Influence of the change in the distribution of space-time population due to COVID-19 pandemic on the distribution of retail outlets

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Summary

The objective of this study is to understand the spatial impact of the pandemic on various kinds of food retailers with a focus on population change. To achieve this goal, we examined the spatial similarity between the distribution of food retail outlets and that of the space-time population before and during the COVID-19 pandemic in a central area of Yokohama, Japan. The similarity was measured by using the kernel density estimation on a street network and the Kullback–Leibler divergence. The results showed that the impact of business closures varied by the type of retail outlets.

KEYWORDS: network spatial analysis, spatial statistics, GIS, KL divergence, economic geography

Introduction

Due to the COVID-19 pandemic, retailers are facing difficulties to operate their businesses. For example, people had to stay home because of an emergency order. The capacity of seats in the eating establishments had been limited to keep social distancing. Assessing the impacts of the dynamic populational change caused by COVID-19 on food retailers is helpful to make a good economic policy.

As the first step to quantify the impact of pandemic on food retailers, this study examines spatial relationship between the distribution of food outlets and that of spatiotemporal population before and during the COVID-19 pandemic. This relationship is examined by the difference calculation between two kernel density distributions, which represent the population distribution and store distribution.

Data and methods

Study area and data

To examine the spatial relationship, we set the study area as the central area of Yokohama City, Japan (**Figure 1**). Yokohama locates on the south side of the Tokyo metropolitan area and is one of the most attractive cities among tourists. The city is also recognized as the first place where COVID-19 patients were widely observed in Japan because the international cruise ship had anchored at the Yokohama port. The study area consists of 15 cells, which are almost equal to 1 km square. The unit of a cell is known as the "Basic Grid Square" defined by the Japanese government. As for the population distribution, we used space-time population data aggregated by each month. This is open data of the estimated population using mobile phones' location, which is publicly available at the Association for Promotion of Infrastructure Geospatial Information Distribution. The advantage to

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use the space-time population data is to have the actual population at a certain time. In other words, we can capture temporary visitors as well as workers and residents. The population data provides three patterns of the time period, i.e., daytime, night, and all day long. This paper used daytime population data. The postal addresses of food retail outlets were provided by Yokohama City Office and we geocoded them. From the various categories, this study chose bars, cafes, and restaurants. The geospatial data of buildings was provided by ZENRIN, Co., and street network data was provided by the Geospatial Information Authority of Japan.

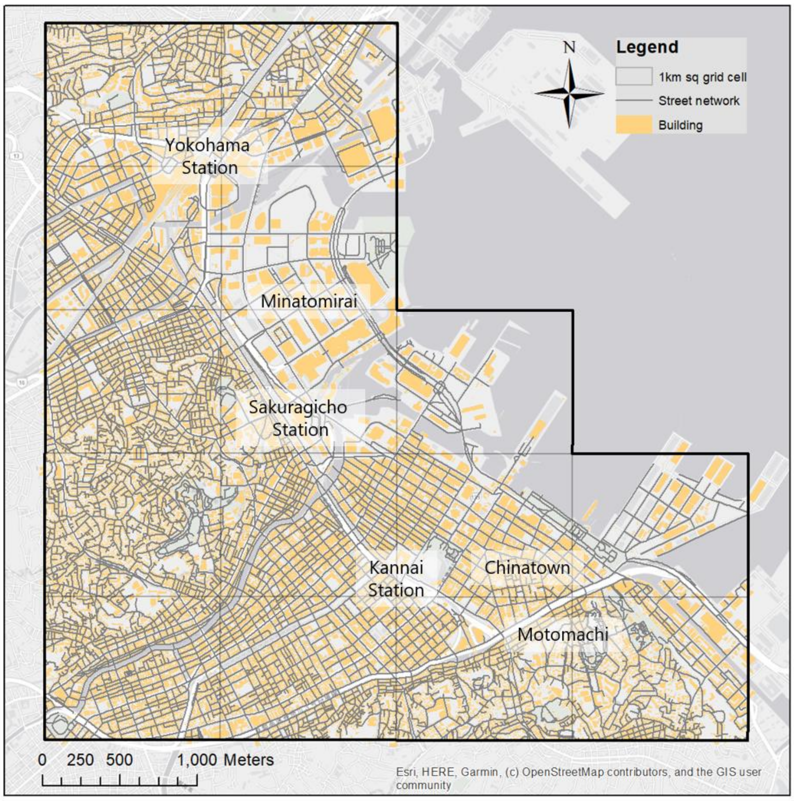


Figure 1 Study area.

Methods

To measure the difference between population and store distribution, we used the Kullback–Leibler divergence here. KL divergence is a type of statistical distance, which is called relative entropy, that is a measure of how one probability is different from a second. For continuous probability distributions O (outlets) and P (population) defined on the same geographical space X, the relative entropy from P to O is defined to be the Equation 1.

$$D_{KL}(O\|P) = \int_x \; log\left(\frac{O(dx)}{P(dx)}\right) O(dx) \tag{1}$$

The value ranges from 0 to infinity. If two distributions perfectly match, the KL value is 0, and the lower the KL divergence value, the better the retail outlets' distribution has been matched with the population's distribution. This method is based on Okabe and Sadahiro (1994); however, for this study, the method is extended to a street network-constrained space instead of a 2D plane and is applied to time series data.

To compare two kernel density distributions, we have to conduct the kernel density estimations of street networks by using area-based population data and point-based retail outlets. For here, we assign people's locations by generating points on the buildings within each cell while considering the building volume. We used SANET (Okabe and Sugihara, 2012) for performing the network kernel density estimation and ArcMap for visualizing the spatial data. The bandwidth of kernel density was set 400 m because it is one of the common thresholds of walkable distance (e.g., Western Australian Planning Commission, 2007).

Results

The space-time population in the study area changed since the COVID-19 outbreak (see **Figure 2**). Corresponding to the declaration of emergency statement and stay-at-home order in April 2020, the daytime areal population decreased. A few months later, the population slightly recovered but it has not reached the equivalent of the population before the pandemic.

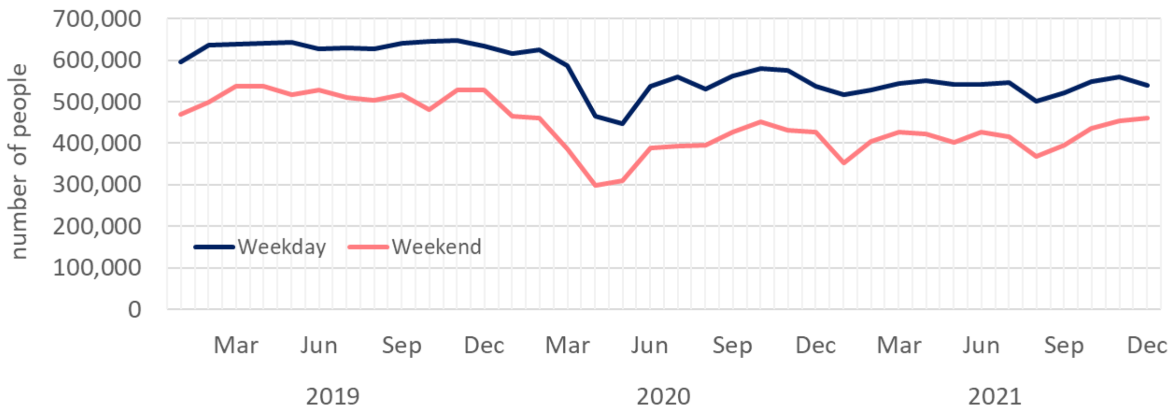
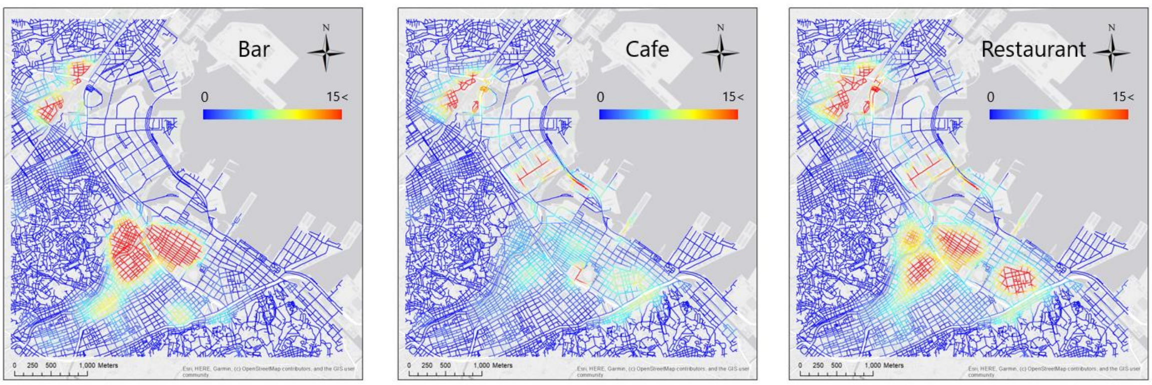


Figure 2 Monthly fluctuations of space-time population in the study area.

To understand the spatial distribution of food retail outlets, we constructed the kernel density maps of each type of outlet (i.e., bars, cafes, and restaurants). As an example, **Figure 3** represented the spatial distributions in June 2020. Bars formed a large cluster in the vicinity of Sakuragicho Station. Cafes formed small clusters in the area of Yokohama station, Minatomirai, and Motomachi. The distribution of restaurants was characterized by the cluster in Chinatown from the other ones.



(a) (b) (c)

Figure 3 Kernel density maps of each type of food outlets (a: 2493 bars, b: 1639 cafés, c: 2754 restaurants) in June 2020.

Table 1 showed the values of KL divergence of *O* from *P* in June 2019, and 2021. In this abstract, we compared the distributions between outlets and populations of the same month. The outcome implies that café locations are most related to daytime population density. On the other hand, bar locations are most different from the population density. In terms of the distributions of cafes and restaurants, the degree of similarity toward population distribution was increased compared to before the pandemic. This might imply a stronger tendency to close outlets located in a less populated area as well as not to open outlets in the area. Because the opening hours of bars are night, it was understandable that the similarity toward daytime populations was less. In addition, bars seemed to be recognized as a place of infection, people might avoid visiting the area where many bars were located more than ever in spite of their outside hours.

Table 1 KL divergence of outlets' density distributions from population's distributions

Time	Bar	Café	Restaurant
June 2019	1.216	0.609	0.644
June 2021	1.300	0.581	0.595

Conclusion

This study examined the influence of the change in the distribution of the space-time population due to the COVID-19 pandemic on the distribution of retail outlets. Our research findings would be useful to assess the economic and social impacts of COVID-19 on businesses as well as to provide some useful evidence that can make a strategic policy that will aid in the recovery of the industry and build resiliency for future emergencies. As a promising future work, we are planning to analyze the time lag between closing businesses and populational change by computing the KL divergence of outlets' density distributions from the forwardly shifted population.

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Biographies

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