

Article

Exploring the Impact of Urban Amenities on Business Circle Vitality Using Multi-Source Big Data

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Abstract: Urban business circles are important locations for economic and social activities. Improving the vitality of urban business circles is conducive to stimulating the potential of the consumer market and promoting sustainable economic development. However, targeted research on the factors influencing business circle vitality is lacking. Therefore, in this study, we aimed to quantitatively examine the impact of the number and diversity of urban amenities on business circle vitality at the street block level using open-source geospatial big data from 32 Chinese metropolises. We found that the number of residential, transportation, educational, cultural, and recreational amenities and the diversity of catering and retail amenities had significant positive impacts on business circle vitality. Catering and retail diversity were the two most critical factors, followed by the number of transportation, cultural, and recreational amenities. However, the effect of urban amenities on business circle vitality varied considerably across different cities and business districts. The results of this study contribute to a holistic understanding of how to improve the vitality of business circles by optimizing urban amenities at the street block level.

Keywords: urban amenities; business circle vitality; big data



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1. Introduction

As urban development gradually moves from the industrial to the post-industrial era, the contribution of traditional resources or capital investments to economic growth diminishes [1]. Modern consumption-based economies have emerged as important sources of economic growth. Thus, the importance of cities increasingly depends on their role as consumption centers [2]. As shown by major cities such as New York, Tokyo and Shanghai, consumption vitality has increasingly become a new driving force of urban development. Since the 21st century, the importance of many major cities has increasingly depended on their role as centers of consumption rather than production [2]. Stimulating the vitality of the consumer market and promoting the development of urban commerce are conducive to maintaining the quality of life of residents and supporting the sustainable development of economies. Furthermore, urban consumption, leisure, and entertainment have become important attractions for young talent and are key to improving cities' competitiveness. Improving urban commercial vitality and creating a favorable consumer environment have gradually become the focuses of local governments in China [3]. The urban business circle is a radiation area where stores expand in a certain direction and distance to attract customers [4]. As a promoter of urban commercial activities, it fulfills important functions such as meeting shopping needs and providing leisure and entertainment. Therefore, exploring the impact of urban amenities on business circle vitality at the street block level is of great practical importance for meeting residents' consumption demands and contributing to sustainable urban development.

However, existing research on business circle vitality and its influencing factors is inadequate. In terms of business circle delimitation, previous researchers have assumed that a business circle radiates outward from a business center while ignoring the fact that people's social and economic activities occur via street networks [2]. Moreover, some studies have delimited business circles based on equidistant grids, which may not reflect the actual spatial structure of a city [4,5].

Furthermore, collecting large-scale data on business circle vitality from fine spatiotemporal units is challenging. In general, business circle vitality can be measured based on the volume or density of pedestrian flow in the business circle [6]. Traditional studies have relied heavily on field survey data to estimate population dynamics. This data collection is cumbersome and time consuming. In recent years, with the rapid development of communication technology, the increasing number of mobile phone users, and wide use of Web2.0 applications, the connection between cyberspace and the geographical location of human activities has been realized [7–9]. Various spatial and temporal marker data, including global positioning system (GPS) data, mobile phone signals, and social media location records, are gradually making it possible to measure urban vitality accurately [10,11]. However, previous studies have examined the vitality of the city as a whole, ignoring the categorical refinement of functions within the city [12–14]. On this basis, scholars have studied the impact of factors such as mixed land use [15,16], the built environment [17–20], the urban landscape [21,22], urban design [23,24], urban traffic planning [25] and urban infrastructure [1] on urban vitality. However, these studies are not well targeted because the functions and social attributes of different areas within the city are different.

The urban business circle is the urban core functional area, with intensive land use and active commercial activities. It is also an important place in terms of enhancing urban consumption vitality, affecting the economic development of the entire city. Therefore, it is very important to conduct in-depth research on business circle vitality in order to propose targeted optimization paths. Research on the impact of urban amenities on business circle vitality is limited. Additionally, there is a lack of research on the heterogeneity of this effect across cities and business circles.

To address the gaps in the existing research, we used multi-source big data and the temporal distance to delimit urban business circles based on the identification of street blocks. Additionally, rather than focusing on urban vitality at the city scale, we studied more refined and targeted business circles and aimed to examine the impact of the number and diversity of urban amenities on business circle vitality at the block level. Moreover, we expanded the study of urban business circle vitality from a single city to 32 cities in China and analyzed heterogeneity across different cities and business circles.

The remainder of this paper follows. Section 2 reviews and summarizes the literature on urban business circle vitality. Section 3 details the data and methodology. Section 4 presents the results of this study. Section 5 discusses the results and Section 6 concludes this paper.

2. Literature Review

2.1. Delimitation of Urban Business Circles

In terms of the delimitation of urban business circles, existing studies are mainly based on the qualitative identification of business centers or the quantitative delimitation of business circles based on point of interest (POI) data. For example, Shi et al. [2] unified the study area as core business circles with a uniform radius of 500 m when analyzing the spatial characteristics of the number of takeouts in Shanghai's business circles. Shi et al. [5] used POI data from shopping centers to visualize the spatial distribution and structural characteristics of Shanghai's business circles through hot spot analysis. These methods typically assume that geographical space is a continuous uniform plane and that the distance between two points can be measured using the Euclidean distance. In reality, geographical spaces are heterogeneous, with various geographical elements along a network of streets [26]. Therefore, scholars have proposed replacing the plane with road network space,

and replacing plane kernel density estimation (KDE) with network KDE [27]. However, both planar and network KDE only change the similarity measurement method for commercial POIs and do not consider the characteristics of road network density in business districts. Based on this, Yang et al. [28] proposed a commercial intersection KDE method that combines road intersections with KDE and used it to identify the central business district of Nanjing using POI data and road networks. In contrast to previous studies, the current study proposes a method to delimit business circles using temporal distance by combining multi-source big data on factors such as POIs and road networks and from sources such as location-based services (LBSs). When customers decide which store to visit, they prefer those where visits take less time. Therefore, temporal distance, which is closer to psychological distance, is more valuable in decision making and can delimit urban business circles with high precision, but has been rarely addressed in previous research [26].

2.2. Urban Business Circle Vitality

With the widespread use of geotagged data, such as mobile phone locations, social media check-ins, and transit smart cards, researchers can capture the concentration of people in cities in a timely and efficient manner [7,9]. This provides new opportunities to measure urban business circle vitality quantitatively. However, only a few quantitative analyses of the factors that influence the vitality of urban business circles have been conducted. Relevant studies have mainly focused on the overall city level [12–14]. Gao et al. [29] found that POI density, building density, and road intersection density had a significant positive effect on urban vitality, using Munich as an example. Mouratidis and Poortinga [30] used geospatial data from the Oslo metropolitan area to establish that urban vitality was mainly shaped by neighborhood density and land use mix. Huang et al. [31] found that urban functions, accessibility, and walkability were associated with urban vitality. Wu et al. [32] argued that a vibrant urban environment relies on effectively developed urban functions catering to residents' needs. Wang et al. [16] measured the urban vitality of Beijing using social media check-in data, finding that enriching land use functions contributed to enhancing urban vitality. Zhang et al. [21] identified convenient transportation, compact city block forms, and diverse building esthetics as the main characteristics influencing the vitality of a city. However, these studies, which were based on the city as a whole, lacked specificity.

In micro-scale studies, different types of activity spaces in cities should be considered. The main types of activity space found in urban business circles relate to commerce, leisure, and entertainment. Commerce is one of the most important functions of a city. A reasonable commercial layout and diversified commercial types are necessary for the occurrence of urban vitality. However, scholars have paid little attention to the urban business circle, which is a representative urban public space. Gao et al. [33] explored business district vitality in Guangzhou using mobile phone data and found that factors such as metro accessibility, POI density, road density, and the land use mixture were positively correlated with business district vitality. However, this study focused on a single city. In the current study, we subdivided various types of urban amenities, explored the impact of amenities on business circle vitality in multiple cities, and analyzed their heterogeneity.

3. Materials and Methods

3.1. Study Area and Data Sources

We selected the built-up areas of 32 representative metropolises in China as the study areas: Beijing, Shanghai, Shijiazhuang, Taiyuan, Xi'an, Jinan, Zhengzhou, Shenyang, Changchun, Harbin, Nanjing, Hangzhou, Hefei, Nanchang, Fuzhou, Wuhan, Changsha, Chengdu, Guiyang, Kunming, Guangzhou, Lanzhou, Xining, Hohhot, Urumqi, Nanning, Yinchuan, Dalian, Ningbo, Haikou, Shenzhen, and Qingdao. Most of these cities are provincial capitals from a wide range of geographic regions, spanning the major economic, political, and cultural regions of China. Furthermore, the data from these cities are relatively complete, reliable, and easy to collect.

The data included the following categories: (1) The first category was street network data. City blocks were generated based on street network data obtained from Gaode Map, which is a popular electronic navigation map in China. The original data contained many details that could lead to mistakes when converting road polylines into block polygons. Therefore, we performed preprocessing to simplify the original data. (2) The second category was LBS data. The density of pedestrian flow in urban business circles was obtained from “Tencent Location Big Data”. Data were collected on 23 October 2019 (weekday), and 26 October 2019 (weekend), at 10:00, 19:00, and 22:00 local time. We averaged the density of the pedestrian flow for these periods. (3) The third category was POI data. We collected POI data from multiple sources. Gaode Map mainly includes location information for POIs, such as transportation, education, healthcare, dining, shopping, finance, attractions, housing, sports, government, and companies, with a total of 13 classifications. Data on the number of residences and office buildings were obtained from “Home Link”, which is a real estate brokerage firm. The location information for various indicators of retail and catering diversity was derived from “Dianping”, which is a popular app used to categorize and rate local businesses. Data were collected from 18 to 20 October 2019. Table 1 lists the sources of each type of data. All data contained longitudinal and latitudinal information. We integrated all data based on latitude and longitude coordinates. There are potential problems in using different data types, such as inconsistent data locations and invalid data. Therefore, we bias-corrected and processed the acquired data.

Table 1. Data sources.

Data	Type	Data source
Street network data		Gaode Map (https://www.amap.com) (accessed on 20 October 2019)
LBS data		Tencent Location Big Data (https://heat.qq.com/bigdata/index.html) (accessed on 23, 26 October 2019)
POI data	Transportation, education and healthcare, etc., 13 classifications	Gaode Map (https://www.amap.com) (accessed on 20 October 2019)
	Residences and office buildings	Home Link (https://www.lianjia.com) (accessed on 18 October 2019)
	Various indicators of retail and catering diversity	Dianping (https://www.dianping.com) (accessed on 18 to 20 October 2019)

3.2. Methodology

3.2.1. Measuring Urban Business Circle Vitality

The explained variable in this study is urban business circle vitality, which can be measured based on the density of pedestrian flow in a business circle. We synthesized road network, POI, and LBS data to measure the density of pedestrian flow in business circles in the selected cities. First, street blocks were identified. The street block network schematic is an abstract representation of physical blocks [26]. Compared to an equidistant grid division, it retains the original spatial structure of the city and does not mechanically divide the urban amenities and environment, resulting in a schematic that better aligns with people’s cognitive habits. We considered a closed polygon (mesh) as the basic unit and used the independence and adjacency of the mesh to form the polygon-growing algorithm. The core ideas of the polygon-growing algorithm are to classify the road network into closed polygons and non-closed line segments and to complete the identification of street blocks through the closed polygon extraction, mapping, and optimization of the main line and the non-closed line segment combination of the auxiliary [24].

Following street block identification, we organized the collected POI data into street blocks for statistical analyses. We classified the blocks according to the most dominant POI category and merged adjacent blocks of the same type. Based on the LBS data, we screened

the blocks classified as businesses and selected those with a pedestrian flow density of more than 1000 people/hm² as potential urban business circles.

As a business circle is defined as a radiation area where stores expand in a certain direction and distance to attract customers [4], we identified the central gathering points for these business blocks based on the data showing the highest pedestrian flow density. We calculated the areas within a 5 min, 10 min, and 15 min walk from the central gathering points. A schematic of this process is shown in Figure 1a. On this basis, we matched the areas within a 15 min walk from the central point to city blocks. We chose 15 min because it is a relatively comfortable and acceptable walking time threshold for most people. We merged the boundaries of the blocks that intersected with those of reachable areas to form the boundaries of the urban business circle (Figure 1b). After delimiting the boundaries of the business circle, we calculated the density of the pedestrian flow in the business circle.

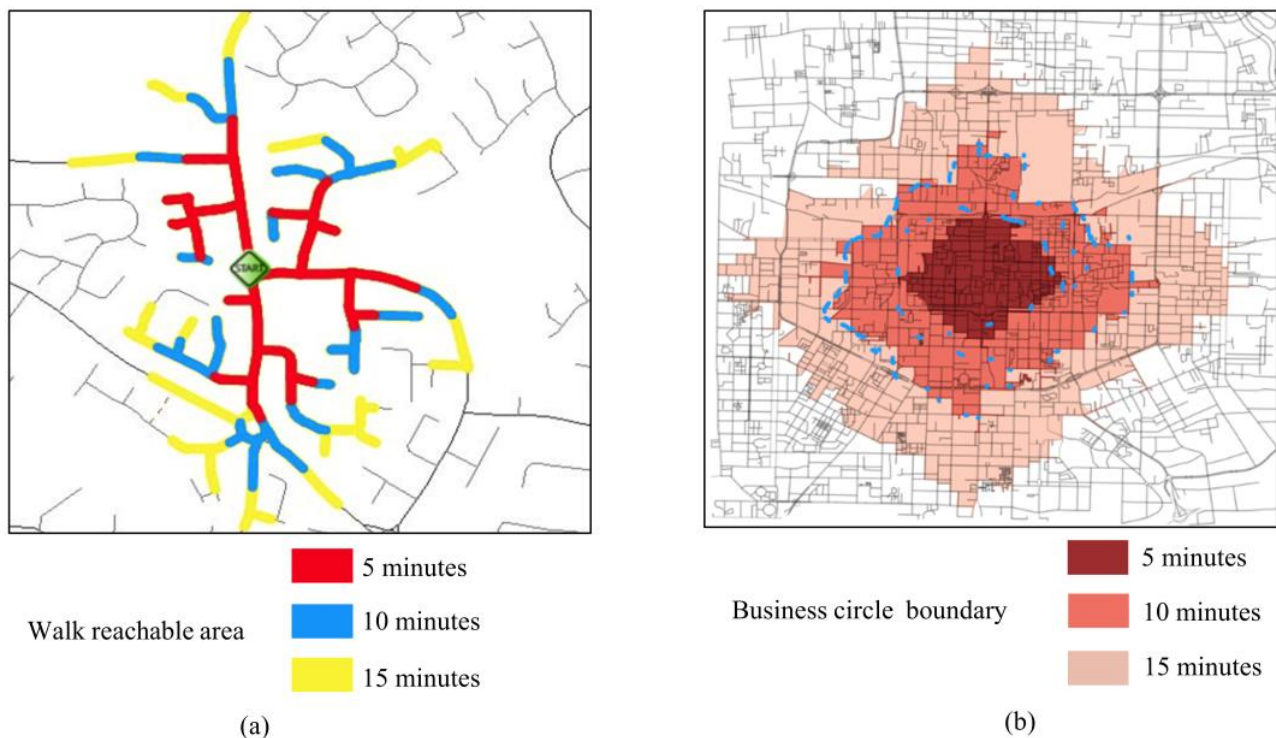


Figure 1. (a) Walk reachable area; (b) business circle boundary (walking time).

3.2.2. Measuring the Number and Diversity of Urban Amenities

In this study, we explored the impact of urban amenities on business circle vitality at the block level. The vitality of an urban business circle depends on its market potential, that is, how many potential consumers can conveniently reach the area [26]. In turn, market potential is influenced by the population living, studying, and working in the area, as well as the transportation accessibility of the area. Therefore, residential, office, educational, and transportation amenities may affect urban business circle vitality. Furthermore, the diversity of retail amenities enables consumers to achieve multiple consumption objectives in a single trip, while different types of catering amenities allow consumers to seek consumption opportunities aligned with their preferences. Therefore, the diversity of retail and catering amenities is an important factor impacting urban business circle vitality. Moreover, consumer demands are becoming increasingly complex as living standards improve. Experience amenities, such as cultural activities and recreation, are increasingly critical for attracting consumers, and their importance in contributing to business circle vitality is becoming more apparent.

In summary, the explanatory variables in this study included the following categories: (1) The first was residential amenities. We measured this using the number of residential

households in the business circle. (2) The second was office amenities. We used the number of office buildings in the business circle as a proxy. (3) The third was educational amenities. This included the number of higher learning institutions in the business circle. (4) The fourth was transportation amenities. We measured this based on the number of subway stations in the business circle. (5) The first included cultural and recreational amenities. This included the number of cinemas and theaters in the business circle. (6) The sixth was the catering diversity index. This was calculated using Equation (1). (7) The seventh was the retail diversity index. This was calculated using Equation (2).

Catering amenities in this study included six categories: Chinese restaurants, Western restaurants, dessert stores, fast food restaurants, cafes, and teahouses. Descriptive statistics for the various indicators are shown in Table 2. We utilized the Shannon index, which is commonly used to calculate species diversity in biology, to construct a catering diversity index as follows:

$$Catering_i = - \sum_{j=1}^5 \frac{R_{ij}}{R_i} \times \ln\left(\frac{R_{ij}}{R_i}\right) \quad (1)$$

where $Catering_i$ represents the diversity of catering in the i th business circle; R_i denotes the total number of catering amenities in the i th business circle; and R_{ij} denotes the number of catering amenities in category j in the i th business circle. The greater the variety of catering amenities and the more evenly the different types of catering amenities are distributed, the greater the catering diversity index.

Table 2. Descriptive statistics of catering and retail amenities.

Variable	Mean	Std.	Max.	Min.
Chinese restaurant	528.39	354.45	2142	0
Western restaurant	29.96	37.81	352	0
Dessert store	10.19	12.99	110	0
Fast food restaurant	97.12	69.44	442	0
Cafe	16.80	21.33	214	0
Teahouse	17.77	30.09	320	0
Clothing store	289.93	301.91	2100	0
Pet store	5.82	5.85	37	0
Sports store	0.73	1.51	19	0
Baby supply store	45.12	40.97	335	0
Appliance and electronics store	33.39	36.62	339	0
Supermarket	7.87	8.08	53	0

Retail amenities included six categories: clothing stores, baby supply stores, sports stores, appliance and electronics stores, pet stores, and supermarkets. Descriptive statistics for the various indicators are shown in Table 2. Using the Shannon index as a reference, we constructed a retail diversity index as follows:

$$Retail_i = - \sum_{j=1}^5 \frac{S_{ij}}{S_i} \times \ln\left(\frac{S_{ij}}{S_i}\right) \quad (2)$$

where $Retail_i$ denotes the retail diversity of the i th business circle; S_i denotes the total number of retail amenities in the i th business circle; and S_{ij} denotes the number of retail amenities in category j in the i th business circle.

3.2.3. Control Variables

We controlled for other factors affecting business circle vitality, such as proximity to nearby business circles [33], the economic development level of the city, and the average temperature of the city [34]. The control variables in this study included the distance to the nearest neighboring business circle (DN), urban GDP, and annual average urban

temperature. The data for the control variables at the city level were obtained from the China Urban Statistical Yearbook 2020.

3.2.4. Analysis Methods

To understand the effect of various urban amenities on business circle vitality, we constructed an econometric model, as shown in Equation (3). We used ordinary least squares as the regression method with which to estimate the impact of various explanatory variables on the explained variable.

$$\ln(Vitality_i) = \beta_0 + \beta_1 \ln(X_i) + \beta_2 \ln Z_i + \varepsilon_i \quad (3)$$

where the explained variable $Vitality_i$ is the density of pedestrian flow in the business circle; the explanatory variable X_i refers to the indicators of various amenities in the business circle; Z_i is the control variable; β_0 , β_1 , and β_2 are the parameters to be estimated; and ε_i represents the disturbance term. Descriptive statistics of the relevant variables and indicators in this study are presented in Table 3.

Table 3. Descriptive statistics of relevant variables.

Variable	Mean	Std.	Max.	Min.
Vitality	3562.32	821.85	1100	7218
Residential	23,922.64	30,166.92	186,321	0
Office	15.94	35.72	230	0
Educational	6.57	8.32	48	0
Transportation	5.94	9.00	69	0
Cultural	4.50	5.17	13	0
Catering	0.79	0.21	1.40	0
Retail	0.72	0.18	1.09	0
DN	2.40	5.50	8.65	0
GDP	114,801.20	32,228.12	189,568	54,439
Temperature	15.59	4.62	24.40	5.10

4. Results

4.1. Analysis of Urban Business Circle Vitality

Following the methodology described above, we measure the vitality of 1471 business circles in 32 major cities across China. Among these, Beijing ranked highest with 152 business circles, Guangzhou ranked second with 109 business circles, and Shanghai ranked third with 105 business circles. A boxplot of the vitality of each city's business circles is shown in Figure 2. The x shapes in Figure 2 represent the average vitality of all business districts in the city. Overall, the vitality of business circles was higher in southern cities than in northern cities and higher in eastern cities than in midwestern cities. Business circles in Shenzhen, Guangzhou, and Shanghai had the greatest vitality. The business circle vitality of Shanghai, Changsha, and Shenzhen fluctuated markedly, whereas that of Harbin, Shenyang, and Dalian was more stable. Among all the business circles, the most vital were the Renmin South and Dong Men business circles in Shenzhen, followed by the Tianhe and Gang Ding business circles in Guangzhou.

We selected Beijing and Shanghai as examples in order to refine the urban block distribution and business circle vitality. We chose these two cities as representatives because Beijing and Shanghai are the political and economic centers of China, respectively. Figure 3a,b show the distribution and vitality measurements of street blocks with pedestrian flow densities of over 1000 people/hm² in Beijing and Shanghai, respectively. Based on this, we identified street blocks that could be classified as business blocks in each city.

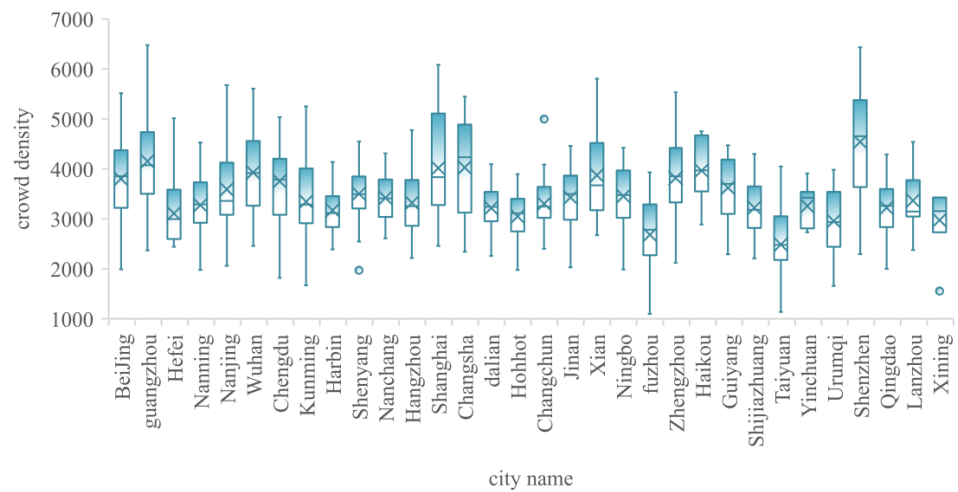


Figure 2. Boxplot of business circle vitality in 32 major cities.



Figure 3. (a) Vitality of street blocks in Beijing; (b) vitality of street blocks in Shanghai; (c) vitality of business blocks in Beijing; (d) vitality of business blocks in Shanghai; (e) vitality of business circles in Beijing; (f) vitality of business circles in Shanghai.

Figure 3c,d show the measurement results for the vitality of street blocks classified as businesses in Beijing and Shanghai, respectively. Finally, based on the delineated boundaries of the business circles, Figure 3e,f show the vitality measurement results for the major business circles in Beijing and Shanghai, respectively. Figure 3e shows that Beijing's business circles were mainly distributed along the ring roads, showing a form of outward expansion centered on the Inner Ring. Business circles with high vitality included Guo Mao, Dong Zhimen, and San Litun. Figure 3f shows that the business circles in Shanghai with the highest vitality mainly included Wu Jiaochang, Bund, and Lu Jiazui.

4.2. Benchmark Regression Analysis

The regression results for the impact of urban amenities on business circle vitality are presented in Table 4. Model 1 includes the explained variable and all explanatory variables. Model 2 further introduces control variables at the block level in addition to the variables used for Model 1, and Model 3 introduces city-level control variables in addition to these variables. The regression results from each model show that most urban amenities had significant positive effects on the vitality of business circles. First, the positive impact of the number of residential amenities on business circle vitality was significant at the 1% level, but the influence coefficient was small. In China's urban planning, large business complexes are mostly located at sites that are independent of residential areas. This plan expects the functional zoning of large-scale commercial and residential areas to minimize the impact of commercial activities on the residential environment. Therefore, the coefficient of influence of residential amenities was small.

Table 4. Estimation results of the benchmark regression.

Variables	Model 1	Model 2	Model 3
Residential	0.010 *** (0.003)	0.009 *** (0.003)	0.011 *** (0.003)
Office	0.011 (0.011)	0.010 (0.011)	0.009 (0.010)
Educational	0.068 *** (0.024)	0.062 *** (0.010)	0.059 *** (0.011)
Transportation	0.080 *** (0.015)	0.079 *** (0.015)	0.077 *** (0.015)
Cultural	0.150 *** (0.024)	0.152 *** (0.024)	0.159 *** (0.023)
Catering	0.499 *** (0.096)	0.504 *** (0.096)	0.488 *** (0.116)
Retail	0.977 *** (0.096)	0.982 *** (0.095)	0.921 *** (0.127)
DN		−0.026 * (0.015)	−0.026 * (0.015)
GDP			0.048 ** (0.020)
Temperature			0.007 (0.013)
Constant	12.974 *** (0.105)	12.989 *** (0.105)	12.837 *** (0.167)
Obs	1471	1471	1471
R ²	0.143	0.148	0.176

Note: robust standard errors in parentheses. * $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

Second, the number of office amenities had an insignificant positive impact on business circle vitality. The vacancy rate in office buildings in China has been increasing annually. Most office buildings are planned and constructed ahead of time, ignoring the current economic development of the city and failing to attract enough enterprises and people, resulting in the planning effect falling short of expectations.

Third, the number of educational amenities had a significant positive impact on business circle vitality. Students—particularly college students—are among the most dynamic consumer groups. They typically have more time and opportunities to spend than other demographic groups and are prone to impulsive spending.

Fourth, the regression results show that transportation amenities had a significant positive effect on business circle vitality, with a large coefficient of influence. Urban subways ease travel difficulties caused by congestion, reducing the time cost for consumers to travel to business circles and increasing the accessibility and market potential of business circles.

Fifth, cultural and recreational amenities had a significant positive impact on business circle vitality, with a large coefficient of 0.159. With improvements in people's living standards and the development of e-commerce, consumers' offline consumption demand has gradually tended toward entertainment and cultural experiences. Business circles are no longer just shopping spaces, but have developed into integrated service spaces.

Sixth, the diversity of retail amenities had a significant positive impact on business circle vitality, with the largest impact coefficient. Diversified retail amenities meet consumers' diverse needs. Despite the impact of e-commerce, offline retail remains irreplaceable in terms of merchandise, services, and environmental experience, which remain important factors in attracting people to business circles.

Seventh, the diversity of catering amenities had a significant positive effect on business circle vitality, with a large impact coefficient of 0.488. A wide variety of catering amenities can meet the preferences of different groups of people and attract consumers of different ages and incomes and consumers from different regions. Moreover, the public's consumption demand for business circles has evolved, shifting from a single shopping mode to deeper modes involving experience, emotion, and socialization. Catering amenities provide people with convenient places for communication and gathering.

4.3. Heterogeneity Analysis

We explored the heterogeneity of the impact of urban amenities on business circle vitality among different cities and business circles. To this end, we first divided China's southern and northern cities according to the geographical boundary of the Qinling–Huaihe Line. Columns 1 and 2 in Table 5 present the regression results. The impact coefficients of transportation amenities, cultural and recreational amenities, and catering diversity were significantly higher in southern cities than in northern cities. This may be due to the higher number of migrants and more frequent international trade and commerce in southern cities, which are typically more diverse in terms of cultural exchanges and types of cuisine.

Table 5. Estimation results for regional heterogeneity.

Variables	(1)	(2)	(3)	(4)	(5)
Residential	0.001 (0.006)	0.015 *** (0.004)	0.010 ** (0.004)	−0.006 (0.007)	0.019 * (0.010)
Office	0.013 (0.015)	0.014 (0.012)	0.013 (0.012)	−0.038 (0.018)	−0.039 (0.027)
Educational	0.070 *** (0.017)	0.052 *** (0.014)	0.059 *** (0.013)	0.070 *** (0.021)	0.096 ** (0.039)
Transportation	0.085 *** (0.022)	0.053 ** (0.021)	0.109 *** (0.021)	0.087 *** (0.025)	0.011 (0.033)
Cultural	0.175 *** (0.035)	0.148 *** (0.030)	0.365 *** (0.071)	0.159 *** (0.034)	0.109 *** (0.032)
Catering	0.640 *** (0.152)	0.165 (0.187)	0.689 *** (0.144)	0.438 * (0.245)	0.701 (0.557)
Retail	0.849 *** (0.152)	0.838 *** (0.254)	1.020 *** (0.141)	0.633 *** (0.147)	1.011 (0.659)
Control	YES	YES	YES	YES	YES
constant	12.554 *** (0.304)	12.973 *** (0.173)	12.972 *** (0.141)	12.903 *** (0.176)	12.536 *** (0.925)
Obs	636	835	878	353	240
R ²	0.204	0.170	0.186	0.224	0.262

Note: robust standard errors in parentheses. * $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

Second, we categorized the 32 cities into eastern, central, and western regions according to their geographical locations. The regression results are shown in Columns 3, 4, and 5 of Table 5. Moving from east to west, the impact coefficients or significance of transportation amenities, cultural and recreational amenities, catering diversity, and retail diversity regarding business circle vitality diminished. One reason for this difference is that the traffic in eastern cities is relatively congested. Improvements in transportation amenities can support more convenient travel, thus increasing the vitality of business circles. Another factor contributing to this variation is that the populations of western cities are relatively sparse, and the consumption demand of the cultural markets is relatively small. The construction of large-scale cultural amenities can be costly and trigger local debt problems. Additionally, the eastern coastal cities opened earlier, leading to better-developed logistics and trade compared to that in western cities. As a result, catering and retail amenities have become more diverse.

Third, we divided the 32 cities into first-tier cities and others. The first-tier cities included Beijing, Shanghai, Guangzhou, and Shenzhen. Columns 1 and 2 in Table 6 present the regression results. The impact coefficients of cultural and recreational amenities, catering diversity, and retail diversity were greater for first-tier cities than for other cities. Residents of first-tier cities have relatively higher incomes and education levels and tend to participate more in cultural activities. The theaters in first-tier cities also have more frequent performances and a wider variety of programs than those in other cities. Moreover, first-tier cities are home to relatively more business enterprises and populations from different regions and countries. The greater diversity of catering and retail amenities in first-tier cities can cater to a wider range of consumer demands.

Table 6. Estimation results for heterogeneity.

Variables	(1)	(2)	(3)	(4)
Residential	0.068 * (0.036)	0.009 ** (0.004)	0.003 (0.003)	0.019 ** (0.008)
Office	0.021 (0.019)	−0.019 * (0.011)	0.017 * (0.010)	−0.073 (0.042)
Educational	0.011 (0.023)	0.081 *** (0.013)	0.042 *** (0.012)	0.110 *** (0.027)
Transportation	0.134 *** (0.047)	0.057 *** (0.014)	0.080 ** (0.035)	0.072 *** (0.012)
Cultural	0.221 *** (0.046)	0.106 *** (0.025)	0.187 *** (0.024)	0.071 (0.060)
Catering	1.004 *** (0.223)	0.335 ** (0.139)	0.621 *** (0.124)	0.419 (0.271)
Retail	0.978 *** (0.223)	0.900 *** (0.141)	0.992 *** (0.233)	0.756 *** (0.126)
Control	YES	YES	YES	YES
constant	12.908 *** (0.338)	12.737 *** (0.212)	13.258 *** (0.165)	12.484 *** (0.309)
Obs	406	1065	1132	339
R ²	0.195	0.201	0.116	0.280

Note: robust standard errors in parentheses. * $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

Finally, according to the presence or absence of shopping centers in business circles, we classified the 1471 business circles into two types: business complexes and neighborhood businesses. Columns 3 and 4 of Table 6 show the regression results. For large business circles dominated by shopping centers or complexes, the coefficients of all urban amenity variables, except residential amenities, were significantly positive. This type of business circle was mostly located in the center of the city, with a large number of supporting office buildings, and was separated from the urban residential area. Therefore, the positive effect was significant for office amenities but not for residential amenities. For business circles dominated by neighborhood businesses, the coefficients were significantly positive

for residential amenities and insignificant for cultural and recreational amenities. This is because most consumers in this type of business circle are nearby residents. Moreover, cultural and recreational amenities such as theaters or cinemas need to be supported by a larger consumer market and have higher market entry thresholds. They are seldom located in neighborhood business circles.

5. Discussion

The existing literature mainly focuses on the vitality of entire cities [12–14,35]. These large-scale studies have failed to differentiate between the functional areas within cities and thus lack pertinence. In the current study, we focused on targeted urban business circles. In contrast to the previous delineation of business circles based only on POI data [4,5,32], we utilized street network, POI, and LBS data to delimit urban business circles by temporal distance, which is more consistent with the characteristics of residents' actual daily economic activities. On this basis, we visualized urban business districts and business circle vitality at the street block level, thus presenting more detailed and representative measurement results.

This study focused on the impact of urban amenities on business circle vitality at the block level. The results show that urban amenities had a significant positive impact on business circle vitality. Unlike previous studies that combined all amenity data [1,16,17,19,21,23], we subdivided different types of urban amenities. The results demonstrate the important role of retail diversity, catering diversity, transportation amenities, and cultural and recreational amenities in enhancing business circle vitality, and highlight the insignificant role of office amenities. This information is important for optimizing urban amenities and enhancing the vitality of business circles. Optimizing the urban business circle requires that attention be paid to the diversification and differentiation of catering and retail amenities. Cultural and recreational amenities need to provide richer immersive experiences and diversified services. The construction of urban transportation amenities needs to be coordinated with the development of other urban amenities to create synergy. The promotion of urban business circle vitality requires the spontaneous formation of economic and social networks among various market players. The government can assist with this process, but it is not appropriate to intervene excessively by, for example, overplanning a large number of office buildings. For a long time, China's land-centered urbanization sprawl has been out of balance with actual market demand, resulting in many skyscrapers being unused or abandoned [15]. Urban planners need to be people-centered in order to adapt the layout and design of amenities to local demographic and economic conditions [36]. Governments need integrated strategic land use planning that meets actual market demands to obviate opportunistic and speculative land markets. These insights could inform strategic planning and regeneration practices for urban sustainability in China, as well as other economies facing transformation and demands for improved urban quality of life.

To our knowledge, this is the first study to extend the examination of urban business circle vitality from a single city to 1471 business circles in 32 cities. A larger sample size allowed us to achieve greater heterogeneity compared to that in previous studies [37,38]. Additionally, we explored the variation in the impact of urban amenities on business circle vitality across different cities and business circle types. We believe that these heterogeneity analyses have practical applications. Large geographical differences exist in China, such as those between the north and south and those between the east and west. Therefore, policy implementation should consider the geographical environment in which urban business circles are located and optimize the quantity, quality, and diversity of various urban amenities according to local conditions. The enhancement of urban business circle vitality cannot be achieved by blindly investing in the construction of high-end urban amenities that lack a consumption base among local residents. Urban managers should emphasize the importance of context-specific planning and design when formulating spatial

strategies for urban business development, considering the specific vitality characteristics of business circles in different areas.

6. Conclusions

In this study, we explored the impact of urban amenities on business circle vitality at the block level using multi-source big data. Overall, this study serves as a valuable reference for sustainable urban development measures. The results are as follows:

- (1) Most urban amenities, such as residential, transportation, educational, cultural, and recreational amenities, and the diversity of catering and retail amenities had a significant positive effect on business circle vitality, but the effect of the number of office amenities was not significant. The diversity of catering and retail amenities was one of the most critical factors.
- (2) The effect of urban amenities on business circle vitality was characterized by large regional heterogeneity. The positive impacts of transportation amenities, cultural and recreational amenities, and catering and retail diversity were greater in the southern and eastern cities than in the northern and midwestern cities.
- (3) There were large city-level differences in the impact of urban amenities on business circle vitality. The positive effects of cultural, recreational, catering, and retail amenities were greater in first-tier cities than in other cities.
- (4) The impacts of urban amenities on different types of business circles were heterogeneous. For business circles dominated by shopping centers, the positive impacts of all urban amenities, except residential amenities, were significant. For business circles dominated by neighborhood businesses, the positive impact of residential amenities was significant, while the impact of cultural and recreational amenities was not.

This study had some limitations. For example, we could not control for all the factors affecting urban business circle vitality, such as policy systems and cultural practices, which are challenging to quantify. Although we analyzed urban business circle vitality based on multiple types of spatiotemporal big data, future studies can include additional types of data such as social media comment data, traffic trajectory data, and credit card transaction data. Finally, future researchers should consider using spatial econometric or geographically weighted regression models to better explore the impact of urban amenities on urban business circle vitality.

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