Study on the impact mechanism of population distribution before and during the COVID-19 in high density urban area: a case study of Tianjin central area

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Summary

In this paper, Tianjin central area is taken as an example to calculate the urban population density index (PDI) as the dependent variable of Multiscale Geographically Weighted Regression (MGWR) through Baidu heat map, indicating the population distribution during the epidemic. MGWR is used to study the relationship between the multifunction of urban housing, commerce, service, industry and population distribution before and during the COVID-19. The research results can provide scientific support for urban epidemic prevention strategies.

KEYWORDS: high density area; COVID-19; population distribution; urban function; Tianjin

1. Introduction

COVID-19 spreads worldly, which has a severe impact on urban life. Reducing contact rates and restricting mass gathering are the primary prevention strategies to deal with the epidemic spread in high-density urban areas. It effectively controlled the epidemic but also changed the original state of urban operation. China has taken active epidemic control measures to minimize public gathering activities, such as shutdowns, online learning platforms. For one thing, these epidemic control measures control the mobility of different functional spaces. For another thing, residents' demand for urban functions has changed during the epidemic. The combined effect of the two leads to changes in the interaction between functional space and residents. Urban population dynamics can become a critical perspective to understand the interaction (Recker et al., 2008) and provide helpful information for decision-makers to build a resilient city.

Based on the above cognition, the study analyzed the relationship between urban functions and population distribution before and during the epidemic in the Tianjin high-density area. Specifically, (1) the urban population density index (PDI) was calculated by Baidu heat map, and we took November 29, 2019, and February 27, 2020, as representatives before and during the epidemic. (2) described changes in the distribution of population density during the epidemic. (3) Multiscale Geographically Weighted Regression (MGWR) was used to analyze the relationship between population density and urban functions.

2. Data and methodology

2.1. Baidu heat map

Baidu heat map is one of the most typical representatives of population distribution. It is based on LBS platform mobile phone user location data and calculates the population density of different locations in real-time. Considering that the fluctuation of the number of users within a day, the average PDI in the two periods is calculated by day (10:00~16:59) and night (17:00~22:00). We divide the heat into 7 grades. The formula of PDI is as follows:

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$$PDI_i = \frac{\sum_{g=1}^{7} HV_g * N_{i,g}}{\sum_{i=1}^{n}\sum_{g=1}^{7} HV_g * N_{i,g}} \quad (1)$$

where PDI_i is the population density index of sample i; HV_g represents the assignment of grade g; $N_{i,g}$ denotes the number of grade g in ith grid; n is the number of samples.

2.2. POI data

POI data contains accurate spatial information, which can be used to characterize the utilization of functional space. In this paper, POI is divided into four categories. According to the proportion of POIs, the residential function intensity (I_R), commercial function intensity (I_C), service function intensity (I_S), and industrial function intensity (I_I) are calculated.

2.3. MGWR

Usually, a city phenomenon is determined by multiple spatial processes at different scales (Shen et al., 2020). Therefore, Geographically Weighted Regression (GWR) still has limitations. Fotheringham, A.S., W. Yang and W. Kang proposed MGWR (Fotheringham et al., 2017), which allows each variable to have different bandwidths based on GWR. In this paper, MGWR is carried out by MGWR 2.2, and the adaptive bi-square function and AICc criterion are used.

3. Results

3.1. Changes in the Operational Scales

Table 1 The spatial bandwidths of MGWR

Variable	Before		During	
	Day	Night	Day	Night
I_R	633	109	89	87
I_C	871	3600	3600	3600
I_S	52	283	137	835
I_I	3205	551	3600	3598

Table 1 shows significant differences in the bandwidth of function variables before and during the epidemic. The action scale of industrial and commercial functions during the epidemic period becomes the global scale. This shows that residents are not sensitive to the spatial locations of commercial and industrial functions during the epidemic. The effect scale of residential life function during the epidemic is significantly smaller, accounting for about 2.4% of the total samples. Besides, almost all urban function variables have smaller diurnal variations in bandwidth during the epidemic, except for service functions. The function bandwidth of service function has a significant difference between day and night during the epidemic. That is, there are still significant differences in population distribution between day and night in the service function area. This may be because service function areas still have commuting characteristics during the epidemic.

3.2. Spatial Pattern Analysis of Coefficients

Table 2 Statistical description of MGWR coefficients

Variable		Before				During			
		Mean	STD	Min	Max	Mean	STD	Min	Max
I_R	Day	0.119	0.035	0.053	0.203	0.450	0.158	0.097	0.934
	Night	0.304	0.102	0.111	0.643	0.515	0.184	0.110	1.073
I_C	Day	0.272	0.029	0.176	0.345	0.123	0.002	0.117	0.128
	Night	0.242	0.002	0.238	0.245	0.082	0.002	0.078	0.086
I_S	Day	0.425	0.192	-0.497	1.180	0.283	0.120	0.068	0.619
	Night	0.219	0.087	0.054	0.484	0.125	0.050	0.042	0.245
I_I	Day	0.036	0.006	0.025	0.046	-0.026	0.003	-0.030	-0.020
	Night	0.075	0.038	-0.058	0.154	-0.032	0.004	-0.038	-0.025

Table 2 shows that the impact of urban functions on population aggregation changes before and during the epidemic. Before the epidemic, the effect of functions on population aggregation was mainly positive.

In terms of daytime, the average impact intensity of I_S is the largest. The second is I_C. At night, the average impact of I_R and I_C is relatively strong. During the epidemic, the coefficient of I_R significantly increases. Whether day or night, the average impact intensity of I_R is the largest. That is, the demand for residential functions during the epidemic is generally increasing. The average coefficients of the others are smaller. Residents' demand for commercial, services, and industrial functions weakened, especially for commerce.

We can find that the epidemic has led to the change of the behaviour pattern through the comparison. Before the epidemic, residents take service and commerce as the core of their daytime activities, and residence and commerce as the core of night activities. During the epidemic, residents take living space as the core of a single activity day and night.

Figure 1 and **Figure 2** show the spatial and temporal impact of urban functional elements on PDI. The insignificant grid unit indicates that the analyzed function has a weak ability to interpret PDI. The spatial characteristics of I_R and I_C on PDI after the epidemic are similar to those before the epidemic. Regardless of the epidemic, residential and service functions' spatial heterogeneity is stronger than that of commercial and industrial functions. The diurnal difference in the impact of residential functions on PDI during the epidemic is small. The overall spatial characteristics are similar to the night before the epidemic. It is because blockade measures were implemented in Tianjin communities in the early stage of the epidemic. So, the activities' scope is relatively small, mainly in the residential area and the surrounding area. It is similar to the living conditions at night before the epidemic. One noticeable difference is that the fringe zone was significantly affected by residential functions after the epidemic. From the perspective of spatial distribution, the impact of service functions on PDI is relatively consistent. Service functions as the fundamental guarantee of life, still serving during the epidemic. Therefore, it has the characteristics of commuting, manifested in the apparent changes in the day and night. However, during the epidemic, people's mobility to public cultural facilities, education areas, and transportation and logistics areas have weakened. The intensity of commercial functions' impact generally decreases during the epidemic, and residents' mobility to the physical commercial space is generally weakened. Significant changes have taken place in the impact of industrial functions on PDI after the outbreak. The impact changes from positive to negative. It is consistent with the background that companies require employees to work remotely during the epidemic.

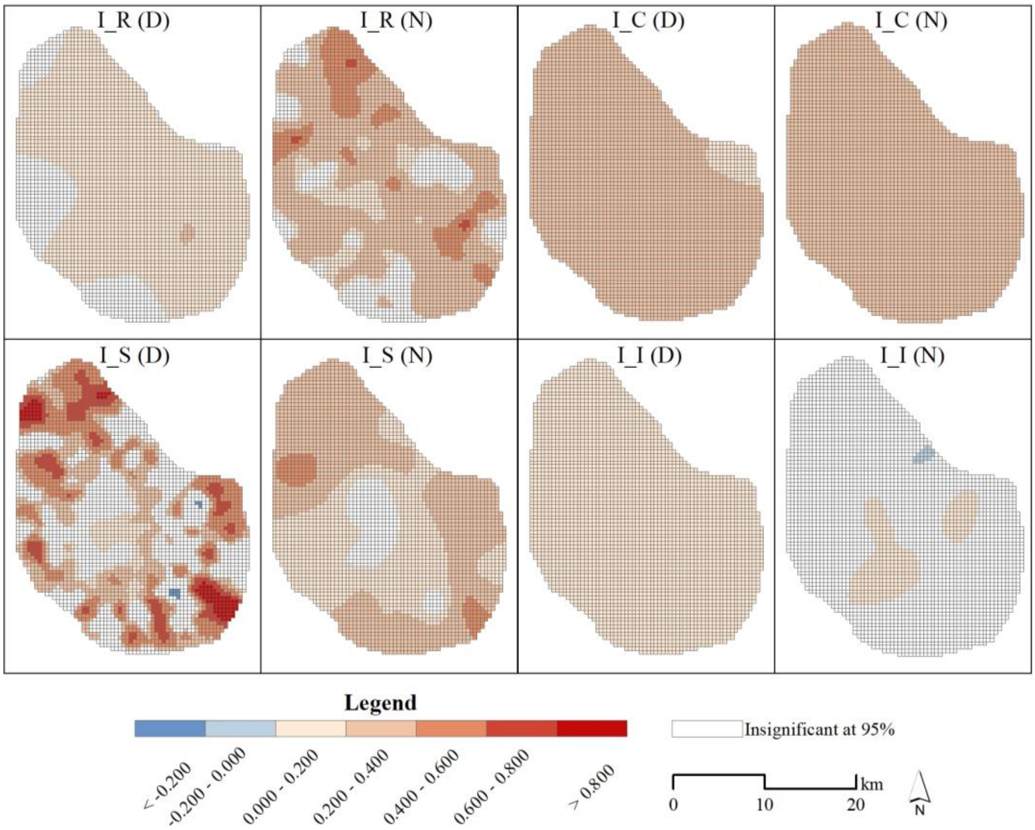

Figure 1 Spatial pattern of coefficients before the epidemic. D means in daytime. N means at night.

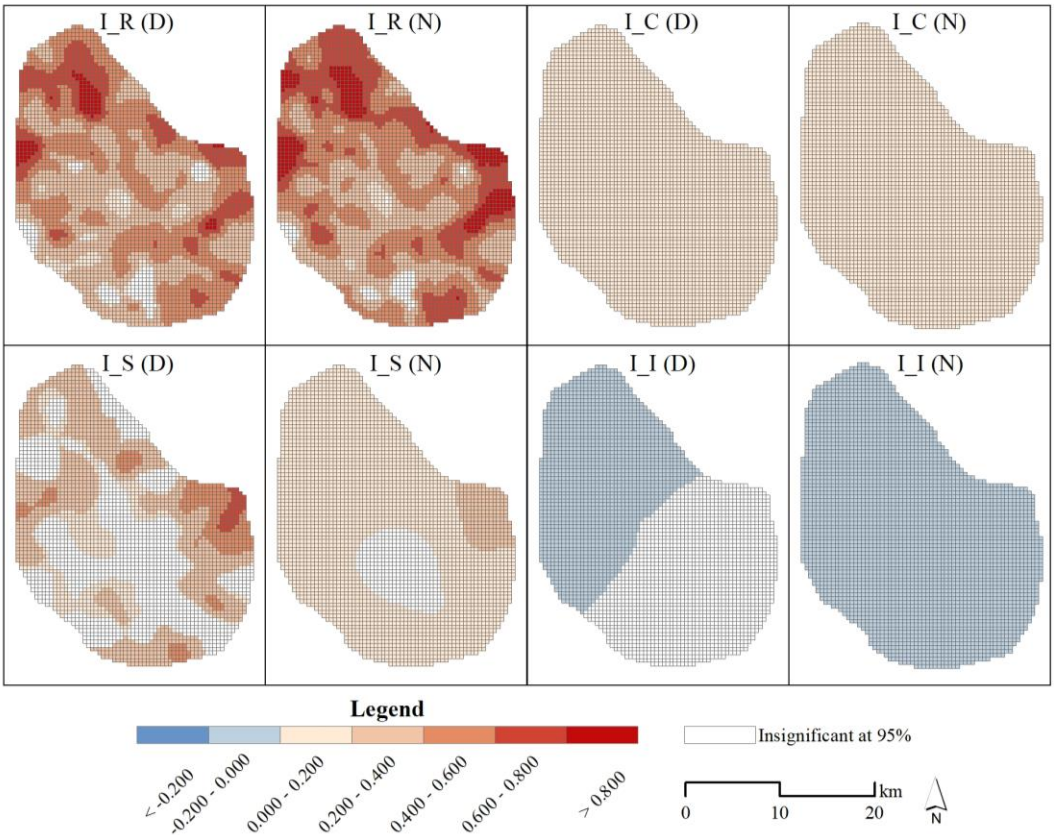

Figure 2 Spatial pattern of coefficients during the epidemic. D means in daytime. N means at night.

4. Conclusion

In this study, MGWR was used for the first time to analyze the impact mechanism of population distribution in high-density urban area before and during the COVID-19. The results showed that: (1) During the epidemic, the diurnal variation of functional requirements became smaller. (2) As the basic guarantee of life, the impact of service function on population distribution is relatively stable. People' s demand for culture, education, transportation and logistics functions is relatively weak. (3) The mobility of residents to commercial and industrial functions is significantly weakened during the epidemic. (4) Residential space became the core of residents' activities during the epidemic.

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References

FOTHERINGHAM, A. S., YANG, W. & KANG, W. 2017. Multiscale Geographically Weighted Regression (MGWR). *Annals of the American Association of Geographers*, 107**,** 1247-1265.

RECKER, W., DUAN, J. & WANG, H. 2008. Development of an Estimation Procedure for an Activity-Based Travel Demand Model. *Computer-Aided Civil and Infrastructure Engineering*, 23**,** 483-501.

SHEN, T., YU, H., ZHOU, L., GU, H. & HE, H. 2020. On Hedonic Price of Second-Hand Houses in Beijing Based on Multi-Scale Geographically Weighted Regression: Scale Law of Spatial Heterogeneity. *Economic Geography*, 40**,** 75-83.

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