Research on creating spatial analysis models for developing COVID-19 Vulnerability Index Map in Hanoi City

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Abstract

The COVID-19 epidemic is gradually being pushed back in Vietnam as well as around the world, but the emergence of different variants of the SARS COVI 2 virus remain a risk that could lead to a resurgence of the disease . Therefore, preparing sopportive information for epidemic prevention, especially disease risk maps based on spatial data, is essential to ensure that Vietnam can live safely with the SARS COVI virus 2. This paper presents a method for creating a COVID-19 sensitive map of Hanoi city using the QGIS technology. From there, areas at high risk of rapid infection when there are initial cases in the community and regions at high risk of outbreak can be identified in this map. This information helps the government plan to prioritize early vaccine coverage as well as propose reasonable epidemic prevention measures.

Keywords: *COVID, CVI map, QGIS, Hanoi.*

1. Introduction

The world is currently facing a special health problem due to the outbreak of a new coronavirus disease called COVID-19. This is a great threat to humanity. The virus has spread to almost all over the world, and the impact of the pandemic is being felt in nearly every aspect of our lives. Until now, there is no effective medicine that can be used to prevent and treat COVID-19. Therefore, to control the transmission of the COVID 19 virus, it is necessary to rely on community and use non-pharmaceutical interventions (NPIs), such as distancing social, protecting vulnerable groups, limiting public events and implementing global lockdowns. These measures are primarily to minimize the spread of COVID-19 person-to-person through social distancing (Nande, Adlam et al. 2021).

Studies conducted in the US (Amram, Amiri et al. 2020), India (Acharya and Porwal 2020), UK (Nicodemo, Barzin et al. 2020, Daras, Alexiou et al. 2021), Brazil (Santos, Siqueira et al. 2020) , Bangladesh (Rahman, Islam et al. 2021), European Union (Fu, Wang et al. 2021), Palestine (Shadeed and Alawna 2021) have shown that disease risk maps have effectively contributed to improving effectiveness of epidemics prevention, playing an important role in saving human lives as well as effectively overcoming the economic and social consequences caused by the pandemic. Therefore, since the COVID-19 pandemic appeared in the world, there have been many studies to establish disease risk maps such as COVID Vulnerability Index Map, Pandemic Vulnerability Index Map. The purpose of these maps is to identify high-risk locations for disease outbreaks, and then provide the most effective and appropriate adaptive methods based on population conditions, living conditions, infrastructure, healthcare, etc. in order to avoid human losses and maintain economic development at the maximum possible level (Acharya and Porwal 2020).

Till now, COVID-19 risk mapping has been reported in many nations in the world using various approaches. According to (Raju K, Lavanya R et al. 2020), one of tools that helps people can understand the disease is Geographic information systems (GIS). GIS provide a great framework for integrating disease-specific data with population settlements, social and healthcare facilities, and the surrounding natural environment. It also offers data that are highly appropriate for analyzing data and showing trends. (Sangiorgio and Parisi 2020) proposed the multicriteria approach and GIS technology for hazard evaluation of Covid-19 in urban district lockdown. Similarly, GIS-based MCDA was utilized to establish the COVID-19 vulnerability map for the West Bank, Palestine (Shadeed and Alawna 2021). In addition, in order to potentially vulnerable areas of the COVID-19 infection which can aid government organizations in maintaining disease management and preventing its spread, (Malakar 2022) generated the COVID-19 vulnerability map West Bengal, India through the GIS platform and an integrated fuzzy MCDM approach. On the other hand, this method also applies in constructing the COVID-19 vulnerability model in China (Gao, Jiang et al. 2022), assessing of COVID-19 vulnerability risk (Wyszyński, Grudziński et al. 2022), determining main social vulnerability indicators in the pandemic in Iran (Moslehi, Dehdashti et al. 2023), establishing COVID-19 susceptibility mapping (Sarkar 2020)

In addition GIS-based MCDA approach, (Dahu, Alaboud et al. 2023) confirmed the role of application satellite imaging, remote sensing technology, and geospatial data in identifying features and relationship that are connected to the global dissemination and mortality rate of COVID-19. Furethermore, (Mehmood, Bao et al. 2022) concluded that, in the upcoming years, the application of remote sensing technology will enable far more efficient monitoring and management of global pandemic risks. There are, this technology has been widely applied in research on the COVIDS pandemic. (Kanga, Sudhanshu et al. 2022) used remote sensing, GIS technology and local knowledge-based method to effectively solve the contagion of COVID 19 disease in India. In consultation with the local authorities, they spatially delineated different hazards zones and the activities that are permitted there. Besides, (Toulkeridis, Seqqat et al. 2022) used satellite images to analyze SARS-CoV-2 infection among susceptible populations in Ecuador. Additionlly, *combination of the Bayesian network and the GIS technology also used to build a model for analyzing the vulneratble regions due to the outbreak of* pandemic *i*n Bangkok, Thailand. This model employed to perform a scenario analysis led to the discovery of strategies for vulnerability management.

To be able to generate disease risk maps, spatial data plays an important role, as input for models to determine the disease risk index (Amram, Amiri et al. 2020). Based on statistics on the location of COVID-19 cases, it is possible to create correlations between some spatial information such as population density, per capita income, living conditions with risk of disease outbreak, etc. (Acharya and Porwal 2020). This spatial information can be collected through open data sources, or can be determined indirectly by spatial analysis models through existing spatial data such as, distribution of land covers, population data, etc. (Franch-Pardo, Napoletano et al. 2020).

In Vietnam, there have been studies to determine the location of diseases such as malaria (Bui and Pham 2016), geographical analysis of the occurrence of diarrhea caused by shigellosis bacteria in Vietnam (Kim, Ali et al. 2008), or the geographical distribution of dengue fever in Hanoi City (Thanh Toan, Hu et al. 2013). These studies show that geographic information/spatial information can contribute to improving the effectiveness of disease prevention, protecting people's lives, and ensuring health safety for Vietnam. In addition, GIS technology has also been proven to be effective in zoning the risk of covid-19 epidemic to decentralize the level of impact (Canh, Son et al. 2022). Besides, to forecast and zone epidemic areas to be able to provide the most accurate and fastest solutions, (Sơn, Nga et al. 2022) applied local geographical regression models to assess the epidemic situation throughout the city focusing on areas forecasted to have a high and very high infection risk. However, the COVID-19 epidemic is a new disease and appears rapidly, so there is almost no experience and not many studies using spatial data for forecasting and identifying epidemic risks. This study focuses on using spatial data and GIS to create spatial analysis models to for establishing the COVID-19 sensitivity maps for Hanoi city.

2. Study area

Hanoi, the capital of the Socialist Republic of

Vietnam, is located between 20°53′ to 21°23′ north latitude and between 105°44′ to 106°02′ east longitude. It is the political, economic, cultural, scientific, and technical center of the whole country (Uy and Nakagoshi 2008). Located within the Red river delta of Northern, Ha Noi is the region with the highest density of population in the nation with almost 22 million people living there in an area of over 21,000 km^2, more than 8 million of whom live in urban zones (General Statistics Office 2020). The region around Hanoi is made up of plains near the southeast coast and is bounded to the north and west by mountains and hilly regions, including some significant national parks, such as Ba Vi and Tam Dao (Van den Berg, Van Wijk et al. 2003).

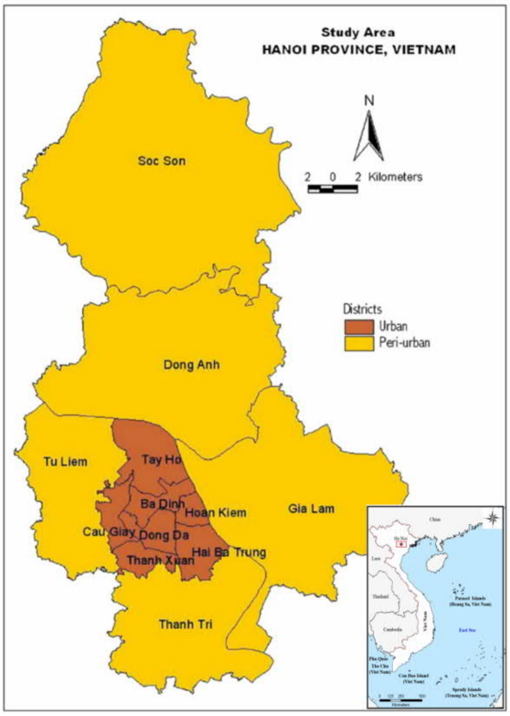

Figure 1. The study area (Thapa and Murayama 2008)

Rys.1 Obszar badań (thapa i Murayama, 2008)

3. Methodology and data

3.1 Used data

During the research process, data on COVID-19 infections in Hanoi during the period 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

Tabela 1 Żródła i dane uzyte w badaniach

Data	Description	Source
Population density		(http://www.worldpop.org.uk/)
Land cover	2019 - 2021	https://www.eorc.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

In the above data, 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

The principle of determining sensitive areas is based on the number of F0 cases in a specific area (after identifying the location of the F0 cases on the map). Then, the ratio between the area with F0 cases (it can be a ward or commune, a district, a neighborhood, a residential group, etc.) and the total area in the study area will be determined. The higher this ratio means the greater the sensitivity of that area. In addition, for the purpose of centralized community screening, after determining the position of F0 cases on the map, the sensitivity index of the area where F0 cases live is calculated. Depending on the percentage value of this sensitivity index (it can be an average, high or very high sensitive area), the range for community testing can be identified (ie, the radius of the area that needs to be tested can be determined) (Figure 2). The COVID-19 susceptibility map is established according to the following process:

Quantify the values that characterize the sensitivity level 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 centrer, and supermartket 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 (Sơn, Nga et al. 2022):

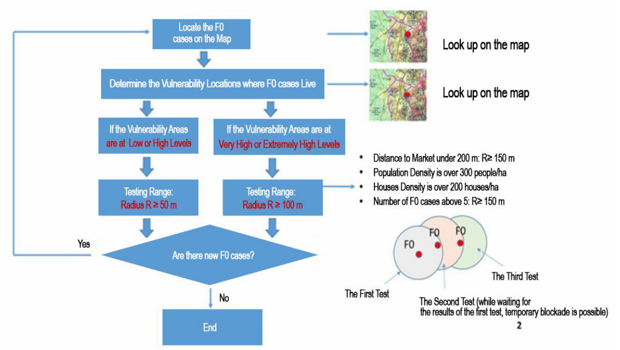

Figure 2. Focused community screening testing
Rys.2. Skoncentrowane badania przesiewowe społeczności

$$Sensitive\_Index_i = W_{Po}*Po\_Index_i + W_{Ma}*Ma\_Index_i + W_{Ap}*Ap\_Index_i + W_{Su}*Su\_Index_i + W_{In}*In\_Index_i + W_{Sh}*Sh\_Index_i \quad (1)$$

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 centrer 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 (Sơn, Nga et al. 2022):

$$Relative_{Sensitive_{Index_i}} = 100 * \frac{Sensitive_{Index_i}}{Max_{of_{Sensitive_{Index}}}} \quad (2)$$

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, ading 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.

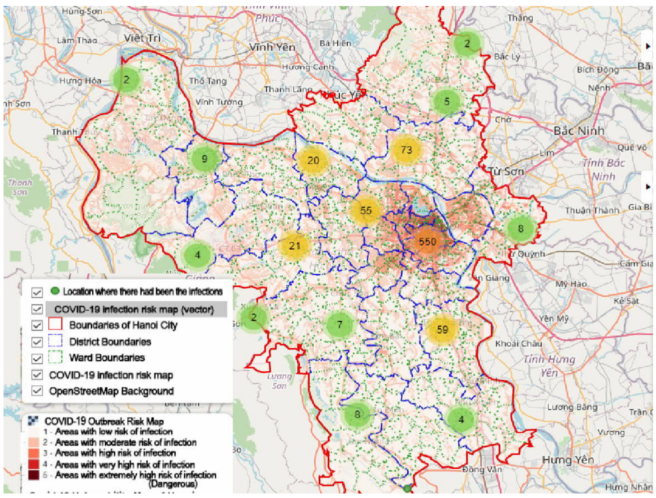

Figure 3. COVID-19 Vulnerability Map of Hanoi city
Rys.3. Mapa podatności na COVID -19 dla miasta Hanoi

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).

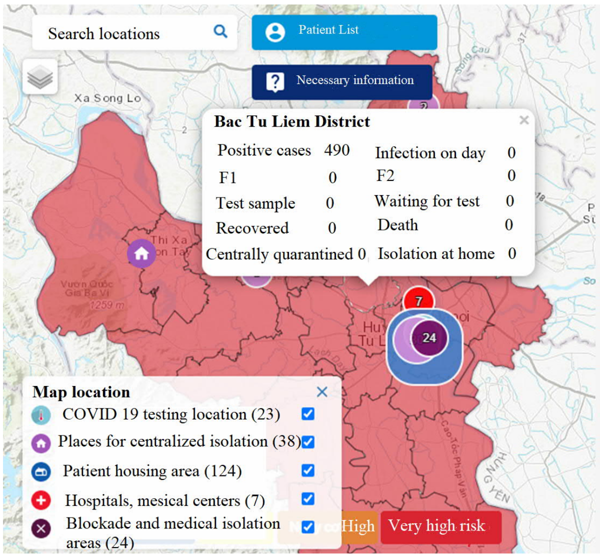

Figure 4. Statistics on the COVID-19 epidemic in Bac Tu Liem district, Hanoi city

Rys.4. Statystyki propoagacji epidemii COVID-19 w dzielnicy Bac Tu Liem w Hanoi

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.

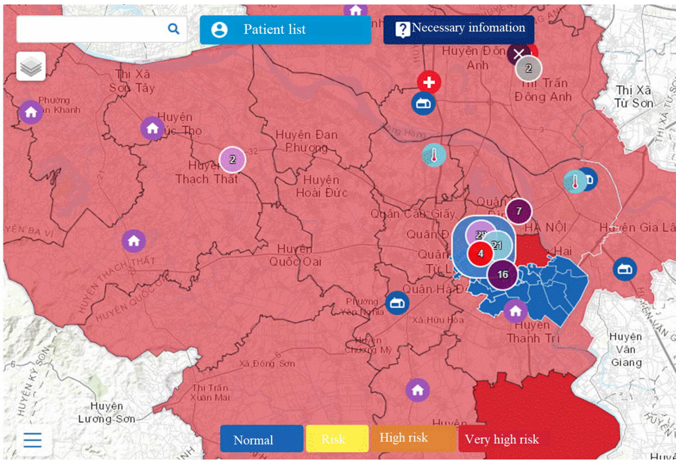

Figure 5. The risk map of COVID 19 infection in Hanoi city

Rys.5. Mapa ryzyka infekcji COVID-19 w Hanoi

Notably, information related to the epidemic in any location can also be accessed. Figure 6 is an example of data search in Thanh Xuan district:

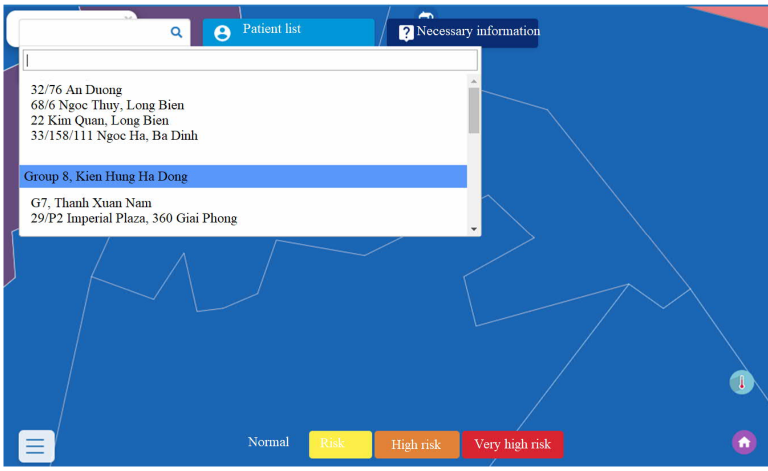

Figure 6. Search any area in Hanoi city

Rys.6. Selekcja danych w obszarze miasta Hanoi

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).

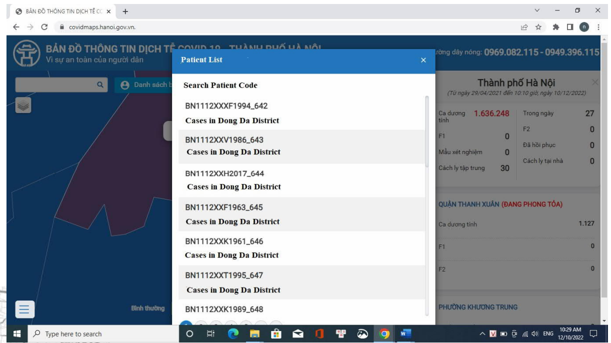

Figure 7. Displaying the list of F0 patients in the search area

Rys.7. Lista pacjentów grupy F0 w obszarze selekcji

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

The study proposed the method for generating a COVID-19 sensitive map of Hanoi city using the QGIS technology. These maps will help identify high-risk areas for development of epidemics, thereby providing reasonable adaptation methods based on population conditions, living conditions, infrastructure, healthcare, etc. in the most effective way. This minimizes human losses while still maintaining economic development at the maximum possible level. On the other hand, researching models allows the identification of disease risk indicators from spatial data, as well as spatial analysis models that determine necessary information for epidemiological modeling such as population density, living conditions, information about population demographics, age, etc. It is also a necessary preparation to respond to the emergence of respiratory infectious diseases as well as other infectious diseases in the future.

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Conflicts of Interest

The authors declare no conflict of interest.

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Badania nad stworzeniem modeli analizy przestrzennej na potrzeby opracowania Mapy Wskaźnika Podatności na Covid-19 w mieście Hanoi

Epidemia Covid-19 jest stopniowo wycofywana w Wietnamie, a także na całym świecie, jednak pojawienie się różnych wariantów wirusa SARS COVID 2 pozostaje ryzykiem, które może doprowadzić do nawrotu choroby. Dlatego przygotowanie informacji wspomagających zapobieganie epidemiom, w szczególności map ryzyka chorób opartych na danych przestrzennych, jest niezbędne, aby Wietnam mógł bezpiecznie żyć z wirusem SARS COVID 2. W artykule przedstawiono metodę tworzenia mapy miasta Hanoi wrażliwej na COVID-19 z wykorzystaniem technologii GIS. Stamtąd na tej mapie można zidentyfikować obszary o wysokim ryzyku szybkiej infekcji, gdy w społeczności występują pierwsze przypadki, oraz regiony o wysokim ryzyku wybuchu. Informacje te pomagają rządowi zaplanować priorytetowe traktowanie wczesnego objęcia szczepieniami, a także zaproponować rozsądne środki zapobiegania epidemii