

Simulation of COVID-19 Trend in Selangor via SIR Model of Infectious Disease

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HIGHLIGHTS

- Malaysian government took proactive measures and efficient strategies after recognizing the alarming trend of COVID-19.
- The population of infected individuals in Selangor is estimated to predict the percentage of infection.
- The SIR model aims to forecast the number of individuals susceptible to infection, actively infected, or recovered from the disease.
- Basic reproduction provides an indication of concerning an outbreak.

ABSTRACT

Coronavirus Disease 2019 (COVID-19) was initially reported in December 2019 in Wuhan City, China, as a result of a respiratory pandemic. Since then, the infection has spread rapidly and uncontrollably around the globe, prompting the World Health Organization (WHO) to declare it a pandemic. The study's overall objective is to imitate the COVID-19 infectious trend in Selangor. The SIR model is used to forecast infection and the course of COVID-19 diffusion and estimate the fraction of the population infected. As a result, the Susceptible, Infectious, and Recovered (SIR) model was used to accomplish the study's aims. From March 23, 2020, to June 30, 2020, 100 days of COVID-19 data were extracted from a database on the Malaysian Ministry of Health's website. The RStudio software was used to analyse data on infectious trends in this study. The SIR model is used to predict the basic reproduction ratio, R_0 , based on actual and simulated infectious trends for comparison. The value of the basic reproduction ratio for simulating the infectious trend is 2.0, and the basic reproduction ratio for modelling the infectious trend with the entire population of Selangor is 1.15429. According to the findings of this study, the reproduction ratio would affect the number of infected individuals by reducing the number of recovered individuals. The effectiveness of lockdown in preventing COVID-19 disease in Selangor was demonstrated by a significant reduction in the basic reproduction ratio, R_0 .

Keywords: SIR Model, COVID-19, Infectious Trend, Selangor, Reproduction Ratio

INTRODUCTION

Coronavirus Disease (COVID-19) is a type of SARS-CoV-2 virus classified as a coronavirus associated with the severe acute respiratory syndrome. SARS-CoV-2 is a zoonotic virus with striking genetic similarities to bat coronaviruses. It is associated with a bat-borne virus, implying that it evolved from a bat-



borne virus. COVID-19 is a short form of the word ‘CO’ for corona, ‘VI’ for a virus, and ‘D’ for disease. Officials in Wuhan City, China, announced the first cases of COVID-19 in December 2019 as detected by a respiratory epidemic in China (Unicef, 2020). Since then, the epidemic's geographical expansion has been rapid and uncontrollable, resulting in the World Health Organization declaring it a pandemic (WHO). Two million two hundred thirty thousand four hundred thirty-nine positive COVID-19 cases were reported globally on April 17, 2020, with 150,810 fatalities and 564,210 full recoveries (WHO, 2020).

COVID-19 has a variety of various effects on different persons. Most infected persons will experience mild to moderate symptoms and heal on their own. Fever, dry cough, and tiredness are the most prevalent symptoms associated with COVID-19. Individuals must seek emergency medical treatment if they develop major symptoms such as breathing difficulty or shortness of breath, thorax or pressure, and voice or movement loss. COVID-19 was disseminated through direct contact with the infected individual's respiratory tract and coughing and sneezing. People may contract the disease by touching their faces and virus-infested surfaces (Unicef, 2020). Infected individuals in the percentage of 80% who recovered from the illness without hospital care. Another 15% get severely unwell and need breathing care, while the other 5% get seriously ill and need treatment (WHO, 2020). The first COVID-19 wave, which occurred between January 25, 2020, and February 26, 2020, was brought into Malaysia by three instances involving three Chinese tourists who entered via Johor from Singapore on January 23, 2020, according to Health Minister Datuk Seri Dr Dzulkefly Ahmad (New Straits Time, 2020). Chinese nationals are involved in the first three cases. They are a 66-year-old coronavirus patient receiving treatment in Singapore after spending several days under quarantine in a hotel in Johor Bharu. They were then transferred to the Sungai Buloh Hospital in Selangor for additional care.

Malaysia's Ministry of Health and Government implemented a state wide 'Movement Control Order' (MCO). MCO is responsible for implementing new clusters on the specified site if the requisite cases occur. Even the Ministry of Health's number of cases was uncertain, and residents believe MCO will help slow the COVID-19 outbreak in Selangor. Experts believe that a complete lockdown in Selangor is necessary to contain the growing number of Covid-19 infections because a total lockdown would endanger the nation's economic recovery. Given the circumstances in Selangor, economists feel that the long-term advantages outweigh the short-term costs. However, the trend of COVID-19 cases was unexpected, requiring various measures to deal with the pandemic and contain the epidemic in Selangor. Researchers, therefore, recreate the infectious trend of the COVID-19 epidemic in Selangor using the Susceptible, Infectious, and Removed (SIR) mathematical model so that this modelling can represent various types of real situations in Selangor.

METHODOLOGY

The MCO implemented prohibitions against movements, international meetings, travel, and forced closures of enterprises, industries, governments, and education demands to control the spread of SARS-CoV-2, the virus that causes COVID-19 in Malaysia. As a result, secondary data were gathered for this study from a database available on the Ministry of Health Malaysia's website. There are 100 days of COVID-19 data collected from March 23, 2020, until June 30, 2020. The data consists of information such as the number of confirmed, recovered, death, and cumulative cases in Selangor (MOH, n.d.)

Model Formulation

In Fred Brauer's revisited paper, W. O. Kermack and A. G. McKendrick developed the mathematical model (SIR) in 1927, which considered a fixed population with three compartments. (Brauer, 2005). The model is



intended for those who are susceptible, infectious, and have recovered. The SIR model is fairly realistic for infectious diseases that are transmitted from person to person and for which recovery confers long-term resistance. S, I, and R are variables that indicate the population size of each compartment at any particular time. To show that even if the total population size remains constant, the number of susceptible, infectious, and recovered individuals can change over time. Make the exact values S(t), I(t), and R(t) is a function of t (time). These functions were developed for a specific disease in a population to forecast probable outbreaks and put the disease under control.

Figure 1 shows the process of the mathematical model of the SIR model. The Susceptible, Infectious, and Removed are states in which an individual progresses in sequence.



Figure 1: The SIR Model

Let N be the constancy of the population of individuals who live in Selangor in 2020.

$S(t)$ = The number of susceptible individuals able to contact the disease.

$I(t)$ = The number of infective individuals capable of transmitting the disease.

$R(t)$ = The number of recovered individuals who have become immune.

β = transmission rate of disease.

γ = removal rate.

A set of ordinary differential equations may explain the evolution and dynamics of the SIR model as follows:

$$\frac{dS}{dt} = -\frac{\beta IS}{N}, \quad (1)$$

$$\frac{dI}{dt} = \frac{\beta IS}{N} - \gamma I, \quad (2)$$

$$\frac{dR}{dt} = \gamma I, \quad (3)$$

where S, I, and R represent, the susceptible, infected, and recovered total number of individuals representing each compartment. N is the total population size.

Since,

$$\frac{dS}{dt} + \frac{dI}{dt} + \frac{dR}{dt} = 0 \quad (5)$$

Follows that,

$$N = S(t) + I(t) + R(t), N = \text{constant} \quad (6)$$

The dynamics of the infectious class depends on the following ratio,



$$R_0 = \frac{\beta}{\gamma}, \quad (7)$$

It's called a basic reproduction ratio. This ratio is derived as the expected number of new infections or called as secondary infections from a single infection in a population. R_0 indicate the severity of the outbreak of an infectious disease of COVID-19.

If the value of reproduction ratio is,

$$R_0 < 1, \quad (8)$$

Each infected individual will only infect one other individual, and the disease will eventually die out.

$$R_0 = 1, \quad (9)$$

Each infected individual will infect one more individual, and the disease will continue to spread yet remain stable.

$$R_0 > 1, \quad (10)$$

Each infected individual will infect other individuals, and the disease will continue to spread and expand, with the potential to become a pandemic.

Numerical Solution

A numerical simulation of the infectious trend of COVID-19 in Selangor was conducted to analyse the infection and course of COVID-19 spread. The SIR model forecasts the future dynamics of epidemics simulated by the SIR model using Microsoft Excel to extract parameters from collected data and R-software to solve the SIR model numerically. The basic reproduction ratio R_0 , provides S indications concerning an outbreak:

1. Whether or not the outbreak will evolve into a pandemic scale.
2. The epidemic's initial rate of spread.
3. The proportion of the susceptible population that will get infected in the end.
4. In a population, the equilibrium fraction of susceptible individuals.

FINDINGS AND DISCUSSIONS

Solutions of The SIR Model

The chart in **Figure 2** illustrates the total number of new cases, total number of recovered cases, and total number of mortality cases of COVID-19 in Selangor every week. In this work, this data was used to mimic the infectious trend using the SIR model.



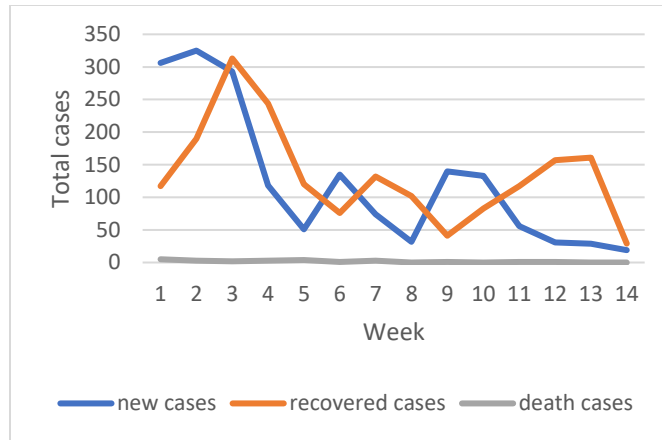


Figure 2: The difference of total new cases, recovered cases, and death cases of COVID-19 in Selangor per week

To find the solution for COVID-19 cases in Selangor, the value of the parameters β , γ , and μ that calculated based on **Table 1**. For the initial condition, the value of parameters was then substituted into Eq (1) until Eq (3). **Table 1** depicts the initial condition values for instances of COVID-19 in Selangor, as determined by the starting condition. Estimates of the fundamental reproduction number R_0 are shown in **Table 2**. From March 24, 2020, to March 26, 2020, the transmission rate (β) and the removal / recovery rate (γ) were measured.

Table 1: The values of parameters for COVID-19 cases in Selangor

Parameters	COVID-19 in Selangor
N	6520000
β	1.29076
γ	0.62963

Table 2: Initial condition's values for cases of COVID-19 in Selangor.

Initial Condition	COVID-19 in Selangor
$S(0)$	0.99993
$I(0)$	5.7515E-05
$R(0)$	0

Table 3: Basic reproduction number (R_0), transmission rate (β) and removed / recovery rate (γ).

Date	R_0	β	γ
24 th March 2020	2.05003	1.29076	0.69263
25 th March 2020	1.21778	0.13786	0.11321
26 th March 2020	2.50083	0.16239	0.66667



The data of covid cases for the infectious trend that has been simulated by days is represented on the x-axis of the graph. The y-axis, on the other hand, depicts the prevalence of COVID-19 cases in Selangor in 2020.

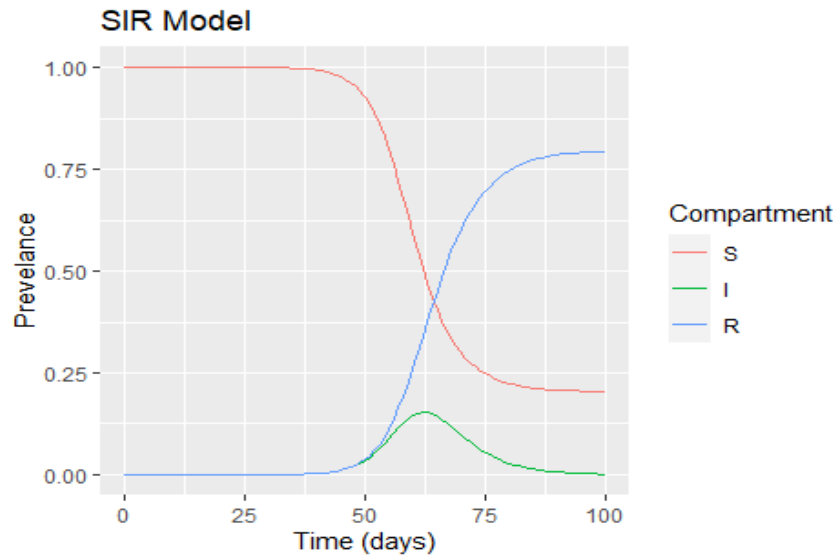


Figure 3: The SIR model for COVID-19 cases in Selangor

Figure 3 illustrates the graph for COVID-19 cases in Selangor using the SIR model. The red line represents the simulated number of susceptible individuals, the green line represents the simulated number of infected individuals, and the blue line represents the simulated number of recovered numbers of infected individuals. This graph covered a period of 100 days. The results indicate that the number of probable sick individuals in the red line fell by 37 days. Within 63 days, the number of infected persons depicted by the green line begins to rise and reaches a peak of 0.13 prevalence. Meanwhile, the blue line depicting the number of people who recovered from various diseases reaches 0.82 prevalence, the largest number of afflicted people in Selangor in 87 days. After 93 days, the disease has stopped spreading, implying that it only spread for 67 days.

The SIR model is initialized (at the time $t = 0$) using the total population, $N = 6520000$ with the initial condition $S(0) = S_0 = 6513480$ (99.9% from the total population), and $I(0) = I_0 = 6520$ (0.1% from the total population). The basic reproductive number R_0 for this study uses the average $R_0 = 1.154292396$ from the calculation using Python. The average recorded number of days of recovery is to be 3 days based on the selected recovered cases in Selangor. It follows the recovery cases rate $\gamma = 0.368$ and the value of transmission rate $\beta = 0.425$. Finally, with the values of S_0 , I_0 , and R_0 the differential equations were solved the values compartments at each time point (days) beginning from day zero (March 23, 2020) until day 100 (June 30, 2020). As a result of Eq. (7)

$$R_0 = \frac{\beta}{\gamma} = \frac{0.42548}{0.36861} = 1.15429$$

For the simulated infectious trend with the same total population, N and the initial condition of $S(0)$ and $I(0)$ were used. The parameter of beta and gamma were assumed as the recovery cases rate, $\beta = 0.50$, the



value of transmission rate, $\gamma = 0.25$, and the average of recovery is assumed to be 4 days for recovered cases in Selangor. Then, the reproductive number, R_0 for this simulation using the formula below. Eq (7) gives the following information:

$$R_0 = \frac{\beta}{\gamma} = \frac{0.50000}{0.25000} = 2.00000$$

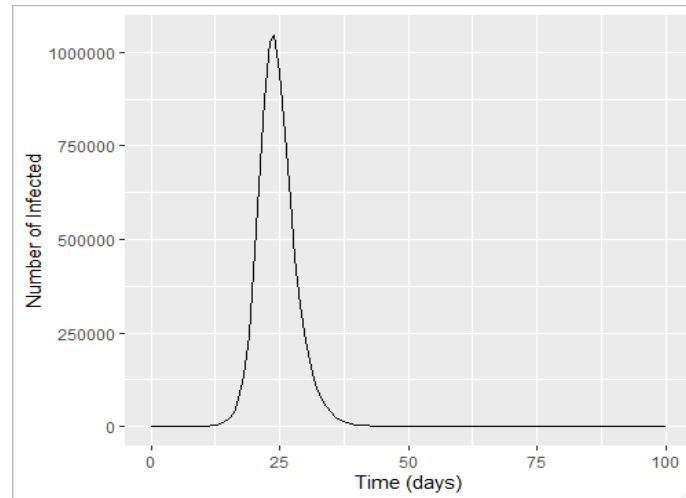


Figure 4: The actual infectious trend for 100 days

Figure 4 shows the graphs of the actual infectious trend of COVID-19 in Selangor for 100 days. The *x-axis* represents the duration of time in days, and the *y-axis* represents the total number of infected individuals with coronavirus diseases. In the initial stage, day zero to day 12 (April 4, 2020), the actual trend reach a peak value of more than 1000000 individuals on day 20 to 24, and going downwards after day 25 (April 17, 2020), the simulation remains constant after day 50 until after day 100 (June 30, 2020).

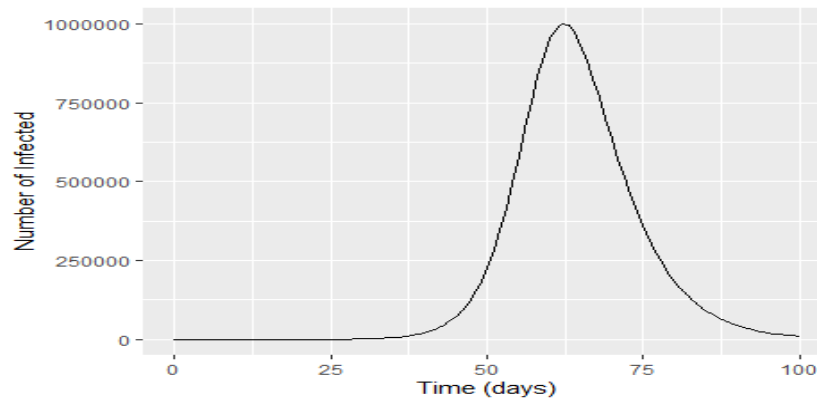
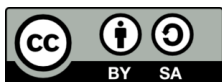


Figure 5: The simulated infectious trend for 100 days

Figure 5 illustrates the trend of simulated COVID-19 infection in Selangor over a 100-day period. The *x-axis* indicates the duration of the disease in days, while the *y-axis* indicates the total number of persons affected by it. The simulation remains consistent from day 0 to day 25 during the early period. From day



38, the simulation trended upward, reaching a peak of 1000000 persons on day 62. (May 22, 2020). The simulated trend continues to decline after day 64, almost approaching zero on day 94.

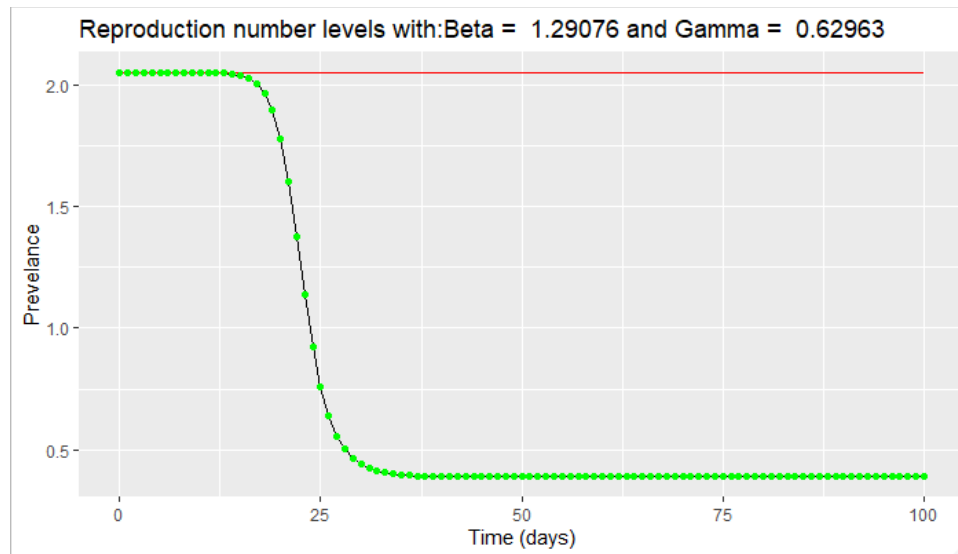


Figure 6: The reproduction number level for actual infectious trend

Figure 6 represents the graphs of reproduction number levels for actual infectious trend with the parameters of $\beta = 1.29076$ and $\gamma = 0.62963$. Based on the result, the green line shows that the reproduction number starts to decline from day 13 and reaches zero after day 31.

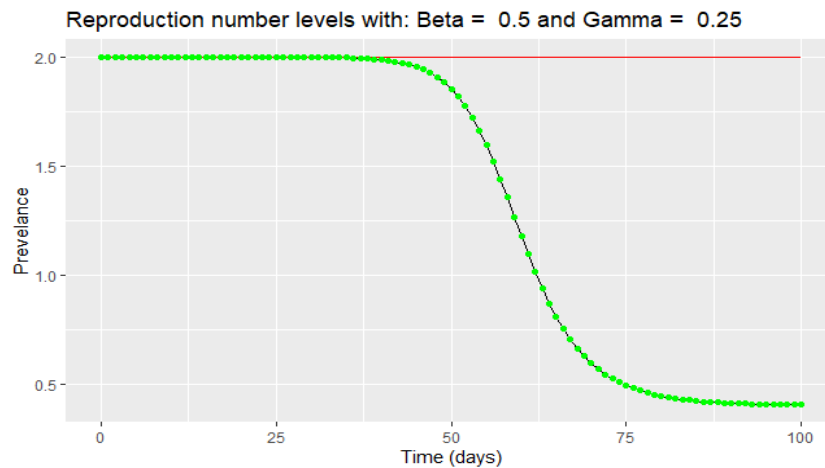


Figure 7: The reproduction number level for simulated infectious trend

Figure 7 show graphs of reproduction number levels for a simulated infectious trend with the parameters $\beta = 0.50000$ and $\gamma = 0.25000$. According to the results, the green line indicates that the reproduction number begins to decline on day 43 and reaches one on day 75.



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

The reproduction number, R_0 , is the product of the ratio of β and γ in Equation (7). The basic reproduction ratio for actual infectious trend is 1.15429, while the value of basic reproduction ratio for simulated infectious trend is 2.00000. This showed that the reproduction ratio of the simulated infectious trend was higher than the actual infectious trend. Since the value of R_0 for both infectious trends is greater than 1, each infected individual will infect other individuals, and the disease will continue to spread and expand with the potential to become a pandemic.

CONCLUSIONS

The basic reproduction ratio, R_0 , is predicted using the SIR model in this analysis based on real and simulated infectious trends for comparison. The value of the basic reproduction ratio for simulating the infectious trend is 2.00000, whereas the basic reproduction ratio for modelling the infectious trend with the entire population of Selangor is 1.15429. This showed that the simulated infectious trend had a higher reproduction ratio than the actual infectious trend. The disease will spread to more people due to each infected person. Given that the values of both infectious trends are greater than 1, the disease will likely spread further and become a pandemic. The Lockdown should continue to reduce the value of the basic reproduction ratio.

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