Original Article

Early Stage of COVID-19 Spreading and Simulation Trend using The Spatiotemporal Epidemiologic Modeler (STEM), Case Study in Jakarta

Maya Genisa[1], Abdul Manaf Abdullah[2], Solehuddin bin Shuib[3], Juniarti[4]

[1] YARSI University.

[2] Universiti Teknologi MARA.

[3] Universiti Teknologi MARA.

[4] YARSI University.

Email: maya.genisa@yarsi.ac.id[1], abdulmanaf@uitm.edu.my[2], solehuddin2455@uitm.edu.my[3], juniarti@yarsi.ac.id[4]

DOI: 10.47750/pnr.2022.13.S01.201

Abstract

COVID-19 virus is transmitted from human to human through splashes of saliva when the sufferer coughs, sneezes, or talks and is inhaled by the people around him. The spread of this virus started from the Chinese city of Wuhan in December 2019 which quickly spread to cities outside Wuhan including Jakarta, Indonesia. The same is in other countries, the local government in Jakarta taking some emergency decisions to minimize the virus spreading including the movement control order (MCO). This paper discusses the simulation of COVID-19 spreading in the early stage in Jakarta using a different model of disease spreading available on The Spatiotemporal Epidemiologic Modeler (STEM). The focus of this simulation is to see the effect of MCO on the COVID-19 spreading in the local area in Indonesia. The result shows that the MCO contribute to the decreasing of case number with some certain period of lag time.

Keywords: COVID-19, movement order, simulation, vaccination.

INTRODUCTION

Lung infection (Pneumonia) caused by the COVID-19 virus has spread throughout the world tremendously, Indonesia is no exception. Not only causing deadly pathogens, this virus attack has seized the attention of governments around the world including WHO, not only crippling the entire world economy, but also causing tremendous panic in the world community. The number of victims who contracted and died was reported to be very unreasonable.

The spread of the COVID-19 disease that attacks the lungs has affected more than 4 million people worldwide in just a few months and killed no less than 200,000 people. Meanwhile, in Indonesia, this virus has infected more than 14,000 people with no less than 1000 deaths in just 4 months. The local government's efforts to reduce the spread of this virus are to limit the mobility of the population by staying away from crowds of people and social distancing because this virus is spread through patient droplets, so social distancing is highly recommended. Human movement between regions is closed to prevent transmission from one area to another.

Under these circumstances, WHO has declared an international emergency. Researchers from various fields have participated to solve this global problem. Various strategies from governments around the world have been taken to try to narrow the spread of this virus and save many people from the spread of this virus. However, humans as a social community cannot necessarily isolate themselves completely from the infected community. The movement of humans from one place of the outbreak to another will become a carrier and become a source of spread in a new place. This will bring its own problems for the local government to control the movement of the spread of this virus. Population mobility is an important factor in the spread of the COVID-19 virus.

Therefore, this research is proposed to contribute to the handling of national emergencies in dealing with the spread of the

COVID-19 virus through a research modeling the spread of the COVID-19 virus by focusing on the effect of population mobility by land, air and sea. It is hoped that the results of this study can be used as a reference for carrying out a policy of isolating an area to inhibit the spread of virus infection.

EARLY STAGE OF COVID-19 VIRUS SPREADING IN INDONESIA

Corona virus or commonly known as COVID-19 is a virus that is transmitted from human to human through splashes of saliva when the sufferer coughs, sneezes, or talks and is inhaled by the people around him. This virus is predicted to be transmitted through the eyes, nose and mouth with the target of this virus is the lungs. The spread of this virus started in the Chinese city of Wuhan in December 2019 which quickly spread to cities outside Wuhan in mainland China and eventually spread to countries that had flight contact with China (Wu et al., 2020).

According to a report from the Indonesian Ministry of Health as of February 15, 2020, there has been a decrease in the number of COVID-19 patients in China while outside China has increased. In Indonesia at that time, it was reported that there were still no infected from 19 provinces tested, namely: DKI Jakarta, Bali, Central Java, Riau Islands, West Java, East Java, Banten, North Sulawesi, Jogja, East Kalimantan, South Sulawesi, Jambi, West Papua, NTB, Bengkulu, West Kalimantan. , Central Kalimantan, Southeast Sulawesi and Maluku.

The spread of the virus in Indonesia was officially reported in February 2020 in the Depok area with two sufferers. The initial contact spread as described was through a crowd of 50 people in Jakarta (Ihsanuddin,2020). Until the end of March 2020, it was recorded that the spread of the virus in the city of Depok had reached 121 people spread across all sub-districts in Depok. The Depok government continues to carry out efforts to prevent the spread in the form of socialization and disinfectants (Yandwiputra,2020).

In the DKI Jakarta area, it was reported from the official website of the DKI government, that on 20/3/2020 210 people were positively infected with a death toll of 19 people and spread throughout the Jakarta area as shown in Fig 1.

Fig 1. Map of the positive spread of Coronavirus infection in the area of Jakarta as of 20/3/2020. (Faradila, 2020).

Jakarta, which is connected by land to the Bogor, Tangerang, Bekasi, and Depok areas is certainly the center of distribution to other areas. Also, Jakarta has a density of flight services throughout Indonesia which was recorded at the beginning of 2019 reaching 16,093 flights, and is the second largest city in the world. And there were 6.63 million domestic passengers in November 2019 (Pink,2020). There is a potential for spread to other cities in Indonesia. 40 days after the discovery of the Corona case, the virus infection has reached almost all provinces in Indonesia, as reported by Kompas (Naufal,2020). In the next phase, it is reported that not only Jakarta has become the epicenter of the spread of COVID-19, but other cities such as Bali, Central Java, West Java, East Java and South Sulawesi have become new epicenters with an increasing number of sufferers.

PANDEMIC SPREADING MODEL

The spread of infectious/pandemic diseases that attack humans is often studied through modeling methods. The purpose of modeling the spread of this pandemic is to predict how widespread the spread of this disease can be and also to plan strategies for how public health can be planned to reduce the impact of the spread of the disease. Various mathematical models of the spread of infectious diseases have been used by several researchers, the following are:

S-I-R Model

One of the simplest models is the S-I-R model (Milner and Pugliese, 1999). In this model, the population is divided into 3 categories: Susceptible (S) or people who have not been infected, Infectives (I) are people who have been affected and have hopes of recovering, and the Removed category (R) is people who have been affected and recovered by having immunity to the disease or the person who dies from the disease. This model has been applied in Latin America in cases of the spread of dengue fever, the spread of swine flu in the Netherlands and Norovirus in Belgium. From this model can provide lessons on how to prevent the spread of the disease.

In the case of the spread of the COVID-19 virus, this model tells how “stay at home” and “social distancing” are isolating from the exposed population. So it automatically becomes part of the “R” category of this model. The population categorized as "S" can be assumed as the population at the beginning of the case. While the average number of individuals who are not exposed is assumed to be R0. Where if R0 is smaller than one, then the pattern of spread of infection will decrease drastically. But when R0 is greater than one then the number of infected population will increase exponentially.

S-I-S Model

In the previous model, namely the SIR model, it is possible to have a population category that has recovered from the disease and has immunity to the disease, so there is an "R" category that can be removed from the total infected population. When there is a pandemic where the patient is exposed to the disease and can be cured again, but the patient does not have immunity to the disease and can be infected again after recovering and there are no patients who die from this disease, then the SIR model is no longer relevant for modeling this kind of disease. . For example, the sexually transmitted disease gonorrhea. This disease is categorized as a sexually transmitted disease. Patients can be cured of this disease, but the person does not have immunity to the disease, one day he can be infected again. And this disease is not classified as a deadly disease, so there is no "R" category for this disease, so the model that can be used is the S-I-S model. The population of susceptible will never be excluded but will be cured.

In the case of COVID-19, recovered patients have the same immunity to this disease as other diseases such as SARS-CoV-2. One thing that complicates the handling of this COVID-19 case is that carriers/patients do not immediately show symptoms at the beginning of being infected. As a result, patients will have the potential to become carriers of the spread of the virus, especially if mobility and social distancing or self-isolation are not applied. Therefore to model the spread of the virus-like this. It is necessary to add a population class, where patients are infected but do not show symptoms and act as carriers for spreading the virus.

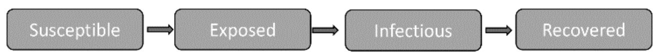
C-I-R Model

When a disease allows an infected person not to immediately show symptoms, then that person has the potential to be a carrier or carrier of the disease, as is the case in the case of the spread of HIV/AIDS. Infected patients, sometimes do not show symptoms of illness for a long period. So that person will act as a carrier in the spread of this disease. The same thing happened in the case of the spread of COVID-19. This disease allows someone who is infected but does not immediately show symptoms of illness for a certain period. The presence of these people marks the spread of the disease to be difficult to control. For this reason, the recommended mathematical modeling is to change the S-I-R model to a C-I-R model where a new population called "Carrier" needs to be added to the model. Population "C" is to represent the carrier-class population which is a class that is very vital in the spread of this virus such as people with HIV/AIDS.

S-E-I-R Model

The mathematical model that will be used in modeling the spread of COVID-19 is the S-E-I-R compartment model. In this model the population is divided into 4 groups or classes, namely: Class S, E, I and R, which are "Susceptible", "Exposed", "Infected" and "Removed" classes, respectively. The “exposed” class is the class in which the transitional phase is where individuals who have been exposed but are not yet infected. This class will be "latent" in the spread of the virus, where the virus already exists in itself but cannot infect other people. The rule in this model is that each individual cannot occupy two different classes in the same period. The class schematic in the SEIR model is shown in Fig 2.

Fig 2. SEIR model



METHODOLOGY

Mathematical Model of COVID-19 Spreading

The mathematical model used in modeling to simulate the spread of COVID-19 is the S-E-I-R compartment model. In this model the population is divided into 4 groups or classes, namely: Class S, E, I, and R, which are "Susceptible", "Exposed", "Infected" and "Removed" classes, respectively. The “exposed” class is a class where the transitional phase is where individuals who have been exposed but are still not infected. This class will be "latent" in the spread of the virus, where the virus already exists in itself but cannot infect other people. The rule in this model is that each individual cannot occupy two different classes at the same time. The class schematic in the SEIR model as shown in Fig 2, where the rate of each class is expressed in a mathematical formula as the following differential equation:

$$\frac{dS}{dt} = \mu N - \mu S - \beta \frac{I}{N} S$$

$$\frac{dE}{dt} = \beta \frac{I}{N} S - (\mu + \alpha) E$$

$$\frac{dI}{dt} = \alpha E - (\gamma + \mu) I$$

$$\frac{dR}{dt} = \gamma I - \mu R$$

Where: α = incubation parameter, μ= mortality rate, = number of individual contacts per unit time, and N = S+E+I+R. where S, E, I, and R are the total population of each class.

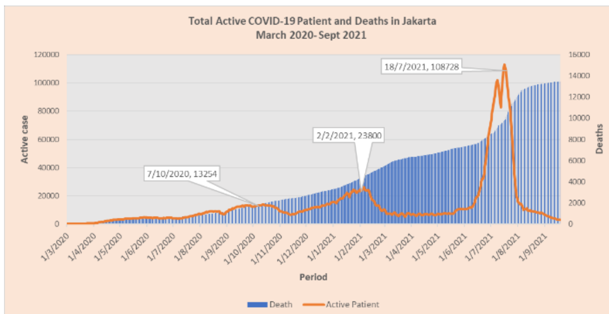
The modeling of the spread of the COVID-19 virus are carried out using the open-source STEM (Spatiotemporal Epidemiological Modeler) software provided by the Eclipse Foundation which can be obtained free of charge. The advantage of this tool is that the calculation model and components can be customized so that they can match the scenario to be tested. In addition, this software provides facilities to add scenarios with the intervention. So that the effect of the intervention can be measured.

RESULT AND DISCUSSION

Statistical of COVID-19 in Jakarta

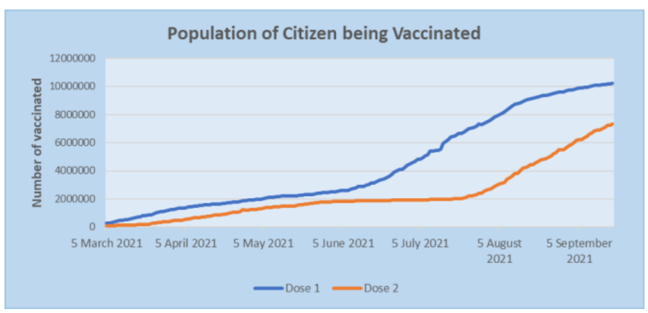
Analysis was done from March 2020 to September 2021 in Jakarta. In this period, there are three peaks of the active case which are on 7th October 2020, 2nd February 2021, and 18th June 2021. While the deaths increased from March 2020 to September 2021 as shown in Fig 3.

Fig 3. Statistical case of COVID-19 in Jakarta from March 2020 to September 2021.



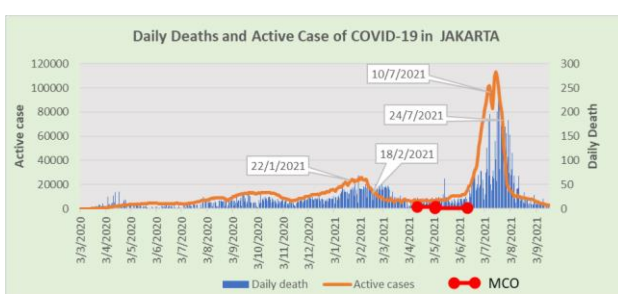
Meanwhile, the vaccination in Jakarta starts from March 2020 to September 2021 as shown in Fig 3. Vaccination was given in two doses, doses 1 and doses 2. The target of the population being vaccinated in June 2021 was two million and 10 million in September 2021. The achieved vaccinated population is shown in Fig 4.

Fig 4. Vaccinated population in Jakarta from March 2020 to September 2021.



As applied in another city, the local government in Jakarta during that time also applied for the Movement Control Order (MCO). The implementation was applied partially and totally to the local movement. During that period from March 2020 to September 2021, there were eight times MCO implemented for different weeks. The MCO was implemented by following the peak of the active case in Jakarta as shown in Fig 5.

Fig 4. Effect of MCO on COVID-19 Cases in Jakarta from March 2020 to September 2021.

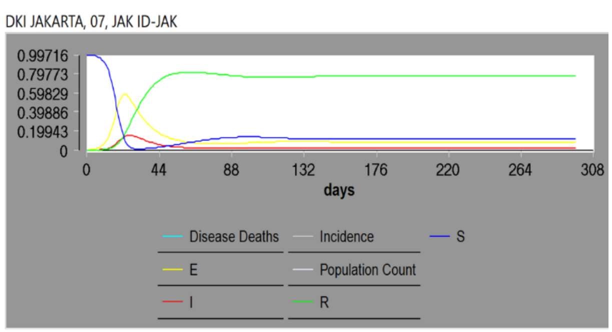


The peak of daily death following the peak of an active case, however, occurred by two weeks delayed from the active case peak. A combination between the implementation of MCO and vaccination was effectively decreasing the active case in Jakarta. There are cooling down period from 3rd March 2021 to 3rd June 2021 where the active case can be maintained flat, there is no increment in the active case. The active case was increased suddenly from 3rd June 2021 to 3rd July 2021 when the MCO is canceled. From 3rd July 2021 to 3rd August 2021, the active case can be decreased after MCO is implemented again. It showed that the MCO in the local district in Jakarta effectively affects the COVID-19 spreading.

Simulation of COVID-19 Spreading in Jakarta

Simulation of COVID-19 spreading in Jakarta was done using STEM software focusing only on the Jakarta area with a population of 18,000 people per km^2. The transportation mode considered is only land transportation. In this study, Jakarta was compartmentalized into five districts which are Central Jakarta, East Jakarta, North Jakarta, South Jakarta, and West Jakarta. The border of Jakarta was Tangerang, Bogor, and Bekasi city. Transportation inter cities was only land transportation. Even Jakarta is connected to the other cities through air and water transportation mode, however, in this simulation only land transportation is included.

The simulation period was only limited to the first 300 days since the COVID-19 case was reported in Jakarta. The parameters included in the calculation were transmission rate, incubation time, mortality, and recovery rate. The output was predicted using SEIR model. The simulation results is shown in Fig 5a. The results show that the recovered population slowly increased at the beginning of the case, but significantly increase after about 1.5 months and maintained a high. In terms of the exposed, there is a significant exposed peak that occurred in less than one month where the MCO is still not implemented yet. Once MCO is implemented, there is a significant decrement in the infected case which is followed by the trend of infected cases. Of course, this simulation is subject to change when the parameters input is changed. It will depend on how many constraints are involved and how the complexity of the model that is used. The illustration of the spreading of the COVID-19 case in Jakarta resulting from the simulation is shown in Fig 5b.



(a)

(b)

Fig 5b shows the spreading of COVID-19 in Jakarta (Red Circle) screenshot at 300 days since the case was reported. Of course in this software, the progress of daily case distribution around the targeted area of simulation is also possible to be captured. The simulation was able to capture the spreading of COVID-19 timely and spatially. Looking at the flexibility of the software, it is also able to be implemented for other kinds of diseases or pandemics in the certain local area or nationally. Of course, the characteristic of diseases and the rule of government to treat the pandemic can be simulated. The early study on how to manage the pandemic can be useful to prevent unwanted risk, especially for a human being who lives in the district area of the pandemic.

CONCLUSION

In the early period of the spread of COVID in DKI Jakarta from March 2020 to Sept 2021, it can be concluded that:

There are several peaks in the increase in active cases followed by an increase in deaths. Peak rise in recurrent positive cases with a slowing period of repetition from the beginning of the spread. The effect of PSBB is seen to slow the peak of the increase in daily positive cases. Daily cases of death follow a pattern of daily increase in positive cases. STEM can be used to simulate the spread of a pandemic such as COVID 19, but the input parameters in the simulation need to be set up to be adjusted to the case data. Simulation studies of pandemic spread using STEM have the potential to be used for other pandemic and diseases which is spread through the air or intermediaries such as mosquitoes in DHF.

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