces. Data visualisation and spatial analysis methods, including spatial autocorrelation analysis, are then used to intuitively present the spatial clustering distribution characteristics of office spaces in different years within the study area, describe their evolutionary trends, and thereby verify the hypothesis.

For the exploration of the spatial patterns and typological characteristics of office centres, the process is as follows: First, POI data and LBS data are used to identify office centres within the study area. Basic geographic data, including POI data, AOI data, and road network data, are utilised in spatial calculations to obtain proxy descriptive parametres representing the locational, morphological, and functional environmental attributes of the identified office centres. Subsequently, the PCA method is applied to reduce the dimensionality of these parametres to extract the most critical feature elements. Finally, the HCA method is employed to classify the identified office centres and analyse their groupings.

3.2 Research Method

(1) Standard Deviational Ellipse Analysis
This study uses standard deviational ellipse to summarise the spatial characteristics of geographic features, including central tendency, dispersion, and directional tendency. The ellipse represents the spatial distribution direction and range of employment position data.

(2) Spatial Autocorrelation Analysis
Spatial autocorrelation analysis can examine whether the attribute values of elements with spatial locations are correlated with the attribute values at neighbouring spatial points, including global spatial autocorrelation and local spatial autocorrelation. The global Moran's I index is used to analyse the overall spatial correlation and spatial differentiation of the region, and then the Getis-Ord Gi* statistics are used to create hotspot and cold spot maps with statistical significance.

(3) Principal Component Analysis (PCA)
Principal Component Analysis (PCA) is a commonly used dimensionality reduction method that transforms a large number of complex linearly correlated variables into a smaller number of linearly independent principal components through orthogonal transformation, while preserving the main characteristics of the data and reducing its dimensionality. It effectively eliminates redundant information and extracts key features, thereby simplifying complex datasets. PCA projects high-dimensional data into a low-dimensional space by maximizing variance retention, and these principal components can be used for data visualisation, classification, clustering, and other applications.

(4) Hierarchical Cluster Analysis (HCA)
Hierarchical Cluster Analysis (HCA) is a method for grouping samples based on the similarity of their characteristic data. This method constructs a hierarchical clustering dendrogram by iteratively merging or splitting the most similar samples or clusters. The clustering process is conducted according to specific linkage criteria (such as nearest neighbour, farthest neighbour, and average linkage between groups). Ultimately, by analysing the hierarchical structure of the dendrogram, the optimal number of clusters and grouping schemes are determined based on research needs, revealing the inherent natural grouping patterns within the sample data.

3.3 Research Case

The case, Yangpu District (Figure 1), is located in the northeast part of Shanghai's central urban area, on the northwest bank of the lower reaches of the Huangpu River, covering an area of 60.61 square kilometres. It has jurisdiction over 12 sub-districts (the smallest administrative division in China). As of December 2024, Yangpu District has a population of 1.1997 million, with a density approaching 20,000 people per square kilometre. In the 2023 "15-minute community life circle" initiative in Shanghai, Yangpu District has delineated 33 15-minute community living circles, each with a population of approximately 36,000 and covering an area of about 1.8 square kilometres.

Yangpu District is located on the outskirts of the traditional work centre and has undergone industrialisation, rapid urbanisation, and urban renewal since its establishment as a district in 1960. Some areas of WJC Sub-district were planned as a sub-centre of Shanghai in 1991, while some areas of JPL Sub-district were planned as a regional centre in 2004. Additionally, the district is rich in educational and scientific resources, with 14 various types of higher education institutions, which accounts for more than one-third of the total number of higher education institutions in Shanghai. Therefore, there are various types of urban spaces present, including urban centres, new and old residential areas, remnants of industrial factories, and knowledge-intensive areas around universities. In terms of industry and economy, by 2024, the added value of the tertiary sector will account for 90.0% of the district's GDP, with traditional and emerging office industries such as new media, the internet, technological innovation, and finance being the key development targets for Yangpu District. In summary, Yangpu District is an excellent case study for researching office spaces and office centres.

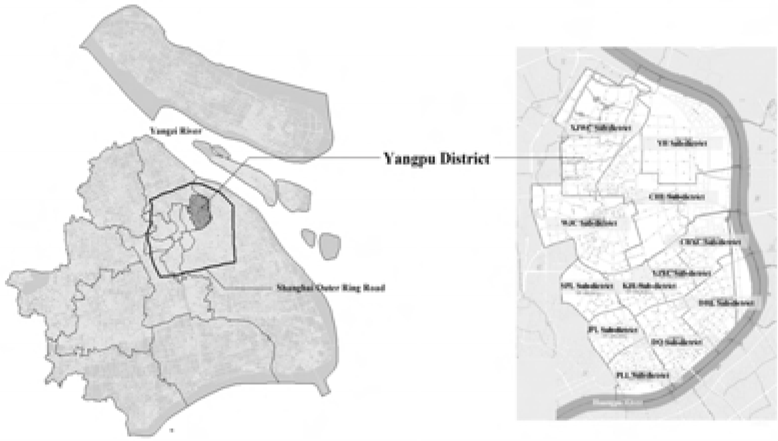

Figure 1. The location of Yangpu District

3.4 Data Description

In the hypothesis verification section, this study adopts a grid with a side length of 300 metres to describe the evolution trend phenomenon of the macroscopic office space distribution in Yangpu District, in order to lay the research foundation. By analysing the aggregation characteristics, characterisation accuracy and computational efficiency of employment facilities using spatial units of 100 metres, 300 metres, 500 metres and 1000 metres, it is found that the 300-metre grid can better represent the spatial distribution within Yangpu District.

Considering that this study mainly focuses on the distribution of office space and the identification of office centre locations at a more refined scale, although using the regular grid cutting base map as the analysis unit can effectively unify the research scale, this method has the following significant drawbacks: (1) Spatial fragmentation: The regular grid ignores the natural boundaries of the urban texture and may cut the complete functional areas into different grids; (2) Scale untruthfulness: Fixed grids are difficult to reflect the spatial heterogeneity between the dense road network in the central urban area and the sparse road network in the suburbs. Therefore, in the feature research section, an attempt is made to adopt the logic of “natural demarcation - functional integration” to divide the research units. The office centre land units are specifically delineated mainly through road and land use functions. The plots (different land use function sections) within the blocks (units enclosed and demarcated by urban public roads) are taken as the basic research units. The specific methods are as follows: By adopting the OSM open map to obtain the vector data of the entire road network in Shanghai, the four-level road network (expressways, main roads, secondary roads, and important branch roads) within Shanghai was extracted, and extract the centre line of the road network to simplify the road network into a single line. Reconstruct the topological network model again to eliminate redundant nodes and hanging points (node spacing) 50m automatic merge. The generated network model is used to cut the blocks to obtain the initial block units, and then the plot within the block are divided by referring to the land resource survey and unit planning of Yangpu District. Finally, inspect the plots and eliminate the area. For 200m^2 of fragmented patches, reduce the number of cracked plots and inspect the hard boundaries with expressways and major water systems. Cross-plot consolidation is prohibited. Finally, the area of Yangpu District was divided into 2,002 research units (Figure 2).

The point of interest (POI) data used in this study comes from Amap and is updated to 2024. Integrating the research of other scholars and the 20 major industry categories in the “National Economic Industry Classification Standard (GB/T 4754-2017),” this study selects the following data as categories related to the business office industry (Table 1), covering five major categories: life services, finance and insurance, automotive services, science and education culture, and corporate enterprises from the POI data accessed through Amap. To ensure the consistency between industry classification standards and POI data, this study cleaned the POI data for Yangpu District from 2014, 2019, and 2024, filtering to include key information such as company name, address, type, and geographical coordinates. The dataset contained 2,425 points in 2014, 3,975 in 2019, and 2,982 in 2024, leading to the establishment of a GIS spatial database for subsequent research.

In addition, the LBS data used to identify office centres comes from the Baidu Huiyan data platform, covering the period from November 11 to 17, 2024, with data selected from weekdays at 10, 11, 14, 15, 16 and 17 o'clock. The rest of the spatial data is sourced from the Amap, Baidu Map, and OSM. Considered that some indicators involve descriptions of the surrounding environment of plots, this study uses a 300-metre buffer zone around each plot as the calculation range. Specific data descriptions detailed in Table 2.

Figure 2. Research unit on Plot Accuracy in Yangpu District

Table 1. Office POI Types

Industry Type	POI Data Content
E - Construction industry	Construction companies, architectural firms
K - Real Estate Industry	Real estate companies, sales centres, real estate agencies, property management companies
P - Education Industry	Cultural and educational companies, training institutions
R - Culture, Sports, and Entertainment Industry	Cultural media companies, animation design companies
I - Information Transmission, Software, and Information Technology Service Industry	Telecommunication business halls, graphic and text advertising companies, postal services, information technology service companies
M - Scientific Research and Technical Service Industry	Technology companies, high-tech companies, research institutes

J - Financial Industry	Banks, securities companies, trading companies, insurance companies, futures companies
L - Leasing and Business Service Industry	Car rental companies, machinery rental companies, daily necessities rental companies, advertising companies, management consulting companies, law firms, accounting firms, assessment firms, certification firms, patent firms, talent markets

Table 2. Spatial data sources

Data Name	Data Description	Data Source	Data update time
Office function - Point Data	Data points that describe the distribution of office functions. Obtained based on the classification and screening of Amap POI.	Amap API https://lbs.amap.com/api	2014 -2019-2024
Behavioural activity heat - Point Data	Vitality statistics of urban at different times based on "mobile device location services".	Baidu Huiyan https://huiyan.baidu.com	2024. Sep.11-17
Urban road network – Polyline Data	Urban road network information, including road classification	Open Street Map https://openstreetmap.org	2024
Urban architecture - Polygon Data	Urban completed building data, including location, area, and height, number of floor.	Baidu Map	2024
Urban functional area - Polygon Data	Urban functional zone data, including functional classification, location and area.	Amap API https://lbs.amap.com/api	2024
Urban public/commercial service - Point Data	Data points that describe the distribution of public/commercial service. Obtained based on the classification and screening of Amap POI.	Amap API https://lbs.amap.com/api	2024

4 Distribution Characteristics of Office Spaces in Yangpu District

4.1 Overall Distribution Exhibits a Trend of Decentralisation

Using the standard deviation ellipse analysis method, we visually compare the spatial distribution of POI data for business office enterprises in Yangpu District for the years 2014, 2019, and 2024. In this analysis, the first-order standard deviation ellipse covered 63% of the point elements within the study area. Specifically, the standard deviation ellipse for 2014 had a long axis of 2710.14 metres and a short axis of 1902.63 metres(Figure 3a); in 2019, the long axis was 3041.61 metres and the short axis was 2055.78 metres(Figure 3b); and in 2024, the long axis measured 3306.87 metres and the short axis was 2013.33 metres(Figure 3c). The standard deviation ellipses from 2014 to 2019 show significant expansion in both the long axis and short axis, with the area also increasing, indicating a trend from concentration to decentralisation in the distribution of business office enterprises in Yangpu District over these five years. From 2019 to 2024, the changes in the standard deviation ellipse are minimal, suggesting that on a macro scale, the decentralised characteristics relative to 2014 have been maintained, while potential adjustments in the distribution structure at the micro level are occurring, which is a topic for further research.

Figure 3a, 3b, 3c. The standard deviation ellipse of office space distribution in 2014, 2019 and 2024

4.2. Evolutionary Pattern of "First Dispersal, Then Re-aggregation" Forms Hierarchical Office Centres
Quantitative visualisations of the POI data of business offices in Yangpu District for the years 2014, 2019, and 2024 were conducted, utilizing the local spatial autocorrelation Getis-Ord G* statistic to identify hotspots and describe the aggregation characteristics of business office functions over different periods. According to the illustrations, in 2014(Figure 4a, 5a), the business office functions in Yangpu District were primarily aggregated around important urban functional areas, including the WJC urban sub-centre and the JPL regional centre. By 2019(Figure 4b, 5b), the area of business office function hotspots significantly increased in the WJC sub-centre and JPL regional centre, with a few point-like and linear business office hotspots emerging in the central hinterland outside the urban core. In 2024(Figure 4c, 5c), the planned urban sub-centres and regional centre business office functions continued to enhance; additionally, more business office functions concentrated in the central hinterland and certain areas in the northern suburbs, forming point-like decentralised office centres.

Figure 4a, 4b, 4c. Statistical description of office POI distribution (Jenks) in 2014, 2019 and 2024

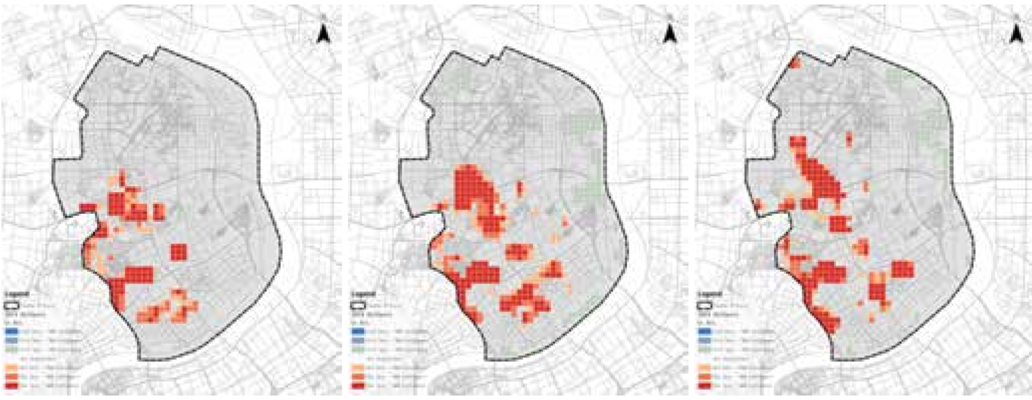

Figure 5a, 5b, 5c. Identification of Office Hotspots in 2014, 2019, and 2024

Quantitative visualisation of the changes in the number of business office POIs within the grid from 2014 to 2019 and from 2019 to 2024 was conducted to explore the evolutionary pattern of the distribution of business office functions in Yangpu District. The chart reveals that between 2014 and 2019(Figure 6a), most areas in Yangpu District, including some hinterland regions primarily characterised by residential functions, showed an increasing trend in the number of office enterprises. The area with the largest increase was the rapidly developing WJC urban sub-centre. During this period, the number of office POIs in the central urban area of Shanghai, including traditional business office centres like People's Square and Lujiazui, was sharply declining. From 2019 to 2024(Figure 6b), there was a decrease in the number of business office enterprises in most residentially dominated areas in Yangpu District, while a few grids within the reduction area showed significant increases. Specific sectors that saw growth included the WJC urban sub-centre, KIC Space, the National University Science Park of SUFE, Changyang Innovation Valley, and Yangpu Riverside.

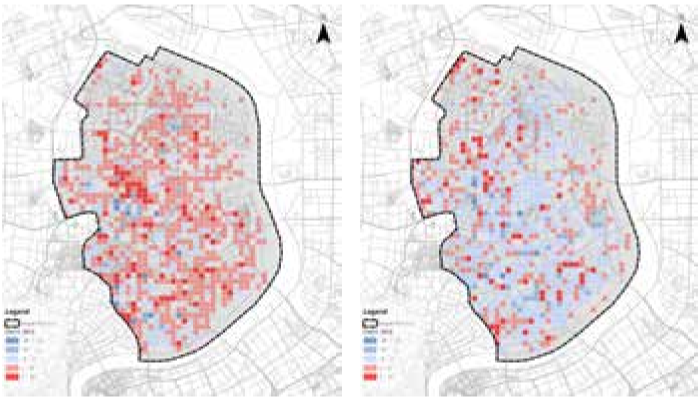

Figure 6a, 6b. Changes from 2014 to 2019 and from 2019 to 2024

Overall, the preliminary description of the evolutionary pattern during the 2014-2019 phase is that office functions dispersed significantly from the urban office centres of Shanghai to the emerging urban sub-centres and residential blocks outside the urban core in Yangpu District. In the 2019-2024 phase, the business office functions that surged in Yangpu District during the previous five years began to re-aggregate at a microscopic scale in localised areas. While the urban sub-centres and regional centres continue to develop, the functionality of secondary point-like office centres outside the urban core is also steadily enhancing.

5. Exploration of the Spatial Patterns and Typological Characteristics of Office Centres in Yangpu District

5.1 Identification of Office Centres

The identification of office centres in Yangpu District employs a "function-heat" dual-verification method. The data used consists of cleaned 2024 office POIs in Yangpu District and 2024 LBS data. Utilizing ArcGIS software, spatial overlay statistics were conducted on the density of office POI points within plots (research units), and natural breaks were applied for visualisation (Figure 7a). Additionally, kernel density calculations were performed on 100-metre precision point LBS data to conduct overlay statistics of crowd activity heat during office hours for each research unit from November 11 to 17, 2024, with natural breaks again used for visualisation (Figure 7b). Ultimately, research units exhibiting significantly high values in both office function and activity density were selected, resulting in the identification of 197 office centres in Yangpu District.

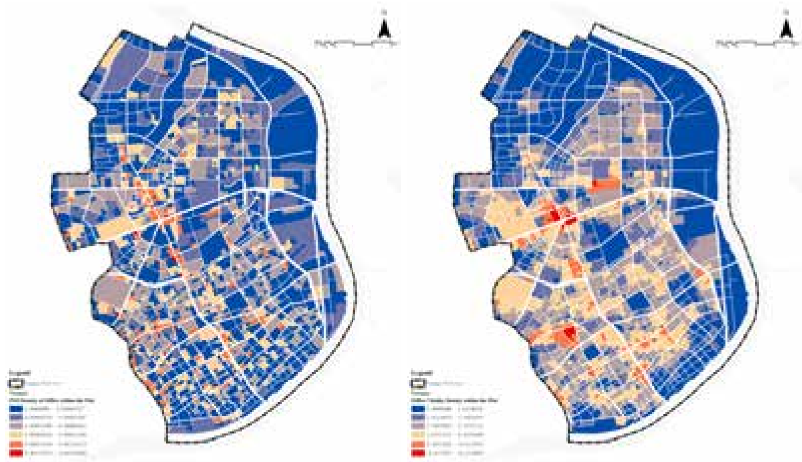

Figure 7a. Office centre identified based on functional data
Figure 7b. Office centre identified based on behavioural activity data

5.2 Spatial Pattern Analysis Framework and Key Factor Extraction

The formation and evolution of office centres are the results of the synergistic effects of multiple factors. To systematically deconstruct the spatial organisational logic of office centres in Yangpu District, this section extracts spatial pattern characteristic analysis factors from multiple dimensions, aiming to transcend the limitations of traditional one-dimensional research by incorporating the locational potential, material carriers, and functional environments of office centres into a unified analytical system. In the end, 17 key influencing factors were summarised and extracted for research, forming a dynamic and multidimensional spatial analysis system. The extraction logic for core factors across various dimensions is described in Table 3.

Table 3: Key Characteristic Factors and Descriptions of the Spatial Patterns of Office Centres

Dimension	Indicator		Description
Location	Loop Location	virtual variable	The location relationship of office centres in the city (within the inner ring, from the inner ring to the Middle ring, from the Middle ring to the Outer Ring)
	Transportation Location	km	The distance from the office centre to the main and secondary roads of the city
	Public Transportation Location	km	The distance from the office centre to the subway station
Form	Spatial Density	m^2/km^2	The ratio of the total base area of buildings to the total area of the plot
	Floor Area Ratio	Score	The ratio of the total floor area of all buildings within the plot to the total area of the plot
	Maximum Building Height	m	The maximum building height within the plot
	Road Network Density	km/km^2	The ratio of the total length of the road network around the office centre to the total area of the buffer zone
Function and environment	Educational Density	pcs/km^2	The POI density of schools, training institutions, etc. around the office centre
	Traffic Density	pcs/km^2	The POI density of subway stations and bus stops around the office centre
	Medical Density	pcs/km^2	The POI density of hospitals, clinics, etc. around the office centre
	Catering Density	pcs/km^2	The POI density of restaurants, cafes and other facilities around the office centre
	Culture, Sports And Entertainment Density	pcs/km^2	The POI density of museums, theaters, gyms, etc. around the office centre
	Poi Shannon Index	Score	Measure the diversity and degree of mixture of different types of POIs around the office centre
	Proportion Of Residential Land	km^2/km^2	The proportion of residential land area around the office centre
	Resource Distance	km	The distance from the office centre to universities and research institutions
	Central Distance	km	The distance from the office centre to the city centre
	Green Space Distance	km	The distance from the office centre to the public park

5.3 Principal Component Analysis

After collecting all the indicators, a preliminary data quality check was conducted to eliminate indicators with severe missing data or insufficient variability. Then, Z-Score standardisation was applied to different dimensions and data types to create a standardised data matrix, eliminating weight shifts caused by numerical differences. During this process, dummy variable elements were also standardised through methods such as feature multiplication, resulting in a matrix with only 0 and 1. The variable "ring location" was split into three variables: "within the inner ring," "between the inner and middle rings," and "between the middle and outer rings."

The final summary results are shown in Appendix Figure x1-x17. Subsequently, the SPSS tool was utilised to perform PCA on the 17 indicators based on the correlation coefficient matrix for dimensionality reduction analysis, yielding a total of 12 principal components (PC1-PC12). According to the Total Variance Explained in Table 4 and the scree plot shown in Figure 8, the cumulative explanation rate of the first 5 principal components is approximately 80.2%, with a notable gap compared to the subsequent eigenvalues. Therefore, considering spatial complexity and interpretability, this study comprehensively uses the first five principal components to characterise the spatial patterns of office centres.

Table 4. Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.348	28.900	28.900	3.348	28.900	28.900
2	1.748	15.567	44.466	1.748	15.567	44.466
3	1.547	13.888	58.355	1.547	13.888	58.355
4	1.230	11.250	69.605	1.230	11.250	69.605
5	1.152	10.599	80.203	1.152	10.599	80.203
6	0.773	5.442	85.646			
7	0.632	4.270	89.915			
8	0.577	3.810	93.726			
9	0.374	2.119	95.844			
10	0.243	1.529	97.373			
11	0.195	1.327	98.701			
12	0.180	1.299	100.000			
Extraction Method: Principal Component Analysis.						

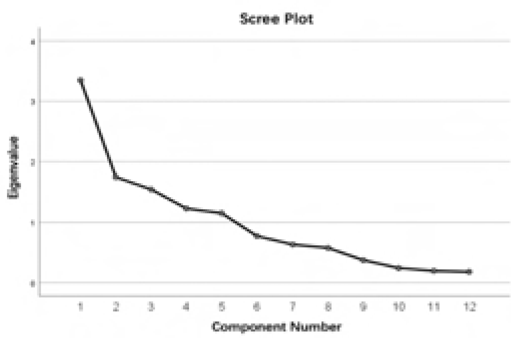

Figure 8. Scree Plot

Based on the component loading matrix (Table 5) to better explain the correlation between each principal component and each element. The specific analysis is as follows:

Table 5. Component Matrix

	Component 1	2	3	4	5
Zscore(Floor Area Ratio)	0.247	0.650	-0.511	0.396	0.035
Zscore(Maximum Building Height)	0.297	0.574	-0.670	-0.104	-0.065
Zscore(Building Density)	-0.095	0.014	0.099	0.369	0.145
Zscore(Road Density)	0.436	0.374	0.600	0.053	-0.032
Zscore(Distance to the Metro	-0.530	-0.257	-0.033	0.416	-0.102
Zscore(Distance to the City Center)	-0.676	-0.117	-0.078	0.090	0.347
Zscore(Distance to the Main Road)	-0.292	0.516	0.242	-0.270	0.452
Zscore(Distance to Universities/Research Institutions)	0.166	0.534	0.608	-0.457	0.055
Zscore(Proportion of Residential Area within the Buffer Zone)	-0.415	-0.028	-0.127	-0.067	0.732
Zscore(Education POI Density within the Buffer Zone)	0.799	-0.211	-0.119	-0.016	0.421
Zscore(Culture and Sports POI Density within the Buffer Zone)	0.820	-0.289	0.036	0.042	0.193
Zscore(Catering POI Density within the Buffer Zone)	0.816	-0.311	-0.019	0.148	0.186

Extraction Method: Principal Component Analysis.
a 5 components extracted.

(1) PC1 (explanation rate 28.9%): Urban centrality, comprehensive support intensity, and transportation accessibility. From the loading matrix, we can see that the indicators with a large positive loading in PC1 include: density of dining POIs (0.816), density of cultural, sports, and entertainment POIs (0.820), and density of educational POIs (0.799), as well as the density of public services and commercial facilities. Additionally, road density (0.436), maximum building height (0.297), and floor area ratio (0.247) also contribute positively. The corresponding indicators with significant negative loadings include: distance to the central area (-0.676), distance to the subway station (-0.530), and proportion of residential land nearby (-0.415). Overall, combining the two significant negative loadings of "distance to the central area" and "distance to the subway station" (-0.530), along with the high density of various public services/commercial facilities (dining, cultural entertainment, education, etc.), PC1 represents a gradient from high-support, high-function mixed-use in the city centre to low-support, low-mix in the outer ring and suburbs. It reflects the characteristics of the urban core area, manifested as high-density public service facilities, central location advantages, and high-rise, high-intensity building layouts. Higher scores indicate proximity to the core urban area, with convenient public transportation and comprehensive facilities, as well as a high degree of spatial mixing in functional layouts.

(2) PC2 (explanation rate 15.6%): Emerging areas outside the centre and high-intensity TOD development. In PC2, the indicators with a significant positive loading include: floor area ratio (0.650), building height (0.574), and road density (0.374) related to public services and commercial facilities. Moreover, road density (0.436), maximum building height (0.297), and floor area ratio (0.247) contribute positively as well. The corresponding indicators with significant negative loadings include: densities of various public services/commercial facilities, distance to the subway station (-0.257), and distance to the central area (-0.117). PC2 reflects development characteristics of high-intensity urban expansion areas around subway stations from the city centre. Higher scores indicate areas near the city centre that are well-serviced by public transportation, primarily focusing on business office functions, with high road network density, small plot sizes, and high building development intensity, embodying the features of emerging urban functional areas.

(3) PC3 (explanation rate 13.95%): Old city renewal. In PC3, the primary positively loaded variables include: road density (0.600) and distance to universities/research institutions (0.608), while the main negatively loaded variables are floor area ratio (-0.511) and maximum building height (-0.670). Overall, combined with the high road density reflecting a mature road network foundation and significantly lower-than-average development intensity (with floor area ratio and building height as strong negative loadings) and density of public/commercial services, PC3 characterises areas of old city renewal where spatial forms are constrained by historical textures, following a gradual renewal model. It is characterised by a high-density road network post-renewal, dominated by low-rise, high-density large-scale buildings, markedly lower development intensity than emerging business districts, and spatial separation from core higher education and residential areas.

(4) PC4 (explanation rate 11.3%): Island effect of scientific and educational resource concentration. In PC4, the main positively loaded variable is distance to the subway station (0.416), while the significant negatively loaded variable is distance to universities/research institutions (-0.457). This loading combination indicates that areas with higher PC4 scores are closer to universities/research institutions but have significantly poorer accessibility to the subway. Overall, PC4 reveals the spatial mismatch between areas of high concentration of scientific and educational resources and public transportation infrastructure (especially rail transportation), reflecting typical characteristics of traditional cultural and educational districts or emerging scientific and educational parks (such as university towns without subway access) — despite the high concentration of educational functions and substantial knowledge spill over, they form relatively isolated "office enclaves" due to insufficient rail coverage.

(5) PC5 (explanation rate 10.6%): Centrality of residential communities. In PC5, the main positively loaded variables include: proportion of surrounding residential land (0.732), density of educational POIs (0.421), distance to the central area (0.347), and distance to main roads (0.452). This combination points to urban peripheral residential communities dominated by residential function and educational service: a high proportion of residential land and dense educational facilities drive community functionalities, while the positive loading for distance from the city centre (0.347) further reinforces its spatial location characteristics. Therefore, PC5 represents community service centres in the urban fringe or suburbs, centred on residential functions, supported by education-related facilities. Higher scores indicate greater distance from the city centre and main roads, reflecting the characteristics of peripheral residential community service centres.

5.4 Hierarchical Cluster Analysis

This study primarily references the HCA methods and parametre designs used by Dibble et al. in urban morphology research. Euclidean distance is employed as the measure of similarity between observation points (office centres). The linkage method selected is Ward's linkage, which tends to generate clusters with minimised variance and higher homogeneity within groups, making it widely used in urban morphology studies. In terms of selecting the number of clusters, this research tested various group numbers (k=3, 4, 5, etc.) and found that the clustering effect is optimal when k=5. The HCA clustering operations were completed using SPSS.

Based on the results of HCA, this study categorises office centres into 5 different spatial patterns (Figure 9) each exhibiting unique location characteristics, spatial forms, and functional environments. The arithmetic averages of PC1 to PC6 by cluster were calculated to characterise the results and features of each specific cluster (Table 6).

Table 6. HCA clustering results and Characteristic Interpretation of Office Centres in Yangpu District

	PC1	PC2	PC3	PC4	PC5
Cluster1	0.1779	1.0025	-2.3231	0.5437	-0.5773
Cluster2	-1.5839	-0.8558	-0.0114	0.4277	-0.5464
Cluster3	0.5596	1.5005	1.6086	-0.9275	-0.4962
Cluster4	-1.7495	0.1151	-0.1886	-0.3148	1.5482
Cluster5	6.6383	-1.6928	0.149	0.3588	0.5753

Among them, Cluster 1 (East Shanghai Lehoo Square, Sanhaowan Plaza, Yangpu Technology Building, China (Shanghai) Entrepreneur Public Training Base, Baodi Square, etc.) exhibits typical characteristics of newly built Transit-Oriented Development (TOD) commercial buildings that overflow from the central area, with a core focus on high-rise office buildings located near the urban centre and subway stations. Cluster 2 (Huantongji Industrial Circle, East Shanghai Technology Park, Fudan University South Campus, Shanghai University of Finance and Economics Science and Technology Park, etc.) is characterised by knowledge spillover around universities and the re-use of existing land to form industrial clusters. It leverages university resources and research institutions, possessing strong capabilities for technology promotion and application. Some areas are developed or updated based on existing plots around the universities, creating diverse spatial forms that support the development of knowledge-intensive industries. Cluster 3 (Interlink Baodi, Changyang Innovation Valley, Dongfanggu Creative Park): This cluster includes a combination of industrial relics from the old city and newly built commercial buildings forming comprehensive industrial parks, showcasing the integration of traditional urban renewal and creative industries. These areas, despite having a high historical background and urban hinterland advantages, utilise industrial buildings to concentrate technology promotion, professional technical services, and creative cultural industries, resulting in a more diversified industrial structure and significant urban renewal demands. Cluster 4 (Xuhui Plaza, Core Area of Xinfengcheng Residential District, Guohe 1000 Community Commercial Centre, etc.): This cluster features small-scale decentralised community service centres and office We-work spaces, located within areas primarily designated for residential functions, mixing with newly built large public buildings such as apartment buildings, community commercial centres, and community clubhouses. These spaces are typically smaller in scale, possess a certain degree of transportation convenience, and generally serve as office spaces preferred by small and micro-enterprises and start-ups. Cluster 5 (WJC Urban Sub-Centre): This cluster demonstrates characteristics typical of a high-energy urban CBD core area.

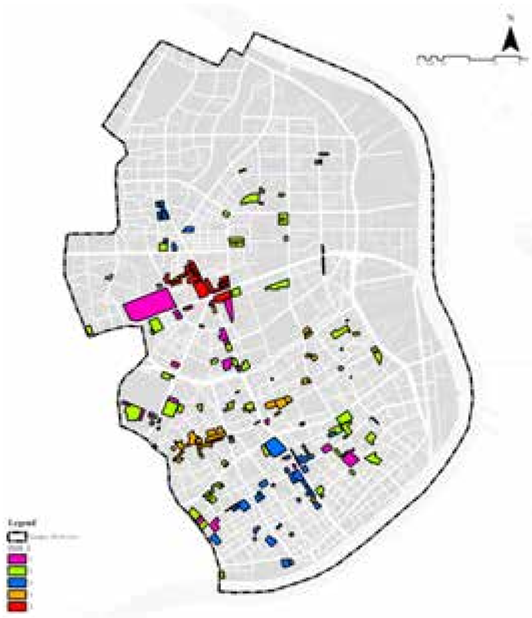

Figure 9. HCA clustering results

6 Conclusions

The main purpose of this study is to explore the distribution patterns and typological characteristics of urban office spaces and office centres in Yangpu District, Shanghai, at a fine scale. Through the integration of geographic information big data and field research, a series of important conclusions have been drawn.

Firstly, the study found a significant phenomenon of dispersion and re-aggregation in office spaces. This indicates that, with the rapid development of information technology, office spaces have gradually expanded from traditional Central Business Districts (CBDs) to peripheral areas, forming several small-scale office centres between specific locations. This trend reflects the ongoing evolution of the work-residence relationship in cities, as the advancement of communication technology and changes in office patterns have led to a demand for flexibility and diversity in the working environment, particularly among the younger generation.

Secondly, the analysis shows that office centres are typically located in areas with a mixture of urban functions, urban centrality, convenient public transportation, and close proximity to residential communities and universities. This finding emphasises the importance of integrating office spaces with urban functions.

Furthermore, through hierarchical cluster analysis, the study identified five types of office centres in Yangpu District: newly constructed TOD commercial buildings that overflow from the central area, mini industrial clusters formed by knowledge spillover and re-use of existing land around universities, comprehensive industrial parks that result from the renewal of industrial relics in the old city and newly built commercial buildings, decentralised small-scale office We-work spaces in community service centres by function multiply used, and high-energy urban CBD core areas.

This research contributes to a deeper understanding of urban office spaces in the internet era and provides theoretical support and practical guidance for the development and refined organisation of business office functions and employment spaces in Shanghai and other megacities in China.

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Appendix: Description of the characteristics of the Office Centre in Yangpu District

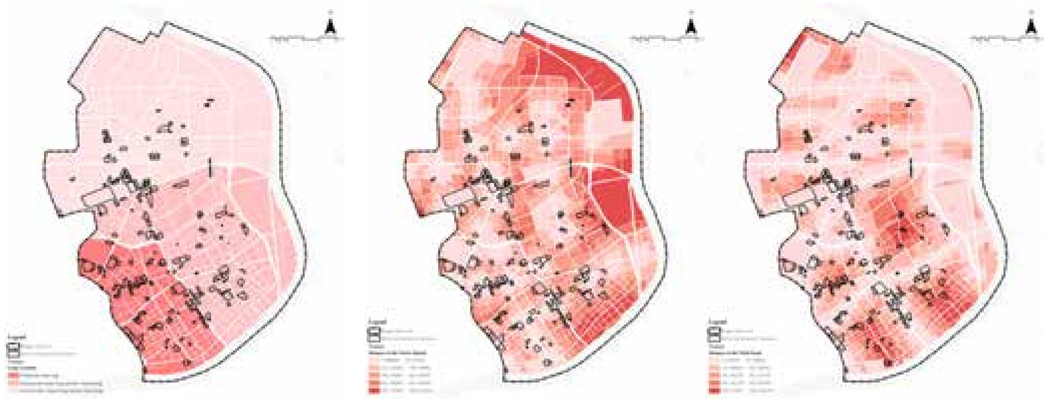

Figure x1. office centre feature - Loop Location
Figure x2. office centre feature - Public Transportation Location
Figure x3. office centre feature - Transportation Location

Figure x4. office centre feature - Spatial Density
Figure x5. office centre feature - Maximum Building Height
Figure x6. office centre feature - Floor Area Ratio

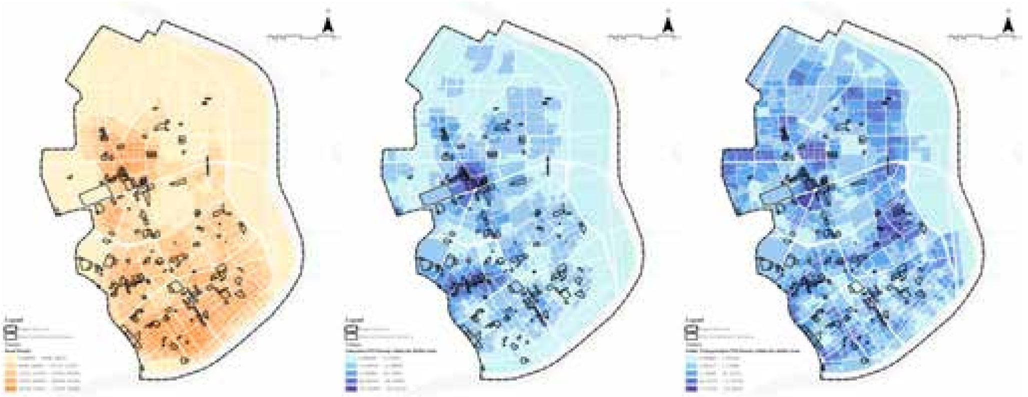

Figure x7. office centre feature - Road Network Density
Figure x8. office centre feature - Educational Density
Figure x9. office centre feature - Traffic Density

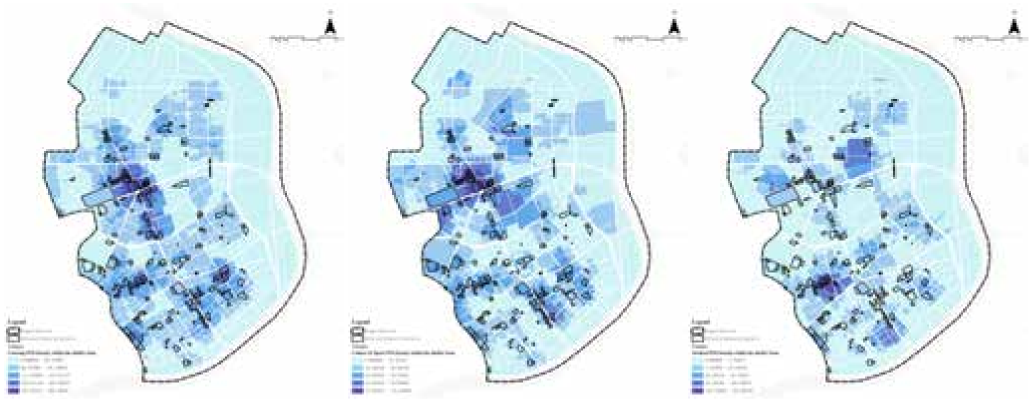

Figure x10. office centre feature - Catering Density
Figure x11. office centre feature - Culture, Sports And Entertainment Density
Figure x12. office centre feature - Medical Density

Figure x13. office centre feature - Poi Shannon Index
Figure x14. office centre feature - Proportion Of Residential Land
Figure x15. office centre feature - Central Distance

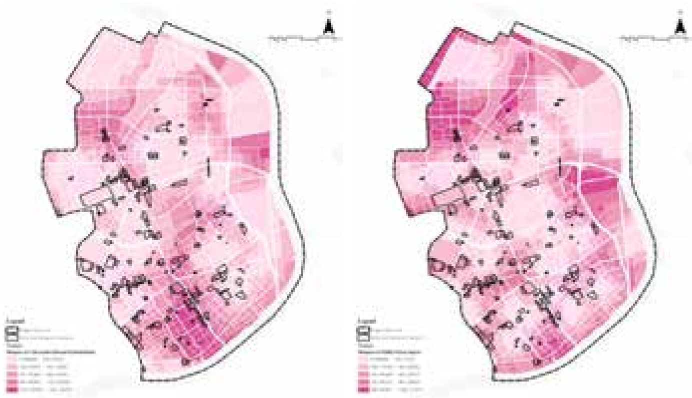

Figure x16. office centre feature - Resource Distance
Figure x17. office centre feature - Green Space Distance