Doctoral Dissertation

Exploring Associational Factors to COVID-19 and Evaluating Non-pharmaceutical Interventions and Recovery Measures: Perspectives of Built Environment and Human Mobility

(Summary)

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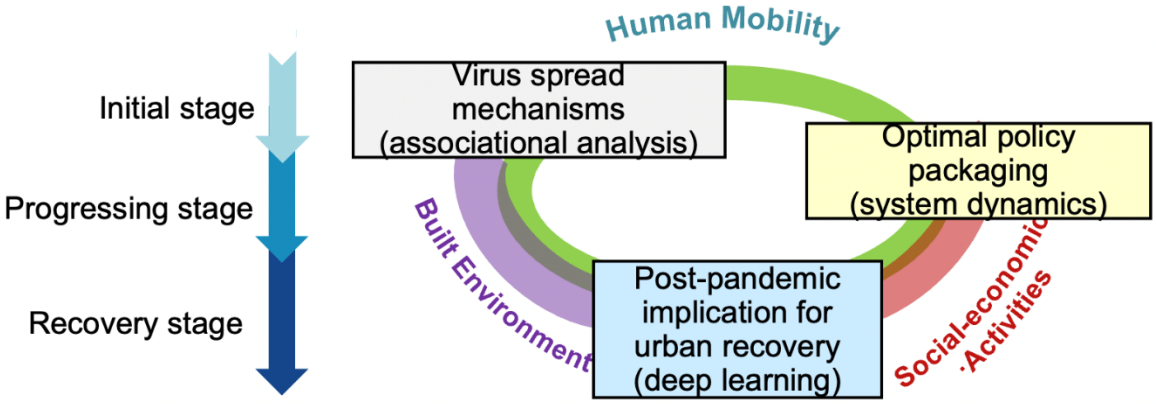
The whole world has been attacked by COVID-19 (i.e., Coronavirus Infectious Disease, emerged in 2019) since the end of 2019, leading to more than 5.2 billion infections (infection rate: 6.6%) and more than 6.2 million deaths (1.2% of infected persons and 0.1% of the whole population). Even though such pandemics are not the first time in human history, the above data suggest that human society has not well learned lessons from the history. Badly, the growth of total infection cases in 2022 (up to May 2022) was much faster than that in both 2020 and 2021. This means that countries all over the world may have not well learned lessons from each other during the COVID-19 pandemic, either. It is predicted that such public health threats will occur in future, too. Thus, how to prepare for future pandemics is an urgent global issue. In response to such a global concern, *this research aims to present scientifically sound insights into pandemic policymaking from perspectives of human mobility and the built environment*, by exploring associational factors to COVID-19 and evaluating non-pharmaceutical interventions and recovery measures based on massive multi-source data and advanced modeling approaches.

For achieving the above aim, this research was implemented through the following three tasks.



1. *Exploring virus spread mechanisms: Exploring associations of the spread of COVID-19 with the built environment and human mobility*
2. *Balancing pandemic control and economic development*: An integrated pandemic-tourism-transport-employment analysis
3. *Examining influential factors to the recovery from COVID-19*: The urban recovery associated with the built environment factors and pre-pandemic socio-economic patterns

The first task focuses on China during a short period before and after Wuhan was locked down in January 23, 2020. This short period before the COVID-19 pandemic was declared by WHO allows us to approximate the representation of the virus spread mechanisms, without being seriously affected by external interventions, in a relatively reliable way, even without detailed epidemiological data.

The second task attempts to provide scientifically sound answers about how to balance pandemic control and economic development in the context of tourism in Cambodia. Tourism is targeted because it is one of the most seriously affected sectors by COVID-19, which is closely related to economic development, especially in countries that are highly dependent on tourism. Cambodia is such a tourism-dependent country. The above case study country, China, was not targeted because it has adopted zero-tolerance pandemic policies, making the analysis of co-existence with COVID-19 impossible. At least, all developing countries have not such an ability like China to implement zero-tolerance pandemic policies, while many developed countries do not have such a social-political system like China, allowing them to follow the zero-tolerance policies.

The third task attempts to provide scientifically sound answers how to make cities resilient to pandemics, especially in the field of urban planning. Here, Nagoya, Japan, other than cities in China or Cambodia, is targeted, mainly because human mobility data at smaller spatial scales could only be obtained Nagoya, but similar data could not be obtained from China and Cambodia.

Massive multi-source data

Massive data used for the above analyses include: population mobility data, such as trains information from the epicenter of pandemic to other cities in China, inter-city number of flights and population flow in China, inter-township connections across townships in China, mobile phone signaling data in Nagoya, time-series international flight in Cambodia, changes in human public transportation utilizing in Cambodia; raster data such as nighttime light satellite across China and Nagoya, Japan, aerial images in Nagoya; land use and built environment data such as distribution and density of public facility (public open space, comprehensive hospital and clinic, point of interests, travel time to the nearest hospital, etc.) in China and in Nagoya, transportation facilities (road network, road intersections, stations, etc.) in China and in Nagoya, land use in Nagoya at block level and built-up area in China at township level; spatial administrative unit data, such as township-level administrative boundaries, community-level administrative boundaries; social-economic data, such as total tourist consumption, contribution of tourism to employment, hospital beds in Cambodia and the aging population in China across cities.

Context-sensitive modeling approaches

The following modeling approaches are combined for implementing different tasks, including local indicators of spatial association (LISA), bivariate local indicators of spatial association (BiLISA), mixed geographically weighted regression (MGWR) and network analysis in the field of spatial analysis, random forest (RF), partial dependence

plots (PDP), convolutional neural network (CNN) model, and guided Grad-CAM (GG-CAM) model in the field of machine learning, system dynamic (SD) in complexity science field, and K-means, Getis-Ord Gi in statistical analysis field.

Integrated findings

Firstly, both the spread of COVID-19 virus and the urban recovery from it are highly associated with the built environment, which is the main part of urban planning, land management and design of urban functions. This suggests that preparing for future pandemics should be given sufficient attention in urban policy, where spatial disparities should be well addressed. Secondly, the built environment is closely related to human mobility, which is at the core of balancing pandemic control and maintaining economic activities, where strict quarantine measures and key stakeholders' (tourists and firms) cooperation are most important, where spatial heterogeneities should be better reflected. Thirdly, human mobility is a powerful driver for the socio-economic development. Both pandemic control and recovery policymaking should be carefully made at the facility level that is directly connected with individuals' activity participation and trip making, where individual heterogeneities should be properly incorporated. Finally, methodologically, this study has figured out that mixed data-driven methodologies (related to deep learning and spatial analysis, etc.) are useful to simultaneously analyze multi-source and multi-scale massive data, involving various complexities, for deriving the above integrated findings and policy implications related to pandemic-sensitive urban planning and design as well as mobility policies.

Integrated policy implications

Considering that the COVID-19 virus is invisible, seamless and comprehensive pandemic policymaking must be implemented by involving various stakeholders, covering the pre-pandemic, during-pandemic and after-pandemic recovery periods. All findings also presents useful insights into the development of post-pandemic society.

[Importance of preparedness] Lack of reliable data has been a serious barrier for taking effective pandemic policy measures. In this regard, policies supporting data sharing for emergent crises must be made. Because careful self-protection can keep people away from the infection, it is necessary to encourage more and more people to form a virus-sensitive lifestyle, as a key part of public education.

[Exploring a proper level of the growth of human mobility] It is true that human mobility is one of the most important drivers of the virus spread and economic development; however, it is necessary to figure out a proper level of the growth of human mobility for sustainable development for mitigating the various serious impacts of "Great Acceleration" (https://www.anthropocene.info/great-acceleration.php) on both human society and nature.

[Making economic activities to be human friendly] The current pandemic re-emphasizes the importance of human-scale urban development. Long-distance commuting should be avoided. Traditional business practices of having to start working at the same time (e.g., 08:00 am or 09:00 am) should be completely abolished for releasing people from painful peak-hour commuting. Neighborhoods supporting people's daily lives should be redeveloped at a human scale, at least by meeting people's fundamental needs in life.

[Human-scale urban development in association with planetary health] Distancing and working-from-home pandemic policies allows policymakers to re-recognize the roles of green and open spaces in improving people's quality of life, especially nearby people's residential areas. Quality urban development should be human-oriented rather than economy-oriented, where concerns about both human and nature health as well as social exclusion should be well addressed: i.e., planetary health should be better positioned in urban development.

[Digitalizing the anchoring roles of points of interest (POIs) in pandemic control and urban recovery/resilience] Key urban facilities are not only associated with the virus spread but also related to long-lasting urban recovery and resilience. For controlling the pandemic, key POIs should be effectively managed. When the pandemic-influenced situations become a new normal, services within the key POIs could be better re-designed for attracting more people while keeping virus infections at a very low level. Digital technologies should be better used to manage the anchoring roles of POIs in both pandemic control and urban recovery/resilience.