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Technical Note

# Responding to Future Compound Disasters: Findings from COVID-19 Cases in Japan's Urban Areas

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**Abstract** The novel coronavirus (COVID-19) pandemic is a pervasive global issue. In Japan, the number of confirmed COVID-19 cases is especially greater in prefectures with, or adjacent to, densely populated cities. Hence, COVID-19 can be regarded as an urban disaster in Japan. To address current and future compound disasters in urban areas caused by pandemics and natural hazards (e.g., high-magnitude earthquakes), disaster response requires understanding that urban factors might increase the risk of infection. This study shall clarify how the COVID-19 infection in Japan might have been affected by urban factors related to population, in order to arrive at an effective compound disaster response. It employs a correlation analysis to evaluate correlations between the percentage of infection in Japan's major cities and the four indicators of population-related urban factors: population density, number of restaurants per capita, percentage of population inflow, and percentage of foreign residents. The study then uses a multiple regression analysis to estimate the impact of each of these four indicators on COVID-19 infection. It eventually considers how best to conduct disaster response activities for preventing an increased risk of infection during compound disasters. The results showed positive correlations between the percentage of COVID-19 infection and the four indicators in 43 major cities, with percentage of population inflow having the most significant impact. Japan's current disaster response policies premises a physical move to affected areas while noting COVID-19 countermeasures. Hence, disaster response activities should take greater care to limit physical dispatch and utilize remote assistance.

**Keywords:** COVID-19, Pandemics, Compound Disaster, Urban Disaster Prevention, Disaster Response

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# 1. INTRODUCTION

The COVID-19 infection is now a pervasive global issue. Other prevalent global disasters include climate change, frequently extreme weather events, and high-magnitude earthquakes. In such circumstances, comprehensive disaster response and societal preparedness for compound disasters are vital. In the recent past, COVID-19 has caused unprecedented damange across the world. Since the confirmation of the infection in 2019, several variants of the COVID-19 virus have emerged; following that of the Delta, the latest prevalence is of the Omicron variant. Current statistics state the cumulative number of COVID-19 cases in the world as 461.68 million (as of March 16, 2022); the United States has the largest number of confirmed cases at 79.59 million, followed by India and Brazil (Johns Hopkins University 2022).

In Japan, the cumulative number of positive polymerase chain reaction (PCR) tests is 5.81 million (as of March 16, 2022) (MHLW 2022a). By prefecture, Tokyo has the largest number at 1.14 million, followed by Osaka, Kanagawa, Aichi, Saitama and Chiba (NHK 2022). This indicates that there are more COVID-19 cases in prefectures with, or adjacent to, densely populated cities. Thus, COVID-19 can be regarded as an urban disaster in Japan (Kawata 2021). Hence, an elaborate up-front planning and support system is urgently needed to prepare for compound disasters, especially in urban areas. The COVID-19 infection primarily occurs through droplet transmission when an infected person coughs, sneezes, converses and so on; it could also spread through contagion and aerial infection in specific environments (NIID 2021; NCRH 2022). Therefore, in Japan, it is recommended to avoid the “3 Cs” (closed spaces, crowded places, and close-contact settings), apart from taking basic countermeasures like maintaining social distance, wearing a mask and washing hands, to avoid the spread of the disease (Kantei 2021; MHLW 2022b; NCRH 2022). In addition, envisaging the possible spread of the disease beyond a certain level, and a consequently overwhelmed medical service system, Japan has taken countermeasures for restricting people’s movements. This includes the “COVID-19 Declaration of State of Emergency” that allows prefectures to impose stay-at-home orders, restrict events, reduce business hours of restaurants, etc., and the municipal-level “Priority Preventive Measures” (CORONA 2022; NCRH 2022). Furthermore, the government started its COVID-19 vaccination drive in February 2021, and approximately 80 percent of the entire population has taken the second dose (Kantei 2022; NCRH 2022).

Since COVID-19, Japan’s Basic Disaster Management Plan, the highest-level plan which constitutes the basis for disaster management activities, has been updated such to incorporate infectious disease countermeasures, including COVID-19, into conventional disaster prevention measures. In this context, the relevant policies such as disaster responses, evacuation and sheltering have noted COVID-19 countermeasures like avoidance of the 3 Cs, as well asbasic countermeasures like maintaining social distance, wearing a mask, and washing hands. The response to the current and future compound disasters caused by pandemics in urban area, and natural hazards like high-magnitude earthquakes (for e.g., Tokyo Inland

Earthquake and Nankai Trough Earthquake) requires a physical move to the affected area, with adequate understanding of urban factors that could increase the risk of infection. COVID-19 has taught that it is necessary to ascertain the factors peculiar to urban areas where infection is pervasive. There is a positive correlation between COVID-19 infection and population density at the prefectural level (NITech, 2020; Shirabe *et al*. 2020). However, statistical analyses at the city level are insufficient in specifying the correlations and effects between COVID-19 infection and population-related urban factors. The questions that arise include: which are the urban factors that could increase COVID-19 infection and how do they do so, and, based on the key factor, how should disaster responses be conducted to prevent increased risk of infection during compound disasters. This study clarifies the effects of population-related urban factors on COVID-19 infection in Japan, to arrive at an effective compound disaster response.

## 2. METHODOLOGY

First, this study evaluated the correlations between COVID-19 infection in Japan's major cities, and each of the population-related urban factors, based on publicly available statistical data. A correlation analysis was conducted to measure the strength of the linear relationship between the two variables. The CORREL function and scatter diagram feature of Microsoft Excel were used to conduct the analysis. The study then estimated the impact of urban factors on COVID-19 infection, utilizing a multiple regression analysis that measures the impact of explanatory variables on a dependent variable. IBM's SPSS Statistics software (version 27) was employed for this analysis. This shows how simple statistical analyses can provide objective insights for preventing the risk of infection during disaster response activities. Moreover, they provide statistical evidence to the up-front planning and support system for addressing compound disaster responses. Based on the results, this study considered how disaster response activities should be conducted during compound disasters.

This study used "the percentage of persons infected with COVID-19" as a dependent variable of COVID-19 infections. The percentage was obtained by dividing the cumulative number of COVID-19 cases by the population of Japan's 43 major cities. These cities included 23 special wards of Tokyo, and 20 ordinance-designated cities other than Tokyo. The cumulative number of cases by city was searched at COVID-19-related websites of each city, and the number of positive PCR tests released as of May 16, 2021, was used. The population of each city was obtained from the 2015 census (e-Stat 2017).

This study assumed that three urban factors — population density due to residence, formation of temporary population density, and population inflow from outside — impacted the spread of COVID-19 infection, and applied the four related indicators (i.e., explanatory variables), as shown in Table 1. The population density of each city was obtained from the 2015 census (e-Stat 2017). The number of restaurants per capita in each city was calculated by

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dividing the number of restaurants per 1,000 people as per the 2016 Social Life Statistical Index (e-Stat 2016), by 1,000. The percentage of population inflow in each city was obtained by dividing the population inflow in the 2015 census by the daytime population. The percentage of foreign residents in each city was derived by dividing the number of foreign residents as per the 2020 Statistics of Foreign Residents (e-Stat 2020), by the city's population.

**Table 1.** Urban factors and their indicators applied

| Urban factors | Indicators (explanatory variables) | Reference/Calculation |
|---|---|---|
| Population density due to residence | Population density | 2015 census |
| Formation of temporary population density | Number of restaurants per capita | The number of restaurants per 1,000 people, divided by 1,000 |
| Population inflow from outside | Percentage of population inflow | Population inflow divided by daytime population |
| | Percentage of foreign residents | Number of foreign residents, divided by city population |

## 3. RESULTS

### 3.1 Correlation between COVID-19 infection and the four indicators

Fig. 1 shows the correlation between the percentage of COVID-19 infection in Japan's major cities, and each of the four indicators of population-related urban factors: population density, number of restaurants per capita, percentage of population inflow and percentage of foreign residents. The results showed a positive correlation between COVID-19 infection and the four indicators in 43 major cities. The correlation coefficient for population density was 0.702. However, in comparison to the population density, the percentage of COVID-19 infection was particularly high in Tokyo's Shinjuku-ward and Minato-ward. The coefficient for the number of restaurants per capita was 0.489, but in comparison to this, the percentage of COVID-19 infections was again high in Tokyo's Shinjuku-ward and Minato-ward, while being extremely low in Chiyoda-ward. The coefficient for the percentage of population inflow was 0.775, wherein the percentage of COVID-19 infections in Tokyo's Shinjuku-ward stood out again, while that in Chiyoda-ward was negligible. The coefficient for the percentage of foreign residents was 0.778, with a relatively high and low percentage of COVID-19 infection in Tokyo's Shibuya-ward and Shizuoka prefecture's Hamamatsu city, respectively. A key finding was that Shinjuku-ward was the most positively deviated in three out of four correlations, while

Chiyoda-ward was the most negatively deviated in two correlations. As such, it is vital to explore potential factors peculiar to these cities.

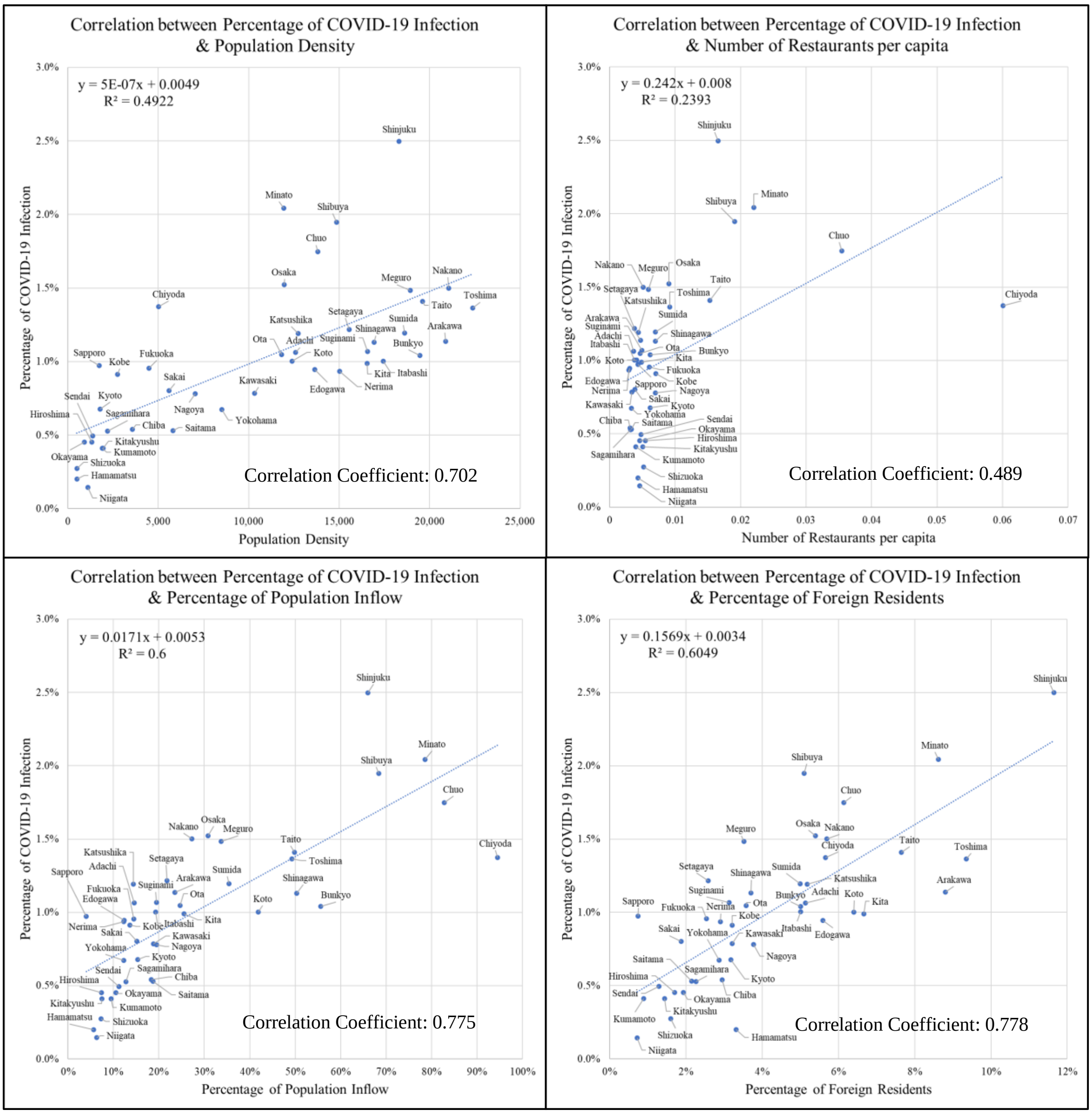


**Figure 1.** Correlation between the percentage of COVID-19 infection and four indicators.

### 3.2 Effects of the four indicators on COVID-19 infection

Fig. 2 illustrates the impact of the four indicators (explanatory variables) on the percentage of COVID-19 infections (a dependent variable), through a multiple regression analysis. The results revealed that the significance probability was 0.000. The standardized coefficients of each indicator were as follows: 0.298 for population density, 0.010 for the number of restaurants per capita, 0.451 for the percentage of population inflow, and 0.257 for the percentage of foreign residents. In other words, the percentage of population inflow had the most significant impact on that of COVID-19 infection, followed by the impact of population density.

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | | Correlations | | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. | Zero-order | Partial | Part | Tolerance | VIF |
| 1 | (Constant) | .003 | .001 | | 3.587 | <.001 | | | | | |
| | Population Density | 2.101E-7 | .000 | .298 | 2.201 | .034 | .702 | .336 | .174 | .340 | 2.945 |
| | Number of Restaurants per capita | .005 | .086 | .010 | .055 | .957 | .489 | .009 | .004 | .206 | 4.861 |
| | Percentage of Population Inflow | .010 | .005 | .451 | 2.183 | .035 | .775 | .334 | .172 | .146 | 6.849 |
| | Percentage of Foreign Residents | .052 | .027 | .257 | 1.912 | .063 | .778 | .296 | .151 | .345 | 2.901 |

a. Dependent Variable: Percentage of COVID-19 Infection

**Figure 2.** The SPSS output of multiple regression analysis.

The results reveal that it is important to make efforts to avoid population inflow and density in the context of disaster response activities. It is particularly important to prevent an increased risk of infection when those involved in disaster response are dispatched to the affected areas. In Japan, the inter-municipality mutual assistance system, a centralized system for making the best use of human resources from municipalities across Japan, was established by the Ministry of Internal Affairs and Communications in March 2018 (MIC 2019). As part of this system, municipal personnel from non-affected prefectures are dispatched to the affected municipalities to support disaster response operations and manage large-scale disasters. However, this involves a physical move to the affected areas. During the heavy rainfall of July 2020, personnel who were dispatched to Kumamoto prefecture’s Kuma village to assist the affected people in shelters got further infected by COVID-19, raising concerns about a cluster at the shelter (Disaster Management 2021). Hence, optimal human resource allocation through limited physical dispatch of personnel and increased remote assistance using information and communication technology (ICT) are steps towards preventing population inflow into affected municipalities when responding to compound disasters caused by pandemics.

## 4. CONCLUSION

This study ascertained the effects of population-related urban factors on COVID-19 infection in Japan, in order to arrive at an effective compound disaster response. Statistical evidence can be useful for preparing an elaborate up-front planning and support system to address compound disaster responses. The study used a correlation analysis to evaluate the correlations between the percentage of COVID-19 infection in Japan’s major cities, and four indicators of population-related urban factors. These included the population density, number of restaurants per capita, percentage of population inflow and percentage of foreign residents. The study then estimated the impact of urban factors on COVID-19 infection through a multiple regression analysis. It eventually considered how disaster response activities should be conducted to prevent increased risk of infection during compound disasters. The results show positive correlations between the percentage of COVID-19 infection and the four indicators in 43 major cities. The percentage of population inflow had the most significant impact on that of COVID-19 infections.

Since COVID-19, Japan’s Basic Disaster Management Plan has been updated to incorporate infectious disease countermeasures, including COVID-19, into conventional disaster prevention measures. In this context, the existing inter-municipality mutual assistance has noted COVID-19 countermeasures like avoidance of the 3 Cs and basic countermeasures like maintaining social distance, wearing a mask, and washing hands. However, it still premises a physical move to the affected areas. The disaster response support is being developed uniformly across Japan without emphasizing urban characteristics, which might increase the risk of infection. Thus, the findings from this study are helpful to give utmost caution to the physical move in urban areas when conducting response activities to compound disasters caused by pandemics. As such, optimal human resource allocation should be considered through limited physical dispatch of supporting personnel and higher remote assistance using ICT.

While the results are specific to Japan and use its publicly available data only, readers might find them applicable to similar situations in other countries. Moreover, this study does not consider the temporal variability of population-related urban factors on COVID-19 infection, throughout the changing circumstances. Future studies should include a time-series analysis of urban factors, pursue more relevant indicators of urban factors, and further consider how to conduct an effective compound disaster response.

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