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Identifying the Geography and Determinants of O2O Online Retailers in Megacity in Central China: A Case Study of Zhengzhou City

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Abstract: In recent years, O2O e-commerce, represented by online group-buying, has developed vigorously, which had significant impacts on urban commercial space. Zhengzhou City is a rising national central city in China, and its e-commerce development level is ahead, but relevant researches are rare. Therefore, the data of online retailers of Meituan.com was collected and combined with Baidu map and Baidu heat map data. Then, we adopted the methods such as spatial statistics and geodetector to explore the geography and determinants of O2O online retailers in Zhengzhou urban area. The main conclusions are 1) The spatial development of O2O online retailers is characterized by significant global high-value agglomeration. 2) The agglomeration areas of different types of O2O online retailers are different. Most of them are concentrated in the old urban area within the Third Ring Road of Zhengzhou City, forming five comprehensive agglomeration areas. 3) The areas with the high e-commerce development level are mainly concentrated in the northeast and southwest of the *x*-shaped region formed by the intersection of Lianyungang-Lanzhou and Beijing-Guangzhou railways. Erqi Square and Guomao 360 Plaza are at the highest development level, followed by Zhongyuan Wanda Plaza and Daxue Middle Road. The development level at other areas is relatively low. 4) Zhengzhou's O2O commercial pattern is highly dependent on physical business. The population distribution, especially the population distribution during the nightlife period, plays a vital role in its spatial development, followed by accessibility. The influences of physical distance are slightly larger than that of time cost, but the difference between them is little. In addition, travelling costs have the least impact. This paper could provide certain references for urban commercial planning.

Keywords: O2O online retailers; geodetector; kernel density; spatial development; Zhengzhou City, China

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1 Introduction

Since the 1990s, e-commerce has developed rapidly in the world with the widespread application of information and communication technology. It has changed people's consumption patterns, which caused great challenges to traditional commerce. This has aroused widespread discussion in the academic community (Lu et al., 2013; Calderwood and Freathy, 2014; Comi and Nuzzolo, 2016; Shi, 2017; Zhou et al., 2018). The research on

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e-commerce in the geography mainly focuses on three aspects: 1) the impact of e-commerce on the development of traditional commerce (Cao, 2012; Comi and Nuzzolo, 2016); 2) the spatial development characteristics of e-commerce (Anderson et al., 2003; Farag et al., 2006a; Weltevreden et al., 2008); 3) the reconstruction effect of urban commercial space caused by e-commerce (Weltevreden and Atzema, 2006; Cao, 2012; Xue et al., 2019). Over the past decade, China's e-commerce has achieved rapid development (Song et al., 2019), especially online retail industry, which has consistently ranked first in the world. According to different operating models, China's online retail industry can be divided into two types: remote-deal e-commerce and local-deal e-commerce (Shi, 2017). The former usually refers to B2C (Business to Consumer) and C2C (Consumer to Consumer) e-commerce, such as Taobao.com and Jingdong.com; the latter mainly refers to O2O (Online to Offline) e-commerce, such as Meituan.com and Nuomi.com (Shi, 2017). Compared with the former, the relationship between local-deal e-commerce and urban physical commerce is more complicated. It connects cyberspace and physical space, and it not only depends on physical commerce, but also presents a unique spatial differentiation law (Shi, 2017). This is undoubtedly a phenomenon worthy of in-depth study for geographers who have a strong tradition of the spatial research.

The academic research on spatial development law of e-commerce is mainly carried out from two aspects: consumers' online shopping behaviors and stores' adoption of online marketing behaviors (Shi, 2017). For consumers' online shopping behavior, the most far-reaching theories are the innovation diffusion hypothesis and efficiency hypothesis proposed by Anderson (Anderson et al., 2003). The former shows that residents in developed areas or urban centers are more inclined to shop online (Farag et al., 2003; 2006b; 2007). The latter holds that residents in backward areas or urban suburbs prefer online shopping (Mokhtarian, 2004; Farag et al., 2006a; Ren and Kwan, 2009). Many studies have proved the rationality of the two viewpoints from different aspects (Farag et al., 2006b; Wang et al., 2013; Hao et al., 2016). However, some scholars have questioned this. They argued that spatial attribute has no effect on online shopping (Farag et al., 2005; Krizek et al., 2005; Zeng and Chen, 2013). Regarding the online marketing behavior of stores, some people believe that the rapid development of logistics systems has reduced distribution costs, and promoted the emergence of e-commerce retailers in urban suburbs or rural areas (Anderson et al., 2003). Others point out that stores in areas with higher urbanization level or in urban centers are more likely to adopt e-commerce marketing strategies (Weltevreden and Atzema, 2006; Weltevreden et al., 2008). Many studies from Chinese scholars have confirmed the above two viewpoints. From the macro perspective, the researches (Shi et al., 2018) showed that the e-commerce spatial development in China tend to follow the efficiency hypothesis. At the micro level, the study of Qin et al. (Qin et al., 2014) explored the spatial characteristics of catering industry in Nanjing urban area based on the public praise, which showed an obvious law of decreasing by circle pattern. Most classical location theories consider that physical distance is the core element of traditional urban commercial spatial development. In addition, population density, trading area scale, and traffic flow also have important influences (Shi et al., 2016a). For e-commerce, existing studies showed that economic development level, industrial structure, population size, residents' income, express logistics conditions, information level are the main factors affecting residents' online shopping behavior (Zhu and Chen, 2013; Song et al., 2019). In addition, more and more scholars have begun to pay attention to the role of 'time cost' (Liu et al., 2004) and 'spatial variables' (Ren and Kwan, 2009) in the e-commerce spatial development (Liu et al., 2004; Shi et al., 2016a; b).

Chinese scholars' researches on the e-commerce spatial development has started late, but developed very fast. The existing researches mainly focus on B2C and C2C e-commerce. In recent years, there are few studies on O2O e-commerce (Shi et al., 2016b; Shi et al., 2019a; Zhang et al., 2019). There are many researches on the national e-commerce spatial development in China at the city and county level (Shi et al., 2018; Song et al., 2019). Besides, coastal areas of China (Xi et al., 2014; Zhen et al., 2018), Northeast China (Shi et al., 2019a), Chengdu City (Shi et al., 2016b; 2019b) are also research hotspots. Only few researches focused on the Central China. Ding et al. (Ding et al., 2016) have studied the C2C e-commerce spatial development pattern in the Central China, but this is the macro analysis at city and county level, and lack the micro analysis of the urban area, especially the study of O2O e-commerce. Hen-

an Province is the most populous province in China and the largest economic province in Central China. As the capital of Henan Province, Zhengzhou City ranks top of e-commerce development in China . It is one of the first batches of national e-commerce model cities, and has established China (Zhengzhou) cross-border e-commerce comprehensive pilot area. In addition, the rapid development of big data technology provides a solid data foundation for e-commerce research. There are many researches based on big data platforms such as Dianping.com (Qin et al., 2014), Taobao.com (Song et al., 2019), Baidu map (Shi et al., 2019a). Meituan.com is one of China's largest living services e-commerce enterprises, which is also known as a typical O2O e-commerce platform. Therefore, the data of Meituan.com are very representative and have high value of scientific research. Many scholars have applied it to e-commerce research (Shi et al., 2016a; 2016b; 2018; Shi, 2017), which shows good results. In this paper, we used web crawler technology to obtain online stores data of Meituan.com, combined with the data of Baidu map and Baidu heat map, adopting methods such as spatial statistics and geodetector. Then, we revealed the spatial development laws of different types of O2O online retailers in the urban area of Zhengzhou City, and explored its core location factors. This paper will be helpful to understand the logic of urban commercial spatial development in China in the information age, and provide references for the policy formulation.

2 Materials and Methods

2.1 Study area

Zhengzhou City (112.7°E–114.23°E, 34.27°N–34.97°N) is the capital of Henan Province, China's National Central City, national comprehensive transportation hub, trade and logistics center (Fig. 1). It has six municipal districts, five county-level cities and one county. In 2018, the total retail sales of consumer goods reached 426.81 billion yuan (RMB), and the cross-border e-commerce transactions reached 57.13 billion yuan, ranking the forefront of China (Zhengzhou Municipal Bureau Statistics, 2019a; Dahe Daily, 2019). The study region of this paper is the main urban area, namely Zhongyuan District, Erqi District, Guancheng Hui District, Jinshui District and Huiji District (Fig. 1). The total area is 1010 km^2, the built-up area is 515.91 km^2 (Zhengzhou Municipal People's Government, 2019), the permanent population is 5.08 million (Zhengzhou Municipal Bureau Statistics, 2019b), and the GDP is 470 billion yuan (Zhengzhou Municipal Bureau Statistics, 2019c).

2.2 Data sources

The data in this paper are mainly from four aspects. 1) Information of O2O stores is from Meituan.com. From 17 July to 13 August 2018, we collected all the online stores' information of Meituan.com in the main urban area of Zhengzhou City by using the web crawler tool, with 70 633 records. Each record contains 17 attribute informationsuch as the store name, longitude and latitude, classification, score, commodities' (services') quantity, *etc*. We eliminated invalid stores, merged stores with small quantity, and finally got 34 677 pieces of stores' information in six categories, including gourmet services, living services, beauty services, entertainment services, healthcare services, and home-decoration services. 59 982 group-buying commodities (services) were released, as shown in Table 1. 2) The data required for the accessibility index calculation of the trading areas are from Baidu map. According to the names of 80 trading areas in Zhengzhou City provided by Meituan.com (Fig. 1), the search route function of Baidu map was used to collect the least time, shortest distance and minimum cost information of taking public transportation (bus or subway) from one trading areas center to another trading areas center. 3) The population density data are from Baidu heat map. Using the web crawler tool, the population heat data at 10:00, 16:00, 20:00 and 24:00 in the working day of Zhengzhou urban areas are collected. The spatial resolution is about 2 m, and the pixel gray value (DN) is between 52 and 194. DN = 52 is the background value, which represents no population or small population. DN ≥ 53 represents a population distribution. 4) The vector data are from the Resource and Environment Data Cloud Platform (http://www.resdc.cn), and some of the data are obtained by vectorization of various thematic maps after the spatial registration.

2.3 Research methodology

(1) Development level evaluation index

In this paper, the number of stores, the number of commodities (services), and the public praise of stores are selected to comprehensively evaluate the e-commerce

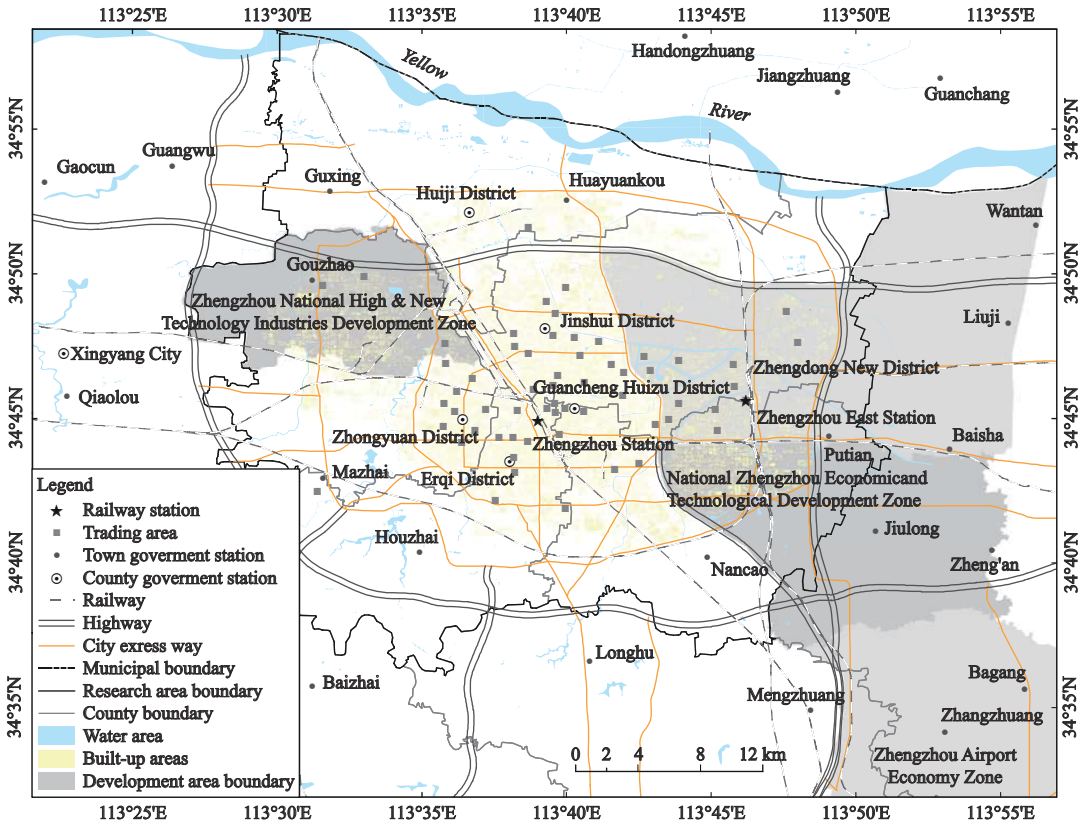

Fig. 1 Location of study area and sampling sites in Zhengzhou City

Table 1 The classification statistics of stores on Meituan.com in Zhougzhou City

Main classification	Classification	Store		Commodity (Service)	
		Number	Proportion / %	Number	Proportion / %
Gourmet services	Snacks, fast food, dessert drinks, hot pot, western food, *etc*.	22340	64.423	32249	53.764
Living services	Flowers, study and training, maintenance, matching glasses, *etc*.	4585	13.222	16907	28.187
Beauty services	Cosmetology, hairdressing, manicure and eyelashes, *etc*.	4199	12.109	7414	12.360
Entertainment services	Massage, sports and fitness, games, cinemas, *etc*.	1795	5.176	2835	4.726
Healthcare services	Pharmacy, physical examination, dentistry, other health services, *etc*.	1104	3.184	575	0.959
Home decoration services	Home textile, decoration building materials, home appliances, *etc*.	654	1.886	2	0.003
Summary		34677	100	59982	100

development level. According to the comprehensive scale index model proposed by Shi (Shi, 2017), we constructed the development level evaluation index model. It refers to the evaluation of a certain type of e-commerce development level. The formula is:

$$E_i=\frac{W_1N_i+W_2P_i+W_3Q_i}{A}\quad P_i=\sum_{j=1}^{N_i}p_j\quad Q_i=\sum_{j=1}^{N_i}q_j \quad (1)$$

where E_i is the evaluation index. W_1, W_2, W_3 represent the weight of the number of stores, the number of commodities (services), and the public praise of stores. In this paper, the weight values are determined by expert consultation method and they are 0.4, 0.3, and 0.3 respectively. N_i, P_i and Q_i are the stores' number, the sum of the evaluation values of commodities' (services') quantity, the sum of evaluation values of stores' public praise for a certain type of store in the regional unit, respectively. A is the area of the regional unit (km^2), i refers to a certain type of O2O e-commerce in the regional unit, and j represents the stores of a certain type of O2O e-commerce in the regional unit. p_j and q_j are the standardized values of commodities' (services') quantity and stores' public praise of a certain type of store re-

spectively, and max-min standardization method is adopted.

(2) Spatial statistical analysis

This paper mainly uses spatial autocorrelation analysis, high/low clustering analysis and kernel density analysis to describe the spatial development pattern of O2O Online Retailers in Zhengzhou City. Spatial autocorrelation analysis includes global spatial autocorrelation and local spatial autocorrelation. The former is used to test the general trend of spatial autocorrelation of spatially adjacent regional unit attribute values in the whole study region level (Getis and Ord, 1992), and Moran's I is used to describe it in this paper. The local spatial autocorrelation reflects the degree of correlation between the attribute values of local units and the same type of attribute values of adjacent units in the study region (Wang et al, 2019). In this paper, the hotspot analysis is used to measure it. If the statistic Z-score > 0, the higher the Z-score, the higher the agglomeration degree of high-value (hot spot). If Z score < 0, the lower the Z-score, the higher the agglomeration degree of low value (cold spot) (Wang et al, 2019). High/low Clustering analysis is mainly used to explore whether there is a global high-value/low-value clustering phenomenon in the study region (Mitchell, 2005). The calculation results will return the observed General G index (G_o), expected General G index (G_E), Z-score and other information. If Z-score is positive and $G_O/G_E > 1$, there is a high-value clustering. If Z-score is negative and $G_O/G_E < 1$, there is a low-value clustering (Mitchell, 2005). Kernel density analysis is used to generate a continuous density surface based on the input point feature data, reflecting the data aggregation status of the whole region (Zhao et al, 2018).

(3) Standard deviation curve method

The stores' data of Meituan.com is a kind of point of interesting (POI) data, which follows the relevant characteristics of normal distribution . According to the law of normal distribution, the O2O commercial agglomeration areas in Zhengzhou City is divided into core area ($x \geq \mu + 3\sigma$), intermediate area ($\mu + 2\sigma \leq x < \mu + 3\sigma$) and fringe area ($\mu + \sigma \leq x < \mu + 2\sigma$) (Wu et al., 2016), based on the results of kernel density analysis (μ is the mean value of the development level evaluation value of O2O online retailers in the study region, and σ is the standard deviation). Many scholars have used this method to conduct researches on urban crime hotspots, urban commercial areas and other aspects (Yu et al., 2015; Wu et al., 2016).

(4) Accessibility index

Accessibility refers to the difficulty of entering a certain area (Shi et al., 2016b). As public transportation (bus, subway) is the main way of travel for urban residents, the accessibility index calculation is based on public transportation, such as the time, distance and cost accessibility index. The calculation formula is

$$A_i = \frac{1}{n-1}\sum_{j=1}^{n} t_{ij} \qquad \forall\, i \neq j\ , \tag{2}$$

where A_i is the time (distance or cost) accessibility index of trading area i. t_{ij} is the time (distance or cost) required in Baidu map from trading area i to trading area j based on public transportation. n is the total number of trading areas. The accessibility index is inversely related to accessibility. Thus, the higher the A_i value, the worse the accessibility is.

(5) Geodetector

The method includes four detectors such as factor detection, risk detection, ecological detection, interaction detection (Wang et al., 2010; Wang and Xu, 2017). The factor detector mainly detects the spatial differentiation of dependent variables, and the extent to which the independent variables can explain this spatial differentiation, measured by the q value. The mathematical expression is as follows (Wang et al., 2010).

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} \tag{3}$$

where h = 1, 2, …., L is the strata of the independent variable or dependent variable. N_h and N are the number of units in layer h and the whole region, respectively. ${\sigma_h}^2$ and σ^2 are the variance of the dependent variable in the layer h and the whole region, respectively. The value range of q is [0, 1]. The larger the value, the stronger the explanatory power of the independent variable to the dependent variable, and vice versa. The q value satisfies the non-central F distribution by transformation (Wang et al., 2010).

$$\begin{aligned} F &= \frac{N-L}{L-1} \times \frac{q}{1-q} \sim F(L-1, N-L; \lambda) \\ \lambda &= \frac{1}{\sigma^2}\left[\sum_{h=1}^{L} \overline{Y}_h^2 - \frac{1}{N}\left(\sum_{h=1}^{L} \sqrt{N_h}\,\overline{Y}_h\right)^2\right] \end{aligned} \tag{4}$$

where λ is a non-central parameter. $\overline{Y}_h$ is the mean value of the dependent variable of layer h. According to Formula (4), it is possible to test whether the q value is sig-

nificant.

We used Geodetector to identify the contribution of core location factors to the O2O online retailers' spatial development of Zhengzhou City. The kernel density value of the comprehensive evaluation of e-commerce development level is selected as the dependent variable. The accessibility index and population density are selected as the independent variable. To eliminate the errors caused by inaccurate spatial positioning, we took the center point of 80 trading areas as the center, and made a buffer zone of 500 m (optimal bandwidth), then took the mean kernel density of the buffer zone as the comprehensive evaluation value (dependent variable) of the e-commerce development level of each trading area. In addition, the independent variables must be type variables according to the requirements of Geodetector. The independent variables selected are all numerical variables, which should be grouped. To determine the least difference within the group and the greatest difference between groups, we applied natural breaks method (Jenks) to group. To select at least two samples in each group, the variables are divided into 2–10 groups.

3 Results and Analysis

3.1 Spatial development characteristics of different types of O2O online retailers in Zhengzhou City

According to Formula (1), the e-commerce development level of each community / administrative village in Zhengzhou City was evaluated. The natural breaks method was used in five levels, as shown in Fig. 2a–Fig. 7a. The global spatial correlation analysis was carried out by ArcGIS, as shown in Table 2. The Moran's I indexes are all greater than 0, and the P values are all less than 0.01, indicating that the development levels of the six types of O2O online retailers have significant spatial agglomeration characteristics. Among them, the agglomeration of Gourmet and Living Services are the strongest (Moran's $I > 0.3$), while the home decoration services is the weakest (Moran's $I = 0.114$). The high /low clustering analysis shows that G_O/G_E are greater than 1, Z-cores are positive, and P value are less than 0.01, indicating that the e-commerce development level in Zhengzhou City have significant global high-value clustering characteristics, that is, the spatial polarization phenomenon of e-commerce development is prominent, and the most obvious high-value clustering feature is in Beauty services e-commerce ($G_O/ G_E = 3.174$).

We used ArcGIS to analyze the local spatial correlation of different types of e-commerce development levels in Zhengzhou City, as shown in Fig. 2b–Fig. 7b. 1) The areas with the high development level (hot spots) of Gourmet Services e-commerce are concentrated within the third ring road, mainly including Erqi Square, Guomao 360 Plaza, Daxue Middle Road, Dashiqiao, Zhongyuan Wanda Plaza, *etc*. However, the cold spots are distributed outside the third ring road (Fig. 2b). 2) The high-value agglomeration areas of Living Services e-commerce mainly included Erqi Square, Dashiqiao, Guomao 360 Plaza, Zhongyuan Wanda Plaza, Daxue

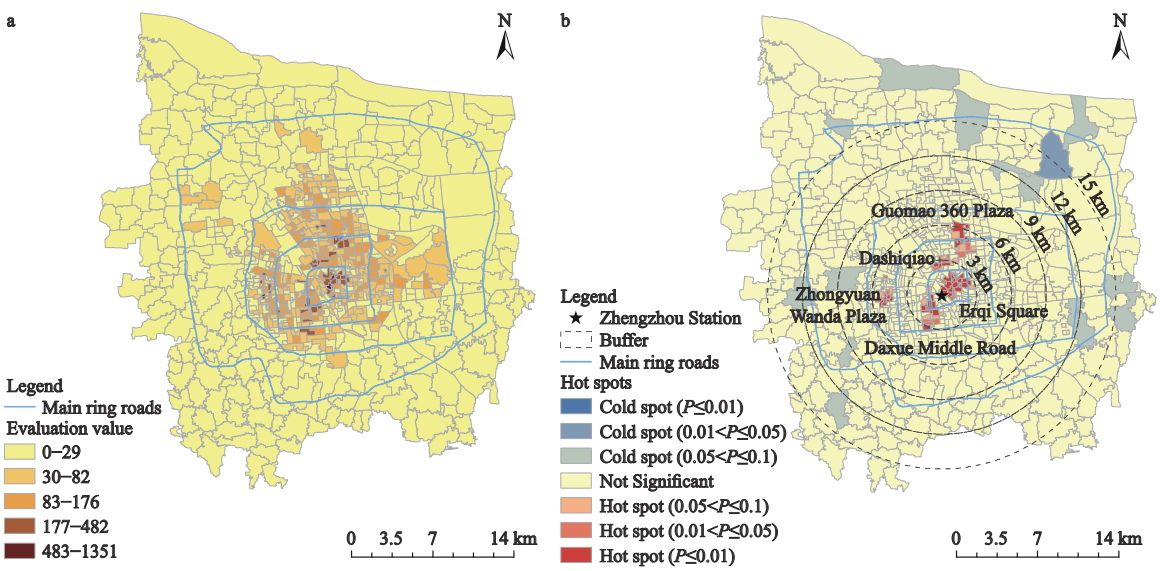

Fig. 2 The development evaluation (a) and hotspot analysis (b) of Gourmet Services e-commerce in Zhengzhou City

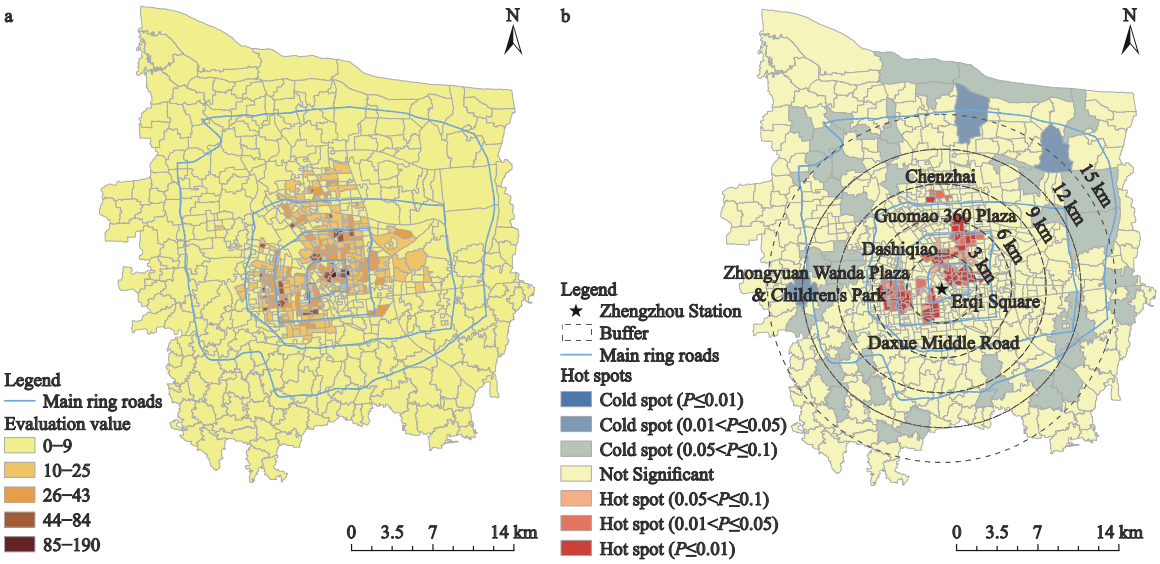

Fig. 3 The development evaluation (a) and hotspot analysis (b) of Living Services e-commerce in Zhengzhou City

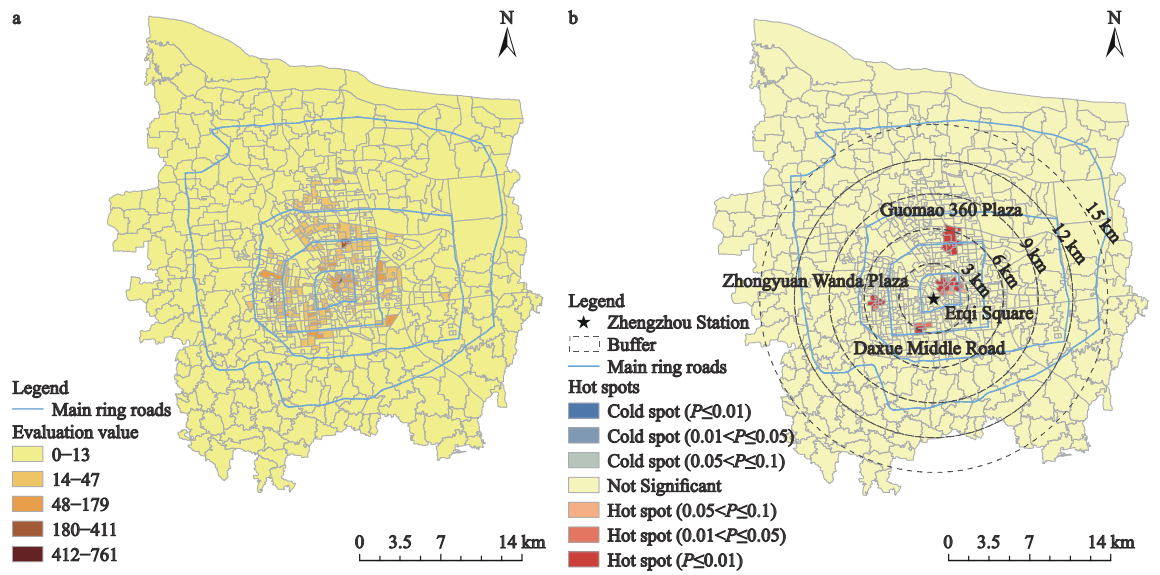

Fig. 4 The development evaluation (a) and hotspot analysis (b) of Beauty Services e-commerce in Zhengzhou City

Middle Road and Chen Zhai, and the main areas are interconnected. The low-value agglomeration areas are mainly near the fourth ring road (Fig. 3b), including Longzihu University Town with 200 thousand teachers and students, which indicates a serious shortage of living service facilities in the area. 3) The areas with the high development level of Beauty Services e-commerce are isolated and scattered with a small area. They are mainly concentrated in Guomao 360 Plaza, Erqi Square, Zhongyuan Wanda Plaza, Daxue Middle Road and other areas. There are large shopping malls with the large flow of people and many customer groups, which is conducive to the development of service industry. The agglomeration level of other areas is not significant (Fig. 4b). 4) The high-value agglomeration areas of Entertainment Services e-commerce are mainly distributed in Erqi Square, Dashiqiao, Guomao 360 Plaza, Daxue Middle Road, Manhattan Plaza, Zhongyuan Wanda Plaza, Chenzhai and other areas, where Erqi Square, Dashiqiao and Guomao 360 Plaza have been connected, showed a 'Z-shaped' distribution. The agglomeration levels of other areas are relatively low (Fig. 5b). 5) The hotspots of Healthcare Services e-commerce are distributed in a belt. Trading areas, such as Zhongyuan Wanda Plaza, Children's Park, Daxue Middle Road, Dashiqiao, Erqi Square are connected from west to east in a 'V'

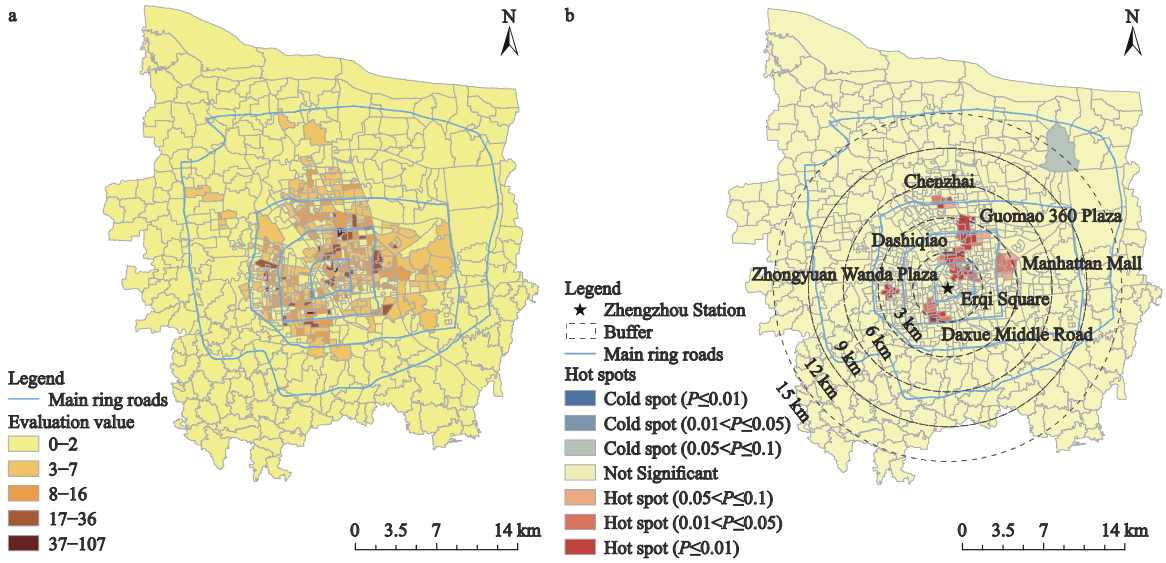

Fig. 5 The development evaluation (a) and hotspot analysis (b) of Entertainment Services e-commerce in Zhengzhou City

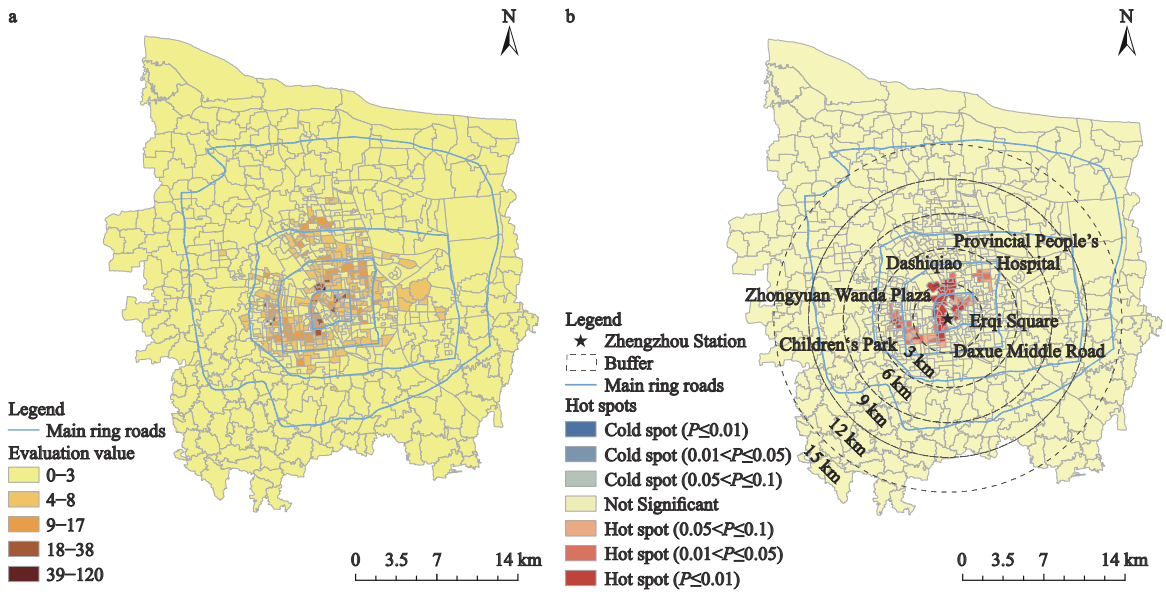

Fig. 6 The development evaluation (a) and hotspot analysis (b) of Healthcare Services e-commerce in Zhengzhou City

shape. An agglomeration area is also formed near the Henan provincial people's hospital, and the agglomeration level in other areas was not significant (Fig. 6b). 6) The distribution of high-value agglomeration areas of Home-decoration Services e-commerce is discrete. The largest one is the Phoenix City-East Building Materials Market area in the east, followed by Xiyuan International Center-Children's Park and Shenglong City-Dihu area in the southwest, Erqi Square area in the middle, Guomao 360 Plaza and Chenzhai areas in the north are the smallest (Fig. 7b).

Although the hotspots of different types of e-commerce are different, most of them are concentrated in the old urban areas within the third ring road of Zhengzhou City, within 6 km from the city center (Zhengzhou railway station). Beyond 6 km, only the e-commerce of Living Services, Entertainment Services and Home-decoration Services have formed two agglomeration areas, namely, Chenzhai and East Building Materials Market, both within 8 km, which indicates that the central agglomeration of e-commerce spatial development in Zhengzhou City is high, and the regional development is extremely unbalanced.

In summary, there are 16 major high-value agglomer-

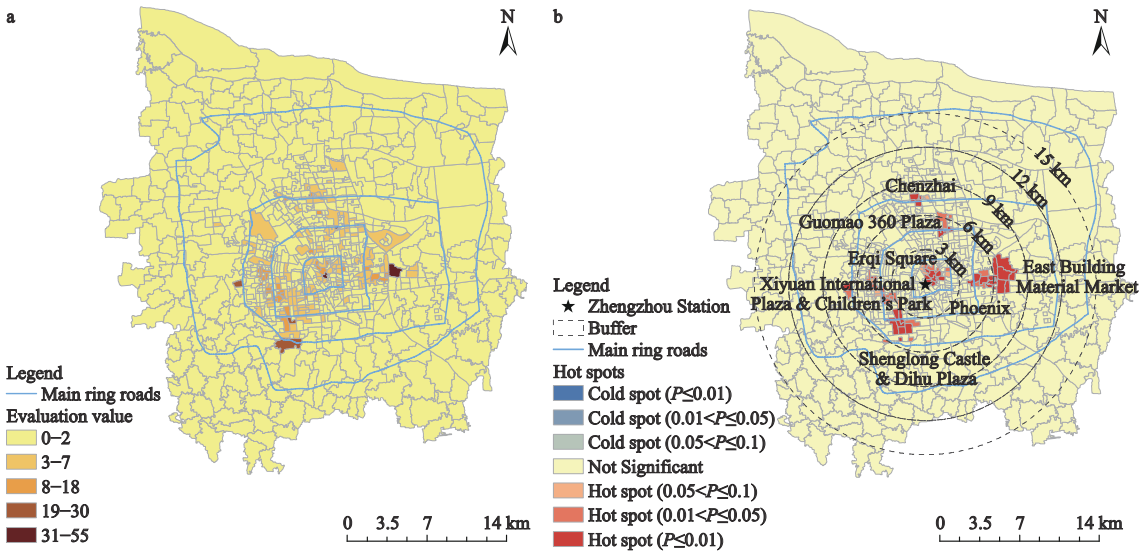

Fig. 7 The development evaluation (a) and hotspot analysis (b) of Home-decoration Services e-commerce in Zhengzhou City

ation areas of O2O online retailers in Zhengzhou urban area, where Erqi Square, Guomao 360 Plaza, Daxue Middle Road, Dashiqiao, Zhongyuan Wanda Plaza are comprehensive agglomeration areas, while the others are specialized agglomeration areas. Erqi Square is the most comprehensive agglomeration area. All kinds of e-commerce development hotspots are distributed there, of which Gourmet, Beauty and Living Services are the most prominent. Guomao 360 Plaza mainly focused on Beauty and Living Services, and the Healthcare Service is relatively weak. The Home-decoration Services in areas such as Daxue Middle Road, Zhongyuan Wanda Plaza, and Dashiqiao are weak. The first two areas have formed the development advantages of Entertainment and Beauty Services, while the e-commerce development in Dashiqiao area is relatively balanced. Among the specialized agglomeration areas, the East Building Materials Market and Shenglong City-Dihu area mainly provide Home-decoration Services, the Healthcare Services of Henan Provincial People's Hospital area is more prominent, the Manhattan Plaza area mainly provides Entertainment Services. The e-commerce development scales and agglomeration levels of other areas are relatively low.

3.2 General spatial development characteristics of O2O online retailers in Zhengzhou City

Geographic information has the spatial scale effect. The above analysis is based on the community/administrative village boundary. The research unit area has a large variation; especially the administrative division area of Zhengdong New District is relatively large. This may cover up the hotspots in local areas. Therefore, it is necessary to conduct a more microscopic analysis based

Table 2 Spatial statistical analysis results of different types of O2O online retailers

Method	Index	Gourmet Service	Living Service	Beauty Service	Entertainment Services	Healthcare Services	Home-decoration
SA	Moran index	0.308	0.346	0.176	0.197	0.279	0.114
	Z-score	16.029	17.492	10.296	10.173	15.515	6.025
	P value	0.000	0.000	0.000	0.000	0.000	0.000
HC	G_O / G_E	2.028	2.037	3.174	1.995	2.702	2.730
	Z-score	13.790	15.208	10.261	9.499	15.037	6.077
	P value	0.000	0.000	0.000	0.000	0.000	0.000
ISA	Bandwidth	250	150	250	350	1300	300
	Z-score	83.969	6.138	21.119	9.800	2.718	10.154
	P value	0.000	0.000	0.000	0	0.007	0.000

Notes: SA (Spatial Autocorrelation), HC (High / low Clustering), ISA (Incremental Spatial Autocorrelation)

on the spatial locations of stores. Firstly, the development level of each store was evaluated according to Formula (1), and then the kernel density analysis is performed using ArcGIS. The bandwidth selection of kernel density function has a great influence on the analysis results, and different bandwidths will produce different agglomeration effects. The appropriate bandwidth can be determined by the Incremental Spatial Autocorrelation tool of ArcGIS, and the criterion is *Z*-score. If the *Z*-score of a distance is statistically significant and located at the maximum peak, the distance is the optimal bandwidth, and the spatial agglomeration is the most remarkable. Table 2 shows that the optimal bandwidth of different types of stores varies greatly, ranging from 150 to 1300 m, with the average of 433.33 m, while the general optimal bandwidth of all types of stores is 500 m, there is little difference between them. Therefore, we set 500 m as the optimal bandwidth for kernel density analysis (Fig. 8a), and conducts a hotspot analysis based on kernel density values (Fig. 8b).

The mean value of kernel density (μ) in the study region was 41.61, and the standard deviation (σ) was 78.54. The area information of each partition is counted, as shown in Table 3. In this paper, the areas that $\mu \le x < \mu + \sigma$ are named as the peripheral area, which is not belong to the scope of the commercial agglomeration areas. The area that $x < \mu$ and non-hotspots are uniformly named as other areas.

Based on the results of standard deviation curve zoning, taking factors, such as the connectivity of commercial agglomeration areas, proximity principle and administrative division, into consideration, we divided the commercial agglomeration areas of Zhengzhou City into 12 major areas (Fig. 9), and the detailed information of each area is shown in Table 4. To facilitate comparative analysis, it is necessary to conduct a comprehensive evaluation of each area based on the area and average kernel density value. First, the area and average kernel density value are standardized by max-min standardization method. Their weights are assigned to 0.4 and 0.6

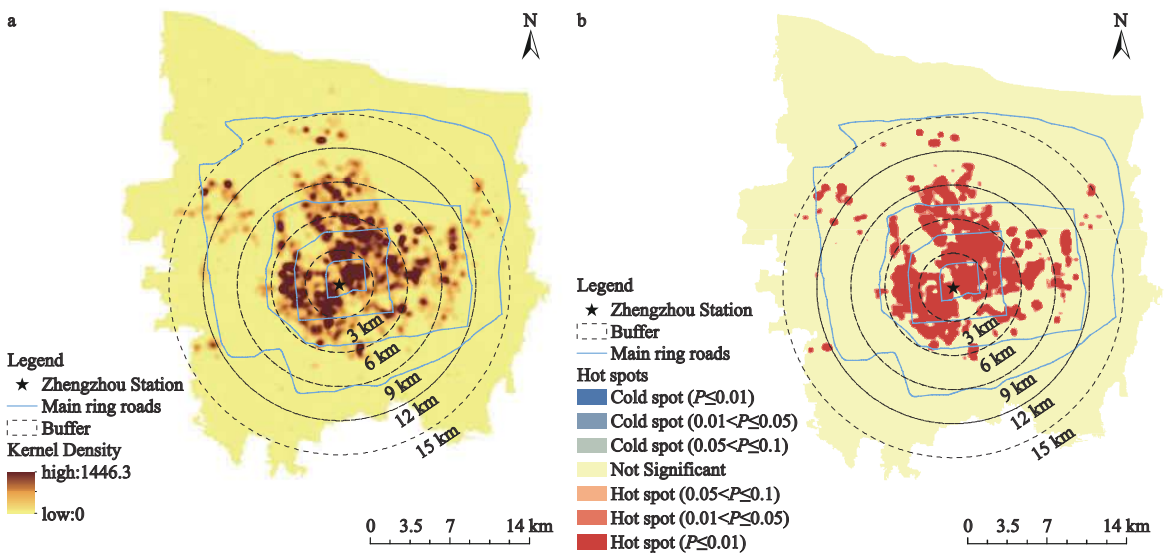

Fig. 8 The kernel density analysis (a) and hotspot analysis of general development of O2O online retailers (b) in Zhengzhou City

Table 3 Statistics of standard deviation curve zoning of O2O commercial agglomeration areas in Zhengzhou City

Category	Area / km^2	Ratio / %
Core area ($x \ge \mu + 3\sigma$, $x \ge 277.22$)	8.21	0.81
Intermediate area ($\mu + 2\sigma \le x < \mu + 3\sigma$, $198.68 \le x < 277.22$)	11.08	1.09
Fringe area ($\mu + \sigma \le x < \mu + 2\sigma$, $120.15 \le x < 198.68$)	34.97	3.43
Peripheral area ($\mu \le x < \mu + \sigma$, $41.61 \le x < 120.15$)	71.69	7.04
Other area	892.26	87.63
Summary	1018.20	100.00

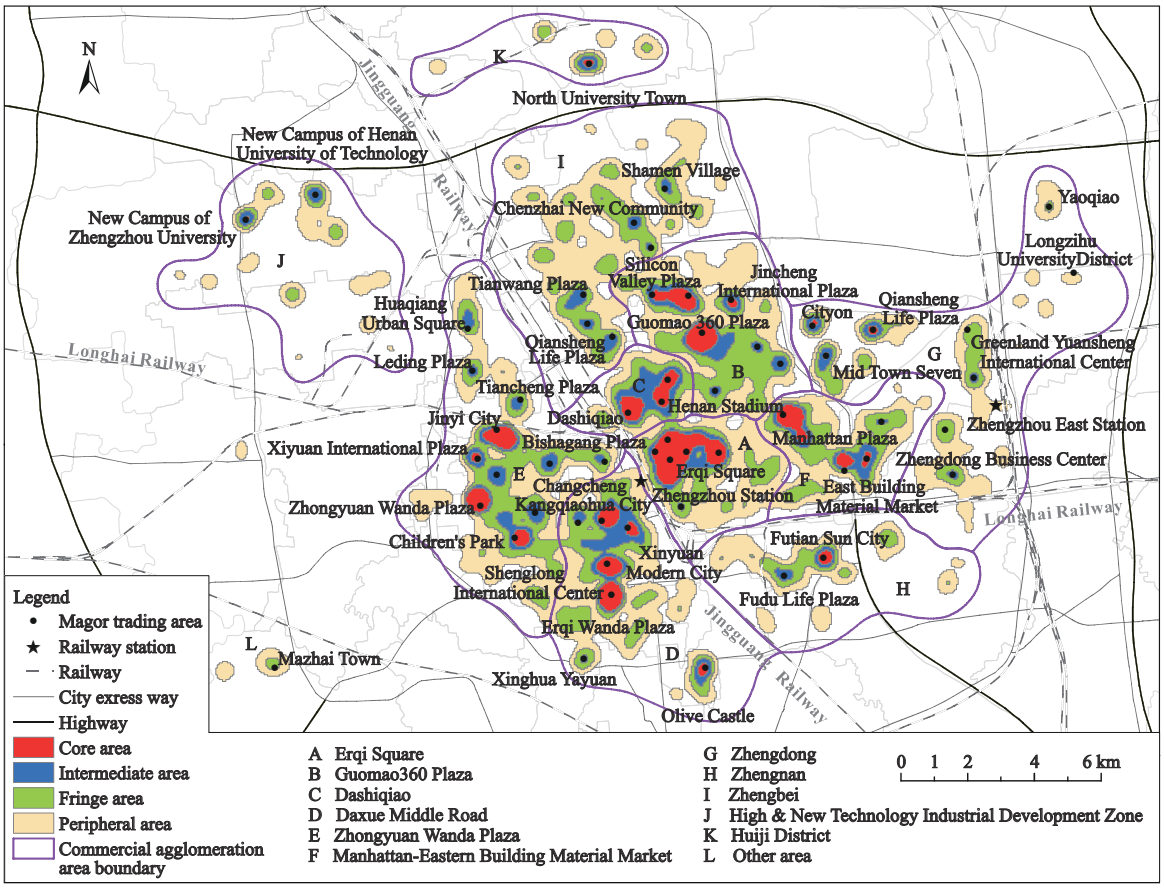

Fig. 9 The zoning of O2O commercial agglomeration areas in Zhengzhou City

Table 4 Statistics of standard deviation curve zoning of O2O commercial agglomeration areas in Zhengzhou City

Agglomeration area	Code	Major trading area	Core area		Intermediate area		Fringe area		Score	Rank
			Area / km^2	Mean	Area / km^2	Mean	Area / km^2	Mean		
Erqi Square	A	Erqi Square, Railway Station, David City, Great Shanghai City, Kingbird City, etc.	**2.02**	**519.12**	0.87	231.87	2.68	149.39	**0.783**	**2**
Guomao360 Plaza	B	Guomao 360 Plaza, Silicon Valley Plaza, Lanbo Bay, etc.	**1.31**	**522.79**	**1.56**	231.52	**5.58**	151.34	**0.801**	**1**
Dashiqiao	C	Dashiqiao, Henan Stadium, Jianwen New Word, etc.	0.93	335.42	1.28	235.15	1.51	**156.11**	0.527	6
Daxue top Road	D	Changcheng Kangqiaohua City, Erqi Wanda, Olive castle, etc.	**1.44**	424.23	**1.99**	228.50	4.97	**152.59**	0.681	4
Zhongyuan Wanda Plaza	E	Jinyi City, Zhongyuan Wanda Plaza, Children's Park, etc.	1.23	**446.08**	**2.15**	227.86	**6.39**	**152.95**	**0.709**	**3**
MEBMM	F	Manhattan Plaza, Eastern Building Material Market, etc.	0.90	380.86	0.99	**235.66**	3.22	149.99	0.560	5
Zhengdong	G	Cityon, Qiansheng Life Plaza, Dennis Mid Town Seven, etc.	0.13	293.93	0.63	229.65	2.78	151.27	0.285	7
Zhengnan	H	Futian Sun City, Fudu Life Plaza	0.15	324.04	0.32	225.60	1.40	148.25	0.226	10
Zhengbei	I	Qiansheng Plaza, etc.			0.87	220.91	**5.14**	151.27	0.203	11
HNTIDZ	J	New Campus of Zhengzhou University, etc.	0.03	281.11	0.29	**236.57**	0.77	148.23	0.277	9
Huiji District	K	North University Town	0.07	301.36	0.15	**235.42**	0.41	148.58	0.282	8
Mazhai Town	L	Mazhai Town					0.13	132.28	0.000	12

Notes: A bold underlined value indicates that the size is in the top three of the column. MEBMM (Manhattan-Eastern Building Material Market), HNTIDZ (High & New Technology Industrial Development Zone)

respectively, and then the weighted summation is carried out to get the evaluation value of each layer of the commercial agglomeration area. Second, weights of 0.5, 0.3 and 0.2 were given to the core area, intermediate area, and fringe area, respectively. Then, weighted summations were performed to obtain the comprehensive evaluation score of each agglomeration area (Table 4).

The spatial development of O2O online retailers in Zhengzhou City has obvious agglomeration and hierarchy. From the macro view, the intersection of Lianyungang-Lanzhou and Beijing-Guangzhou railways divides the Zhengzhou urban area into four regions, which forms an *x*-shape (Fig. 9). The areas with the higher e-commerce development level are mainly concentrated in the northeast and southwest, while the development levels in the northwest and southeast are relatively low. There are obvious gaps between different regions, especially the gaps in the east-west direction. This is also clearly reflected in the above analysis based on the community/administrative village boundary. This shows that the railway, especially Beijing-Guangzhou railway, has a significant effect on the segmentation of commercial space in Zhengzhou City.

According to the comprehensive evaluation of each area (Table 4), 1) Erqi Square area and Guomao 360 Plaza area are in the first level, with the comprehensive evaluation score between 0.78 and 0.80. The core area of Erqi Square area is concentrated and contiguous, including Erqi square, Railway station, David City, Great Shanghai City, Kingbird City, and other trading areas, covering an area of 2.02 km^2. It ranks first in all commercial agglomeration areas, and it is the largest commercial agglomeration area worthy of the name in Zhengzhou City. The core area of Guomao 360 Plaza area is divided into three parts, namely, Guomao 360 square plaza, Silicon valley square-Lanbao bay, Jincheng international square, covering an area of 1.31 km^2, with an average kernel density of 522.79. It ranks first in all areas, and being the second largest commercial agglomeration area in Zhengzhou. 2) Zhongyuan Wanda Plaza area and Daxue Middle Road area are in the second level, with a comprehensive evaluation score of 0.68–0.71. The core areas of the both are relatively scattered. The former mainly includes trading areas such as Zhongyuan Wanda Plaza, Jinyi City, Children's Park, Xiyuan International Plaza, with an area of 1.23 km^2 and an average kernel density value of 446.08, ranking third in the comprehensive evaluation. The latter mainly includes Changcheng Kangqiaohua City, Shenglong International Center, Erqi Wanda Plaza, Olive City, *etc*. It covers an area of 1.44 km^2, with an average kernel density value of 424.23, ranking fourth in the comprehensive evaluation. 3) The Manhattan Plaza-East Building Materials Market area and Dashiqiao area are in the third level, and the comprehensive evaluation value is between 0.52 and 0.56. The former core areas mainly include Manhattan Plaza, East Building Materials Market, Zhongnanhai Zhiyin, *etc*., with an area of 0.90 km^2 and an average kernel density value of 380.86, ranking fifth in the comprehensive evaluation. The latter core areas include Dashiqiao, Henan Stadium, Jianwen New World, *etc*., with an area of 0.93 km^2 and an average kernel density value of 335.42, ranking sixth in the comprehensive evaluation. 4) Zhengdong area, Zhengnan area, Zhengbei area, High & New Technology Industrial Development Zone and Huiji District are in the fourth level, with comprehensive evaluation values ranging from 0.20 to 0.29. These areas basically belong to the peripheral areas or new development zones of Zhengzhou City. The core areas of each area are small in acreage, small in quantity and isolated in spatial distribution, including Futian Sun City, North University Town, Qiansheng Life Plaza, Cityon, Dennis Mid Town Seven, New campus of Zhengzhou University, etc.

3.3 Core location factors of O2O online retailers' spatial development

Based on the existing research results, we hold that the core location factors of O2O online retailers' spatial development mainly included physical business spatial layout, traffic convenience and population density from the micro-scale of urban area (Shi et al., 2016a; Shi, 2017). The former is due to the dependence of O2O e-commerce on local physical business facilities, but limited by the difficulty in obtaining physical business development data at the micro level. Thus, we have not analyzed this factor for the time being. Traffic convenience is the key factor that affects the difficulty of consumers to stores for consumption, which is measured by accessibility index. According to Formula (2), the time (Time_A), distance (Distance_A) and cost (Cost_A) accessibility index of each trading area are calculated. The population density directly affects the number of consumers entering the physical stores, and the areas with

higher population density tend to have larger potential consumer groups. Considering the mobility of urban population, we took the mean value of Baidu heat map at 10:00 and 16:00 in Zhengzhou urban area as the population density during the work period (Popu_work), the data at 20:00 as the population density during the nightlife period (Popu_nightlife), and the data at 24:00 as the population density during the sleep period (Popu_sleep).

Using the Inverse Distance Weighting Method, the spatial interpolation of the accessibility index of 80 trading areas in Zhengzhou City is carried out, as shown in Fig. 10 and Fig. 11a. Time_A, Distance_A, Cost_A of Zhengzhou City showed obvious core-periphery structures, which gradually increase from the city center to the surroundings, indicating that the accessibility is gradually decreasing, especially in the northwest, northeast, and southwest, where a significant low-accessibility zone was formed. From the distribution of Baidu heat map (Fig. 11b–Fig. 12), the old urban area of Zhengzhou City is still the region with the highest population concentration. After years of development, the population agglomeration effect of Zhengdong New District and Economic and Technological Development Zone are prominent. Those areas are connected with the old urban area. The population density of High & New Technology Industrial Development Zone in the west and Huiji District in the north is still relatively low. There are obvious separation zones (sparsely populated

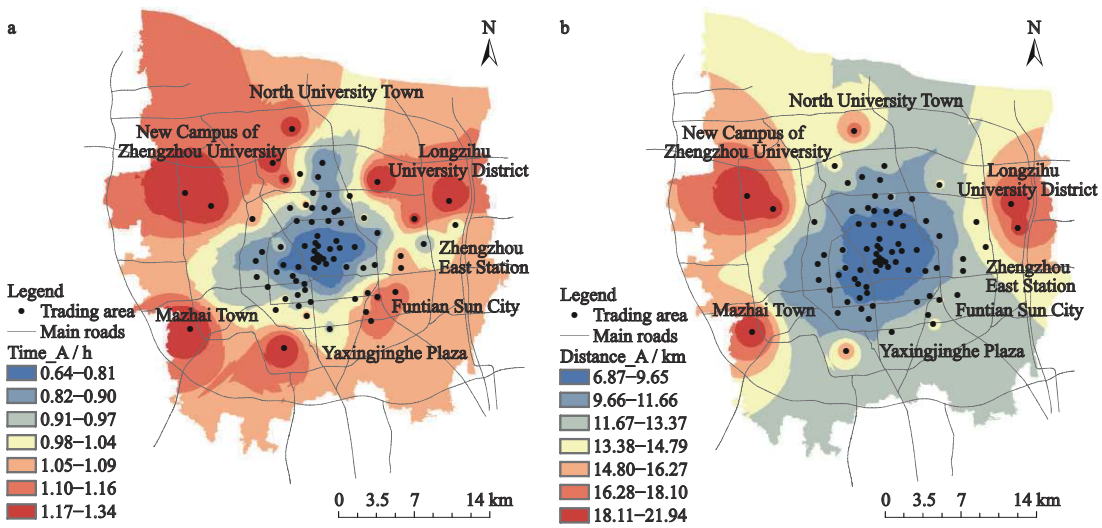

Fig. 10 Spatial interpolation of Time_A (a) and Distance_A (b) in Zhengzhou City

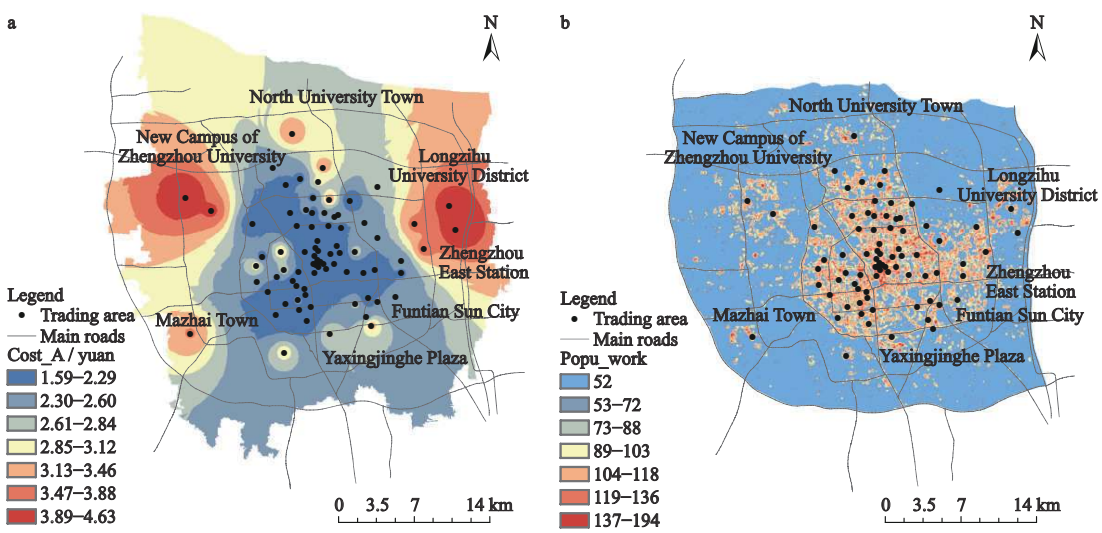

Fig. 11 Spatial interpolation of Cost_A (a) and the map of Popu_work (b) in Zhengzhou City

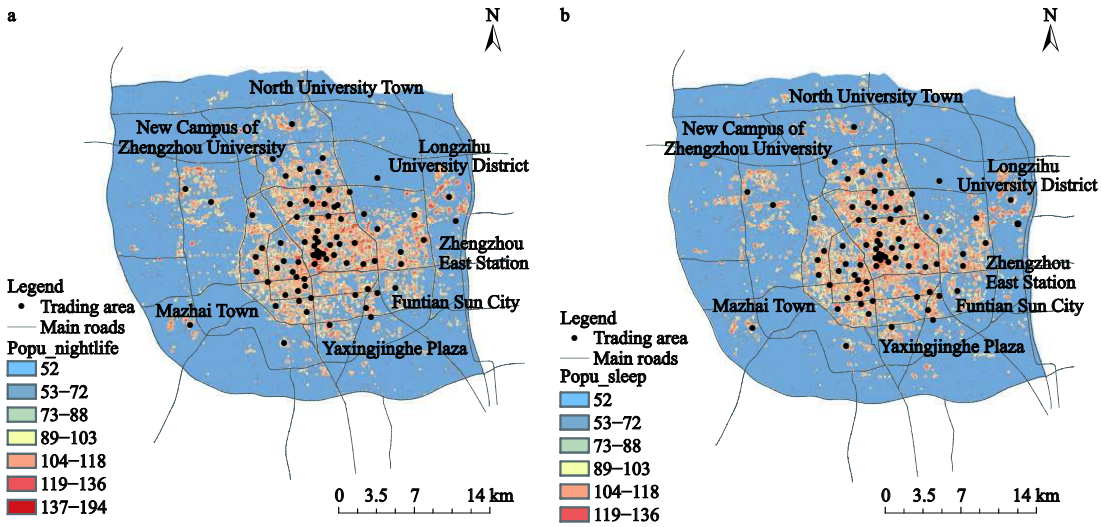

Fig. 12 The map of Popu_nightlife (a) and Popu_sleep (b) in Zhengzhou City

zones) between them and the old urban area.

The evaluation value of the O2O online retailers' development in each trading area was taken as the dependent variable, and the accessibility index and population density were taken as independent variables, which were divided into 2–10 groups. The Factor Detector of Geodetector was used to measure the contribution of each factor to the O2O online retailers' spatial development, as shown in Table 5. With the increase of the number of groups, the q value of each factor basically show a fluctuating upward trend, and most of them reach the significant level, indicating that the influence of each factor on the O2O online retailers' spatial development increases with the increase of the number of groups. Although the q values of each factor vary in different groups, the order remains relatively stable (Table 5), indicating that the effect of each factor on the spatial development of O2O online retailers is relatively stable. For different types of O2O online retailers, in terms of the mean of q values, Gourmet Services, Living Services, Beauty Services and Entertainment Services show similarities, the q value of Popu_nightlife is the largest, followed by Popu_work and Popu_sleep, and the Cost_A is the least. The q value of Distance_A is slightly greater than Time_A, but the difference is not significant. These show that the population density, especially Popu_nightlife, has a greater effect on the spatial development of O2O online retailers than accessibility, which is mainly because the above four types of O2O online retailers are mainly concentrated in densely populated areas such as large shopping malls, specialized markets, schools and resettlement areas, and the distribution of these areas in the urban area tend to be relatively balanced, so the impact of accessibility is weaker than population density. As for Healthcare Services, accessibility, especially Distance_A ($q_{\text{mean}} = 0.31$), has a greater impact on its spatial development than population density ($0.22 \leq q_{\text{mean}} \leq 0.25$), which is mainly due to the fact that this type of O2O online retailers are mainly distributed around large hospitals or medical specialized markets, while the medical resources of Zhengzhou city are mainly concentrated in the old urban area, where the accessibility is relatively high, so the accessibility has a relatively larger impact. For Home-decoration Services, due to its large area and low rent-paying capacity, its location is often chosen to be in peripheral areas far away from the city center and form a specialized market. Although the accessibility here is poor, there are many employment opportunities and a large number of people are gathered here.Therefore, the q value of accessibility is very small ($0.14 \leq q_{\text{mean}} \leq 0.17$), while the q value of population density is relatively large ($0.21 \leq q_{\text{mean}} \leq 0.36$). As for O2O online retailers as a whole, its spatial development influencing factors are basically consistent with those of Gourmet Services (Table 5), because Gourmet Services accounted for the highest proportion of the whole (> 57%, Table 1).

In addition, according to the results of linear regression analysis (Table 6), the development level of O2O online retailers in Zhengzhou city is negatively correlated with the accessibility index (the regression coeffi-

Table 5 Factor detector analysis of O2O online retailers' development and location factors for different groups (q value) in Zhengzhou City

Category	Factors	G2	G3	G4	G5	G6	G7	G8	G9	G10	Mean	Max.	Min.
Gourmet Services	Time_A	0.16***	0.24***	0.34***	0.39***	0.41***	0.41***	0.44***	0.44***	0.55***	0.38	0.55	0.16
	Distance_A	0.18***	0.19***	0.33***	0.35***	0.42***	0.45***	0.52***	0.53***	0.54***	0.39	0.54	0.18
	Cost_A	0.11***	0.13***	0.21***	0.18***	0.20**	0.18**	0.21**	0.20*	0.22*	0.18	0.22	0.11
	Popu_work	0.29***	0.40***	0.57***	0.59***	0.59***	0.59***	0.60***	0.60***	0.60***	0.54	0.60	0.29
	Popu_nightlife	0.29***	0.43***	0.61***	0.62***	0.63***	0.63***	0.63***	0.63***	0.65***	0.57	0.65	0.29
	Popu_sleep	0.28***	0.40***	0.47***	0.51***	0.52***	0.53***	0.54***	0.59***	0.59***	0.49	0.59	0.28
Living Services	Time_A	0.29***	0.36***	0.41***	0.48***	0.49***	0.49***	0.47***	0.49***	0.50***	0.44	0.50	0.29
	Distance_A	0.31***	0.31***	0.44***	0.47***	0.49***	0.52***	0.55***	0.54***	0.53***	0.46	0.55	0.31
	Cost_A	0.14***	0.16***	0.21***	0.20***	0.23***	0.21**	0.26***	0.25**	0.26**	0.21	0.26	0.14
	Popu_work	0.42***	0.48***	0.49***	0.53***	0.54***	0.55***	0.55***	0.57***	0.57***	0.52	0.57	0.42
	Popu_nightlife	0.38***	0.52***	0.54***	0.56***	0.57***	0.59***	0.59***	0.60***	0.60***	0.55	0.60	0.38
	Popu_sleep	0.39***	0.47***	0.50***	0.52***	0.53***	0.51***	0.51***	0.54***	0.53***	0.50	0.54	0.39
Beauty Services	Time_A	0.08**	0.16***	0.22***	0.27***	0.31***	0.32***	0.31***	0.33***	0.37***	0.26	0.37	0.08
	Distance_A	0.13***	0.12***	0.21***	0.20***	0.26***	0.31***	0.35***	0.35***	0.36***	0.26	0.36	0.12
	Cost_A	0.08**	0.09**	0.12**	0.10	0.12	0.11	0.16	0.17	0.14	0.12	0.17	0.08
	Popu_work	0.23***	0.31***	0.34***	0.37***	0.37***	0.38***	0.37***	0.37***	0.40***	0.35	0.40	0.23
	Popu_nightlife	0.23***	0.34***	0.40***	0.40***	0.40***	0.42***	0.42***	0.41***	0.44***	0.38	0.44	0.23
	Popu_sleep	0.23***	0.26***	0.32***	0.30***	0.31***	0.32***	0.33***	0.35***	0.36***	0.31	0.36	0.23
Entertainment Services	Time_A	0.18***	0.20***	0.23***	0.28***	0.30***	0.28***	0.28***	0.33***	0.33***	0.27	0.33	0.18
	Distance_A	0.22***	0.21***	0.29***	0.30***	0.34***	0.37***	0.35***	0.40***	0.39***	0.32	0.40	0.21
	Cost_A	0.13***	0.12**	0.17***	0.17**	0.18**	0.17*	0.23**	0.22*	0.20	0.18	0.23	0.12
	Popu_work	0.33***	0.42***	0.42***	0.46***	0.45***	0.45***	0.47***	0.48***	0.51***	0.44	0.51	0.33
	Popu_nightlife	0.31***	0.47***	0.49***	0.50***	0.50***	0.51***	0.51***	0.50***	0.54***	0.48	0.54	0.31
	Popu_sleep	0.31***	0.35***	0.42***	0.41***	0.43***	0.43***	0.44***	0.47***	0.44***	0.41	0.47	0.31
Healthcare Services	Time_A	0.17***	0.19***	0.19***	0.22***	0.24***	0.28***	0.25**	0.27**	0.34***	0.24	0.34	0.17
	Distance_A	0.16***	0.20***	0.33***	0.33***	0.32***	0.34***	0.34***	0.36***	0.38***	0.31	0.38	0.16
	Cost_A	0.10***	0.15***	0.13**	0.14**	0.24***	0.18**	0.20**	0.23**	0.26**	0.18	0.26	0.10
	Popu_work	0.20***	0.14***	0.18**	0.24***	0.25***	0.23**	0.27**	0.35***	0.28**	0.24	0.35	0.14
	Popu_nightlife	0.19***	0.15***	0.18**	0.23***	0.23**	0.23**	0.23**	0.32***	0.23*	0.22	0.32	0.15
	Popu_sleep	0.22***	0.17***	0.24***	0.24***	0.25***	0.28***	0.27***	0.30***	0.32***	0.25	0.32	0.17
Home-decoration Services	Time_A	0.09**	0.09**	0.15**	0.16**	0.19**	0.20**	0.20*	0.22**	0.26*	0.17	0.26	0.09
	Distance_A	0.09***	0.12**	0.11**	0.16**	0.16**	0.19**	0.22**	0.23**	0.24*	0.17	0.24	0.09
	Cost_A	0.06**	0.09**	0.17***	0.13*	0.14*	0.16*	0.15	0.16	0.17	0.14	0.17	0.06
	Popu_work	0.18***	0.23***	0.39***	0.39***	0.39***	0.40***	0.43***	0.42***	0.43***	0.36	0.43	0.18
	Popu_nightlife	0.15**	0.26***	0.36***	0.36***	0.36***	0.41***	0.41***	0.40***	0.51***	0.36	0.51	0.15
	Popu_sleep	0.14***	0.12**	0.15**	0.21***	0.20**	0.23**	0.21**	0.30**	0.32**	0.21	0.32	0.12
Whole	Time_A	0.18***	0.26***	0.35***	0.40***	0.43***	0.42***	0.43***	0.45***	0.53***	0.38	0.53	0.18
	Distance_A	0.20***	0.21***	0.35***	0.36***	0.42***	0.46***	0.52***	0.52***	0.52***	0.39	0.52	0.20
	Cost_A	0.12***	0.13***	0.20***	0.18***	0.21***	0.18**	0.22**	0.21*	0.23*	0.19	0.23	0.12
	Popu_work	0.32***	0.43***	0.56***	0.59***	0.59***	0.59***	0.59***	0.60***	0.60***	0.54	0.60	0.32
	Popu_nightlife	0.32***	0.46***	0.60***	0.61***	0.61***	0.62***	0.62***	0.62***	0.64***	0.57	0.64	0.32
	Popu_sleep	0.31***	0.41***	0.48***	0.50***	0.51***	0.52***	0.53***	0.57***	0.58***	0.49	0.58	0.31

Notes: G2 indicates the data was divided into two groups, and so on. *, **, *** represent passing the significance level test of 0.1, 0.05 and 0.01, respectively

Table 6 Linear fitting analysis of O2O online retailers' development and location factors in Zhengzhou City

Category	Factors	Linear fitting equation	SC	R^2 values	F-statistics	Significance
Gourmet Services	Time_A	$y = -383.363x + 477.893$	–0.565	0.320	36.655	0.000
	Distance_A	$y = -19.397x + 330.578$	–0.520	0.271	28.952	0.000
	Cost_A	$y = -73.553x + 300.813$	–0.400	0.160	14.864	0.000
	Popu_work	$y = 4.792x - 358.551$	0.694	0.482	72.481	0.000
	Popu_nightlife	$y = 5.097x - 383.460$	0.746	0.556	97.845	0.000
	Popu_sleep	$y = 5.043x - 362.540$	0.693	0.480	71.945	0.000
Living Services	Time_A	$y = -74.170x + 92.760$	–0.670	0.450	63.707	0.000
	Distance_A	$y = -3.840x + 65.199$	–0.631	0.399	51.691	0.000
	Cost_A	$y = -13.604x + 56.974$	–0.454	0.206	20.200	0.000
	Popu_work	$y = 0.815x - 57.884$	0.724	0.524	85.874	0.000
	Popu_nightlife	$y = 0.818x - 57.206$	0.734	0.538	90.861	0.000
	Popu_sleep	$y = 0.835x - 56.345$	0.703	0.494	76.236	0.000
Beauty Services	Time_A	$y = -105.215x + 129.239$	–0.458	0.210	20.744	0.000
	Distance_A	$y = -5.333x + 88.914$	–0.423	0.179	16.953	0.000
	Cost_A	$y = -20.557x + 81.541$	–0.330	0.109	9.549	0.003
	Popu_work	$y = 1.331x - 101.886$	0.569	0.324	37.394	0.000
	Popu_nightlife	$y = 1.452x - 112.392$	0.627	0.394	50.660	0.000
	Popu_sleep	$y = 1.394x - 102.341$	0.565	0.320	36.652	0.000
Entertainment Services	Time_A	$y = -27.452x + 35.757$	–0.516	0.267	28.369	0.000
	Distance_A	$y = -1.517x + 26.583$	–0.519	0.269	28.736	0.000
	Cost_A	$y = -5.936x + 24.706$	–0.412	0.170	15.929	0.000
	Popu_work	$y = 0.357x - 25.508$	0.659	0.434	59.926	0.000
	Popu_nightlife	$y = 0.368x - 26.201$	0.687	0.471	69.550	0.000
	Popu_sleep	$y = 0.371x - 25.382$	0.650	0.423	57.114	0.000
Healthcare Services	Time_A	$y = -13.468x + 16.893$	–0.490	0.241	24.709	0.000
	Distance_A	$y = -0.742x + 12.371$	–0.492	0.242	24.846	0.000
	Cost_A	$y = -2.706x + 10.969$	–0.363	0.132	11.869	0.000
	Popu_work	$y = 0.131x - 8.800$	0.470	0.221	22.149	0.000
	Popu_nightlife	$y = 0.130x - 8.461$	0.468	0.219	21.895	0.000
	Popu_sleep	$y = 0.139x - 8.967$	0.471	0.222	22.283	0.000
Home-decoration Services	Time_A	$y = -10.178x + 12.328$	–0.368	0.136	12.250	0.000
	Distance_A	$y = -0.525x + 8.526$	–0.346	0.119	10.585	0.002
	Cost_A	$y = -2.413x + 8.749$	–0.322	0.104	9.030	0.004
	Popu_work	$y = 0.149x - 12.044$	0.529	0.280	30.326	0.000
	Popu_nightlife	$y = 0.150x - 11.974$	0.538	0.290	31.786	0.000
	Popu_sleep	$y = 0.126x - 9.230$	0.425	0.181	17.184	0.000
Whole	Time_A	$y = -623.050x + 774.897$	–0.581	0.338	39.762	0.000
	Distance_A	$y = -31.735x + 537.750$	–0.538	0.290	31.817	0.000
	Cost_A	$y = -119.262x + 486.427$	–0.410	0.168	15.779	0.000
	Popu_work	$y = 7.731x - 578.869$	0.708	0.501	78.425	0.000
	Popu_nightlife	$y = 8.170x - 613.743$	0.756	0.572	104.094	0.000
	Popu_sleep	$y = 8.037x - 575.648$	0.698	0.487	74.093	0.000

Note: SC (Standardized Coefficients)

cients are negative), and positively correlated with population density (the regression coefficients are positive). From the standardized Coefficients (SC) and the goodness of fit (R^2), we can draw similar conclusions consistent with the above analysis based on Geodetectors. Besides Healthcare Services, population density, especially Popu_nightlife, has a greater explanatory power for the spatial development of other types of O2O online retailers than accessibility. Accessibility, mainly refers to Time_A and Distance_A ($-0.492 \leq SC \leq -0.490$), has a slightly greater impact on the spatial development of Healthcare Services than population density ($0.468 \leq SC \leq 0.471$).

4 Discussion

Traditional e-commerce, such as B2C and C2C, has aroused early attention from the academic community. Due to its small dependence on physical space, the location selection within a city shows a law that no longer follows the traditional location theory (Lu et al., 2011), while it still follows the hierarchical expansion path on the macro scale (Wang and Lu, 2011). O2O e-commerce not only has online stores, but also offline physical stores. According to different commodity (services) delivery scenarios, it can be divided into Store O2O and Home O2O (Chen, 2019; Zhang et al., 2019). Store O2O is the traditional O2O model, which mainly operates experiential goods (services). The delivery place is offline physical stores, and it is represented by experiential online group-buying such as the catering and photography (Chen, 2019). Home O2O mainly deals with convenience goods (services) related to daily life, and delivers goods (services) to your home via instant Express / logistics, such as take-out and cleaning services (Chen, 2019; Zhang et al., 2019). Previous studies revealed that the two kinds of e-commerce show different spatial development laws. Store O2O requires customers to consume in stores, so its spatial development is still restricted comparatively by physical stores' location, and shows a certain degree of traditional business location characteristics. The agglomeration degree from the city center to the periphery decreases gradually, and at the same time, new commercial agglomerations are formed in urban suburbs with good time accessibility (Wang, 2014; Zhang et al., 2019). Home O2O is an emerging O2O mode, which relies heavily on instant express / logistics. For its products need to be delivered (served) to the door, so its location selection is limited by the delivery time and scope of express / logistics and the location of target customers (Chen, 2019; Shi et al., 2019a). The research object of this article is online stores of Meituan.com, which basically belong to Store O2O in terms of the types of goods (services). The results show that different types of stores have significant spatial agglomeration, indicating that their spatial development have significant location characteristics instead of being homogeneous. Generally, the commercial development level of the central urban area is relatively high and that of urban periphery is relatively low, but it is not the traditional monocentric urban spatial structure. The area with the high development level in the central urban area is divided into several relatively independent commercial centers, and several high-level commercial agglomeration areas have emerged in urban periphery, indicating that the core-periphery structure is being broken and the polycentric Spatial development pattern is being formed gradually. In addition, all kinds of O2O online retailers' agglomeration areas are basically areas with high level of physical business development. They have large shopping malls, professional markets or central plaza, with a large crowd of people and complete service facilities, indicating that the development of O2O e-commerce has a strong dependence on physical business facilities.

Many factors affect the physical commercial spatial layout, including direct influencing factors such as location characteristics, traffic conditions, consumer attributes and competitive environment, as well as indirect influencing factors such as regional economy, policy and planning, history and culture (Chen, 2019). O2O e-commerce has the nature of 'semi-virtual', which is developed on the basis of physical stores. Therefore, the above factors that affect physical commerce's development still have effect on its spatial development. However, this effect is somewhat weakened by network platform and express / logistics. Thus, the current academic debate on this aspect is still fierce (Shi, 2017; Chen, 2019). Some scholars believe that the spatial pattern of Store O2O is still considerably influenced by traditional location theories, but the time that spent by consumers going to physical stores has a greater impact than physical distance on business activities, and become the primary factor in its location selection (Shi et al., 2016a, b). Other scholars think that Store O2O is less influenced by consumers' location and show more freedom in loca-

tion selection. However, Home O2O mainly sells instant goods (services), and is more sensitive to physical distance because of the limitation of delivery time and distance of ex-press/logistics (Chen, 2019). In addition, some other researchers insist that Home O2O has further broken through geographical restrictions, and its spatial development rules basically conformed the innovation diffusion hypothesis, showing a spatial diffusion law that contrary to the Store O2O (Shi et al., 2019a; Zhang et al., 2019). It can be seen that there is no consensus has been reached in the academic community, and the conclusions even somewhat contradict each other. The reason may be that the penetration of e-commerce into physical business is too fast, new commercial forms and business models emerge one after another, while the theoretical research can not keep up with the development of business practice. On the whole, existing studies showed that the factors affecting O2O online retailers' spatial development mainly include physical business spatial layout, business organization forms, types of goods (services), the penetration level of information technology, logistics distribution conditions, consumer distribution, and Traffic convenience (Shi, 2017; Chen, 2019; Zhang et al., 2019). However, the above factors play different roles. From the perspective of the business operation process, the physical commercial spatial layout and consumer distribution represent merchants and consumers, respectively. The logistics distribution conditions and traffic convenience are the links that connect them. The above four factors form a closed loop of O2O business activities, and become the key elements of its spatial development. For Store O2O, convenient transportation facilitates consumers to reach physical stores quickly for consumption. Therefore, we considered that physical commercial spatial layout, traffic convenience, and consumer distribution are the core location factors affecting the spatial development of O2O online retailers in Zhengzhou city. However, we have not analyzed this factor because of the difficulty in obtaining the spatial distribution data of physical business. This is also the shortcoming of this study, and the follow-up studies should be further improved. According to the analysis results, the contribution of population density to the spatial development of O2O online retailers in Zhengzhou City is greater than that of the accessibility, especially the population density in the nightlife period, which indicates that the Zhengzhou's O2O commercial spatial development is more dependent on consumer distribution. The contribution value of time accessibility and distance accessibility had been estimated. However, there are little differences. The overall contribution of time accessibility is slightly larger than that of distance accessibility. However, it is not enough to show that time cost has exceeded distance and become the primary factor in the location selection of O2O online retailers, which needs further in-depth analysis, and this is somewhat different from the conclusions of Shi Kunbo (Shi et al., 2016a, b). Zhengzhou is a commercial city rising from railway traffic, with poor historical accumulation and short development history. The construction of urban infrastructure takes the railway station as the core to spread around. The facilities in the central urban area are perfect, while those in the peripheral areas are comparatively poor. The spatial distribution of time accessibility and distance accessibility is highly overlapped (Fig. 10). This may lead to the effect of time cost on the spatial development of O2O online retailers in Zhengzhou City has not been fully presented. It could be expected that the time cost will play a more important role with the further improvement of urban peripheral infrastructure construction.

5 Conclusions

1) The development of different types of O2O online retailers in Zhengzhou City has remarkable spatial agglomeration, among which the gourmet services and living services have the strongest agglomeration. The global high-value agglomeration characteristics are obvious, and the spatial polarization phenomenon is prominent. 2) The agglomeration areas of different types of O2O online retailers are different, but most of them are concentrated in the old urban area within the Third Ring Road of Zhengzhou City, within 6 km from the city center (Zhengzhou railway station). There are 16 major high-value agglomeration areas, among which Erqi Square, Guomao 360 Plaza, Daxue Middle Road, Dashiqiao and Zhongyuan Wanda Plaza are comprehensive agglomeration areas, while the others are specialized agglomeration areas. 3) The commercial agglomeration zoning shows that the total area of Zhengzhou O2O commercial agglomeration areas is 54.26 km^2, accounting for 5.33% of the study region, where the core area, intermediate area and fringe area are 0.81%, 1.09% and 3.43%, respectively. The areas with the high develop-

mental level of O2O e-commerce are mainly concentrated in the northeast and southwest of the *x*-shaped region formed by the intersection of Lianyungang-Lanzhou and Beijing-Guangzhou railways. Erqi Square and Guomao 360 Plaza have the highest development level, followed by Zhongyuan Wanda Plaza and Daxue Middle Road, again for Manhattan-Eastern Building Material Market and Dashiqiao, the development level of Zhengdong, Zhengnan, Zhengbei, High & New Technology Industrial Development Zone, Huiji District and other areas is relatively low. 4) Zhengzhou's O2O commercial pattern is highly dependent on physical business, and the population distribution, especially the population distribution during the nightlife period, plays a vital role in its spatial development, followed by the accessibility. The effect of time cost is slightly larger than that of physical distance, but the difference between them is little, and travel costs have the least impact. 5) Local government should make full use of the leading role of population and infrastructure in the service industry, actively guide the population in the central urban area to evacuate to peripheral areas, continuously improve the construction of suburban public service facilities, and promote a more balanced and sustainable development of commercial services in Zhengzhou City.

References

Anderson W P, Chatterjee L, Lakshmanan T R, 2003. E-commerce, transportation, and economic geography. *Growth and Change*, 34(4): 415–432. doi: 10.1046/j.0017-4815.2003.00228.x

Calderwood E, Freathy P, 2014. Consumer mobility in the Scottish isles: the impact of internet adoption upon retail travel patterns. *Transportation Research Part A: Policy and Practice*, 59: 192–203. doi: 10.1016/j.tra.2013.11.012

Cao X J, 2012. The relationships between e-shopping and store shopping in the shopping process of search goods. *Transportation Research Part A: Policy and Practice*, 46(7): 993–1002. doi: 10.1016/j.tra.2012.04.007

Chen Miaorong, 2019. *Study on the Differences and Influencing Factors of Community O2O Online and Physical Commercial Spatial Distribution in Guangzhou*. Guangzhou: South China University of Technology. (in Chinese)

Comi A, Nuzzolo A, 2016. Exploring the relationships between e-shopping attitudes and urban freight transport. *Transportation Research Procedia*, 12: 399–412. doi: 10.1016/j.trpro.2016.02.075

Dahe Daily, 2019. *Zhengzhou's cross-border e-commerce transactions in 2018 amounted to $8.64 billion, ranking third in China*. Available at: https://henan.qq.com/a/20190511/001859.htm. Cited 11 May 2019.

Ding Zhiwei, Zhou Kaiyue, Kang Jiangjiang et al., 2016. The spatial differentiation and influencing factors of the service quality of C2C stores in Central China: a case study of five types of Taobao online stores. *Geographical Research*, 35(6): 1074–1095. (in Chinese)

Farag S, Dijst M, Lanzendorf M, 2003. Exploring the use of e-shopping and its impact on personal travel behavior in the Netherlands. *Transportation Research Record*, 1858(1): 47–54. doi: 10.3141/1858-07

Farag S, Schwanen T, Dijst M, 2005. Empirical investigation of online searching and buying and their relationship to shopping trips. *Transportation Research Record*, 1926(1): 242–251. doi: 10.1177/0361198105192600128

Farag S, Weltevreden J, Van Rietbergen T et al., 2006a. E-shopping in the Netherlands: does geography matter? *Environment and Planning B: Planning and Design*, 33(1): 59–74. doi: 10.1068/b31083

Farag S, Krizek K J, Dijst M, 2006b. E-shopping and its relationship with in-store shopping: empirical evidence from the Netherlands and the USA. *Transport Reviews*, 26(1): 43–61. doi: 10.1080/01441640500158496

Farag S, Schwanen T, Dijst M et al., 2007. Shopping online and/or in-store? A structural equation model of the relationships between e-shopping and in-store shopping. *Transportation Research Part A: Policy and Practice*, 41(2): 125–141. doi: 10.1016/j.tra.2006.02.003

Hao Feilong, Guan Haoming, Wang Shijun, 2016. Study on the influencing factors and spatial distribution of electronic commerce development level in China's cities. *Economic Geography*, 36(2): 1–10. (in Chinese)

Getis A, Ord J K, 1992. The Analysis of Spatial Association by Use of Distance Statistics. *Geographical Analysis*, 24(3): 189–206. doi: 10.1111/j.1538-4632.1992.tb000261.x

Krizek K J, Li Y, Handy S L, 2005. Spatial attributes and patterns of use in household-related information and communications technology activity. *Transportation Research Record*, 1926(1): 252–259. doi: 10.1177/0361198105192600129

Liu W D, Dicken P, Yeung H W C, 2004. New information and communication technologies and local clustering of firms: a case study of the Xingwang Industrial Park in Beijing. *Urban Geography*, 25(4): 390–407. doi: 10.2747/0272-3638.25.4.390

Lu Zi, Li Xiaonan, Yang Lihua et al., 2011. Location orientation of e-shops in China's major cities based on neighborhood facilities: case studies of Shanghai, Shenzhen, Tianjin and Beijing. *Acta Geographica Sinica*, 66(6): 813–820. (in Chinese)

Lu Zi, Wang Wenting, Zhang Qiuluan et al., 2013. The impact of experiential online group-buying on the urban commercial spatial organization. *Human Geography*, 28(5): 101–104, 138. (in Chinese)

Mokhtarian P L, 2004. A conceptual analysis of the transportation impacts of B2C e-commerce. *Transportation*, 31(3): 257–284. doi: 10.1023/b:port.0000025428.64128.d3

Qin Xiao, Zhen Feng, Zhu Shoujia et al., 2014. Spatial pattern of catering industry in nanjing urban area based on the degree of public praise from internet: a case study of Dianping.com. *Scientia Geographica Sinica*, 34(7): 810–817. (in Chinese)

Mitchell A, 2005. The ESRI Guide to GIS Analysis, Volume 2. *Redlands: ESRI Press*, 102-136.

Ren F, Kwan M P, 2009. The impact of geographic context on e-shopping behavior. *Environment and Planning B: Planning and Design*, 36(2): 262–278. doi: 10.1068/b34014t

Shi Kunbo, Yang Yongchun, Bai Shuo et al., 2016a. Spatial characteristics of the experiential online group-buying market in Chengdu. *Geographical Research*, 35(1): 108–122. (in Chinese)

Shi Kunbo, Yang Yongchun, Yang Xin'ao et al., 2016b. Does time dictate the location of e-commerce business? A study of O2O businesses in Chengdu, China. *Acta Geographica Sinica*, 71(3): 500–514. (in Chinese)

Shi Kunbo, 2017. *Spatial Reconstruction of Urban Physical Commerce of China in Information Era: Based on the Perspective of E-Commerce*. Lanzhou: Lanzhou University. (in Chinese)

Shi Kunbo, Yang Yongchun, Bai Shuo et al., 2018. Innovation diffusion hypothesis or efficiency hypothesis: spatial penetration of online-to-offline e-commerce in China based on Meituan.com. *Geographical Reserach*, 37(4): 783–796. (in Chinese)

Shi Xiang, Wang Shijun, Hao Feilong et al., 2019a. The spatial distribution and formation of takeaway O2O catering industry based on entity restaurants comparison in Changchun. *Human Geography*, 34(2): 80–89. (in Chinese)

Shi K B, De Vos J, Yang Y C et al., 2019b. Does e-shopping replace shopping trips? Empirical evidence from Chengdu, China. *Transportation Research Part A: Policy and Practice*, 122: 21–33. doi: 10.1016/j.tra.2019.01.027

Song Zhouying, Yu Yang, Zhu Qiaoling et al., 2019. Spatial characteristics and influencing factors of E-shopping development in China's counties. *Geographical Research*, 38(12): 2997–3009. (in Chinese)

Wang J F, Li X H, Christakos G et al., 2010. Geographical detectors-based health risk assessment and its application in the neural tube defects study of the Heshun Region, China. *International Journal of Geographical Information Science*, 24(1): 107–127. doi: 10.1080/13658810802443457

Wang Jinfeng, Xu Chengdong, 2017. Geodetector: principle and prospective. *Acta Geographica Sinica*, 72(1): 116–134. (in Chinese)

Wang Jianzhu, 2014. Spatial development trends of urban service industries in the information times: a case study of Beijing's catering industry. *Urban Problems*, (11): 90–95. (in Chinese)

Wang Mingfeng, Lu Shan, 2011. Exploring the spatial organization of online retailing: a case study of Dangdang.com. *Geographical Research*, 30(6): 965–976. (in Chinese)

Wang Jinfeng, Liao Yilan, Liu Xin, 2019. Tutorial on Spatial Data Analysis (Second Edition). *Beijing: Science Press*, 30-45. (in Chinese)

Wang Mingfeng, Lu Shan, Yuan He, 2013. Influences of online shopping on consumer behaviors at different shopping locations: a comparative study on city center and suburb. *City Planning Review*, 37(11): 84–88, 95. (in Chinese)

Weltevreden J W J, Atzema O A L C, 2006. Cyberspace meets high street: adoption of click-and-mortar strategies by retail outlets in city centers. *Urban Geography*, 27(7): 628–650. doi: 10.2747/0272-3638.27.7.628

Weltevreden J W J, Atzema O A L C, Frenken K et al., 2008. The geography of Internet adoption by independent retailers in the Netherlands. *Environment and Planning B: Planning and Design*, 35(3): 443–460. doi: 10.1068/b33032

Wu Kangmin, Zhang Hongou, Wang Yang et al., 2016. Identify of the multiple types of commercial center in Guangzhou and its spatial pattern. *Progress in Geography*, 35(8): 963–974. (in Chinese). doi: 10.18306/dlkxjz.2016.08.005

Xi Guangliang, Zhen Feng, Wang Xia et al., 2014. Study on the influencing factors and spatial characteristics of residents' online consumption in Nanjing. *Geographical Research*, 33(2): 86–97. (in Chinese)

Xue Shuyan, Li Gang, Yang Lan et al., 2019. Spatial pattern and influencing factor analysis of attended collection and delivery points in Changsha City, China. *Chinese Geographical Science*, 29(6): 1078–1094. doi: 10.1007/s11769-019-1086-3

Yu W H, Ai T H, Shao S W, 2015. The analysis and delimitation of Central Business District using network kernel density estimation. *Journal of Transport Geography*, 45: 32–47. doi: 10.1016/j.jtrangeo.2015.04.008

Zeng Simin, Chen Zhongnuan, 2013. A review on spatial organization of e-retail and its impact abroad. *Human Geography*, 28(1): 36–42. (in Chinese)

Zhang Yiji, Zhen Feng, Zhang Yiqun, 2019. Adoption of O2O strategies by community retailers in Nanjing. *Economic Geography*, 39(11): 104–112. (in Chinese)

Zhen F, Du X J, Cao J et al., 2018. The association between spatial attributes and e-shopping in the shopping process for search goods and experience goods: evidence from Nanjing. *Journal of Transport Geography*, 66: 291–299. doi: 10.1016/j.jtrangeo.2017.11.007

Zhengzhou Municipal Bureau Statistics, 2019a. *The basic situation of Zhengzhou's economic operation in 2018*. Available at: http://www.zhengzhou.gov.cn/news4/91478.jhtml. Cited 15 Feb 2019.

Zhao Hongbo, Yu Difei, Miao Changhong et al., 2018. The location distribution characteristics and influencing factors of cultural facilities in Zhengzhou based on POI data. *Scientia Geographica Sinica*, 38(9): 1525–1534. (in Chinese). doi: 10.13249/j.cnki.sgs.2018.09.016

Zhengzhou Municipal Bureau Statistics, 2019b. The bulletin of Zhengzhou population sampling survey in 2018. Available at: http://www.ha.stats.gov.cn/2019/06-11/1367947.html. Cited 13 Jun 2019.

Zhengzhou Municipal Bureau Statistics, 2019c. *Zhengzhou Statistical Yearbook*. Beijing: China Statistics Press. (in Chinese)

Zhengzhou Municipal People's Government, 2019. Announcement on the scale of Zhengzhou's urban built-up area in 2018. Available at: http://public.zhengzhou.gov.cn/D0104X/295260.jhtml. Cited 12 Apr 2019.

Zhou Chunshan, Jin Wanfu, Zhang Guojun, 2018. Impact of shipping distance on online retailers' sales: a case study of Maiyang on tmall. *Chinese Geographical Science*, 28(2): 261–273. doi: 10.1007/s11769-018-0945-7

Zhu S Z, Chen J, 2013. The digital divide in individual e-commerce utilization in China: results from a national survey. *Information Development*, 29(1): 69–80. doi: 10.1177/0266666912450168