

VIET NAM NATIONAL UNIVERSITY, HA NOI
CENTRAL INSTITUTE FOR NATURAL RESOURCE AND ENVIRONMENTAL STUDIES

Proceedings of the International conference on
**OCCUPATIONAL SAFETY,
HEALTH AND ENVIRONMENT**

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The first Occupational Safety, Health and Environment (OSHE)

Hanoi, Vietnam October 24-26, 2024



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Building a COVID-19 Vulnerability Index Map for Hanoi City using Spatial Analysis Models

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Abstract: While Vietnam and the rest of the world are pushing back against the COVID-19 pandemic, new SARS-CoV-2 variants still pose a risk of resurgence. To help Vietnam safely coexist with the virus, it's crucial to have supportive information for epidemic prevention, especially disease risk maps based on spatial data. This paper outlines a method for creating a COVID-19 sensitivity map of Hanoi using QGIS. This map identifies areas at high risk for rapid infection from initial community cases and potential outbreaks, providing valuable information for the government to prioritize vaccine distribution and implement effective prevention measures.

Keywords: COVID-19, CVI map, Hanoi.

1. Introduction

The world is grappling with an unprecedented health crisis: the COVID-19 pandemic. This new coronavirus has become a global threat, affecting nearly every aspect of human life. With no specific medication yet available for prevention or treatment, controlling COVID-19's spread relies heavily on community efforts and non-pharmaceutical interventions (NPIs). These include measures like social distancing, protecting vulnerable groups, limiting public gatherings, and implementing lockdowns, all aimed at minimizing person-to-person transmission (Nande, Adlam et al. 2021).

Fortunately, studies from various countries, including the US, India, UK, Brazil, Bangladesh, the European Union, and Palestine, have demonstrated the effectiveness of disease risk maps in improving epidemic prevention. These maps have played a crucial role in saving lives and mitigating the pandemic's economic and social impact (Amram, Amiri et al. 2020; Acharya and Porwal

2020; Nicodemo, Barzin et al. 2020; Daras, Alexiou et al. 2021; Santos, Siqueira et al. 2020; Rahman, Islam et al. 2021; Fu, Wang et al. 2021; Shadeed and Alawna 2021). Consequently, many such maps, like the COVID Vulnerability Index Map and Pandemic Vulnerability Index Map, have been developed since the pandemic began. Their purpose is to pinpoint high-risk areas for outbreaks and then propose tailored, effective responses based on local population, living conditions, infrastructure, and healthcare resources, thereby minimizing casualties and sustaining economic activity (Acharya and Porwal 2020).

Many nations have reported creating COVID-19 risk maps using diverse methods. Geographic Information Systems (GIS), for instance, are invaluable tools for understanding disease patterns (Raju K, Lavanya R et al. 2020). GIS provides an excellent framework for integrating disease data with population distribution, social and healthcare facilities, and the natural environment. It also helps analyze data and identify trends. Approaches like multi-criteria analysis with GIS have been used for hazard evaluation in urban lockdowns (Sangiorgio and Parisi 2020), to create vulnerability maps in Palestine (Shadeed and Alawna 2021), and to generate COVID-19 vulnerability maps in West Bengal, India, aiding government efforts in disease management (Malakar 2022). This method has also been applied to model COVID-19 vulnerability in China (Gao, Jiang et al. 2022), assess risk (Wyszyński, Grudziński et al. 2022), identify social vulnerability indicators in Iran (Moslehi, Dehdashti et al. 2023), and map susceptibility (Sarkar 2020).

Beyond GIS-based multi-criteria analysis, satellite imagery, remote sensing, and geospatial data are crucial for identifying factors linked to COVID-19's global spread and mortality (Dahu, Alaboud et al. 2023). Experts believe remote sensing will significantly improve pandemic monitoring and management in the future (Mehmood, Bao et al. 2022). This technology has been widely used during the pandemic; for example, in India, remote sensing, GIS, and local knowledge helped manage COVID-19 by spatially defining hazard zones and permitted activities (Kanga, Sudhanshu et al. 2022). Satellite images also analyzed SARS-CoV-2 infection in Ecuador (Toulkeridis, Seqqat et al. 2022), and a combination of Bayesian networks and GIS modeled vulnerable regions in Bangkok, Thailand, leading to vulnerability



management strategies.

Crucially, spatial data serves as vital input for these disease risk models (Amram, Amiri et al. 2020). By analyzing the locations of COVID-19 cases, we can identify correlations between spatial information like population density, per capita income, and living conditions, and the risk of outbreaks (Acharya and Porwal 2020). This data can be sourced from open platforms or indirectly derived from existing spatial data, such as land cover distribution or population figures (Franch-Pardo, Napoletano et al. 2020).

In Vietnam, similar studies have focused on diseases like malaria (Bui and Pham 2016), shigellosis-induced diarrhea (Kim, Ali et al. 2008), and dengue fever in Hanoi (Thanh Toan, Hu et al. 2013). These studies highlight how geographic and spatial information can enhance disease prevention, protect lives, and ensure health safety. GIS technology has also proven effective in zoning COVID-19 risk for decentralized impact levels (Canh, Son et al. 2022). While local geographical regression models have been applied to forecast and zone epidemic areas in Hanoi (Son, Nga et al. 2022), the rapid and novel nature of COVID-19 means there's limited prior experience or extensive spatial data studies for forecasting and identifying its risks in Vietnam. This current study aims to address this gap by using spatial data and GIS to develop spatial analysis models for creating COVID-19 sensitivity maps for Hanoi city.

2. Study area

Hanoi, the capital of the Socialist Republic of Vietnam, is a crucial center for the nation's politics, economy, culture, science, and technology (Uy and Nakagoshi 2008). Geographically positioned in the Northern Red River Delta (20°53'–21°23' N latitude, 105°44'–106°02' E longitude), it is Vietnam's most populated region. Its vast area of over 21,000 km² accommodates nearly 22 million people, with over 8 million living in its urban areas (General Statistics Office 2020). The terrain around Hanoi varies, from southeastern coastal plains to mountains and hills in the north and west, which are home to significant national parks such as Ba Vi and Tam Dao (Van den Berg, Van Wijk et al. 2003).

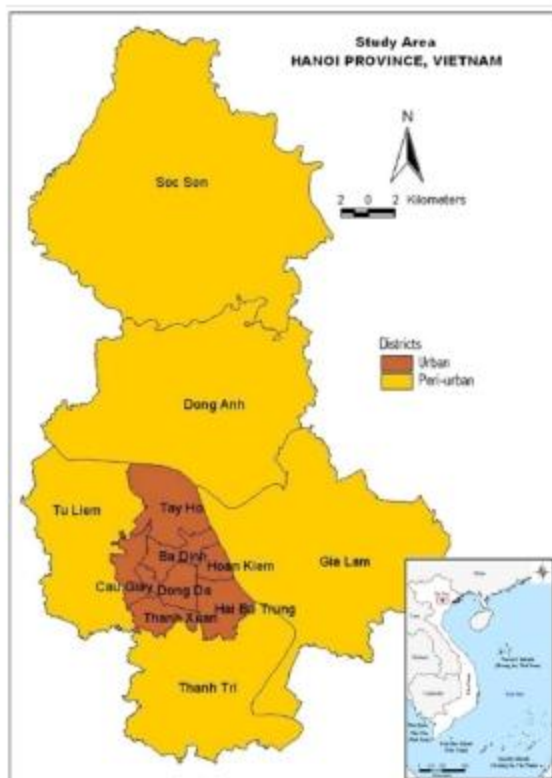


Figure 1. The study area (Thapa and Murayama 2008)

3. Methodology and data

3.1 Used data

For this research, we collected COVID-19 infection data for Hanoi from July 5, 2021 to September 22, 2021 was collected at the Ha Noi Center for Disease Control (CDC Hanoi - 70 Nguyen Chi Thanh, Dong Da, Hanoi); At the same time, some necessary spatial data for establishing disease risk index maps are also obtained such as: land cover data, population data and population distribution, and local market data, commercial centers,

apartments, data on industrial parks, etc. in Hanoi city. Table 1 shows the data and sources used in the study

Table 1. Sources and data used in the study

Data	Description	Source
Population density		(http://www.worldpop.org.uk/)
Land cover	2019 - 2021	https://www.corc.jaxa.jp/
Land cover	10m resolution	Sentinel – 2, Global data 2020
Location of local markets in Hanoi City	2019 - 2021	Google Earth
Location of local markets in Hanoi City	July 5, 2021 to September 22, 2021	Ha Noi Center for Disease Control

We used the locations of over 3,500 F0 cases in Hanoi City (due to the lack of coordinate information, the team had to manually perform geocoding) were used for comparison with the model's results.

3.2 Methodology

Our approach to identifying sensitive areas for COVID-19 is based on the concentration of F0 cases within a specific geographic area (once their locations are mapped). We determined an area's sensitivity by calculating the ratio of the area with F0 cases (which could be a ward, commune, district, neighborhood, or residential group) to the total study area. A higher ratio indicates greater sensitivity.

Furthermore, to facilitate centralized community screening, we calculated a sensitivity index of each size cell 100x100m (equivalent to 01 hectare) includes the total population within a radius of 500 meters and distance from each cell to sensitive geographical objects that easily become centers of epidemic spread such as markets, supermarkets, apartments, industrial areas, commercial centers, etc.

Calculate sensitive indicators for subjects such as: population density, markets, apartment, industrial areas, shopping center, and supermarket on each cell based on the number of people within 500 m in the area with F0 cases, distance from the areas where there are sensitive geographical objects mentioned above to the locations of the F0 cases. From there, the composite sensitivity index is determined based on the following formula (Son, Nga et

al. 2022):

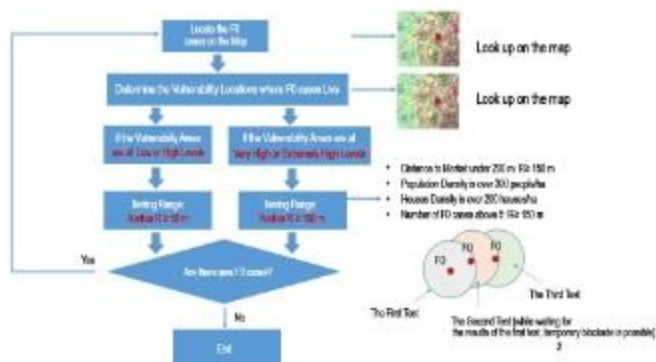


Figure 2. Focused community screening testing

$$\text{Sensitive_Index}_i = W_{Po} * Po_Index_i + W_{Ma} * Ma_Index_i + W_{Ap} * Ap_Index_i + W_{Su} * Su_Index_i + W_{In} * In_Index_i + W_{Sh} * Sh_Index_i \quad (1)$$

In which: W_{Po} W_{Ma} W_{Ap} W_{Su} are the weights of sensitive factors such as population density, market, apartment building, supermarket, industrial area, shopping center respectively.

Because the collected data is not large enough, in this study, the weight values of the above mentioned objects are considered the same and equal to 1

The relative composite sensitivity index value is calculated based on the following formula (Son, Nga et al. 2022):

$$\text{Relative_Sensitive_Index}_i = 100 * \frac{\text{Sensitive_Index}_i}{\text{Max_of_Sensitive_Index}} \quad (2)$$

The research team used open source software Quantum GIS (QGIS) to build spatial analysis models for establishing a map of the risk of COVID-19 infection. According to (Maitieg, Aljamel et al.), in addition to supporting all of the features of a GIS, QGIS is an open-source, cross-platform GIS that operates as a desktop program. Spatial data can be conveniently examined, modified, and analyzed by utilizing QGIS. In order to develop the COVID-19

susceptibility map, it is necessary to prepare base data including population density, land cover, location of local markets in Hanoi City. Then, adding the base layer map and the vector data. The result maps are generated by using QGIS software.

4. Results and discussion

The COVID-19 vulnerability map of Hanoi city was established based on data collected in the period from April 27, 2021 to September 7, 2021 (Figure 3). This map is used to determine the risk and speed of epidemic spread in Hanoi when the epidemic is uncontrollable. This map shows specific information about the testing locations, centralized quarantine places, the patient's home area, the locations the patients come within 14 days and after 14 days, and the position of the hospitals and medical centers, location of blockade and medical quarantine area. In addition, the areas with five risk levels display on the map including low, moderate, high, very high, and extremely high.

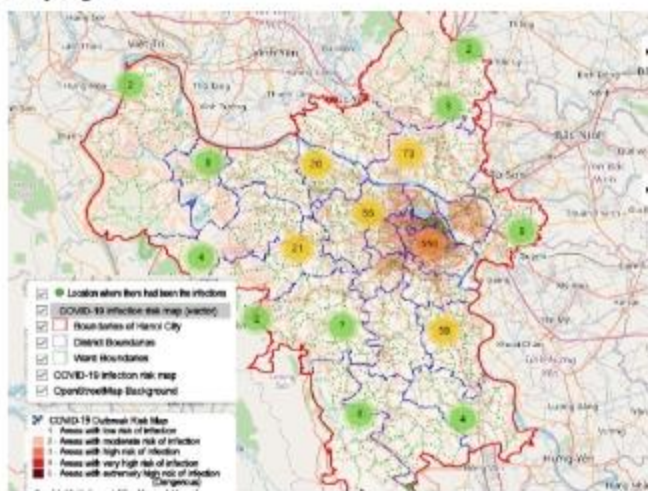


Figure 3. COVID-19 Vulnerability Map of Hanoi city

In addition, data on the number of positive cases, COVID-19 infected cases per day, F1, F2 cases, deaths, recovered cases, test samples and people waiting

to be tested in areas of Hanoi city is also extracted from the map (Figure 4).

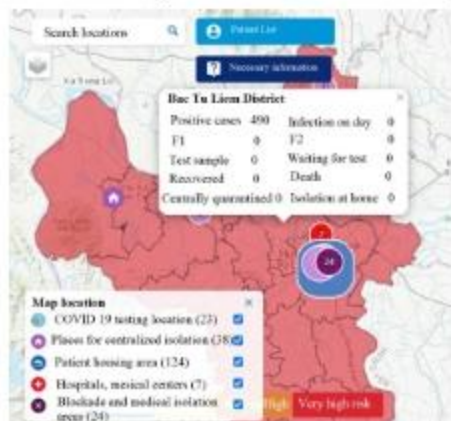


Figure 4. Statistics on the COVID-19 epidemic in Bac Tu Liem district, Hanoi city

In addition, based on indicators of population density, distance to densely populated locations such as markets, shopping centers, industrial parks, supermarkets, shopping centre, etc., the risk map of COVID 19 infection in Hanoi city was also established (Figure 5). On this map, the risk level is divided into 4 levels: normal, risk, high risk, and very high risk.



Figure 5. The risk map of COVID 19 infection in Hanoi city

The screenshot shows a web application interface. At the top, there are two tabs: "Patient list" and "Newcase - in Examination". Below the tabs is a search bar with a magnifying glass icon. The main content area displays a list of patients. The first patient is highlighted in blue. The list contains the following information:

Time	Name	Address
12:56	An Duong	
08:0	Nam Thuy Long Binh	
12	Kieu Quyen Long Binh	
13:150	111 Nguyen Van Ba Dinh	
12:56	An Duong	
08:0	Nam Thuy Long Binh	
12	Kieu Quyen Long Binh	
13:150	111 Nguyen Van Ba Dinh	

At the bottom of the application, there are three buttons: "Newcase", "High risk", and "Very high risk". The "High risk" button is highlighted in orange, and the "Very high risk" button is highlighted in red.

In addition to the number of F0, F1, F2 cases, etc., a specific list of each F0 case in the search area is also displayed on the map (Figure 7).



The application method for research is based on geographical factors such as population, traffic, apartments, etc., so the ability to detect F0 is faster and more focused. In addition, the method used does not depend on the administrative boundaries between two communes or neighborhoods, thus the ability to detect F0 is a larger area in one test. At the same time, based on the risk index map and infection risk map, the determination of testing areas is

flexible, narrowed or expanded depending on the actual detection of F0 cases and the residence characteristics of F0 cases. Based on terrain characteristics, it is possible to reduce the radius of the testing area, thereby reducing the objects of the testing area (For example: separated by canals, large roads, etc.), which means that the cost of testing is reduced. However, this method requires map data with the necessary information to determine the scope of the testing area. Furthermore, in order to the obtained results to be highly reliable, the coordination of testing between neighborhoods and neighborhoods and wards and wards in adjacent areas must be tight and synchronous. Most importantly, there is a risk of missing F0 cases when compared to testing the entire neighborhood or ward.

5. Conclusion

This research introduces a method for creating a COVID-19 sensitivity map of Hanoi using QGIS technology. These maps are designed to pinpoint high-risk areas for epidemic development, allowing for the implementation of tailored and effective adaptation strategies. These strategies will consider factors like population conditions, living situations, infrastructure, and healthcare resources. The ultimate goal is to minimize human losses while simultaneously maximizing economic stability. Furthermore, this research develops models that identify disease risk indicators from spatial data and uses spatial analysis models to generate crucial information for epidemiological modeling. This includes details on population density, living conditions, and demographic data (like age). This work serves as a vital preparation for responding to future outbreaks of respiratory and other infectious diseases.

Conflicts of Interest

The authors declare no conflict of interest.

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