# A Simulation Approach to Predict the Transmission of COVID-19in Bangladesh

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# A Simulation Approach to Predict the Transmission of COVID-19 in Bangladesh


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## Abstract

The coronavirus disease (COVID-19) was first identified in Wuhan, China, in December 2019. Since then, it has been affecting 212 countries and territories around the world. First detected on March 8, 2020, as of April 30, there are 7,667 confirmed COVID-19 cases in Bangladesh, including 130 patients who have recovered and 168 related deaths. We identify the facts of COVID-19 and government's preventive actions taken in Bangladesh and examine the transmission parameters, infection rate, fatality rate, and recovered rate using the publicly available data until April 30. We estimated the transmission parameters using the susceptible-exposed-infected-cured-dead (SEICD) model and linear regression. Based on these parameters, we then predicted the growth of the infection, cure, and deaths and compared them with reported data. The number of patients infected as of April 30 in Bangladesh closely follows an exponential trend. If this trend continues for fewer weeks, there will be around 50,000 infected patients if necessary steps are not seriously taken by the government. There is now breakneck concern regarding the capacity to respond to needs of infected patients effectively and to prevent this pandemic from further spreading in Bangladesh, one of the densest countries in the world. Health authorities might assimilate this analysis into their disease prevention and control decision-making process.



**Keywords:** coronavirus, infected disease, infection rate, prediction, simulation


## Introduction

COVID-19 (previously known as the novel coronavirus- *2019-nCoV*) is the third zoonotic human virus of the century in the world *(1)*. The human being faced the similar type viruses, severe acute respiratory syndrome coronavirus (SARS-CoV) that spread to 37 countries in 2002 and Middle East respiratory syndrome coronavirus (MERS-CoV) in 2012 that spread to 27 countries. Similar to previous infections, COVID-19 exhibited symptoms of viral pneumonia, including fever, difficulty breathing, and bilateral lung infiltration in the most severe cases *(2,3)*. Since its emergence in Wuhan of China, within 2019, it has spread to 212 countries and territories in the world. According to the world health organization *(4)*, the world has had 2,83,3031 confirmed cases as of April 30 and 1,97,352 deaths. Cases are rising daily in Asia, the Americas, and Europe *(4, 5)*.

Bangladesh-one of the densest country in the world -has been affected by this pandemic since the beginning of March 2020. The first case in Bangladesh was confirmed on March 8 and followed by the detection of one or two cases on average in the subsequent days. However, the number of confirmed cases of COVID-19 infection started to increase rapidly from April 5 (Figure 1). As of April 30, there are 7,667 confirmed COVID-19 cases in Bangladesh, including 130 patients who have recovered and 168 related deaths *(6)*. To date, 95% (61/64) of districts and cities with a total population of 16M people are under lockdown. The highest attack rate (326/1M) was observed in Dhaka city (IEDCR).

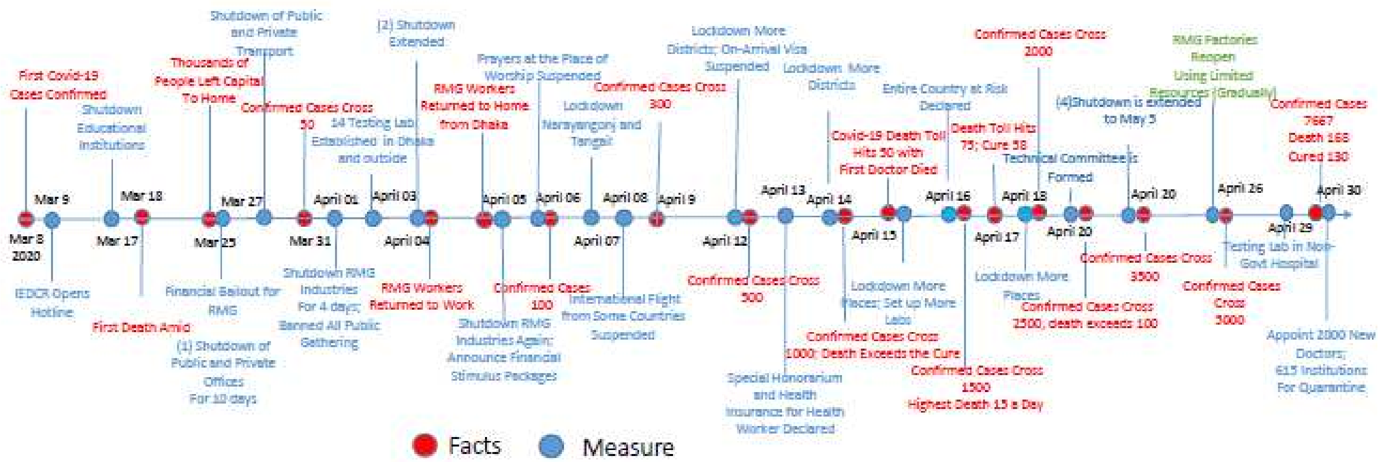


*Figure 1 Timeline of Facts of COVID-19 and Control Measures Implemented in Bangladesh*

The confirmed and death cases are rising rapidly as of the date, and a serious outbreak in Bangladesh is a realistic outcome. The government has been taking lots of actions to prevent this world pandemic (Figure 1). Out of 64 districts, as of April 30, 49 are complete lockdown, and 19 are in partial lockdown. Other controls of measures implemented in Bangladesh from March 8 to April 30 are shown in the developed timeline (Figure 1). After reporting the first confirmed COVID-19 case on March 8, it reached 100 cases on April 06 and exceeded 300 cases within the next three days. Within a week, the confirmed cases become three times.

There are many mathematical models in the literature for estimating the pandemic parameters. Toshikazu Kuniya *(7)* used susceptible-exposed-infected-recovered (SEIR) model to predict the epidemic peak of COVID-19 in Japan using the date from January 15 to February 29. The conceptual model for the COVID-19 outbreak in Wuhan city with consideration of individual behaviors and government's actions has been proposed in *(8)*. Another susceptible-infected-recovered-dead (SIRD) model is used to forecast the outbreak in Wuhan city *(9)*. Researchers estimated the transmission parameters of COVID-19 in South Korea *(10)*, in Japan *(7)* in Italy *(11)* in China *(12,13)*. Lauer and his co-authors estimate using Wuhan's data that under conservative assumptions, COVID-19 cases will show symptoms after 14 days of active monitoring and quarantine. Junyu He. and his colleages compared the transmission trends of Chine with South Korea, Italy and Iran using an SEIR model *(14)* . To the best of author's knowledge, there is no published work predicting the COVID-19 outbreak in Bangladesh, one of the densest countries in the world.

We estimated the transmission parameters through simulation using the susceptible-exposed-infected – cured-dead (SEICD) model and the publicly available data from March 8 to April 30, 2020. The model is explained in the model development section. The reported and simulation results confirm that the growth of infection is in exponential trends. Again using the estimated parameters, we predicted the transmission in Bangladesh until May 31. Detail comparative results are shown by Figures in the result and discussion section.

## Methodology

### *Data Collection*

Institute of Epidemiology Disease Control and Research (IEDCR), Bangladesh, World Health Organization (WHO) are the main sources of data used in this study. We collected data from those sources and used them in our model after matching with each other. The data collection period is from March 8 to April 30, 2020. Data on confirmed cases (infected), quarantine cases, cured, and death cases are collected.

### *Model Development*

According to our model, we divide the population of Bangladesh into five compartments, susceptible, exposed, infected, cured, and death. The following modified model, SEICD is used to simulate the COVID-19 transmission in Bangladesh.

$$\frac{dS(t)}{dt} = -\frac{1}{N}[\beta_1(t)I(t)S(t)] - \frac{1}{N}[\beta_2(t)E(t)S(t)] \tag{1}$$

$$\frac{dE(t)}{dt} = \frac{1}{N}[\beta_1(t)I(t)S(t)] + \frac{1}{N}[\beta_2(t)E(t)S(t)] - \alpha E(t) \tag{2}$$

$$\frac{dI(t)}{dt} = \alpha E(t) - \gamma(t)I(t) - \lambda(t)I(t) \tag{3}$$

$$\frac{dC(t)}{dt} = \gamma(t)I(t) \tag{4}$$

$$\frac{dD(t)}{dt} = \lambda(t)I(t). \tag{5}$$

Here $N$ is the total population of the region of interest, $S(t), E(t), I(t), C(t)$ and $D(t)$ represent, respectively, the number of susceptible, exposed, infected, cured, and dead individuals at time $t$. The exposed population may or may not be infected in the future. The constant $\alpha$ is the probability of an exposed individual to be affected while the $\alpha^{-1}$ is the incubation period (Junyu et. al. 2020). Time dependent parameters $\beta_1$ and $\beta_2$ denote the transmission rate, where $\beta_1$ represents the primary transmission by the infected individual, and $\beta_2$ represents the secondary transmission rate through the exposed individuals. The other two parameters $\gamma$ and $\lambda$ donate the COVID-19 cured and death rate, respectively. The necessary assumptions are made in constructing the SEICD Model is as follows

- Birth and natural death (excluding death due to COVID19) during the epidemic are not considered. Hence at any time $t$, $N=S(t)+E(t)+I(t)+C(t)+D(t)$
- The probability of being susceptible to an infected or exposed individual after recovery is considered as zero.
- The external influence, i.e., weather, herd immunity, vaccination on the outbreak, is not considered in this paper.
- During the forecast, mobility, behavior and social distancing is considered to evolve in the same manner as it from March 08 to April 30-2020.

### *Parameter Estimation*

The parameter estimation is the most crucial part of SEICD model. Optimum estimation of the parameters enables the model to describe the epidemic spread and severity accurately. To estimate the parameters, we use publicly available reported data from March 8 to April 30, 2020. The reported values of $I(t), C(t)$ and $D(t)$ are inserted into the model to determine the $\beta_1$, $\gamma$, and $\lambda$. Once one individual reveals the COVID-19 symptoms soon after he/she is isolated and hospitalized. However, asymptomatic patients are more dangerous as they continue to spread the diseases until the symptom reveals. Hence, the secondary transmission rate is considered much higher than the primary transmission rate, and this study considers secondary transmission is five times the primary transmission rate, thus $\beta_2 = 5\beta_1$. The transmission rate $\beta_1(t)$ depends on government actions such as lockdown, shutdown, social distances, immigration etc., which changes considerably during the pandemic. Considering the $\beta_1$ and $\beta_2$ as constant, thus, questions the accuracy of the model. That's why we use the robust linear regression method to determine the dynamic $\beta_1(t)$ [Jnnuyu et. al]. Other parameters $\gamma$ and $\lambda$ are considered constant as factors they depend on such as the immunity of the population, health facilities, and management of the country, almost remain constant during the epidemic. The estimated $\beta_1(t)$, $\beta_2(t)$ and the SEICD model then are used to determine the best-fitted value for $\gamma$ and $\lambda$ by the following optimization technique.

Let $C_s(t)$and $D_s(t)$ are the number of cured and death cases at time $t$ respectively obtained from the SEICD model.

**Step 1:** Estimate the $\beta_1(t)$.

**Step 2:** Using reported data calculate $\gamma(t)$ and $\lambda(t)$ and estimated $\gamma$ and $\lambda$ with 95% confidence interval by coarse Gaussian regression.

**Step 3:** Use $\gamma_{min}$ to $\gamma_{max}$ from step 2 and find cure rate $\gamma$ for minimum $R(\gamma) = \sum_{t=1}^{54}[C(t) - C_s(t)]^{\,2}$.

**Step 4:** Use $\lambda_{min}$ to $\lambda_{max}$ from step 2 and find death rate $\lambda$ for minimum $R(\gamma) = \sum_{t=1}^{54}[D(t) - D_s(t)]^{\,2}$.

***Numerical Technique***

Once the transmission parameters are estimated, they are used to calculate the infection, cure, and death rate through an iteration technique explained below.

Considering $\dot{X}(t) = \frac{dX(t)}{dt}$ Equation (1-5) can be rewritten in a matrix form as follows

$$\begin{bmatrix} \dot{S} \\ \dot{E} \\ \dot{I} \\ \dot{C} \\ \dot{D} \end{bmatrix} = \begin{bmatrix} -\frac{1}{N}I(t)S(t) & -\frac{1}{N}E(t)S(t) & 0 & 0 & 0 \\ \frac{1}{N}I(t)S(t) & \frac{1}{N}E(t)S(t) & -E(t) & 0 & 0 \\ 0 & 0 & E(t) & -I(t) & -I(t) \\ 0 & 0 & 0 & I(t) & 0 \\ 0 & 0 & 0 & 0 & I(t) \end{bmatrix} \begin{bmatrix} \beta_1(t) \\ \beta_2(t \\ \alpha \\ \gamma \\ \lambda \end{bmatrix}, \tag{6}$$

which can be further written in a simple form

$$\dot{X}(t) = A(t) \times \theta(\mathrm{t}) \tag{7}$$

where, $\dot{X} = [\dot{S} \;\; \dot{E} \;\; \dot{I} \;\; \dot{C} \;\; \dot{D}]^T$, $\theta = [\beta_1(t) \;\; \beta_2(t) \;\; \alpha \;\; \gamma \;\; \lambda]^T$ .

Discretizing the time variable as $t = n\,\Delta t$ we derived the following form of $\dot{X}(t)$ using Euler's Forward Difference Scheme.

$$X(t+1) = \Delta t\dot{X} + X(t) \tag{8}$$

where, $X(t) = [S(t)\ E(t)\ I(t)\ C(t)\ D(t)]^T$ and $\Delta t$ is the time step, and n is a natural number. Combining Equation (7) and Equation (8) we used

$$X(t+1) = \Delta t\,[A(t) \times \theta(t)] + X(t) \tag{9}$$

The values of infection, cure, and death rate were calculated using the equation (9) through number iterations.

## Results and Discussions

*Estimated Parameters*

The parameters used in the SEICD model are presented in Table-1. The $\beta_1$ is dynamic and is a function of $t$. Constant $\gamma$ and $\lambda$ are estimated using the reported data and the model. The pandemic started in Bangladesh with three infected, no cured, and no death individual. The initially exposed people is assumed as 10 using the information of the reported number of individual in contact with the initial infected individuals. Table 1 shows the different parameters used in the SEICD model.

*Growth of Infection*

We found that the available data for the number of patients who are actively infected fit into an exponential model, as reported in Figure-2. Similar behavior we found for the cure and death cases as shown in Figure 3 and Figure 4.

*Prediction of Transmission*

Using the derived values of the parameters $\beta_1$, $\gamma$ and $\lambda$, we again predicted the transmission potentials through simulations until the end of May. The results of the simulations with the reported data are given in Figure 4, 5, and 6. Solid lines depicted the simulation using SEICD model, and dashed lines illustrate the corresponding lower and upper bounds as computed at the limits of the 95% confidence intervals of $\beta_1$. The forecasted scenario of the outbreak is shown in Figure 4 to 6, is characterized by high uncertainty. In particular, simulation result in an expected number of around 80,000 infected cases but with a high variation: the lower bound is at about 48,000 infected cases while the upper bound is at 140,000 cases. Similarly, for the recovered population, the simulation results in an expected number of 5,000, while the lower and upper bounds are at 2,000 and 6 ,000, respectively. Finally, regarding the deaths, simulations result in an average number of 4,400, with lower and upper bounds, 2,800 and 7,000, respectively. The susceptible, exposed, infected, cured, and death trends are presented in Figure-8. Susceptible individuals are decreasing while exposed and infected individuals are increasing.

*Table 1* The values of parameters used in the SEICD model

| Parameters | Description | Value | Reference/Method |
|---|---|---|---|
| N | Total population of the country | $1.6\times10^8$ | |
| S(0) | Initial Susceptible | N-13 | |
| I(0) | Initial Infected | 3 | IEDCR |
| E(0) | Initial Exposed | 10 | IEDCR |
| C(0) | Initial Cured | 0 | IEDCR |
| D(0) | Initial Death | 0 | IEDCR |
| $\beta_1$ | Primary Transmission | Dynamic | Determined |
| $\beta_2$ | Secondary Transmission | $5\,\beta_1$ | Jnnuyu et. al |
| $\alpha$ | Infection rate from exposed | 1/7 | Jnnuyu et. al |
| $\gamma$ | Cure Rate | 0.0035 | Estimated |
| $\lambda$ | Death Rate | 0.004 | Estimated |

We present the above predictions to prepare the people—those who bear the greatest responsibility for national health systems and the government, as well as local health authorities—for what is predicted to happen in the days and weeks to come. They can then implement measures regarding staff resources and hospital beds to meet the challenges of this difficult time. Official numbers of infected people during the COVID-19 virus outbreak in Bangladesh are indicative of the spread of the infection, and of the challenges that will be posed to Bangladeshi hospitals and, in particular, intensive care facilities in the rural area. The present outcome suggests that the government should take careful action to maintain social distances instead of relaxing it.

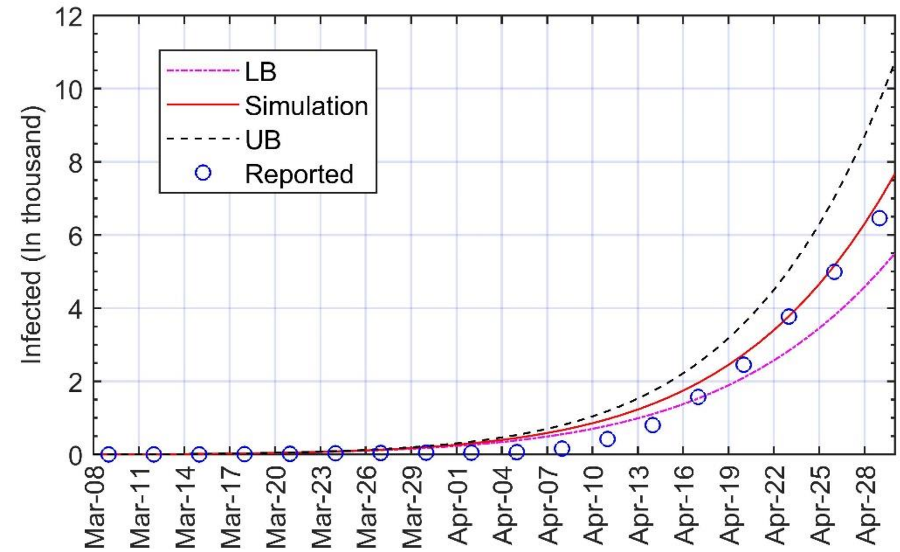


Figure 2 Cumulative number of infected until April 30
(circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

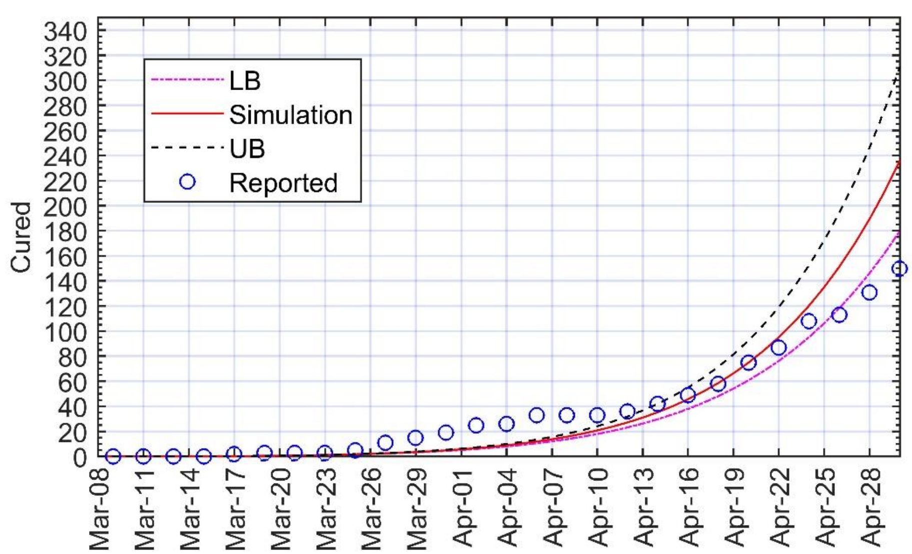


Figure 3 Cumulative number of cured until April 30 (simulated by SEICD and reported)
(circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

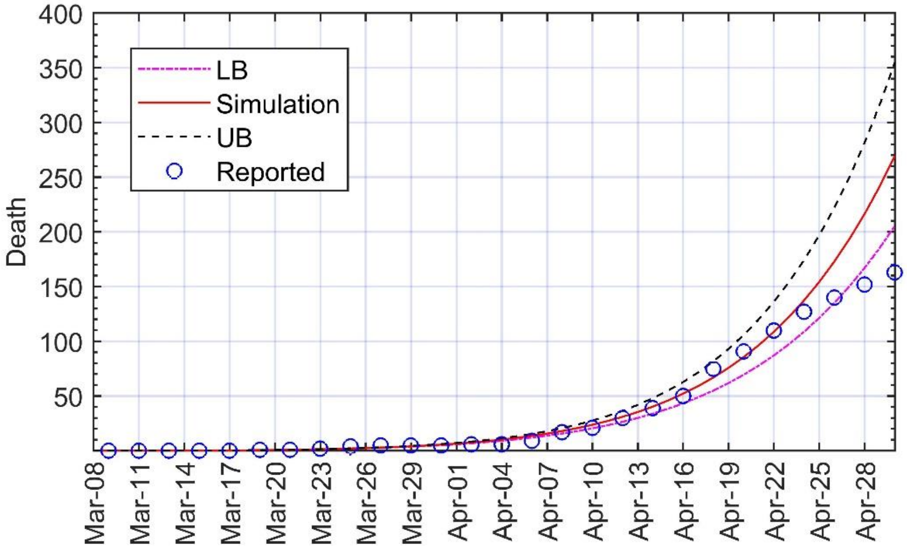


Figure 4 Cumulative number of death until April 30 (simulated by SEICD and reported)
(circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

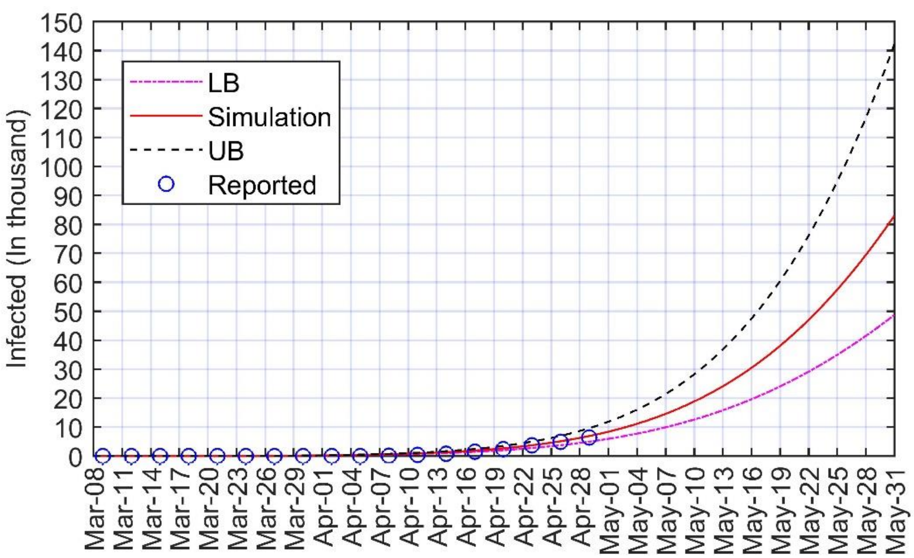


Figure 5 Predicted cumulative number of infected until May 31 (simulated and reported)
(circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

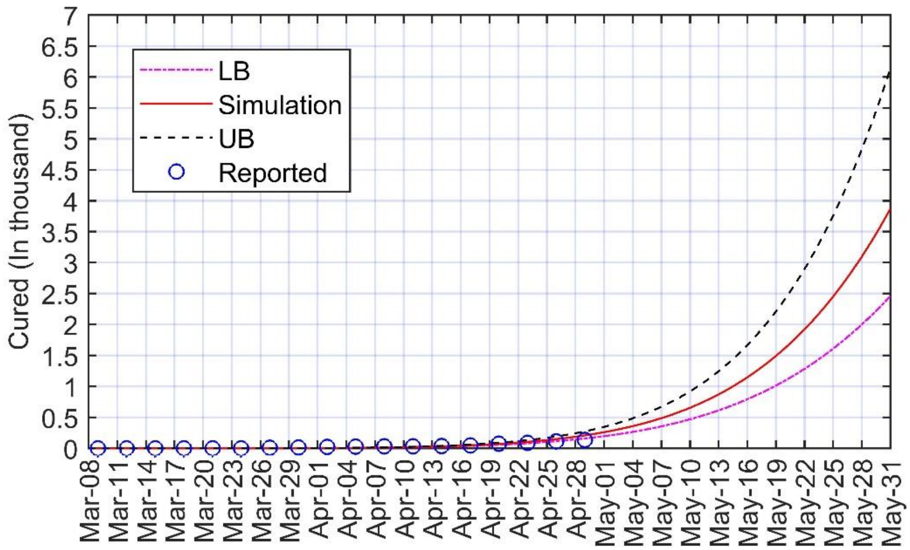


Figure 6 Predicted cumulative number of cured until May 31 (Simulated and Reported)
(circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

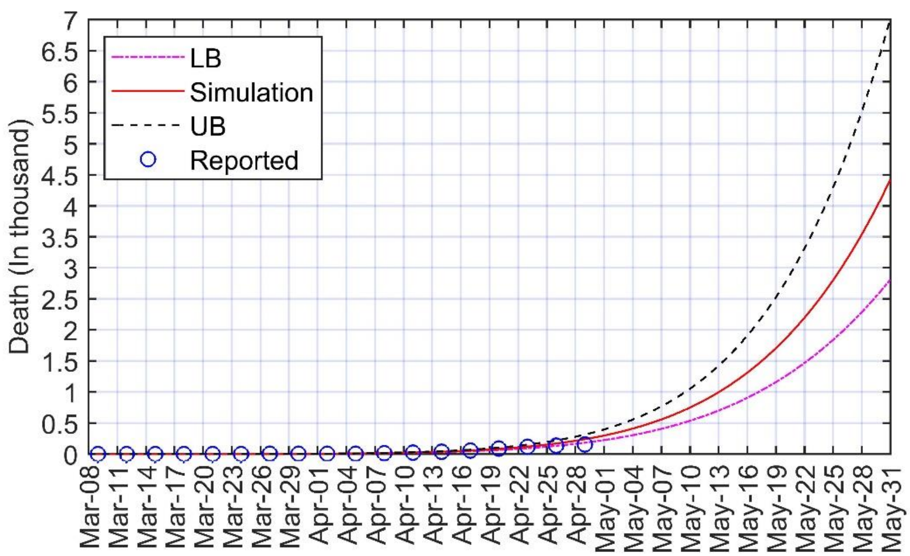


*Figure 7 Predicted cumulative death until May 31 (simulated and reported)*
(circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

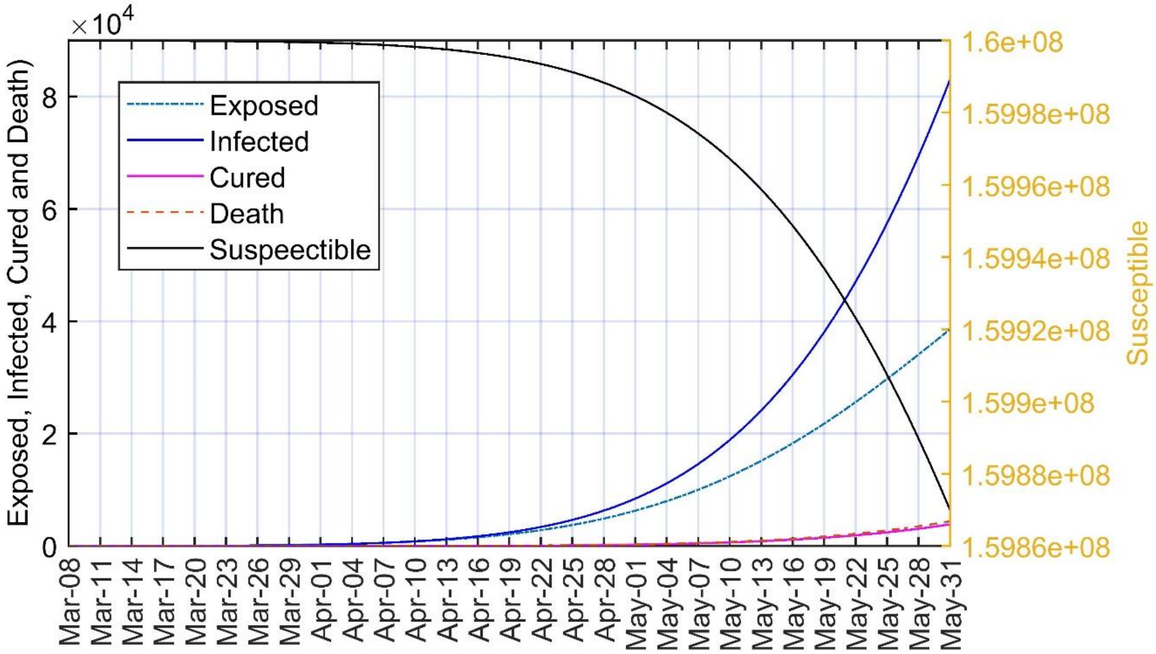


Figure 8 Prediction curve of Susceptible, exposed, infected, cured and death

## Conclusion

In this study, we focused on the transmission potentials of COVID-19 in Bangladesh. We quantitatively described the current transmission conditions in Bangladesh through a simulation approach. Official numbers of infected people during the COVID-19 virus outbreak in Bangladesh are indicative of the spread of the infection. The outcome of this study suggests rethinking the reopening of shopping malls, industries, institutions etc. and maintain the social distances strictly a few more weeks to prevent the spread of infection further. The proposed approach has the potential to monitor disease transmission rates and predict disease case numbers in future situations.

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# Figures

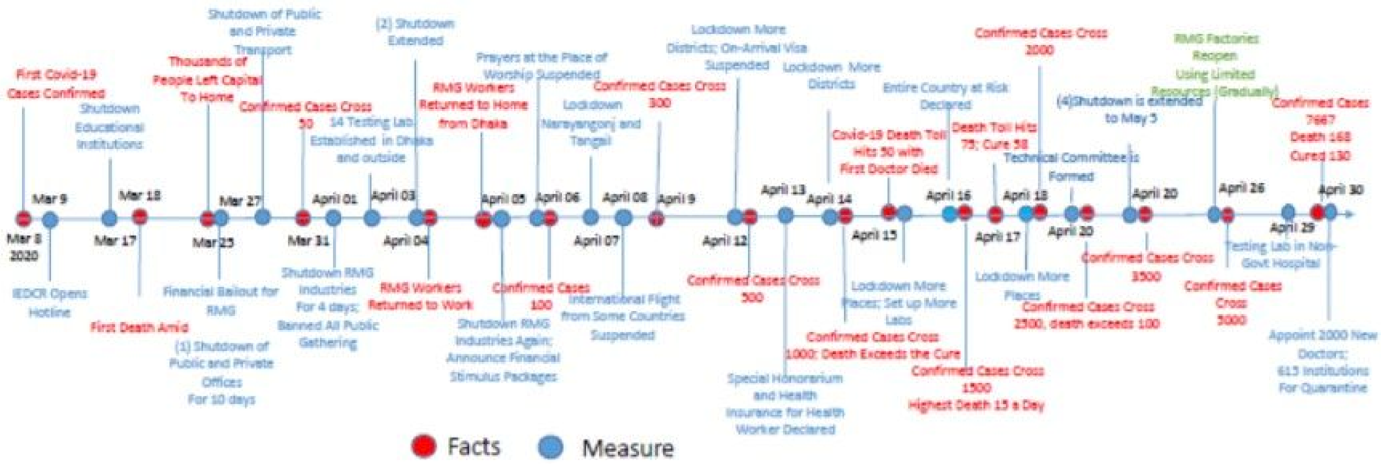


**Figure 1**

Timeline of Facts of COVID-19 and Control Measures Implemented in Bangladesh

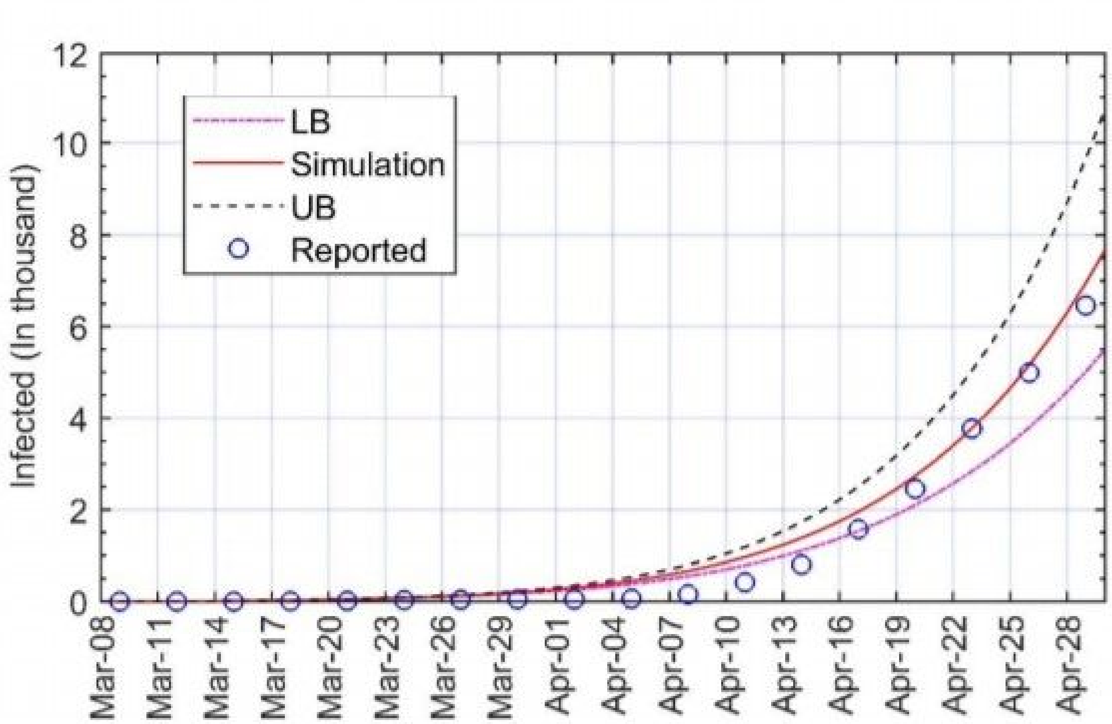


**Figure 2**

Cumulative number of infected until April 30 (circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

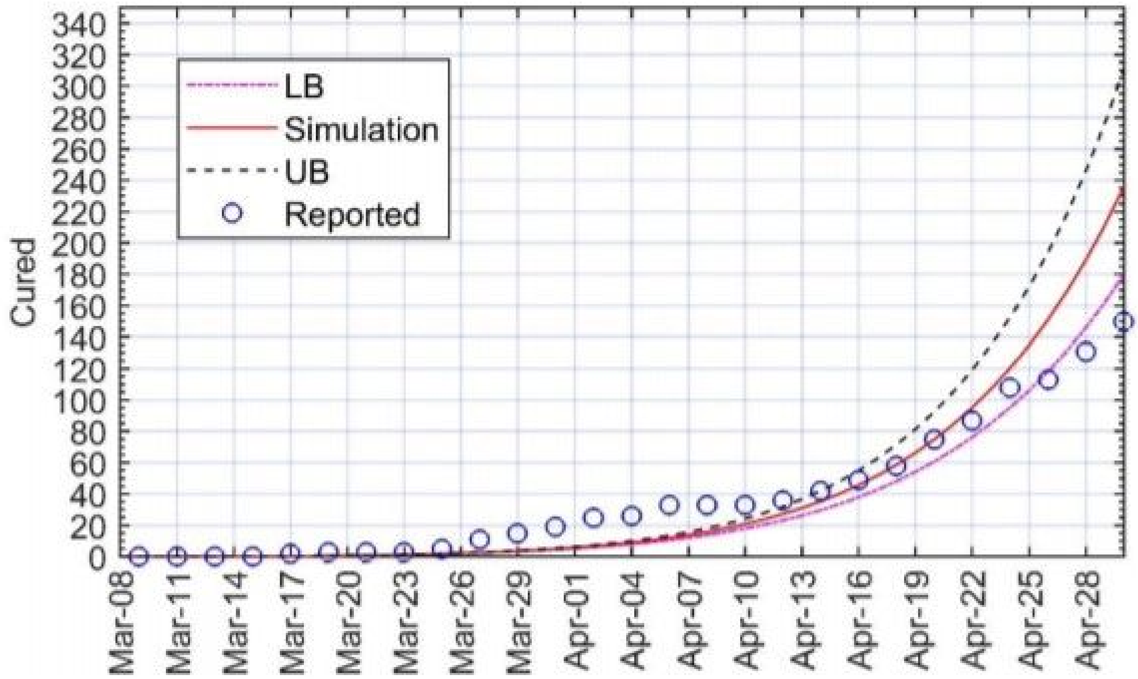


**Figure 3**

Cumulative number of cured until April 30 (simulated by SEICD and reported) (circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

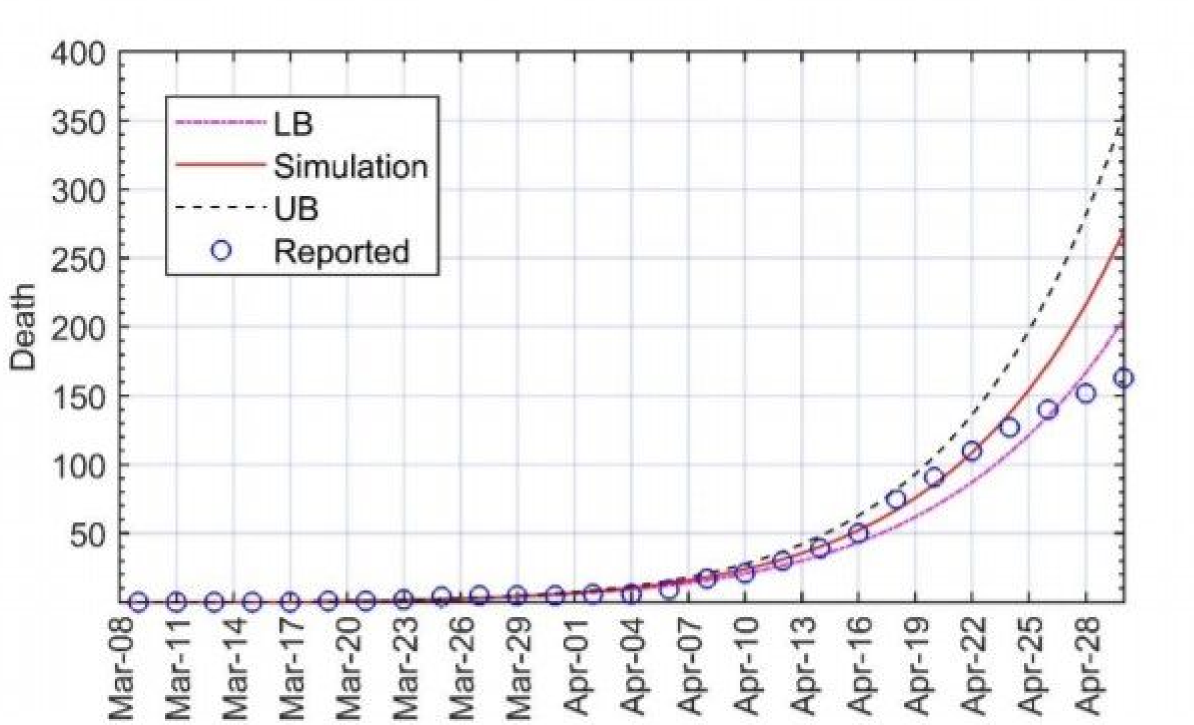


**Figure 4**

Cumulative number of death until April 30 (simulated by SEICD and reported) (circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

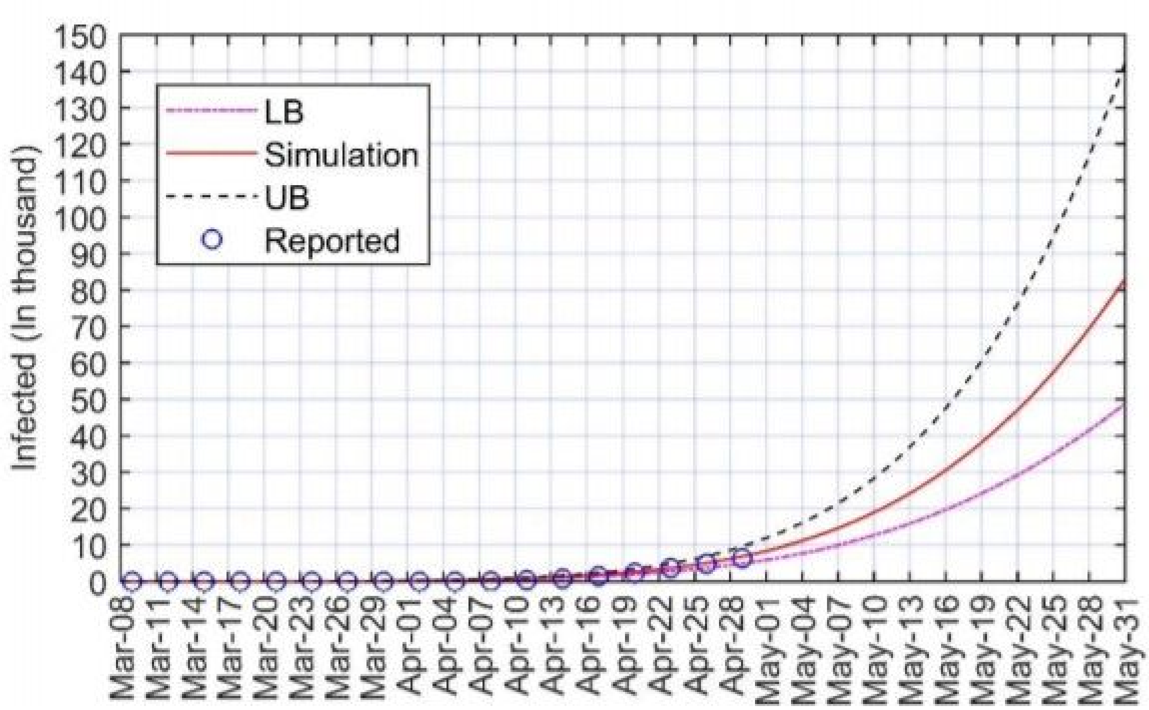


**Figure 5**

Predicted cumulative number of infected until May 31 (simulated and reported) (circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

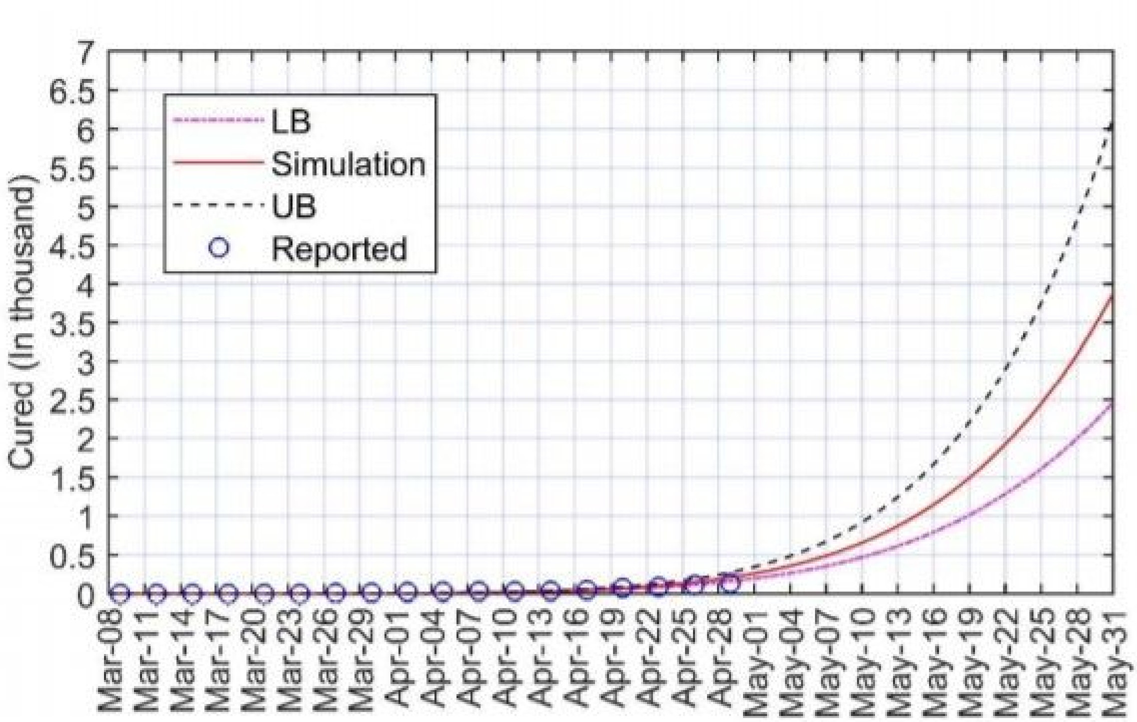


**Figure 6**

Predicted cumulative number of cured until May 31 (Simulated and Reported) (circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

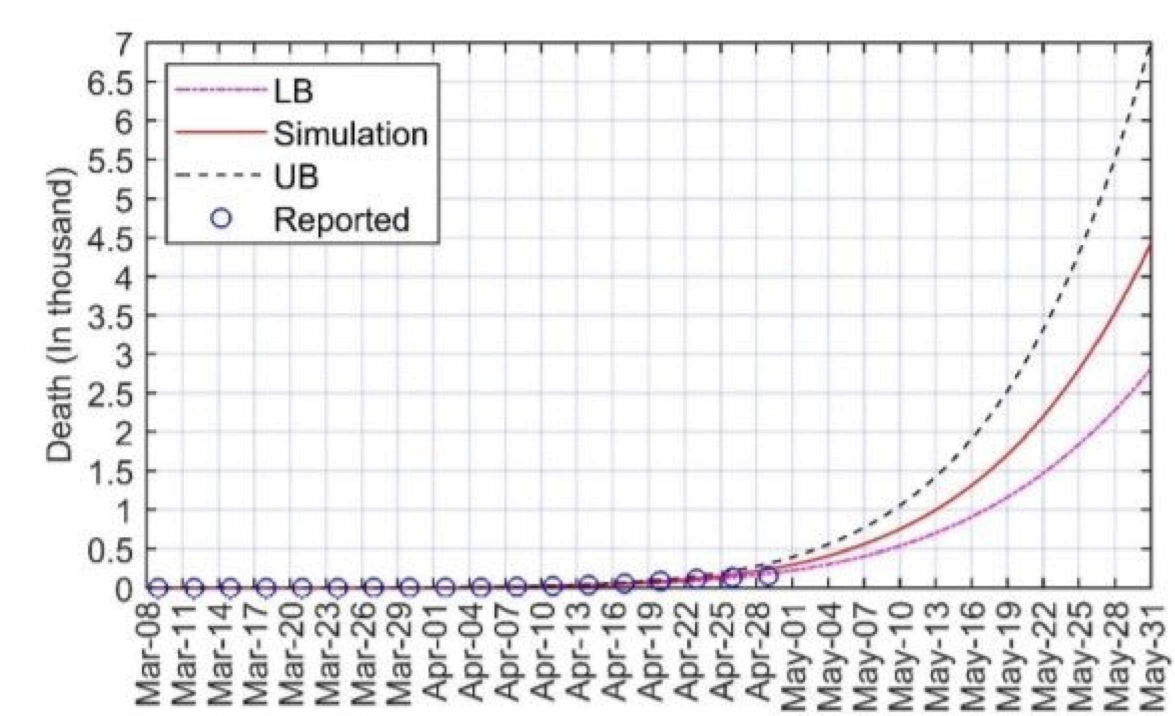


**Figure 7**

Predicted cumulative death until May 31 (simulated and reported) (circle: reported data, solid line: simulated data using SEICD, dotted lines: upper bounds and lower bounds)

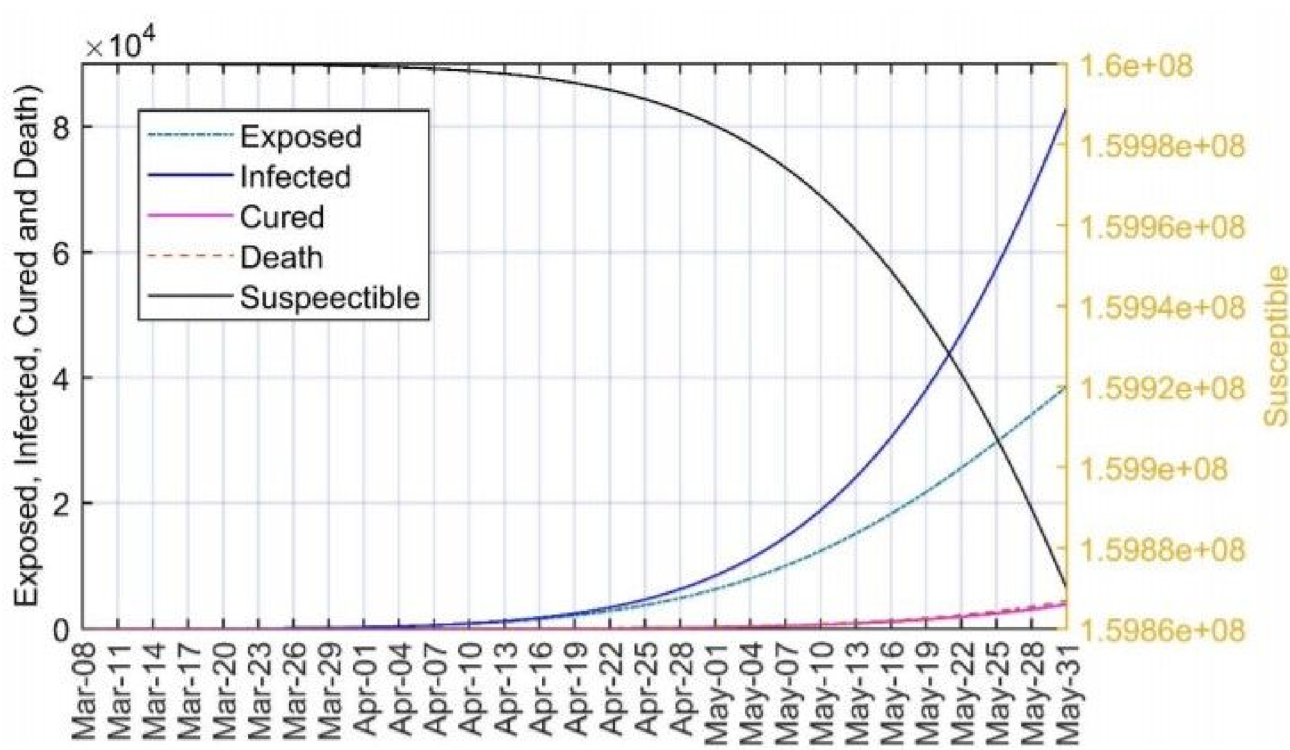


**Figure 8**

Prediction curve of Susceptible, exposed, infected, cured and death