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# DETERMINING THE DYNAMICS OF VIRUS WITH AND WITHOUT THE AVAILABILITY OF VACCINES IN THE CITY OF MANILA USING THE SIR DISEASE MODEL

Venus De Guzman, Sean Aldrich Rebuyas, Cian Margaret Cosep, Rica Caila Gonzales, Mhar Ian Estayan, Shuan Ni Liang

Department of Mathematics and Physics, University of Santo Tomas, España, Manila, Philippines
Department of Electrical and Computer Systems Engineering, School of Engineering, Monash University Malaysia, Subang Jaya, Malaysia

## INTRODUCTION

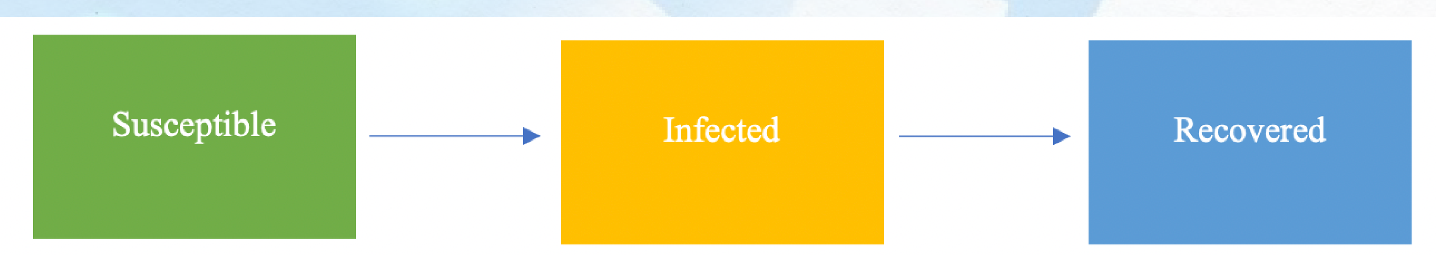
The SIR Model is a characteristic model of disease transmission within a population [1, 2]. It can be modified to account for several key population dynamics such as mortality, birth rates, recovery, and immunity. The transmission of the global pandemic coronavirus disease (COVID-19) virus has started to emerge in 2020 and still remains a global health emergency according to the World Health Organization. This virus evolves overtime and mutates as it moves into population [3]. Hence, it is important to understand the contagious nature of the virus as it is critical in determining how to reduce mortality rate while ensuring to maintain the public health protocols on the population in general. With the availability of vaccines, it is important to highlight how COVID-19 vaccinations has changed the transmission dynamics of the virus in the population overtime.

## OBJECTIVES

- To use the Susceptible-Infected-Recovered (SIR) Disease Model equations to evaluate the spread of COVID-19 infections over a period of time in the City of Manila.
- To describe the effects of vaccination in the COVID-19 infection rate and susceptible rate (comparison between with and without vaccination).

## METHODOLOGY

The SIR Disease Model was used in the study to determine the dynamics of the COVID-19 virus in the population of the City of Manila for the period 2020 – 2022 using Python software. The COVID-19 data from August 2020 – June 2022 were acquired from the official websites of government organizations such as the Department of Health (DOH) and the Local Government of the City of Manila. Parameters for the model which includes number of confirmed cases, recovered cases, death and birth rates, rate of infection, and rate of recovery, among others, were all considered for the simulation using Python software. We set the initial parameters for the calculations in modeling the COVID-19 data for two scenarios - with and without vaccination. For the “without vaccines” scenario, we used COVID-19 data from the start of the pandemic until the month before the vaccines were made available in the Philippines (i.e., August 2020 to June 2021). On the other hand, for the “with vaccines” scenario, we used data generated from July 2021 until June 2022.




The following basic notations were used in the model:
S (t) – number of susceptible individuals at time t.
I (t) – number of infected individuals at time t.
R (t) – number of recovered individuals at time t.
N – total population size

**Without Vaccine Scenario**

$$\frac{dS}{dt} = \mu N - \frac{\beta I(t)S(t)}{N} - \mu S(t)$$
$$\frac{dI}{dt} = \frac{\beta I(t)S(t)}{N} - \gamma I(t) - \mu I(t)$$
$$\frac{dR}{dt} = \gamma I(t) - \mu R(t)$$

**With Vaccine Scenario**

$$\frac{ds}{dt} = (1-p)\mu - \beta is - \mu s$$
$$\frac{di}{dt} = \beta is - \gamma i - \mu i$$
$$\frac{dr}{dt} = \gamma i - \mu r$$
$$\frac{dv}{dt} = p\mu - \mu v$$

## RESULTS AND DISCUSSION

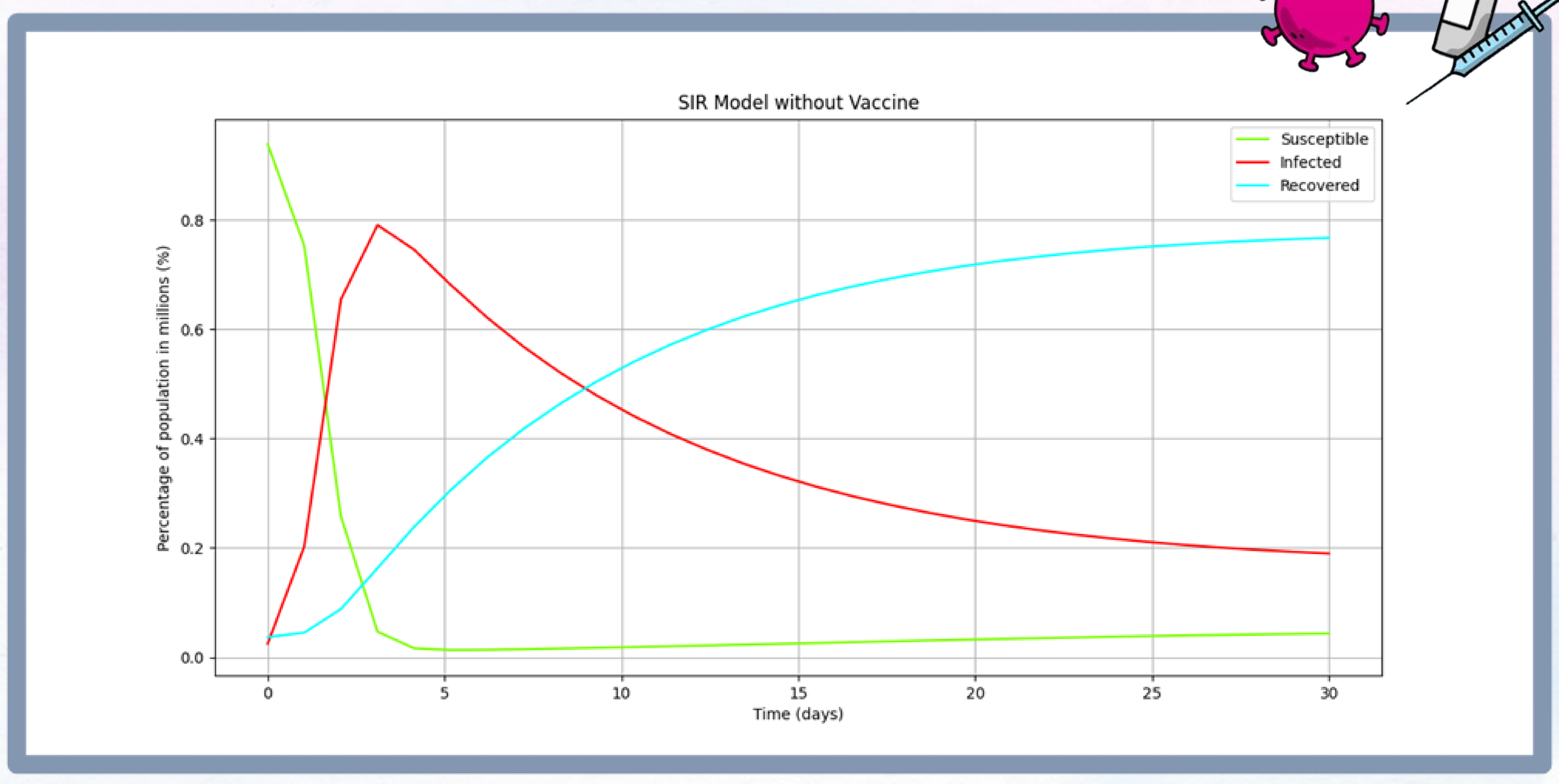



Figure 1. SIR Model generated by Phyton codes of the population without vaccination measured time in days and population as percentage of the total population in millions

- The susceptible population has been observed to abruptly decrease in a span of 5 days.
- About 78% of the population has been infected in the first 3 days since the occurrence of the infection.
- In the absence of vaccination, the recovery rate is significantly lagging as compared to the relatively fast rate of infection

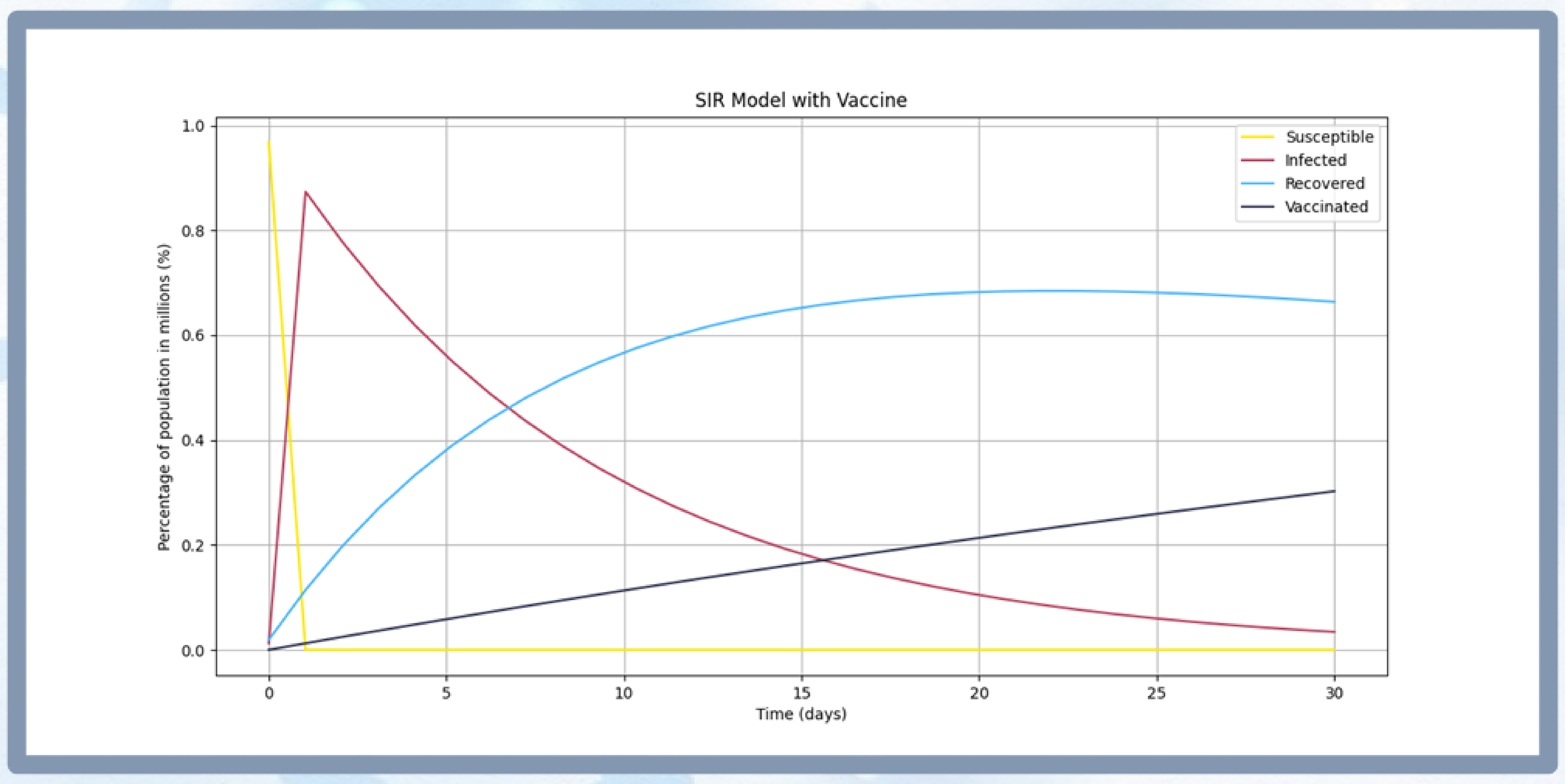



Figure 2. SIR Model generated by Python codes of the population with vaccination measured time in days and population as percentage of the total population in millions

- The peak of the infected group reached about 87% of the population but rapidly decreases in t=1 as the recovery rate and the vaccination rate increases.
- In t=30, the infected population is only at 3.6% of the population. The graph shows a decreasing trend of infected individuals over time that signifies increase in the immunity of the population due to the availability of vaccines.
- A quadratic increase in the recovery rate has been observed as the rate of vaccination increases.

## CONCLUSION

- The SIR model is useful in describing the dynamics of an infectious disease in a given population. The SIR Model is an appropriate model to use in predicting epidemic trend and in investigating the effect of government interventions such as availability of vaccines in preventing the wide spread of the disease.
- With the availability of vaccines in the City of Manila, individuals can rapidly move from susceptible to being infected to being fully-recovered relatively faster as compared to the non-vaccination scenario.
- The vaccination rate can change the dynamic of the virus within the population, it can significantly contribute to the significant drop in the infection rate.

## REFERENCES

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