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Application of Geospatial Data to Major Public Health Emergency Response—A Simulation Study for 2020 COVID-19 Epidemic Management

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Abstract: The numbers of infected people and the planning of emergency medical facilities are the key factors for the response of major public health emergency. The conclusions are as follows: (1) The number of potential infections in Wuhan city based on migration index is close to the actual data, which indicates that migration data is of great significance for supporting public health emergency response; (2) Based on geospatial location technology, emergency medical facilities can be identified quickly, which provides scientific support for the layout of medical staffs' resting places and other supporting logistics. Given the fact that the application of geosciences in major public health events are relatively weak, this study proposes that in the future, we should further explore the establishment of medical geosciences data sharing mechanism, reserve emergency technical capabilities, and make real contribution to the national comprehensive emergency management.

Keywords: COVID-19 epidemic; medical geography; geoscience big data; human-land relationship

1 Introduction

Since December 2019, COVID-19 has spread across China. On January 23, 2020, major public health emergency level 1 response has been launched in most provinces of China. COVID-19 has become a major public health emergency with the fastest transmission speed,

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the widest infection range, and the greatest difficulty in response in China since 1949[1]. In the emergency response of major infectious diseases, the number of infected people is the basis for the planning and arrangement of medical resources[2], while the pre-arranged planning of emergency medical facilities is the core measure for effective response[3]. For example, in the process of the COVID-19 outbreak, infected people were delayed in treatment or caused secondary infection due to the shortage of medical resources and lack of isolation beds, which, to some extent, aggravated the epidemic[4]. At the same time, due to the inadequate monitoring or early problems such as insufficient understanding, the exact number of infected people in Wuhan or Hubei has been in a state of "black box[5]", which makes the emergency medical facilities either under-supplied or over-supplied due to lack of timely and accurate information.

The spatial-temporal nature of public health emergency events (the mobility of the infected objects) and the following response (the resources demand and supply) make it have the common nature of geography study[6]. In a major outbreak period, the organization of efficient emergency dispatch involves a lot of spatial and attribute information[7].

The efficient processing, extraction, analysis, and sharing of these information cannot be separated from the integrated use of geographic information technology[8]. For example, during the SARS period in 2003, the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences applied the geostatistical analysis technology to develop the "National SARS epidemic control and early-alarm geographic information system" for the collection, management, analysis, prevention, and control measures of SARS epidemic information[9]. Therefore, it is essential to carry out the study of the epidemic from the perspective of geoscience and explore the technology to accumulate experience and technology in epidemic emergency management, to improve the supporting capacity of geography in the decision-making[10].

A review of the development of COVID-19, especially the epidemic response in Wuhan, shows that there are two key problems, the prediction of the number of infected people, and the allocation of emergency medical facilities. Although some studies have predicted of infected objects[11–12], they were mainly based on the epidemiology or public health method, and the prediction results are prone to errors because these models were based on low reliable notification data. On the other hand, emergency medical facilities allocation, especially the requisition of isolation points, invited some public criticism due to insufficient consideration of resource constrains[13]. This study developed a model to predict the number of infected objects based on migration index, and established a multi-source data location-selecting procedure to support the allocation of medical resources and facilities.

2 Background and Methods

In terms of the infected subjects prediction, we assume that the early statistics about infected within Wuhan (Hubei), the epicenter of the epidemic, were not good enough to support decision-making, but the statistical data of the infected outside Hubei province were more trustworthy. The rationale under this assumption was that the outbreak of the epidemic in Wuhan in early period made many works out of order, including comprehensive epidemic data collection. By contrast, most of the infected objects outside Hubei were imported and controllable, which made the statistical data more reliable and timely.

Under this hypothesis, we used the Baidu migration scale index and population estimaion data of Wuhan to estimate the number of people who returned from Wuhan in each city. Based on the official reporting of people diagnosed with COVID-19, we estimated the infection rate of the population flowing out of Wuhan. Finally, the potential number of COVID-19 infections in Wuhan was estimated based on the proportion of the migrating population and the population of Wuhan.

Selection of emergency medical resource facilities, especially the temporary isolation point, temporary medical facilities such as shelter, hospitals, was based on relevant standard (the principle of prevention and treatment of infectious diseases hospital location) and a set of spatial data, including: residential community, infrastructure, general hospitals, roads, and building locations. Selection of hotels was based on the accommodation and distance to working hospital.

This spatial planning process can provide scientific reference for the estimation of potentially infected people in Wuhan, the determination of designated hospitals for epidemic response, and the determination of medical staffs' resting places. The research idea is shown in Figure 1.

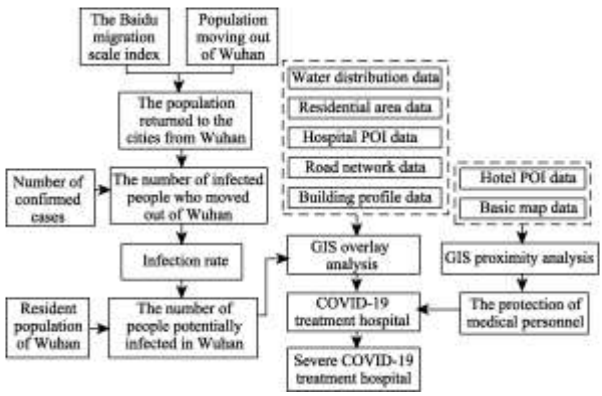

Figure 1 Flow chart of system development

Wuhan POI (Point of Interest) data was collected from Baidu map, and 670,000 pieces of POI data were collected. According to the industry classification standard of POI data on Baidu map, hotel POI data and general hospital POI data were cleaned and separated, and invalid data were removed. Finally, 10,731 pieces of hotel POI data and 244 pieces of general hospital POI data were included. Baidu migration scale index was derived from Baidu migration platform (http://qianxi.baidu.com). Through the comparing the changes of users' location, the number of users whose smart terminal location has changed within 8 hours is counted.

The number of users that have changed their location was used to represent the number of the population moving between provinces or cities. The population scale of Wuhan city from January 10 to January 24 was selected as the basis for calculating the outflow population before the implementation of Wuhan lockdown. The road network data comes from Baidu map data platform, mainly including the traffic network that can ensure the smooth traffic flow of vehicles, such as expressway, urban expressway, national road, provincial road, county road, and nine level road in Wuhan. The statistics of COVID-19 infections were based on data released by National Health Commission of China. Other auxiliary data including Wuhan building outline data, Wuhan water area distribution data, residential district distribution data, and administrative division data were derived from Baidu map data platform.

3 Results and Analysis

3.1 Estimation of the Number of Potential Infections in Wuhan

According to the implementation time of urban management and control measures in Wuhan

(January 23) and the peak time of the increasing number of daily confirmed cases in the whole country outside Hubei province (February 3), the top 100 migration proportion by Baidu from January 10 to 24 was selected for correlation analysis with the cumulative number of confirmed cases in corresponding cities on February 3. We found that the correlation coefficient was 0.935, R^2 was 0.874, and the sig was significantly associated with a value of 0.000.

Based on the official base number of 5 million migrant population in Wuhan, the top 100 cities of Baidu's migration ratio during the period from January 10 to February 3 were calculated. These 100 cities received 4.582 million returnees from Wuhan. According to the number of people who moved to each city and the number of confirmed cases in each city, the ratio of the two was calculated between 0.08% and 3.53%, with an average of 0.51%, indicating that the average infection rate of the people who moved out of Wuhan was 0.51%. Based on the average infection rate and the resident population of 9,083,500 in Wuhan, the COVID-19 infected population in Wuhan was estimated to be 46,000. As of February 25, Wuhan has prepared a total of 21,962 medical beds, plus newly added 2,416 beds in Raytheon and Vulcan Mountain field hospital[14]. There were only 24,378 medical beds available. Since our estimated infected number was 46,000, Wuhan urgently needs to expand medical resources and prevent secondary infection.

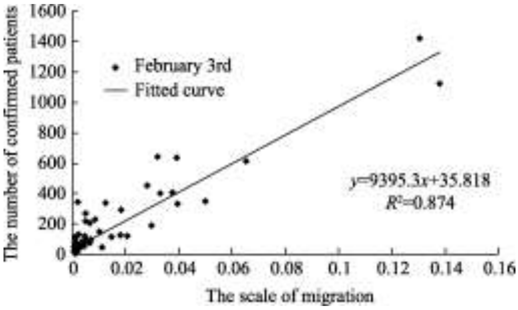

Figure 2 Relation between the number of confirmed patients and the scale of migration

3.2 Site Selection for Emergency Treatment Hospital

3.2.1 Constrains of Site Selection

According to the national standard for infectious disease hospital construction, the sites of infectious disease hospital should avoid densely populated areas; have convenient transportation; regular and flat terrain, stable geological structure; have safe distance from water, harmful gas production and storage sites, food and feed processing enterprises[15]. In order to quickly treat the infected people and make full use of the existing general hospitals and large indoor buildings, the analysis of the location of emergency hospital and temporary isolation points should be carried out. Our spatial analysis integrated POI data, residential, population density, water and road data to determine the area that meet the need for isolation and treatment of infectious disease. Specifically, the site selection for hospital required: 200 m away from residential area, 500 m within major traffic, and 500 m away from water area. According to the population distribution density of Wuhan city, Tyson polygon law was used to define the receiving area of emergency treatment hospitals and temporary isolation treatment points. For areas lacking emergency treatment hospitals and temporary isolation points, field cabin hospitals should be prioritized for consideration (Figure 3).

3.2.2 Result of Hospital Site Selection

Compared with the spatial distribution map of 244 general hospitals in Wuhan, the general hospitals that meet the requirements are determined. In order to reduce the secondary potential infection of emergency treatment hospitals through sewer and aerosol diffusion mode, especially the small scale of a high-rise building is not conducive to more than 100 m from the pollutant dispersion intensifying virus[16], more than 100 m tall buildings around to meet the conditions of hospital overlay analysis, combining with the high-rise building in Wuhan space distribution of worldwide for contingency hospitals around 200 m more than 4,100 m high building of the hospital should be ruled out.

Following the aforementioned rules, 58 hospitals were determined (Figure 4), accounting for 23.78% of the general hospital in Wuhan. With about 13,000 of medical beds, this hospital can't meet the needs of the isolation and treatment of potential infected patient. Therefore, in the future, emergency treatment centers should be added in large warehouses and gymnasiums, or field hospitals should be set up in large open parking lots and gymnasiums in qualified areas.

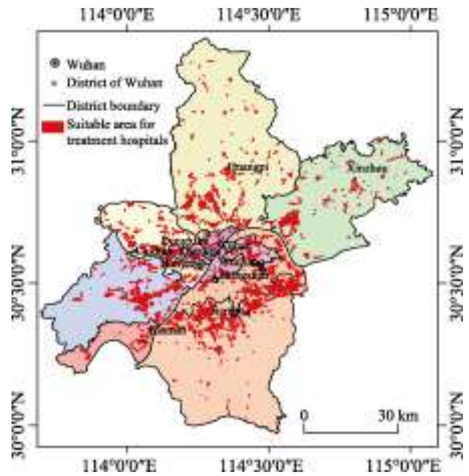

Figure 3 Distribution of qualified areas for emergency response hospital in Wuhan

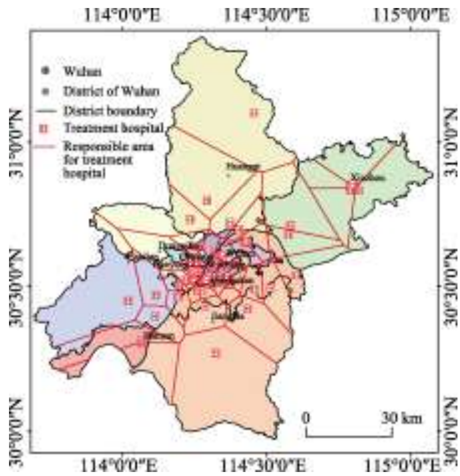

Figure 4 Distribution of potential hospitals for emergency response in Wuhan

3.2.3 Evaluation of Hospital Site Selection

A comparison of the simulated hospitals and the actual hospitals was conducted to evaluate the rationality of the site selection method for emergency response hospitals. 20 designated hospitals and 16 square hospitals were within the qualified areas, accounting for 41.67% of designated hospitals for emergency response. The fact that some designated hospitals were located outside the qualified areas indicated our model using unified criteria could be refined to accommodate the actual need in reality. For instance in the early period, some hospitals with suitable facility but smaller scale were also designated for epidemic response to meet the urgent needs of a large number of infected patients. In the future, with the advance of social and technological capacities, more factors should be considered.

3.3 Site Selection for Supporting Facilities (Hotels)

Medical staff are the key players for the epidemic response. Providing sufficient logistic for medical workers is the basis for their recovery[17]. Based on the neighborhood analysis of the determined emergency treatment hospital and hotel POI data, the hotels within the 500 m buffer zoom of the response hospitals were chosen as the supporting facilities for medical staff. It was found that there were 902 qualified hotels (Figure 5), accounting for 8.41% of the hotel in the city.

Due to lack of data from Wuhan cycling report, jointly edited by Wuhan Transportation Development Strategy Institute and Meituan-Mobai for proxy. The cycling data suggested that the main ridesharing were around hospitals. From January 24 to March 12, a total of 43,000 person-times of medical-related staff have been served, with an average distance of 1.42 km, indicating that the medical staff often chose hotels close to their hospitals.

4 Discussion and Conclusion

In the course of major public health events, due to the shortage of medical resources, some patients were not timely treated and often become the source of secondary transmission. The development of COVID-19 in Wuhan and the medical crisis fully reflect the necessity of layered and graded public health response system within different management units. Based on the relevant national standard and spatial data analysis, the following conclusions can be summarized:

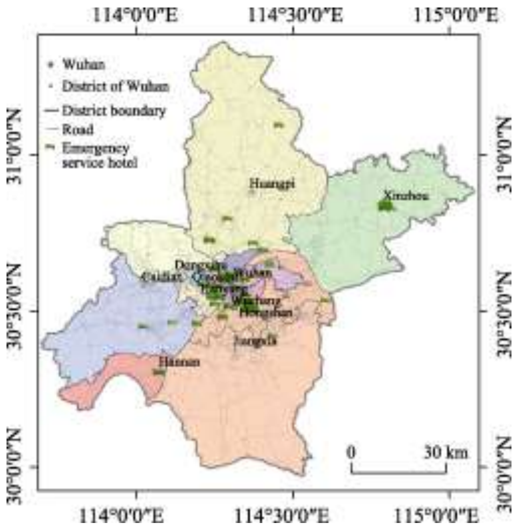

Figure 5 Spatial distribution of qualified emergency service hotel in Wuhan

(1) A migration index based model showed that the number of potential infections in Wuhan is close to the actual statistical data. The migration index has the advantages of high efficiency, low cost, and fine granularity. However, due to the biased sample size of Baidu migration data, there were potential errors in the prediction. If mobile phone signaling data could be combined with index of Baidu, it will greatly improve the accuracy of the modeling.

(2) The appropriate areas for emergency medical facilities were identified using geospatial technology and various data, including basic geographic data such as water and traffic; residential extracted from POI data; and social statistics like population density data. The simulated hospital sites were in good agreement with the actual hospitals designated for emergency response (100% for square hospitals, 41.67% for designated hospitals)/

(3) The appropriate hotels for emergency medical workers were selected to ensure these hotels were in the 500 m buffer zone of their working hospitals. This enabled exhausted medical works to have more time to recover and provide better service.

It is worth noting that, the application of geosciences to emergency response of major public health events are still in its inception. One of the reasons is that it is still difficult to share spatial data of medical cases. In the future, we should promote and establish medical spatial data sharing mechanism. At the same time, we call on geoscientists, especially those in the fields of space economy, geography and space planning, to accumulate emergency data and technologies in their daily research and be well prepared to make more contributions to the future emergency response.

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