THE OUTBREAK'S MODELING OF CORONAVIRUS (COVID-19) USING THE MODIFIED SEIR MODEL IN INDONESIA

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ABSTRACT

Coronavirus Disease 2019 (COVID-19) is an infectious disease caused by a new type of virus called SARS-CoV-2, and by the beginning of 2020 had spread throughout the world, including Indonesia. A high rate of spread of COVID-19 causes the number of patients that infected increase significantly. In this study, mathematical modeling was carried out to predict the number of COVID-19 patients and the duration of the COVID-19 pandemic in Indonesia. The model used is a modified SEIR model (Susceptible, Exposed, Infected, Recovered) with several assumptions such as a constant and homogeneous population, patients who have recovered can not be infected, and the spread only occurs from human to human. Besides, it is assumed that there are individuals who carry out quarantine and isolation. Modeling is done using the help of MATLAB R2015a. The modeling results show that the peak of the COVID-19 pandemic in Indonesia will occur in the middle of May 2020, and the number of infected patients will be about 15000 people. This amount can be reduced if the quarantine and self-isolation process is carried out optimally.

Keywords: COVID-19, corona-virus, matlab, SEIR model, modeling

INTRODUCTION

The coronavirus that first appeared in Wuhan, China, on 8 December 2019 turned into a pandemic outbreak that spread throughout the world, including Indonesia. The disease caused by a coronavirus (COVID-19) was first confirmed in Indonesia with two infected people on 2 March 2020. Over time, that number continued to climb significantly until, at the end of March 2020, as many as 1528 people were declared to have been infected by this pandemic [1].

Coronavirus can spread through physical contact by touching the face and through the air due to coughing and sneezing. Coronavirus can survive on the surfaces for days but can be destroyed in less than a minute by common disinfectants such as sodium hypochlorite, hydrogen peroxide, etc. [2]. The spreading of COVID-19 is difficult to detect because it can be transmitted from people without symptoms [3]. The rate of spread of COVID-19 for human-to-human due to physical contact range from 2.2 [4] to 2.9 [5]. That value means that one person can transmit the disease to two until three people in the vicinity. That values are higher than the SARS spread rate, which is 1.77. The spread of COVID-19 is frightening enough because, so far, there has not been found a vaccine to cure coronavirus patients. To reduce the rate of spread of this disease, the WHO recommends limiting contact with other people by doing physical distancing as far as 1.5 meters or more. Mechanisms of spread and transmission of COVID-19 is still being studied for prevention and mitigation purposes.

Several studies from various countries attempt mathematical modeling to understand the mechanism of the spread of COVID-19. Batista [6] using SIR model to predict the number of coronavirus pandemic cases and shows that as many as 85000 people will be infected. Huang Y [7] also used the SIR model and estimated that more than 1 million people would be infected with coronavirus in Japan, South Korea, Italy, and Iran. This model does not consider the incubation time of the virus, whereas coronaviruses, according to various studies, have an incubation period. The coronavirus incubation period varies from 2 - 10 days [8], five days [9], and 6.4 days [10]. The average coronavirus incubation period is seven days [11].

The SEIR model differs from the SIR model by addition virus incubation time. The SEIR model has been widely used to predict the spread of infectious diseases such as MERS, SARS, and HIV/ AIDS. Tang [11] and Shi [12] used a modified SEIR to modeling the spread of COVID-19 and was quite successful in predicting the number of COVID-19 cases in China.

In this study, a modified SEIR model [12] will be used by adjusting several parameters to predict the total number of COVID-19 cases and the duration of this pandemic in Indonesia.

METHOD

SEIR Model

The SEIR model divides a population into four categories, namely, S (Susceptible), E (Exposed), I (Infected), and R (Recovered). Susceptibles are healthy individuals but have a chance and vulnerable to be infected. Exposed are individuals who have had contact with an infected person but not yet consider infected. Infected are individuals who tested positive for

infection, and Recovered is individuals who are declared cured and are assumed to have immunity to the virus so that they cannot be infected again.

In this study, a modified SEIR model is used with the following assumptions:

1. Constant population numbers (an equal number of deaths balances the number of births)
2. Homogeneous population. Each individual has the same opportunity to make contact with other individuals.
3. The spread of the coronavirus only occurs between humans to humans.
4. Coronavirus has an incubation period of 7 days
5. Individuals affected by COVID-19 can recover
6. Individuals who have recovered cannot be infected again.
7. Some individuals carry out quarantine or self-isolation

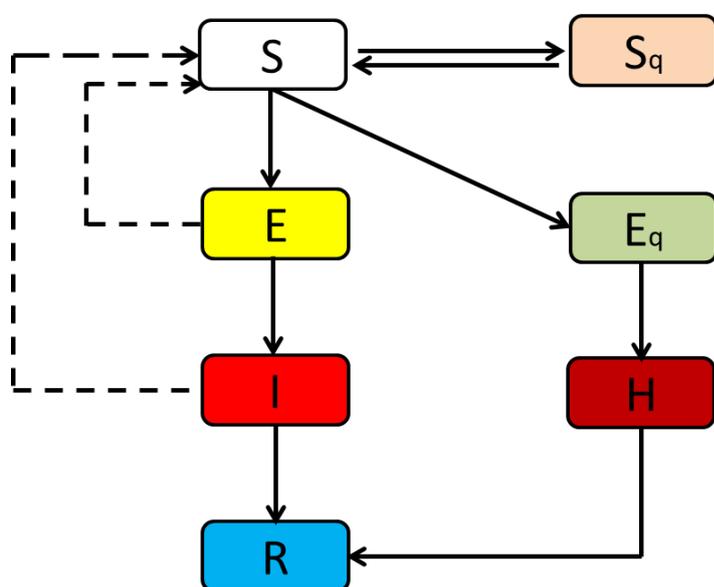The SEIR model scheme used in this study can be seen in the following figure:

FIGURE 1. Modified SEIR Model

where Sq, Eq, and H are isolated susceptible, isolated exposed, and isolated infected, respectively. So that S, E, and I refer to susceptible, exposed, and infected individuals who do not carry out quarantine or self-isolation. The dash-line shows that exposed and infected individuals can infect susceptible individuals who do not carry out quarantine or self-isolation.

The equation used in this SEIR model is the differential equation as follows [12]:

$$\frac{dS}{dt} = -[c\beta + cq(1-\beta)]S(I + \theta E) + \lambda S_q \qquad (1)$$

$$\frac{dE}{dt} = c\beta(1-q)S(I + \theta E) - \sigma E \qquad (2)$$

$$\frac{dI}{dt} = \sigma E - (\delta_I + \alpha + \gamma_I)I \qquad (3)$$

$$\frac{dS_q}{dt} = cq(1-\beta)]S(I+\theta E) - \lambda S_q \qquad (4)$$

$$\frac{dE_q}{dt} = c\beta q S(I+\theta E) - \delta_q E_q \qquad (5)$$

$$\frac{dH}{dt} = \delta_I I + \delta_q E_q - (\alpha + \gamma_H)H \qquad (6)$$

$$\frac{dR}{dt} = \gamma_I I + \gamma_H H \qquad (7)$$

The following is an explanation of the parameters used in the above equation:

TABLE 1. Definition of Modeling Parameters

Parameter	Description
c	Contact rate
β	Probability of transmission
θ	The ration of transmission of exposed to be infected
λ	1/quarantine duration
q	Quarantine ratio
σ	1/incubation time
α	Disease-induced death rate
δ_1	Quarantine rate of the infected
γ_1	The recovery rate of the infected
δ_q	Transformation rate from E to H
γ_H	Recovery rate of H

Parameter Estimation

According to BPS (Central Bureau of Statistics of Indonesia), the population of Indonesia in 2020 is projected to be 271,066,400 people, so the value of S is taken $S = 271 \times 10^6$ [13]. COVID-19 cases were first confirmed in Indonesia on 02 March 2020, when at that time there were two people declared infected, 0 recovered, and 0 death. The incubation time used in this modeling is the average incubation time for seven days. The quarantine time used in this modeling is 14 days. The other parameter values are the estimation results through fitting

models with data on infected patients during March 2020 from the Ministry of Health of the Republic of Indonesia.

TABLE 2. Initial Value

Variable	Value	Variable	Value
s	271×10^6	S_q	100
E	45	H	$I + E_q$
I	2	R	0
E_q	0	-	-

TABLE 3. Parameter Value for Modeling

Variable	Value	Variable	Value
c	3.45	α	2×10^{-3}
β	3×10^{-10}	δ_1	0.18
θ	0.59	γ_1	0.009
λ	1/14	δ_q	0.10
q	1.4×10^{-6}	γ_H	0.125
σ	1/7		

RESULT AND DISCUSSION

After getting the initial value using data from various official sources and determining the value of the modeling parameters through curve fitting with the data of the Ministry of Health of the Republic of Indonesia, then the computation is performed using the Matlab 2015 program. The differential equation in this SEIR model is solved using the Euler Numerical Method, with an integration time step of 0.01 (in units of days). The Matlab code, which is used as a reference in this modeling, originates from Shi [10] after adjusting some parameters according to the conditions in Indonesia. The results obtained are as follows:
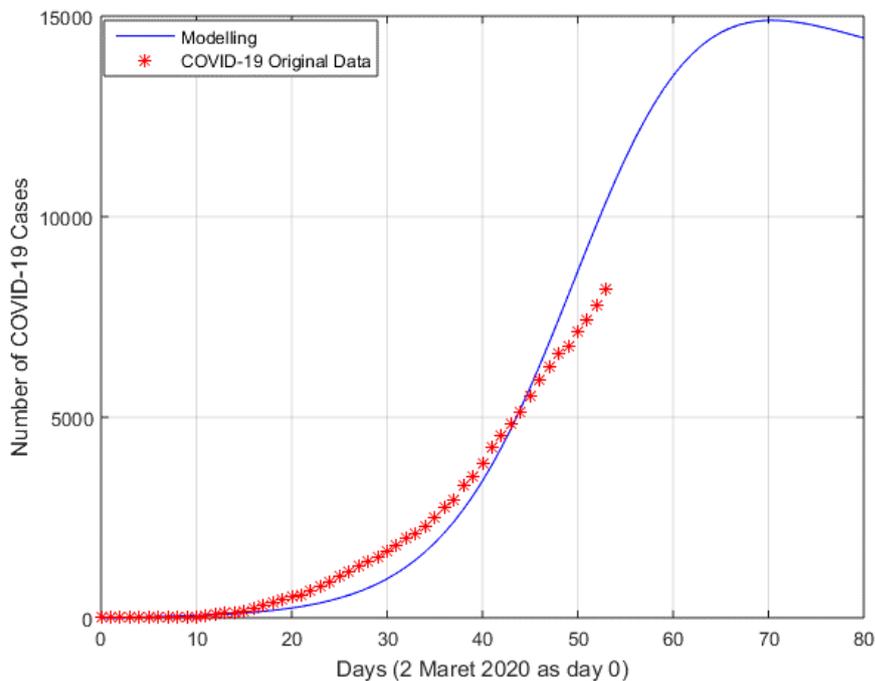
FIGURE 2. Prediction number of COVID-19 cases in Indonesia.

FIGURE 2 shows that the modeling estimate is quite close to the original data from the Indonesian Ministry of Health from March until 24 April 2020. From the modeling results in FIGURE 2 show that the peak of the COVID-19 pandemic in Indonesia will occur in the middle of May 2020, about 70 days after the first case appeared on 02 March 2020. Furthermore, the cumulative number of infected people until the peak of the pandemic will reach 15000 cases, and after, the number will decrease. After that, the value of q (quarantine ratio) is varied to see the effects of the quarantine and self-isolation on the number of patients infected with COVID-19.
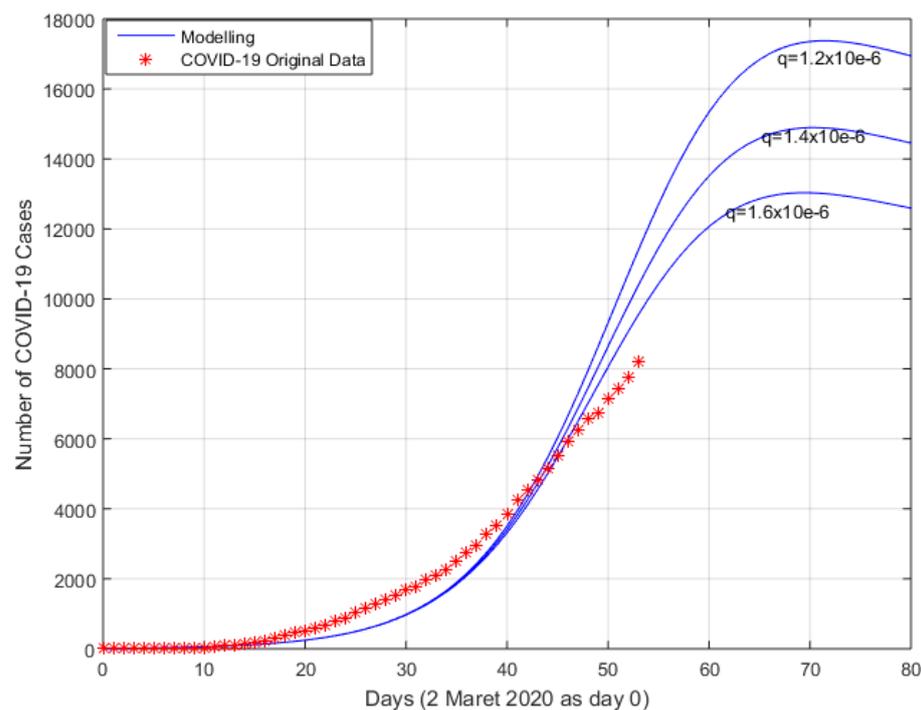
FIGURE 3. Effect of variation value of q on number COVID-19 cases.

The value of obtaining from the ratio between individuals doing quarantine and the total number of individuals. The greater value of q means that more people do quarantine or self-isolation. When the value of q was reduced, there is an increase in the number of infected patients about 2500 people, make the total number of infected individuals become 17500 people. Whereas when the value of q was increased, the number of infected individuals decreased about 2000 people, make the total number of infected individuals become 13000 people. It shows that there is a decrease in the number of patients infected with the added value of q (ratio quarantine) and vice versa. Besides, when the quarantine ratio is increased, there is a shift in the peak of the pandemic to the left, indicating a shorter pandemic duration.

CONCLUSION

Based on the modeling that has been done, the number of COVID-19 patients in Indonesia will reach 15000 cases or more if quarantine and isolation are not carried out to break the chain of the spread of this pandemic. The duration of the COVID-19 pandemic in Indonesia will be about 2 - 3 months and is predicted to reach a peak in the middle of May 2020. The effective prevention to reduce the rate of spread of COVID-19 is quarantine and isolate by staying at home. If you have to leave the house, wearing a mask and practice physical distancing.

REFERENCES

[1] Kemenkes, www.covid19.kemenkes.go.id, Accessed in March and April 2020.

[2] G. Kampf *et al.,* "Persistence of coronaviruses on inanimate surfaces and its inactivation with biocidal agents," Journal of Hospital Infection, 2020.

[3] C. Rothe *et al.*, "Transmission of 2019-nCoV infection from an asymptomatic contact in Germany," New England Journal of Medicine, 2020, vol. 382, no. 10.

[4] Q. Li *et al.*, "Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia," New England Journal of Medicine, 2020.

[5] T. Liu *et al.*, "Transmission dynamics of 2019 novel coronavirus (2019-nCoV)", https://ssrn.com/abstract=3526307, 2020.

[6] M. Batista, "Estimation of the final size of the coronavirus epidemic by the logistic model," medRxiv, 2020.

[7] Y. Huang *et al.*, "Epidemic situation and forecasting of COVID-19 in and outside China," [Submitted], Bull World Health Organ. E-pub: 16 March, 2020.

[8] WHO, Novel Coronavirus (2019-nCoV) Situation Report-7 - World Health Organization (WHO), Jan. 27, 2020.

[9] S. A. Lauer *et al.*, "The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: estimation and application," Annals of internal medicine, 2020.

[10] J. A. Backer *et al.*, "Incubation period of 2019 novel coronavirus (2019-nCoV) infections among travellers from Wuhan, China, 20–28 January 2020," Eurosurveillance, 2020.

[11] Z. Tang, L. Xianbin and H. Li, "Prediction of New Coronavirus Infection Based on a Modified SEIR Model," medRxiv, 2020.

[12] P. Shi, C. Shengli and F. Peihua, "SEIR Transmission dynamics model of 2019 nCoV coronavirus with considering the weak infectious ability and changes in latency duration," medRxiv, 2020.

[13] BPS, "Proyeksi Penduduk Indonesia 2010–2035/BPS-Statistics Indonesia, Population Census and Indonesia Population Projection 2010–2035," 2010.