Project X 2020

**Estimating SARS-COV-2 Virus Transmissions in Singapore using the SIR model**

**Nanyang Girls’ High School**

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# 1. Abstract

In 2019, a new coronavirus was found in Wuhan, China. This virus was later named SARS-COV-2 and causes the disease COVID-19, and has become a global pandemic crisis.

This report aims to use the SIR model (Susceptible-Infected-Recovered) to estimate the spread of the virus in Singapore, specifically the Kermack-McKendrick model. The result is then compared against the actual data collected from 23rd January to 31st March 2020. Based on the results, we discussed the different key junctures in the stages of the viral epidemic and precautions recommended for each juncture.

# 2. The SIR Model Prediction

## 2.1 Prediction

The Kermack-McKendrick model was used to predict the virus as it is simpler and easier to predict. The model consists of 3 systems of differential equations,



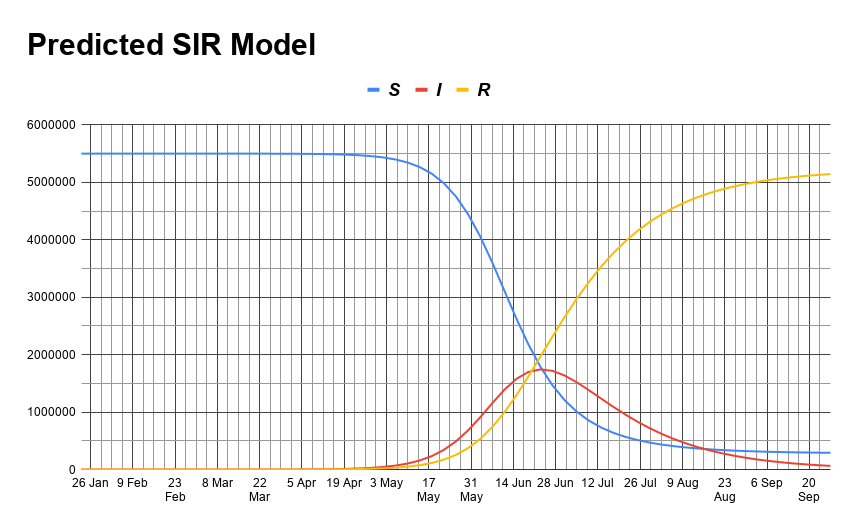
Where is the time (in days), is the total number of individuals susceptible to infection, is the number of infected individuals, is the number of recovered individuals, is the infection rate and is the recovery rate.

is set to be 183 days (from 23 Jan, the first confirmed case in Singapore, to 27 Sept.)

is set be 0.157, and was calculated by us using data collected from Singapore from 23 Jan to 1 April.[[1]](#footnote-0)

is set to be 0.05. (1/20 days per infected person. Estimated recovery time based on different sources.)

The total population is set at 5.5 million, with no changes.

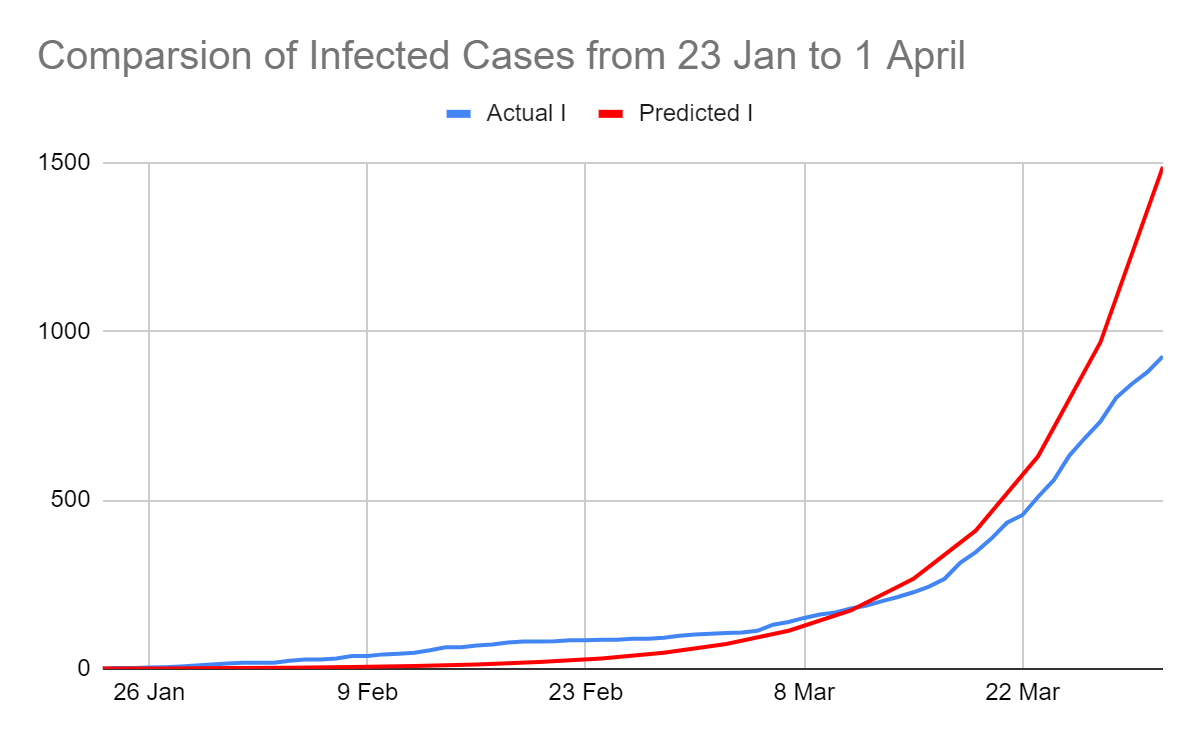


#### Fig 1

The data points are plotted once every 4 days on the graph as to reduce non-whole number data points.

## 2.2 Analysis of results

To analyse the accuracy of our prediction, the data collected of actual COVID-19 cases was used to check against it.



#### Fig 2

The 2 graphs are largely similar, however, after 22 March, the predicted model seems to deviate from the actual data. This could be due to some assumptions made.[[2]](#footnote-1)

We also identified 3 key junctures[[3]](#footnote-2) of viral transmission based on Fig 1,

**Juncture 1: 26 April**

The curve is relatively flat before, but starts to rise fast after this.

**Juncture 2: 26 April to 7 June**

The curve is the steepest at this period, the number of infections at this point increases exponentially.

**Juncture 3: 7 June to 23 June**

The curve is reaching the turning point at this period, and the number of cases will peak around 23 June, action is needed to flatten the curve.

## 2.3 Limitations

This prediction model is based on several assumptions:

1. There is no change in total population, and it is a closed population.
2. The virus does not have a incubation period
3. There are no imported cases
4. There were no efforts made to contain the virus
5. Everyone has equal chance of getting the virus
6. All recovered individuals are immune to the virus.
7. There are no deaths caused by the virus.
8. And other assumptions.

471 words so far. (not including acknowledgements)

# 3. Key Junctures

## 3.1 Juncture 1 (Start to 26 April)

During this juncture, the curve is relatively flat compared to the rest of the curve. During this period, the number of infected cases is small and relatively easy to contain. However, the graph started to escalate dramatically after this period. To prevent a massive outbreak, measures must be taken to stop the virus from spreading in the community effectively during this period. All symptomatic patients should be quarantined and people with close contact with them be given stay-at-home notices, and active contact tracing measures to take place. Awareness on the importance of wearing masks and social distancing should be spread, thus avoiding the spread of the virus by presymptomatic and asymptomatic cases, and proper hygiene practices taught. This may be a challenge as many people may not be aware or understand the gravity of the situation and may not comply with certain measures, thus complicating the process of containment. (149 words for this part)

## 3.2 Juncture 2 (26 April to 7 June)

This juncture is when the number of infected people starts to increase sharply, and the gradient of the curve is the steepest. Governments notice that the virus is a big problem in the society, and put in place measures to make sure that the number of infected cases do not increase exponentially. Big shifts in society are made and people’s lives are affected to prevent further spread of the virus. During this juncture, the whole society accepts the seriousness of the virus and takes major steps into containing it. The main goal is to flatten the curve and slow down the spread of the virus. Although the number of cases are increasing drastically, people understand the gravity of the situation, and understand the measures taken. If the government and the people both play their role well, it will hopefully result in the successful management and containment of the virus. (149 words)

## 3.3 Juncture 3 (7 June to 23 June)

This juncture is when the number of infections begin to peak. The number of infected people increases at a slower rate than before, and after this juncture, the number of cases start to decrease and that is when herd immunity kicks in. At this point in time, healthcare systems are being put under high levels of pressure and are reaching their maximum capacity and capability. The hospital beds would be quickly filled and more hospital beds are needed, and the country can make use of community facilities to help lighten the hospital’s loads. Another challenge is that more professionals are needed to take care of the coronavirus patients, and Singapore needs to consider how to distribute the limited manpower over areas of need, such as further training to take up additional roles. The public needs to continue observe previous healthcare measures such as social distancing as there is now a higher risk of being affected by the coronavirus. (158 words)

# 4. Conclusion

Using the SIR model, we had projected the trajectory for the growth in the number of cases, and this could help in the government's efforts to contain the virus. We have identified critical junctures and preventive measures needed to be taken. This pandemic is projected to be disastrous if no precautions and preventive measures were taken. We should do our part to curb the spread as much as possible.

(90 words)

# 5. References

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# 6. Annexes

Annex A, Annex C: <https://docs.google.com/spreadsheets/d/1P_4dyOxjGTBG2m38KdLjJdXDVXnjGJZ2sAcn-1gtxeQ/edit?usp=sharing>

Annex B: <https://drive.google.com/file/d/1gijdFfa9YSl7uuHVz06HOZOOQja1OJcE/view?usp=sharing>

OR

<https://colab.research.google.com/drive/1WTpibnqfUtl4yj8PpMrp9GpkE33KGOlC?usp=sharing>

OR

<https://github.com/7114180021/SIR-Model-Project-X-2020->

## 6.1 Annex A: Data collected of cases of COVID-19 in Singapore from 23 Jan to 1 April

| Date | New Cases | Recovered | total recovered (B) | total cases | total active cases | beta (infection rate per day, calculated as new case on a given day divided by total cases) |
| --- | --- | --- | --- | --- | --- | --- |
| 23 Jan | 1 | 0 | 0 | 1 | 1 | 1 |
| 24 Jan | 2 | 0 | 0 | 3 | 1 | 2 |
| 25 Jan | 0 | 0 | 0 | 3 | 3 | 0 |
| 26 Jan | 1 | 0 | 0 | 4 | 4 | 0.25 |
| 27 Jan | 1 | 0 | 0 | 5 | 5 | 0.2 |
| 28 Jan | 2 | 0 | 0 | 7 | 7 | 0.2857142857 |
| 29 Jan | 3 | 0 | 0 | 10 | 10 | 0.3 |
| 30 Jan | 3 | 0 | 0 | 13 | 13 | 0.2307692308 |
| 31 Jan | 3 | 0 | 0 | 16 | 16 | 0.1875 |
| 1 Feb | 2 | 0 | 0 | 18 | 18 | 0.1111111111 |
| 2 Feb | 0 | 0 | 0 | 18 | 18 | 0 |
| 3 Feb | 0 | 0 | 0 | 18 | 18 | 0 |
| 4 Feb | 6 | 1 | 1 | 24 | 23 | 0.2608695652 |
| 5 Feb | 4 | 0 | 1 | 28 | 27 | 0.1481481481 |
| 6 Feb | 0 | 0 | 1 | 28 | 27 | 0 |
| 7 Feb | 3 | 1 | 2 | 31 | 29 | 0.1034482759 |
| 8 Feb | 7 | 0 | 2 | 38 | 36 | 0.1944444444 |
| 9 Feb | 0 | 4 | 6 | 38 | 32 | 0 |
| 10 Feb | 5 | 1 | 7 | 43 | 36 | 0.1388888889 |
| 11 Feb | 2 | 2 | 9 | 45 | 36 | 0.05555555556 |
| 12 Feb | 3 | 6 | 15 | 48 | 33 | 0.09090909091 |
| 13 Feb | 7 | 0 | 15 | 55 | 40 | 0.175 |
| 14 Feb | 9 | 2 | 17 | 64 | 47 | 0.1914893617 |
| 15 Feb | 0 | 1 | 18 | 64 | 46 | 0 |
| 16 Feb | 5 | 1 | 19 | 69 | 50 | 0.1 |
| 17 Feb | 3 | 5 | 24 | 72 | 48 | 0.0625 |
| 18 Feb | 6 | 5 | 29 | 78 | 49 | 0.1224489796 |
| 19 Feb | 3 | 5 | 34 | 81 | 47 | 0.06382978723 |
| 20 Feb | 0 | 3 | 37 | 81 | 44 | 0 |
| 21 Feb | 1 | 10 | 47 | 82 | 35 | 0.02857142857 |
| 22 Feb | 3 | 2 | 49 | 85 | 36 | 0.08333333333 |
| 23 Feb | 0 | 2 | 51 | 85 | 34 | 0 |
| 24 Feb | 1 | 2 | 53 | 86 | 33 | 0.0303030303 |
| 25 Feb | 0 | 5 | 58 | 86 | 28 | 0 |
| 26 Feb | 3 | 4 | 62 | 89 | 27 | 0.1111111111 |
| 27 Feb | 0 | 4 | 66 | 89 | 23 | 0 |
| 28 Feb | 3 | 3 | 69 | 92 | 23 | 0.1304347826 |
| 29 Feb | 6 | 3 | 72 | 98 | 26 | 0.2307692308 |
| 1 Mar | 4 | 2 | 74 | 102 | 28 | 0.1428571429 |
| 2 Mar | 2 | 4 | 78 | 104 | 26 | 0.07692307692 |
| 3 Mar | 2 | 0 | 78 | 106 | 28 | 0.07142857143 |
| 4 Mar | 2 | 1 | 79 | 108 | 29 | 0.06896551724 |
| 5 Mar | 5 | 2 | 81 | 113 | 32 | 0.15625 |
| 6 Mar | 18 | 1 | 82 | 131 | 49 | 0.3673469388 |
| 7 Mar | 8 | 8 | 90 | 139 | 49 | 0.1632653061 |
| 8 Mar | 12 | 0 | 90 | 151 | 61 | 0.1967213115 |
| 9 Mar | 10 | 3 | 93 | 161 | 68 | 0.1470588235 |
| 10 Mar | 6 | 0 | 93 | 167 | 74 | 0.08108108108 |
| 11 Mar | 12 | 3 | 96 | 179 | 83 | 0.1445783133 |
| 12 Mar | 9 | 0 | 96 | 188 | 92 | 0.09782608696 |
| 13 Mar | 13 | 1 | 97 | 201 | 104 | 0.125 |
| 14 Mar | 12 | 8 | 105 | 213 | 108 | 0.1111111111 |
| 15 Mar | 14 | 0 | 105 | 227 | 122 | 0.1147540984 |
| 16 Mar | 17 | 4 | 109 | 244 | 135 | 0.1259259259 |
| 17 Mar | 23 | 5 | 114 | 267 | 153 | 0.1503267974 |
| 18 Mar | 47 | 0 | 114 | 314 | 200 | 0.235 |
| 19 Mar | 32 | 7 | 121 | 346 | 225 | 0.1422222222 |
| 20 Mar | 40 | 7 | 128 | 386 | 258 | 0.1550387597 |
| 21 Mar | 47 | 9 | 137 | 433 | 296 | 0.1587837838 |
| 22 Mar | 23 | 4 | 141 | 456 | 315 | 0.07301587302 |
| 23 Mar | 54 | 8 | 149 | 510 | 361 | 0.1495844875 |
| 24 Mar | 49 | 3 | 152 | 559 | 407 | 0.1203931204 |
| 25 Mar | 73 | 5 | 157 | 632 | 475 | 0.1536842105 |
| 26 Mar | 52 | 12 | 169 | 684 | 515 | 0.1009708738 |
| 27 Mar | 49 | 11 | 180 | 733 | 553 | 0.08860759494 |
| 28 Mar | 70 | 15 | 195 | 803 | 608 | 0.1151315789 |
| 29 Mar | 41 | 14 | 209 | 844 | 635 | 0.06456692913 |
| 30 Mar | 35 | 16 | 225 | 879 | 654 | 0.05351681957 |
| 31 Mar | 47 | 12 | 237 | 926 | 689 | 0.06821480406 |
| 1 Apr | 74 | 5 | 242 | 1000 | 758 | 0.09762532982 |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  | average beta |
|  |  |  |  |  |  | 0.1572132305 |

## 6.2 Annex B: Python code used for the prediction model

#NumPy, matplot, etc needs to be installed first

import numpy as np

from scipy.integrate import odeint

import matplotlib.pyplot as plt

# Total population, N.

N = 5500000

# Initial number of infected and recovered individuals, I0 and R0.

I0, R0 = 47, 12

# S0, number of individuals susceptible to infection initially.

S0 = N - I0 - R0

# Infection rate, beta, and mean recovery rate, gamma, (in 1/days).

beta, gamma= 0.157, 1./20

# A grid of time points (in days)

t = np.linspace(0, 183, 183)

# The SIR model differential equations.

def deriv(y, t, N, beta, gamma):

S, I, R = y

dSdt = -beta \* S \* I / N

dIdt = beta \* S \* I / N - gamma \* I

dRdt = gamma \* I

return dSdt, dIdt, dRdt

# Initial conditions vector

y0 = S0, I0, R0

# Integrate the SIR equations over the time grid, t.

ret = odeint(deriv, y0, t, args=(N, beta, gamma))

S, I, R = ret.T

# Plot the data on three separate curves for S(t), I(t) and R(t)

fig = plt.figure(facecolor='w')

ax = fig.add\_subplot(111, facecolor='#dddddd', axisbelow=True)

ax.plot(t, S/5000000, 'b', alpha=0.5, lw=2, label='Susceptible')

print(S, "=S")

ax.plot(t, I/5000000, 'r', alpha=0.5, lw=2, label='Infected')

print(I, "=I")

ax.plot(t, R/5000000, 'g', alpha=0.5, lw=2, label='Recovered with immunity')

print(R, "=R")

ax.set\_xlabel('Time /days')

ax.set\_ylabel('Number (5000000s)')

ax.set\_ylim(0,1.2)

ax.yaxis.set\_tick\_params(length=0)

ax.xaxis.set\_tick\_params(length=0)

ax.grid(b=True, which='major', c='w', lw=2, ls='-')

legend = ax.legend()

legend.get\_frame().set\_alpha(0.5)

for spine in ('top', 'right', 'bottom', 'left'):

ax.spines[spine].set\_visible(False)

plt.show()

## 6.3 Annex C: Output of the Python model

| Date | S | I | R |
| --- | --- | --- | --- |
| 23 Jan | 5,499,999 | 1.0 | 0.0 |
| 27 Jan | 5,499,998 | 1.5 | 0.3 |
| 31 Jan | 5,499,997 | 2.4 | 0.6 |
| 4 Feb | 5,499,995 | 3.6 | 1.2 |
| 8 Feb | 5,499,992 | 5.6 | 2.1 |
| 12 Feb | 5,499,988 | 8.6 | 3.5 |
| 16 Feb | 5,499,981 | 13.2 | 5.7 |
| 20 Feb | 5,499,971 | 20.2 | 9.0 |
| 24 Feb | 5,499,955 | 31.1 | 14.1 |
| 28 Feb | 5,499,930 | 47.8 | 21.9 |
| 3 Mar | 5,499,893 | 73.5 | 33.9 |
| 7 Mar | 5,499,835 | 112.9 | 52.3 |
| 11 Mar | 5,499,746 | 173.6 | 80.6 |
| 15 Mar | 5,499,609 | 266.8 | 124.2 |
| 19 Mar | 5,499,399 | 409.9 | 191.1 |
| 23 Mar | 5,499,076 | 630.0 | 293.9 |
| 27 Mar | 5,498,580 | 968.0 | 452.0 |
| 31 Mar | 5,497,818 | 1,487.4 | 694.8 |
| 4 Apr | 5,496,647 | 2,285.1 | 1,067.8 |
| 8 Apr | 5,494,849 | 3,510.2 | 1,640.9 |
| 12 Apr | 5,492,088 | 5,390.6 | 2,521.1 |
| 16 Apr | 5,487,852 | 8,275.0 | 3,872.6 |
| 20 Apr | 5,481,358 | 12,695.3 | 5,946.7 |
| 24 Apr | 5,471,414 | 19,458.6 | 9,127.2 |
| 28 Apr | 5,456,219 | 29,782.7 | 13,998.6 |
| 2 May | 5,433,068 | 45,485.8 | 21,446.4 |
| 6 May | 5,397,957 | 69,240.0 | 32,802.6 |
| 10 May | 5,345,078 | 104,876.0 | 50,046.2 |
| 14 May | 5,266,260 | 157,672.7 | 76,067.2 |
| 18 May | 5,150,580 | 234,447.7 | 114,971.9 |
| 22 May | 4,984,573 | 343,070.1 | 172,357.0 |
| 26 May | 4,753,825 | 490,795.4 | 255,379.1 |
| 30 May | 4,446,807 | 680,871.9 | 372,321.4 |
| 3 Jun | 4,060,935 | 907,746.4 | 531,318.7 |
| 7 Jun | 3,608,628 | 1,153,215.5 | 738,156.5 |
| 11 Jun | 3,118,709 | 1,387,562.3 | 993,728.8 |
| 15 Jun | 2,629,719 | 1,577,832.0 | 1,292,449.1 |
| 19 Jun | 2,177,747 | 1,699,478.0 | 1,622,775.2 |
| 23 Jun | 1,786,371 | 1,743,855.3 | 1,969,773.6 |
| 27 Jun | 1,463,984 | 1,717,632.2 | 2,318,383.7 |
| 1 Jul | 1,207,381 | 1,636,689.5 | 2,655,929.3 |
| 5 Jul | 1,007,306 | 1,519,421.2 | 2,973,272.8 |
| 9 Jul | 852,849 | 1,382,321.5 | 3,264,829.8 |
| 13 Jul | 733,887 | 1,238,146.7 | 3,527,966.2 |
| 17 Jul | 642,021 | 1,095,765.7 | 3,762,212.9 |
| 21 Jul | 570,679 | 960,780.3 | 3,968,540.4 |
| 25 Jul | 514,875 | 836,340.5 | 4,148,784.3 |
| 29 Jul | 470,882 | 723,887.4 | 4,305,230.3 |
| 2 Aug | 435,928 | 623,739.9 | 4,440,332.1 |
| 6 Aug | 407,947 | 535,521.1 | 4,556,531.6 |
| 10 Aug | 385,393 | 458,455.6 | 4,656,151.2 |
| 14 Aug | 367,099 | 391,566.2 | 4,741,334.6 |
| 18 Aug | 352,178 | 333,802.4 | 4,814,020.1 |
| 22 Aug | 339,946 | 284,119.0 | 4,875,934.7 |
| 26 Aug | 329,877 | 241,522.6 | 4,928,600.1 |
| 30 Aug | 321,557 | 205,096.9 | 4,973,346.1 |
| 3 Sep | 314,659 | 174,013.5 | 5,011,327.1 |
| 7 Sep | 308,926 | 147,534.3 | 5,043,540.2 |
| 11 Sep | 304,147 | 125,009.3 | 5,070,843.2 |
| 15 Sep | 300,158 | 105,870.2 | 5,093,972.0 |
| 19 Sep | 296,821 | 89,623.9 | 5,113,555.6 |
| 23 Sep | 294,025 | 75,844.0 | 5,130,131.0 |
| 27 Sep | 291,680 | 64,163.9 | 5,144,155.9 |

Raw output:

[5499941. 5499933.16671934 5499924.44369511 5499914.72987159

5499903.91271324 5499891.86690543 5499878.45290046 5499863.51530932

5499846.8810873 5499828.3575457 5499807.73011325 5499784.7598545

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5498607.84765975 5498448.63847776 5498271.35825641 5498073.95753371

5497854.15482582 5497609.41044564 5497336.89741048 5497033.46909678

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5456572.14512585 5451691.52961756 5446269.20232261 5440246.61360947

5433559.25727567 5426136.15193937 5417899.29940216 5408763.12279694

5398633.89259301 5387409.14852629 5374977.12976637 5361216.22575594

5345994.4708822 5329169.10239937 5310586.21143004 5290080.52096653

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5152142.48022812 5116017.04103346 5076522.80923739 5033426.70211424

4986496.39475818 4935504.33390667 4880232.45578427 4820477.60013569

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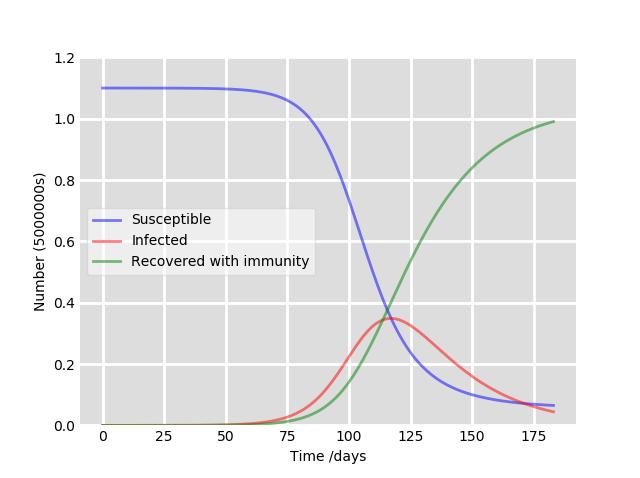
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1. Annex A [↑](#footnote-ref-0)
2. See *2.3 Limitations* [↑](#footnote-ref-1)
3. See *3. Key Junctures* [↑](#footnote-ref-2)