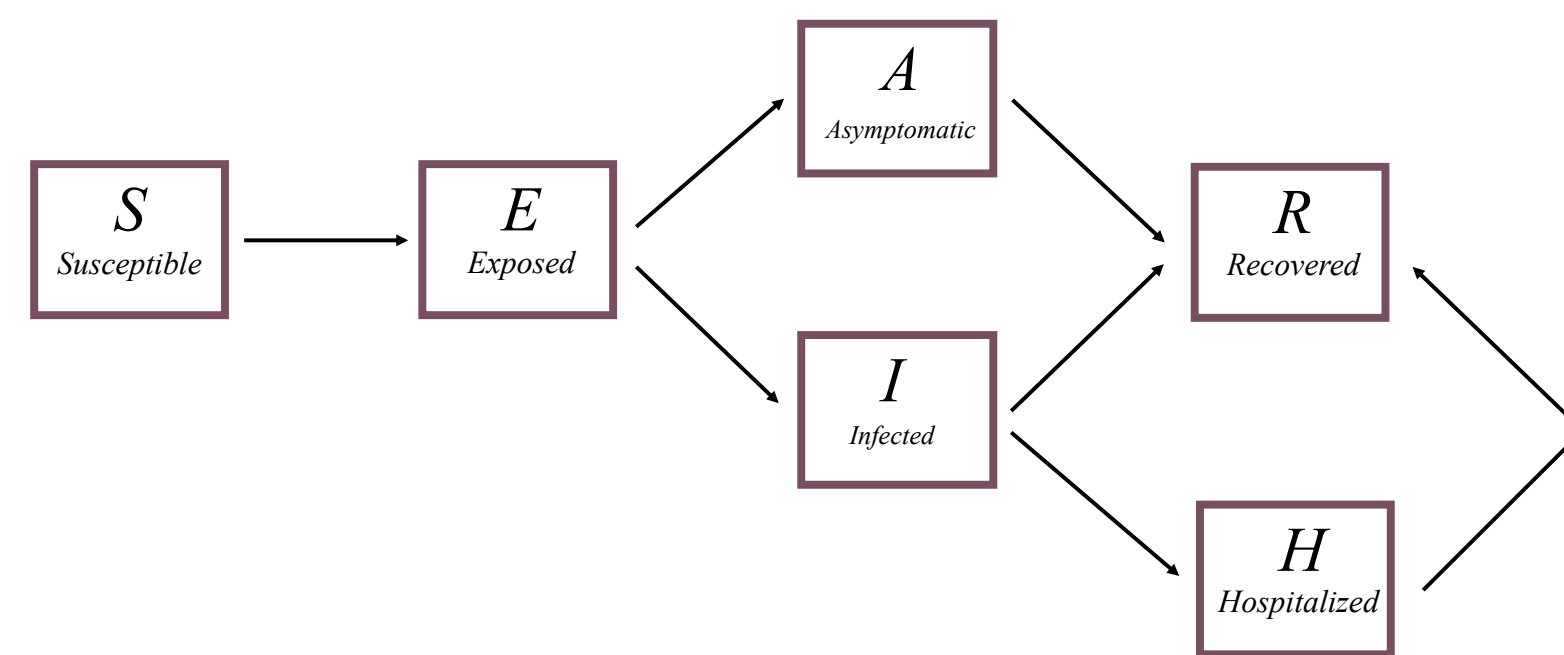


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## Abstract

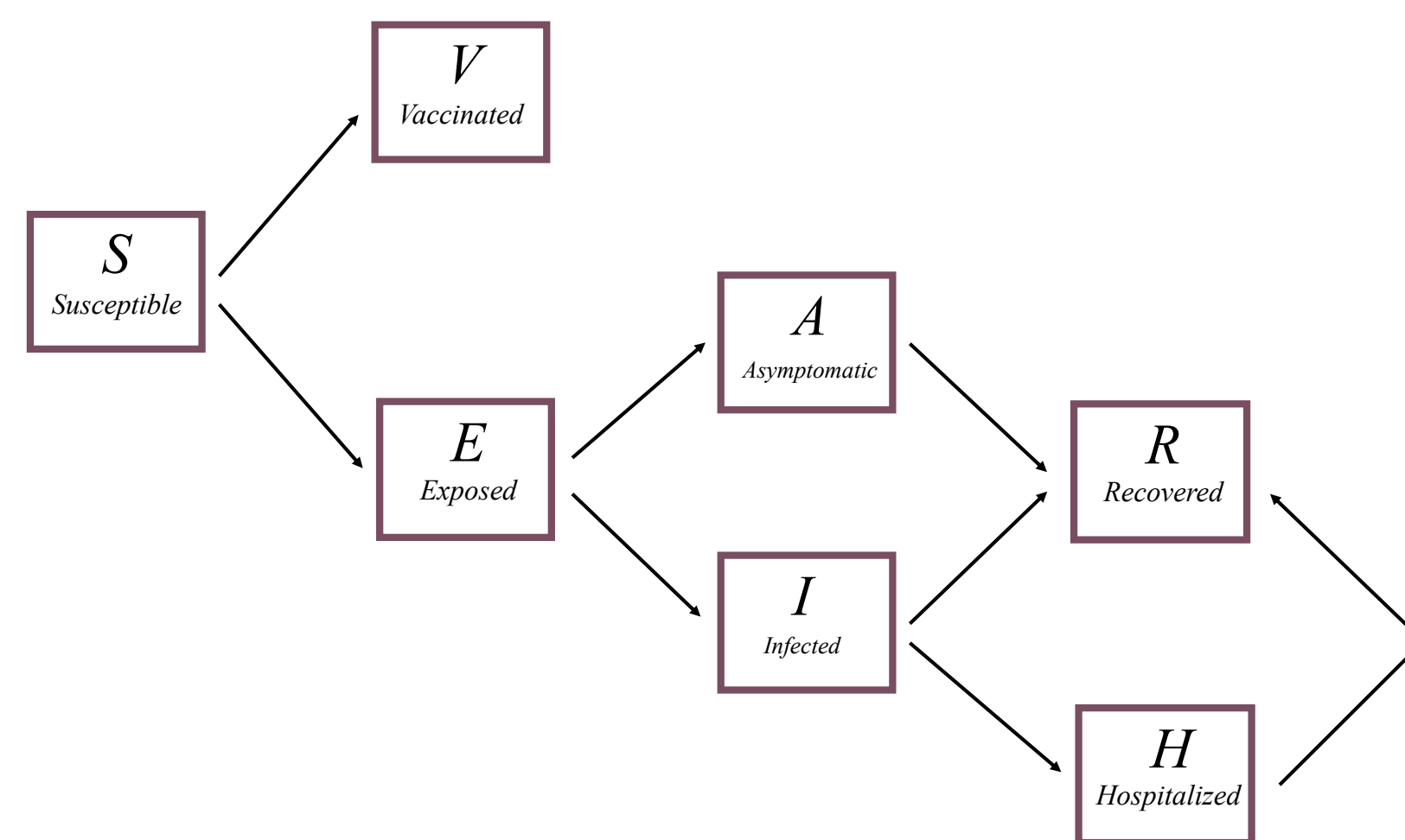
The global impact of COVID-19 has emphasized the need for accurate prediction models to anticipate future consequences and patterns of the disease. With the current rise in COVID-19 cases, an accurate model can help guide communities toward effective quarantine or disease prevention methods. A SEAIR epidemic model has already been developed to analyze social distancing practices<sup>1</sup>. This model acts as a backbone for the new models in the current study. Here, I present two further modified models that account for hospitalization and vaccination. The vaccination model generated predictions that accurately matched real-world data collected following the initial release of the COVID-19 vaccine. This research suggests that the newly developed model may be viable for other similar vector-borne diseases and can help predict vaccination effects on the population.

## Introduction



**Figure 1 | SEAIHR model flowchart**

When the people in the susceptible class are exposed to COVID-19, we assume that they are either asymptomatic or symptomatic. Those who have severe symptoms are hospitalized, and all asymptomatic, infected, and hospitalized people eventually become a part of the recovered class. This flowchart does not account for death due to viral infection.



**Figure 2 | SEAIHVR model flowchart**

After the first COVID-19 vaccine became available to the public in December 2020, people started getting the vaccine in order to have temporary immunity. This reduced the number of people infected with the virus.

### Differential equations used for each model

$$S' = \frac{-aS(I + \theta A)}{N}$$

$$E' = \frac{aS(I + \theta A)}{N} - kE$$

$$A' = (1 - p - q)kE - \gamma A$$

$$I' = pkE - \gamma I - qI$$

$$H' = qkE - \gamma_h H - \delta H$$

$$R' = \gamma(A + I) + \gamma_h H$$

The population is  $N = S + E + A + I + H + V + R$ , where:

S represents susceptible  
E represents exposed  
A represents asymptomatic  
I represents infected  
H represents hospitalized  
V represents vaccinated  
R represents recovered

$$S' = \frac{-aS(I + \theta A)}{N}$$

$$E' = \frac{aS(I + \theta A)}{N} - kE$$

$$A' = (1 - p - q)kE - \gamma A$$

$$I' = pkE - \gamma I - qI$$

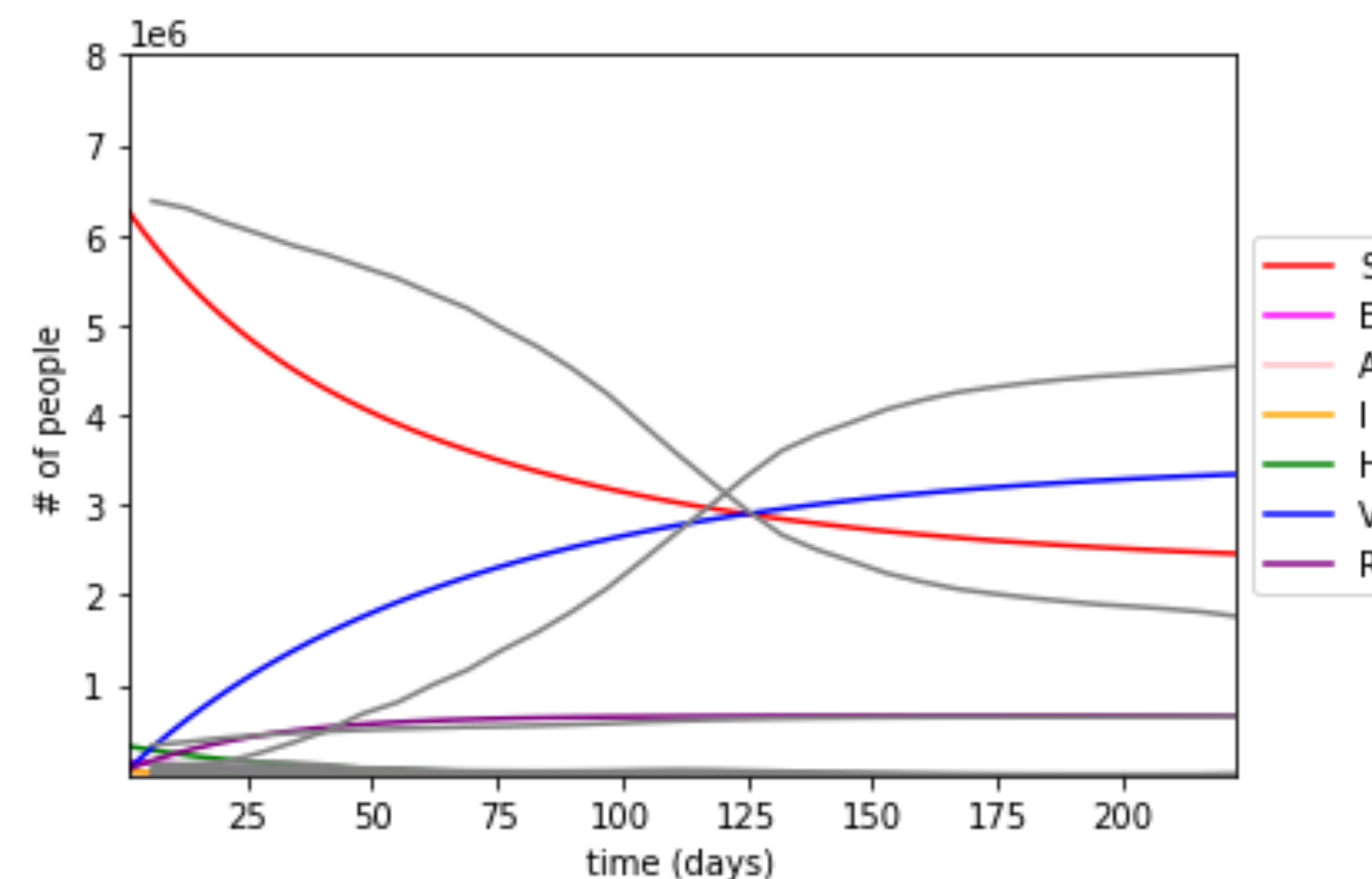
$$H' = qkE - \gamma_h H - \delta H$$

$$V' = \xi S - \eta V$$

$$R' = \gamma(A + I) + \gamma_h H$$

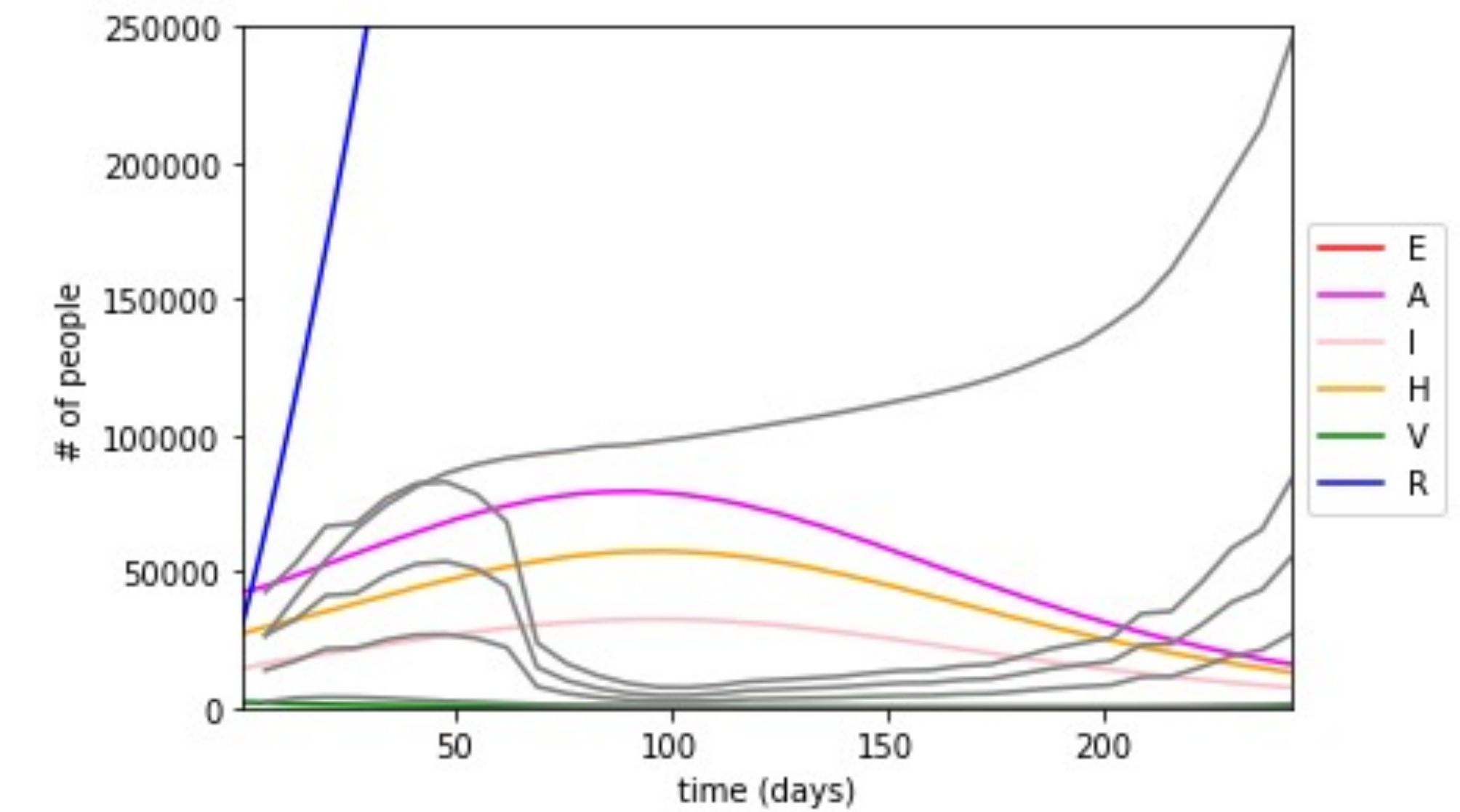
a: per capita effective contact rate  
 $\theta$ : rate at which asymptomatic individuals transmit the disease  
1/k: mean latent period  
p: proportion of infected that are symptomatic  
1/ $\gamma$ : mean infectious period  
q: proportion of infected that are hospitalized  
1/ $\gamma_h$ : mean infectious period for hospitalized individuals  
 $\delta$ : death rate  
 $\xi$ : vaccination rate  
 $\eta$ : rate of immunity loss

## Results



**Figure 3 | SEAIHVR model graph vs real data from Massachusetts (12/26/20-7/31/21)**

Data on the number of people who were infected<sup>2</sup> with the virus, hospitalized<sup>3</sup>, vaccinated<sup>4</sup>, and recovered<sup>5</sup> were collected weekly to plot the gray lines above. The number of people who were susceptible, exposed, and asymptomatic were estimated based on the data collected. The colored lines represent the predicted number of people in each class by the SEAIHVR model. The parameters of the model were changed so they would more accurately represent real events. Because the model is an exponential model, it doesn't capture the logistic growth pattern that the real data follows.



**Figure 4 | SEAIHR model graph vs real data from Massachusetts (4/11/20-12/5/20)**

When the first COVID-19 outbreak occurred, quarantine regulations were implemented within the first two months, which explains the sudden decline in the number of people contracting the virus. However, this model has not been properly fitted yet, as it does not account for the sudden decline in cases.

## Discussion

The vaccination model accurately represents real data collected from Massachusetts. The SEAIHVR model is considered more accurate in predicting future COVID-19 patterns, as long as the current vaccinations remain effective. The SEAIHR model is still in development and is expected to incorporate two sets of parameters, functioning like a piecewise model to account for the quarantine restrictions enforced at that time.

## Acknowledgements

I'd like to thank Professor Ruijun Zhao and Hope Enright of the Department of Mathematics at Minnesota State University, Mankato, for mentoring me and providing guidance for this project. I thank NSF for funding this project and supporting my travel to present this work.

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