Geospatial analysis in managing medical facilities for combating disaster triggered by the COVID-19 pandemic

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Abstract. A new virus emerged, which initially called Novel Corona Virus 2019 and later officially named Coronavirus disease 2019, COVID-19. The COVID-19 spread globally in less than a year since its outbreak in Wuhan, China, as the epicenter. The pandemic was beginning at the end of December 2019, and the World Health Organization just announced as a pandemic in early March 2020. With extremely fast commuting people, the spread of the contagious virus tremendously fast. The world was not ready to face this unprecedented situation. This paper presents an effort to fight the Covid-19 pandemic in Palembang City, the capital of South Sumatra Province, Indonesia. This study utilized information provided by the authority and convert it into geospatial data. Daily based data has been captured by providing tools for the enforcements to collect the data for monitoring purposes as well. The Susceptible, Infected, and Recovered (SIR) model is used in this study to determine the need for medical facility demand and map the dispersion of parameters in elevating infectious diseases. The SIR model is used to determine the effect of social distancing in the community to flatten the curve. The local parameters were used in the lowest administrative boundary of the district. Predictive demand for referred medical facilities can be delineated. From this study, the predicted peak of infected cases has a good agreement with the actual total cases. The result of the analysis can be used to manage the medical facilities to accommodate the demand.

1. Introduction

Novel Corona Virus 2019 (SARS-COV2) is a new virus that was emerged in December 2019 in Wuhan, China. Later, this virus officially named to COVID-19, coronavirus disease 2019. By the ability to transfer from human to human and the millennial commuting activities, it has responsible for spreading the virus to the entire world in less than a year [1], [2]. The COVID-19 spreads remarkably fast compared with the other coronavirus diseases, SARS and MERS, that took four months and 2.5 years to infect 1000 peoples, respectively [3]. China enforced lockdown to the number of their major cities, and Wuhan in Hubei province was the main priority. Despite the enforcement, there were more than 5 million people...
potentially exposed to the virus already left the city by using land transport, domestic flight and international flight to many countries which has a direct flight from and to Wuhan, China. The preliminary study on potential exposure to the virus based on historical people's movement from and to Wuhan has been conducted by a group of researchers from South Hampton University. There were five major cities in China at high risk, and for international travel, Indonesia is ranked number 11 behind Singapore, Vietnam, and Australia. Denpasar, Bali, is one of the major destinations of international travelers from 18 high-risk cities in mainland China [4]. The first confirmed case of COVID-19 in Indonesia was reported in early March 2020 [5].

The World Health Organization (WHO) declared the COVID-19 as a global pandemic on 11th March 2020 [6]. The impact is unprecedented in scale, and global response and coordination are needed to manage the impact. Emergency response to COVID-19 pandemic in digitalize information has given many benefits in modeling, simulation, and predicting the impact of the outbreak [3]. The openness and public domain information provide meaningful data to be used by the authority to calculate and estimate their resources in fighting the pandemic. The homepage Our World in Data publishes research and data on the world's most extensive problems. The data on Covid-19 presented in the form of a chart, map, table, and the raw data available for download. Figure 1 shows the total cases and stringency index of Indonesia, Malaysia, Philippines, Singapore, and China, which is started from 2nd March 2020 when the first 2 cases reported in Indonesia until 21st June 2020. From Figure 1, the effect of stringency, which represents a composite measure based on nine response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 of Malaysia and Singapore that maintain it high, the curve of the case is flattened remarkably. Indonesia and Philippines that release the stringency index early, face hike curve of the total cases daily.

Figure 1. The total cases and stringency index as per 21st June 2020
Geospatial data in Geographical Information System (GIS) can aid in examining the spatial distribution of the disease and improve the quality of response to minimize the impact \cite{3, 7, 8}. GIS as a tool to present spatial data related to the dispersion of COVID-19 recently has become popular. The Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE) among the first institution utilized GIS with ESRI platform published live data related to daily confirmed, death, and recovery cases \cite{3}. Recently, the online web GIS of JHU CSSE provided more results of analysis such as Case-Fatality Ratio (CFR) and Incidence Rate (IR) for the entire globe. The Testing Rate (TR) and Hospitalized Rate is provided only for the United States.

The international organization has also published web GIS applications since the initial outbreak of COVID-19. Other than JHU CSSE, WHO, HealthMap, WorldPop, and EpiRisk have published the data in the GIS dashboard and standard chart presentations. The WHO dashboard provides information on cases daily. The cumulative of the new cases and death cases. WorldPop provides data and peer-reviewed research on open and high-resolution geospatial data with a focus on low-and medium-income countries. Besides, the HealthMap uses informal online sources to monitor outbreaks of disease and to monitor emerging public health threats globally in real-time. It provides various sources of alerts (e.g., respiratory, vector-borne, hemorrhagic, severe, neuro, gastrointestinal, fever, STD, and others) for global and nearby outbreaks. The EpiRisk is a computational framework designed to make it possible to estimate the likelihood of the infected cases being exported from the affected location to other parts of the world through the airline transport network and regular dialing patterns. The EpiRisk displays the top 10 connections, the probability of case exportation, and the top destinations ranked by the relative risk of case importation.

ESRI is a leading company that created ArcGIS, a mapping and spatial analysis software that has provided support and service to the GIS community in using data, science, and mapping for response and recovery of the pandemic. Recently, there are more than 900 maps and applications submitted to ESRI. The maps and applications are developed using ArcGIS online platform as a dashboard, experience, hub, story map, and infographic. The content is mostly presenting the daily cases of positive infected, death cases, and recovery cases. Some maps present the cases in different categories, such as case by sex, case by age, case by ethnicity. Analysis of vulnerability based on comorbidity and age, test facilities, and availability of bed with the number of available ventilators also presented in some maps. There are maps focused on the infectious model in different R0 using CHIME tool in the ArcGIS Desktop. Authority agencies in Indonesia also has been provided information to the public in accordance to battle the pandemic and serve communities and private sector in response to the unprecedented situation using GIS. The National Disaster Management Authority (BNPB), Geospatial Information Agency (BIG) provides information to monitor the daily cases and give supports in fighting the pandemic in Indonesia using GIS-based platforms. This study is aimed to analyze the geospatial data related to COVID-19 in Palembang City for managing the medical facilities.

2. Datasets, method and study area

In this paper, the study area is in Palembang City, which is the capital of South Sumatra Province, Indonesia. It lies between 2°52’ to 3°5’ South latitude and from 104°37’ to 104°52’ East longitude. Palembang City is a historical city with its 1337 years old, based on an inscription found at Kedukan Bukit. The total area of Palembang City is 400.61 km$^2$ based on Governance Section, Palembang Government Municipality. Palembang City is a major hub for industry in Indonesia. The textile, paper, wood, chemicals, pharmaceuticals, rubber, and plastic product. The industrial and plantation products are transported through the Musi River. In 2017, 2018 and 2019, the population growth is 1.01%, 1.26%,
and 1.18%, with a total population of 1.4553 million, 1.4680 million, and 1.6629 million, respectively [9]. Within Palembang City, the high-density area and medium density area are scattered on an average elevation of 4.2 m and 4.8 m, respectively. Palembang City consists of 18 districts and 107 sub-districts.

The processes of developing a GIS-based response to COVID-19 start with mapping the case, map the spread, map vulnerable population, map capacity, and communicate with the map. The data is acquired from the Department of Health of Palembang City and coordinated with the Regional Development Planning Agency and Research Development, Palembang City. Figure 2 shows maps of the distribution of population on the district and sub-district of Palembang City. Cluster analysis for districts in Palembang City based on population age more than 20 years old, tuberculosis cases, and diabetes mellitus (DM) cases. The cluster analysis is vital since there are patients with comorbidity diseases (i.e., chronic obstructive pulmonary disease (COPD), chronic renal failure (CRF), hypertension, and DM). Figure 3 shows the comorbidity and age range of patients where the population with a range of more than 20 years old have the most cases. The cluster map is shown in Figure 4. The cluster analysis is conducted using KMean method with Euclidean's Distance Function. It is found that Sukarami District and Ilir Barat I District shared the same cluster center.

![Figure 2. Map of the population in district and sub-district of Palembang City](image-url)
3. Result and discussion

3.1. SIR analysis

The susceptible, infected, and recovery (SIR) analysis is the basic epidemiology of infectious virus analysis [10], [11]. The SIR analysis can be used in geospatial analysis to determine the hospital impact model using the CHIME (COVID-19 Hospital Impact Model for Epidemics) [12], [13]. A team that develops the analysis tool is from Penn Medicine's Predictive Healthcare. This study used the CHIME toolbox in ArcGIS Pro. The output from the analysis is a SIR forecasted model and demand for the hospitalization. By predicting the infected case and new hospitalization, an adequate bed in the referred hospitals can be predicted. In Palembang City, there are 16 referred hospitals for COVID-19's patients. The variable required for the SIR analysis in the CHIME is hospitalized cases, which is, on average, about 12% of total cases for each district in Palembang City. The doubling time is 10 to 12 days for the first phase of the study, which is started from the 1st recorded cases on 6th April 2020. The percentage of patients that required ICU room and ventilator is set to 0.5% and 0.1% from the hospitalized cases based on data recorded from each referred hospital. The positive cases for each district are shown in Figure 5. Two out of four districts, which are the Sukarami District and Ilir Timur II District, are...
neighborhoods. Ilir Barat I District has the highest cases from the beginning. Kemuning District has a significant increase in positive cases on 15th June 2020.

The main factors in the CHIME tool in SIR model are the doubling time and the number of hospitalized cases given into the model. For the hospital impact, the percentage of hospitalized cases out of the total cases and the duration of hospitalization play a significant role in determining the predicted demand for using medical facilities. Figure 6 shows the month and predicted day of the month of infected cases for Palembang City from its 18 districts and a normal distribution curve of the predicted infected cases. The infected cases are classified into five, and it showed that using data on 13th July 2020, the highest infected cases spread from the end of July to mid of September 2020. The prediction has a good agreement with the fitting curve in polynomial power 4 to the actual cumulative total cases from 6th April 2020 to 13th July 2020, as in equation (1) and Figure 7. The $C$ in equation (1) is the cumulative case on day $d$, and $d$ is the day from the started day when the case was recorded.

![Figure 5. Cumulative positive case per sub-district](image)

![Figure 6. Month and predicted day of the month of infected cases](image)
Figure 6. The month and day of month graph with a normal distribution curve of the predicted infected case for Palembang City.

Figure 7. The polynomial of the fitting curve on the cumulative daily case.

\[ C = -5 \times 10^{-5}d^4 + 0.0079d^3 - 0.199d^2 + 74.584d + 43.114 \]  \hspace{1cm} (1)

The two scenarios of SIR model are drawn as in Figure 8. In this paper, the two scenarios of infectious are based on doubling time of 12 days as applied in the 1st infectious phase (6th April 2020 – 28th May 2020) and 18 days of doubling time as recorded in the 2nd infectious phase (29th May 2020 onward). It shows that the 2nd phase with equivalent doubling time as the 1st phase gave almost identical forecasted peak. Still, in the 2nd scenario, the forecasted peak is a decrement subset of the 1st predicted infected case curve. The prediction has delineated with an assumption that no intervention on increasing the stringency index.

3.2. Facility and demand

The CHIME tool in ArcGIS Pro accommodates the SIR model to predict the hospital impact due to pandemic outbreaks. The geospatial information embedded in the data gives it capabilities to determine the hospitalized needs of the infected patients. The analysis incorporates the geoprocessing tools to evaluate the medical facility locations, demand, and visualization of the availability and accessibility of the facilities. In this section, the delineation of demand and accessibility of the existing referred hospital for COVID-19's patients.
There are 17 referred hospitals for COVID-19 in Palembang City. Figure 9 shows the service area that can reach from the facilities within 15 minutes of driving. The residential area almost covered 100% within the service area in the municipality of Palembang City. The demand analysis from each sub-district to the medical facilities in Figure 10.a, considering the age population distribution and distance from facilities to the demand, has shown that there are two hospitals with less effective in terms of location. The wider the line represents, the bigger demand in regard to the susceptible population by age range. Figure 10.b shows the highest anticipated capacity of the referred hospital with darker red and bigger size symbology. The contour map represented the area with anticipated high COVID-19 cases that need to be accommodated.
Figure 9. The service area of referred hospitals for COVID-19 cases.

Figure 10. Demand and allocated capacity of referred hospitals for COVID-19 cases.

Figure 11 shows the isolation room capacity of the hospital. The hospital RSUD Palembang Bari and RSUP dr. Moh. Hoesin can accommodate more COVID-19 patients. Based on the analysis of demand and forecasted infected cases, three hospitals, which are the RSU Myria, RSUD Siti Fatimah, and RSI Siti Khadijah require to increase the capacity of the isolation room to accommodate the new hospitalized case. For the southern area of Palembang City, the hospital RSU PUSRI require to increase the isolation room capacity.
Figure 11. The isolation room capacity of referred hospitals for COVID-19 cases.

Monitoring daily cases of infected and recovered COVID-19 patient is required to be able to manage the medical facilities. A web-based dashboard has been developed in collaboration works with the Regional Development Planning Agency and Research Development, Palembang City, Universiti Tenaga Nasional, Malaysia, and Universitas Indo Global Mandiri, Palembang. The dashboard presents the daily cases of asymptomatic cases (ODP), close contact case (PDP), positive case, hospitalized case, recovered case, and death case. Figure 12 shows the dashboard as part of an official portal for Palembang City, where it presents the process of mapping the data, map the spread, map the vulnerable population, and map the capacity of the city. The portal can be accessed from https://giscovid19-uigm-gis.hub.arcgis.com/. The portal serves communities and the private sector in response to the unprecedented situation by providing monitoring of aid distribution to the affected communities and provide information on how to stop the spread of the virus and keep healthy.
Figure 12. The monitoring dashboard of COVID-19 daily cases.

4. Conclusion

This paper presents the geospatial analysis related to COVID-19 in Palembang City for managing the medical facilities. From this study, the predicted peak of infected cases has a good agreement with the actual total cases. The CHIME tool can help hospitals to prepare for the worst scenario of the facility demand due to the pandemic. The result of the analysis can be used to manage the medical facilities to accommodate the demand. The authority can use the information to allocate the future development of public or private hospitals or increase the capabilities of the community clinic to be able to accommodate emergency cases daily.

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