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Forecasting Social Distancing impact on COVID-19 in Jakarta using SIRD Model

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Abstract

Coronavirus disease 2019 (COVID-19) is a new emerging disease and a pandemic causing a high number of deaths. It is caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV2) and transmitted via droplets. Several countries including Indonesia had applied social distancing to reduce the disease transmission. In this study, we were using two groups, with social distancing and without social distancing represented by quarantine parameter Q . We predict the peak number in both groups using Susceptible-Infected-Recovered-Deceased (SIRD) model. The aims of this study are to compare the peak number of cases in groups with and without social distancing cases in Jakarta. This study result in a lower peak number and longer days of disease period in group with strict social distancing than in groups without social distancing, the current case number represent quarantine parameter Q 0.4 of SIRD Model. We suggest applying strict social distancing in Jakarta considering the duration, health standard, and other factors affecting COVID-19 cases.

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Nomenclature

N	total population
t	time (day)
R_0	total number of people an infected person infects (basic reproduction rate)
β	rate of transmission
γ	rate of recovery
δ	rate of mortality
ξ	quarantine parameter

1. Introduction

Coronavirus (CoV) is a RNA virus that can infect both animals and humans¹. In humans, these viruses cause vast respiratory tract infections from mild to lethal. Some lethal varieties include Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS)². In December 2019, a new emerging disease called Coronavirus disease 2019 (COVID-19) occurred. It is caused by a virus identical to SARS-CoV and thus was named SARS-CoV-2. It was reported from Wuhan, China, which originated from bats and can be transmitted to humans. Since then, the number of cases has continued to increase rapidly and become a pandemic².

The effectiveness of disease transmission by inhaled droplets produced while coughing, sneezing, or talking underlines the reason for the high number of COVID-19 cases. Moreover, the virus in droplets can last for days on a specific surface and maintain its infectiousness³. There has been a steep increase of COVID-19 cases from March 11, 2020 to June 20, 2020. Accounts for 125,704 to 8,525,042 cases worldwide, 4,610 to 156,973 death cases worldwide⁴. A similar escalating pattern occurred in Indonesia with total cases of 2 on March 2, 2020 to 43,803 on June 20, 2020⁵. This reflects the effective disease transmission and mortality.

Some recommendations to reduce exposure and transmission of COVID-19 are maintaining basic hand and respiratory hygiene, safe food practices, and avoiding close contact. Many governments in the world, including Indonesia stipulate regulations on social distancing in public spaces, lockdowns in several states/provinces/cities and countries, and other regulations that can reduce the growth of the number of COVID-19 cases^{6, 7}. Social distancing policy distribute COVID-19 cases over time which help government when hospital beds are limited with large peak of infections⁸. Therefore, the primary goal of this study was to predict COVID-19 cases based on quarantine level applied in Jakarta.

To test the hypothesis that social distancing policy take effect on COVID-19 peak number in Jakarta, we investigated quarantine level applied in Jakarta. Therefore, we use Susceptible-Infected-Recovered-Deceased (SIRD) model divides population into four compartments (susceptible, infective, recovered, deceased). It uses transmission, recovery, and mortality rate as its parameters. Recovery and mortality rate can be used to determine policy decisions such as expand emergency hospital capacity⁹.

This paper consists of 5 sections starting from the model used for this study in section 2, followed by research methodology in section 3. In section 4, we discuss the experiment results of SIRD modeling for COVID-19 cases in Jakarta correlated with hospital bed density. Finally, we concluded our study with suggestion for government in section 5.

2. Model

In this section we will describe the basic of the SIR model and focus on the SIRD model.

2.1. SIR Model

Susceptible-Infected-Recovered (SIR) model is an epidemiological model that computes the theoretical number of people infected with contagious illness in a closed population over time¹⁰. One of the simplest SIR models [Fig.

1] is the Kermack-McKendrick model. It assumes that the population size is fixed (no births, death do to disease, or deaths by natural causes), incubation period of the infectious agent is instantaneous, and duration of infectivity is the same as length of the disease. It also assumes a completely homogeneous population with no age, spatial, or social structure ¹¹.

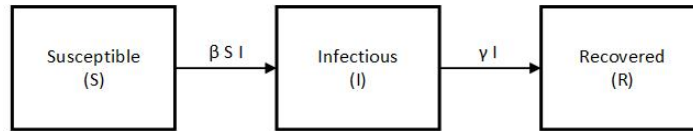


Fig. 1 SIR Model

As mentioned in Fig.1 ^{12,13}, SIR model lead three ordinary differential equations:

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

where

$$D = \frac{1}{\gamma}$$

$$R_0 = \frac{\beta}{\gamma}$$

D is duration of infection. It should be noted that R_0 has a different meaning from R. Basic reproduction number (R_0) is defined as the number of secondary infections caused by a single infected individual ¹⁴; in other words, it determines the number of people infected by contact with a single infected person before his death or recovery. Value of $R_0 > 1$ if the number of infected people highly increases, while $R_0 < 1$ means infection will reduced and finally ceased ^{8,15}.

2.2. SIRD Model

The SIRD model [Fig. 2] ^{16,17} is an elaboration of the basic SIR model. There is a difference with the SIR model, which in this model takes into account the condition of death. The SIRD model was used to formulate an optimal control problem with an expanded epidemic model to compute (non-pharmaceutical) implementation strategy ¹⁸. It also can be used to obtain a quantitative picture of the epidemic ¹⁹.

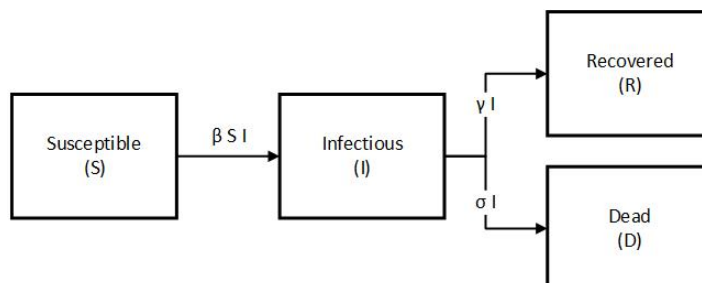


Fig. 2. SIRD Model

This model used the following system of differential equations:

$$\begin{aligned}\frac{dS}{dt} &= -\beta SI / N \\ \frac{dI}{dt} &= \beta SI / N - \gamma I - \delta I \\ \frac{dR}{dt} &= \gamma I \\ \frac{dD}{dt} &= \delta I\end{aligned}\tag{1}$$

where

$$D = \frac{1}{\gamma}$$

$$R_0 = \frac{\beta}{\gamma + \delta}$$

There also an equation defined by Marcelo et al.⁸ shown below:

$$\begin{aligned}\frac{dS(t)}{dt} &= -(1 - \psi(t)) \frac{\beta I(t)S(t)}{N(t)} \\ \frac{dI(t)}{dt} &= (1 - \psi(t)) \frac{\beta I(t)S(t)}{N(t)} - \frac{\gamma I(t)}{1 - \rho} \\ \frac{dR(t)}{dt} &= \gamma I(t) \\ \frac{dD(t)}{dt} &= \frac{\rho}{1 - \rho} \gamma I(t)\end{aligned}\tag{2}$$

In this study, we use the simplest SIRD model calculation from equation (1). Moreover, this equation used in some papers such as paper written by Saptarshi et al, Ahmad et al, and Cintra et al^{19,20,21}.

2.3. Modified SIRD Model with Social Distancing Scenario

The modified SIRD model with social distancing scenario added one parameter to the basic SIRD model. Lockdown and social distancing measures that affect the rate of transmission of infections (β). We added quarantine parameter ξ to designate with or without social distancing, where $\xi \in [0,1]$. Value of $\xi = 0$ when there is no social distancing, while $\xi = 1$ means that infection is contained²².

Hence, the equation become:

First, data that had been collected is cleaned up, such as make sure the data types that exist from each column of rows are proper value. For example, the data type that must be in the “Active Case” column is a date and the province column is a number. It is an important step to ensure the data to be processed is correct and prevent errors to the system. Exploratory data analysis (EDA) then could be performed after data confirmed as a clean data. This step is carried out to understand the contents of the data used, from the distribution of data, frequency, and correlation between data. At this stage we only transform the data to be in the correct format as shown at Table 2.

Table 2. Cases in Jakarta.

Date	Active Case	Recovered	Death
21-Mar	227	17	23
22-Mar	256	22	29
23-Mar	301	23	29
...

After data cleansing and preprocessing processes are done, we move to the modelling stage. This stage is the main stage as the model is build using existing datasets. Epidemiological model used in this study is the SIRD model explained in chapter 2 and the results of this study shown in chapter 4. To simplify the analysis process, graphs or charts are made from the results of the SIRD model. With the SIRD model chart, it can be seen and further evaluated regarding the COVID-19 policy in Jakarta.

4. Result and discussion

According to available data, we found at present there is one wave of COVID-19 pandemic in Jakarta as shown in Fig.4²³. It began in March and escalating steadily until June 2020. Creating a positive linear line.

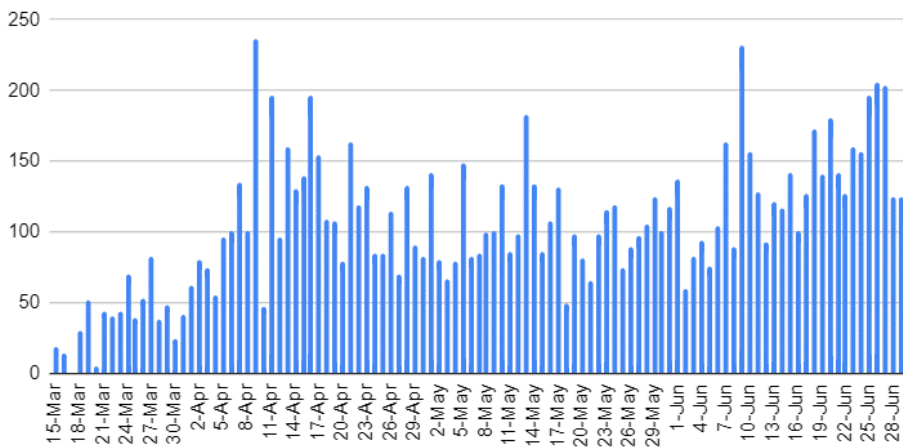


Fig. 4. Distribution of COVID-19 Cases in Jakarta

Using the data and parameters as detailed before in the SIRD model, the following graphs was produced [Fig. 5]. In Fig 5, Q equals to ξ in modified SIRD model equations. In terms of quarantine parameter, current or social distancing situation is identical to $Q=0.4$. This study calculated the MAE in cases with Q 0.1 is 0.185, Q 0.2 is 0.085, Q 0.3 is 0.036, and Q 0.4 is 0.013. The weaken the quarantine policy represented by lower quarantine parameter result in higher and faster peak number of the disease. It shows that in groups with social distancing have lower peak number than group without social distancing. It reflects the rationale of limiting social contact in-order to prevent the surge of infected individuals. The surge capacity of health facility is often limited and could result substandard options including space or hospital beds, health staff, health supplies, and health systems^{24,25}.

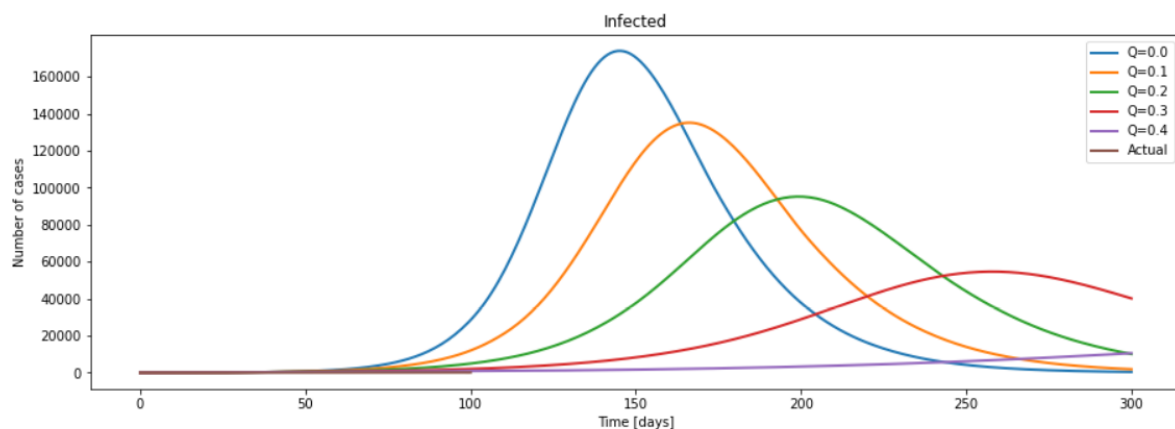


Fig. 5. Prediction of the Peak Number of COVID-19 in Jakarta by SIRD Model

As in Indonesia, substandard option measured in this study is hospital bed density. Compared to a global average of 30/10,000, Indonesia's hospital bed density is considered low with 6.3/10,000 bed to population ratio and further reduction result in even more challenging care under substandard options²⁶. Hence, a policy to limit social contact is best implemented in Indonesia, especially Jakarta as the highest COVID-19 cases area. However, the stricter the quarantine policy also result in longer disease duration. This may be needed to be taken into consideration of implementing social distancing duration.

The limitation of this prediction lies mainly in the assumptions used and the data required from public platforms. During this analysis, we could not be certain whether the number of cases declared each day was entirely calculated on exact same day and not a cumulative of specimens taken days prior to the announcement day. We also did not include active cases emerged during the analysis of this study. We as well did not consider whether the health care capacity will grow larger or remains the same. Nevertheless, this study result could give an idea of how the number of cases will be while implementing social distancing.

5. Conclusion

After the implementation of social distancing, it is considered the peak number of cases will be lower than without implementing social distancing. Limiting social contact among individuals would lessen the curve. It should also be noted that Indonesia still having issue with hospital bed density further adding the burden. We suggest that a strict containment strategy is needed in Jakarta.

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