SIR model to study wave of COVID-19 in India with help of MATLAB

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Abstract:- The aim of modeling COVID-19 epidemic is to gain an insight into the various physical processes that occur in the transmission of diseases. MATLAB is very useful scientific tool to evaluate differential equation and graphically analysis of epidemic model. The various factors of the disease transmission and recovery rate can be evaluated with the help of MATLAB to numerically evaluated differential equations epidemic model. In our model we will also attempt to find the time range of disease that is the time required to epidemic die out which is a very important factor in eradicating the epidemic. Our model also forecasted the number of people effective from the epidemic.

Keywords:- SIR Model, COVID-19, Susceptible, Infected ,Recovered, MATLAB.

INTRODUCTION:

Modelling through MATLAB of any epidemic provides an analysis about the disease with a wide range of predictions. The entire world is suffering COVID-19 epidemic these days. So, it is very essential to model COVID-19 to know how the epidemic spreads and how much time it takes to die out. Fluid dynamics plays an important role in nearly every aspect of the COVID-19 pandemic. Transmission of COVID-19 happens through three routes:-The first route, linked with droplet and second is the contact route of transmission of droplet, whereas third one is called 'airborne' transmission route. Each stage of transmission process is mediated by complex phenomenon, ranging from air-mucous interaction, liquid sheet fragmentation, turbulent jets, and droplet evaporation and deposition, to flow-induced particle dispersion and sedimentation. Therefore, flow physics is play central role in the transmission of COVID-19. Flow phenomena also helpful in mitigate from infections and therefore face mask, hand washing and social distancing should be advocated [11].Any communicable disease can be modelled or formulated with the help of diffusion phenomenon [12]. The epidemic COVID-19 model can be used to evaluate various aspects with the help of software MATLAB. This process can help us understand and evaluate the spread of disease and therefore advocate preventive measure like vaccinations. It has been seen that the disease has varying strengths in different regions of the world. Modelling can be done using differential equations which can give us insight into the modalities of the outbreak of disease especially in epidemic.

Susceptible-infected-removed (SIR) model provides a common model which has been used in various physical system model initiated by Bernoulli [Ref 1760].This model is basic and cannot give an insight to the overall development of the epidemic. Hence, we have designed physics based model with changing climate parameter that is temperature and humidity. Our model can help us to evaluate the data that was taken from the AROGYA SETU APP or www.covid-19india.org. We now introduced classic SIR model, which consists of three simple differential equations.

The spread of an epidemic disease can be modeled by the physics of diffusion phenomenon. The Diffusion phenomenon is described by a simple linear differential equation, $\frac{\partial C}{\partial t} = \kappa \frac{\partial^2 C}{\partial x^2}$, where C is the concentration of the transfer object, κ is called diffusion coefficient for the object, t and x indicate time and space. Diffusion equation represent the collective data of flow [12].

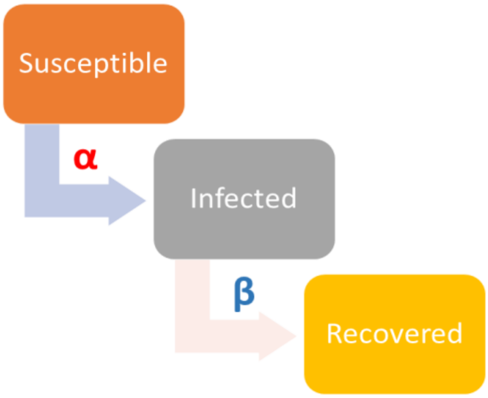
Daniel Bernoulli was a Swiss mathematician who designed first mathematical model for epidemic smallpox. His work has given us an idea about differential mortality for estimation of the rate of deaths attributable for a given disease. In 1897, R.A.Ross did modeling on malaria transmission. He developed a model for spread of malaria. After modelling of malaria epidemic Ross found that the reduction of mosquito population could control in malaria in given region. Kermack WO and Merkendrick AG developed basic epidemic model named SIR in 1927.The SIR (Susceptible-Infected-Recovered) model was first used for explaining the behavior of plague and cholera in London 1865 [13].

SIR Model contains following assumptions:-

S=Susceptible

I=Infected

R=Recovered



Figure(1) SIR Model

A very recent preprint by Ashish Menon et.al.[14] describe SIR model for COVID-19.In this model the total population of a particular region divided into three sections:-

- **Susceptible(S)** →This section represents the number of people who have chanced to infected from diseases.
- **Infected (I)** → This section represents the number of infected people.
- **Recovered(R)** →This section represents the number of people recovered, dead or vaccinated(or developed immune system against the present epidemic).

The basic SIR model used Ordinary Differential equations which are given by the following:-

$$\frac{dS(t)}{dt} = -\alpha S(t)I(t)\text{------------}(1)$$

$$\frac{dI(t)}{dt} = \alpha S(t)I(t) - \beta I(t)\text{---------}(2)$$

$$\frac{dR(t)}{dt} = \beta I(t)\text{--------------}(3)$$

Where, $\alpha =$ Feedback parameters or disease transmission rate

β = Decay rates or recovery rate

S(t)= Susceptible individuals

I(t)= Infected individuals

R(t)=Removed individual

In the above equations non-linear terms exist. We can understand these terms through the following explanations:-

- ❖ The rate of increasing infected people is related to the size of infected individuals and susceptible individuals coming nearly to one another. We can see that in equation (1), the size of this event is proportional to the product of susceptible individuals (S) and infected individuals(I).
- ❖ Equation (1)tell us about the number of susceptible individuals decrease with the growth rate of disease. As we know growth rate is never negative, this means that the S(t) is a decreasing function.
- ❖ Equation(2)tell us about the rate of increase in infectious individuals increase with growth rate and decrease with more individuals getting infectious.
- ❖ Equation(3) tell us about the recovery rate is directly proportional to the number of infectious individuals that is R(t) is an increasing function.

For any scenario total number of population is constant therefore, the Total population (N) is constant that is S(t)+I(t)+N(t)=N(Constant) -----(4).

SIR model can be modified on the basis of behavior of epidemic (Behavior i.e how epidemic transmit one human body to others). Here, we try to find out an mathematical model for COVID-19 epidemic with the help of basic SIR model. Spread of an epidemic depends on many factors like climate, life-style, medical facilities, vaccine availability and the population follows the guidelines or precautions provided by medical authorities. In this research we will try to consider all the factors in which spread of COVID-19 depend.

The work conducted by analytically and numerically using suitable method and software like MATLAB. We have taken data from Indian authorized AROGYA SETU APP or www.covid-19india.org. Here, we developed physics based model using differential equation and find out solution of differential equation using numerical method. Here, We also written code in MATLAB for this model.

We have plotted following graph using the origin software. The data shown in figure2-4 is taken from www.covid19india.org. This data comprises of both the first and second wave of COVID19.The graph given below shows the situation of COVID-19 in India from the period January 2020 to March 2021.

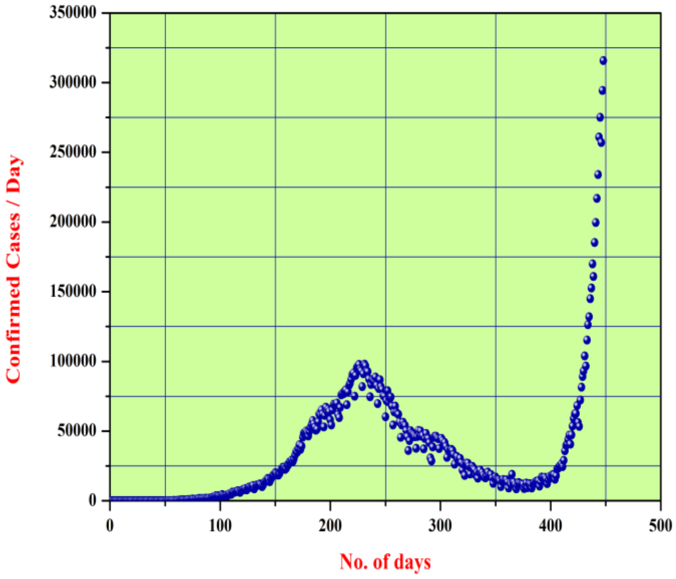


Figure 2: Daily confirmed cases in India. The data is plotted from 30/01/2020.

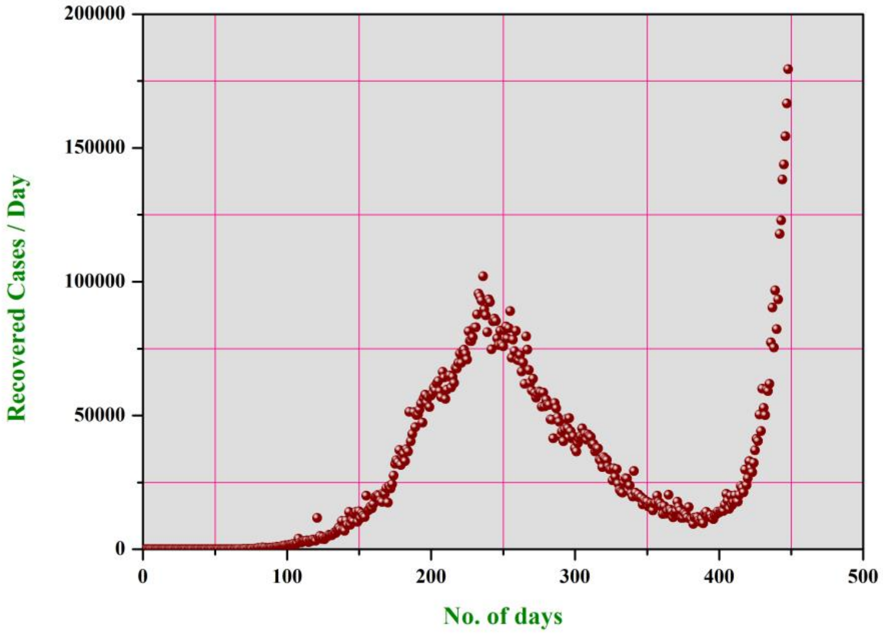


Figure 3: Daily recovered cases in India. The data plotted from 30/01/2020

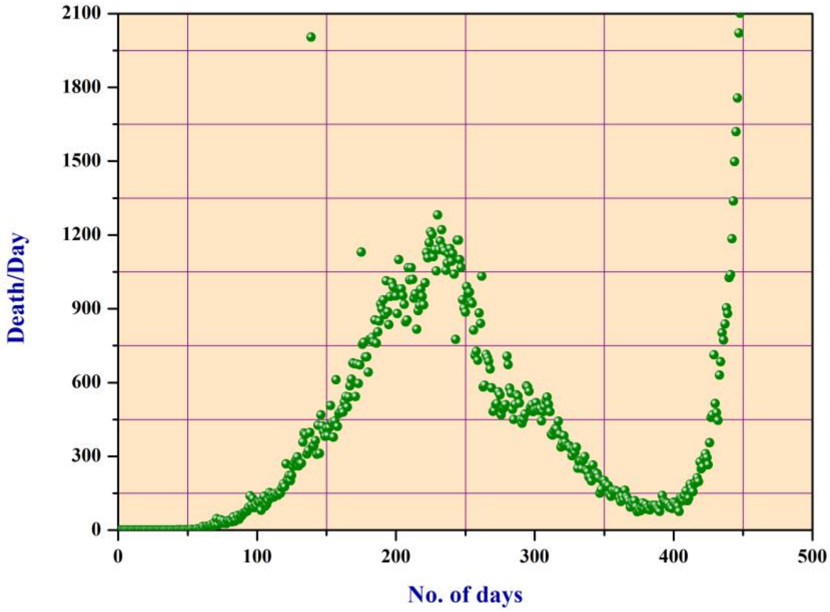


Figure 4: Daily deceased cases in India. The data is plotted from 30/01/2020.

Data mining and model parameter estimation

The number of cases, both daily and cumulative, for confirmed, recovered and deceased individuals is provided at https://www.covid19india.org/. The confirmed cases built the I(t) database and R(t) comprises of the recovered+deceased cases in the present model. We call R(t) as the removed population. These numbers help us to check the reliability of the model adopted and for the model parameter estimation as well. Further, since $\boldsymbol{\beta}$ is directly dependent on the recovery time, we estimated the T value from the recent work of George et al. [2]. In the article, authors have provided the recovery rate for the 28 states and 9 Union Territories(UTs) of India. We computed the weighted mean of the recovery time of the states and UTs to obtain the average recovery time (T) for the country. T was found to be 22.653 days and hence $\boldsymbol{\beta}$ is determined to be 0.0462 /day. $\alpha$was determined by the best fit of the SIR model output to the actual data taken from March 1 to April 21, 2021. The value obtained for α is 0.1080. The data was analyzed from March 1, 2021 when the infected number of daily cases was 12270.Thus, the initial conditions are set to I(0) = 12270, R(0)=0 and S(0) = N - I(0) - R(0). Further, N, the total population is exactly set to 139,11,56,927 in the calculation. The model parameters used in the present work is tabulated in table 1 and the output compared with the actual population is shown in figure 5 and 6. We see a good matching for the confirmed and removed cases and hence the parameters can be relied for further simulations.

TABLE(1):Model Parameter

Parameter	Description	Value
N	Total Population	139,11,56,927
I(O)	Initial infected	12,270
R(O)	Initial removed	0
S(O)	Initial susceptible	N-I(O)
α	Infected rate(per day)	0.1080
β	Recover rate(per day)	0.0462
T	Recovery time	22.653
R_O	Basic reproduction number	2.34

Results

The number of susceptible, infected and recovered individuals obtained from the present modelling is shown in figure (7). We find that the second wave is similar to the first one where the effect spans for almost a year. On a similar line, the peak is observed around the 200th day from the outbreak of the wave. However, around 20% of the population will be affected this time; the number is appreciably high from the first wave data. This is expected, as from figure1 we see that the present number of confirmed cases has already surpassed the peak population of the first wave. The strike is enormous and we forecast that the peak will be observed by the end of September. Considering the seriousness of the present situation, the modelling was done considering the vaccination too. On an average, daily 30,00,000-40,00,000 individuals are vaccinated as per the government data. This number is quite low to bring any effect on the output of the present work and hence not shown here. The vaccination rate required to stop the spread of the epidemic is discussed later in this section. Further, as mentioned earlier the vaccination will start showing its effect only after a few months. Hence, lockdown is the immediate option available to halt this epidemic spread. The basic reproduction number R_0 from the present modelling was determined to be 2.34.

However, with time this number changes and hence the estimation of the effective reproduction number (R_{eff}) is vital to understand the real time impact of the disease. We find from figure

(8) that after 100th day, i.e. from the second week of June, the reproduction number will start decreasing. R_0 remains the same throughout the period, though R_{eff} points that as time passes any infected person will be less likely to infect another individual. The transmission rate directly related to R_{eff} is shown in figure (9).

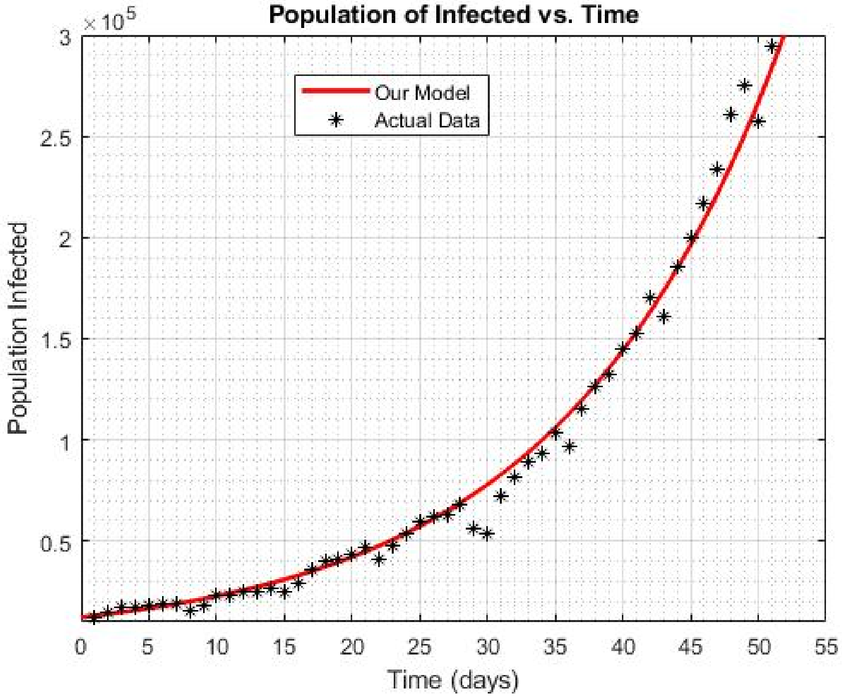


Figure 5:-Daily infected cases for the second wave.The data is plotted from 01/03/2021

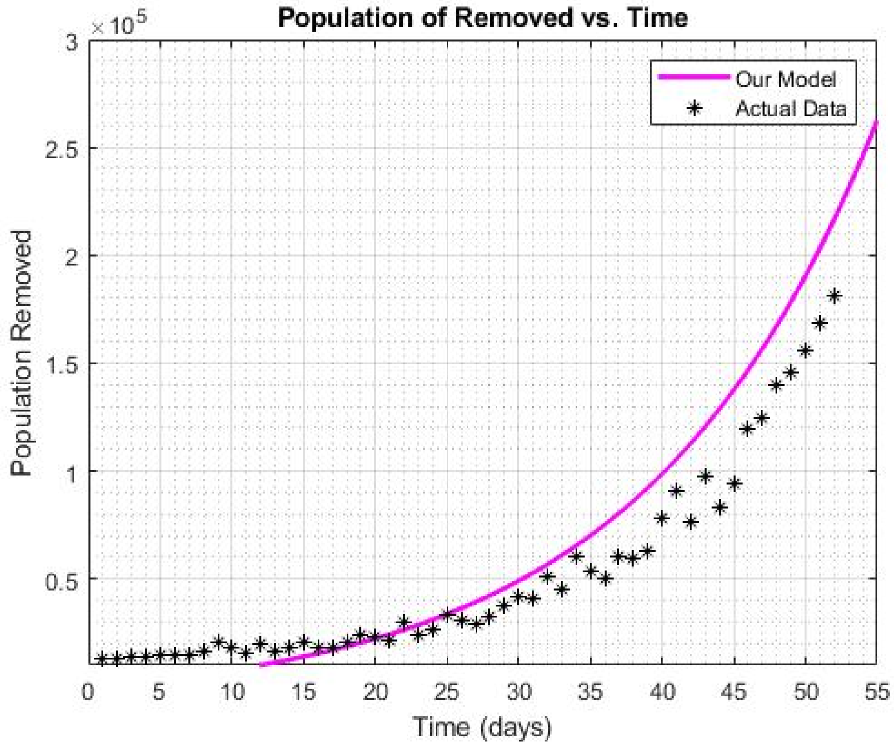


Figure6:- Daily removed (recovered + death) cases for the second wave. The data is plotted from 01/03/2021

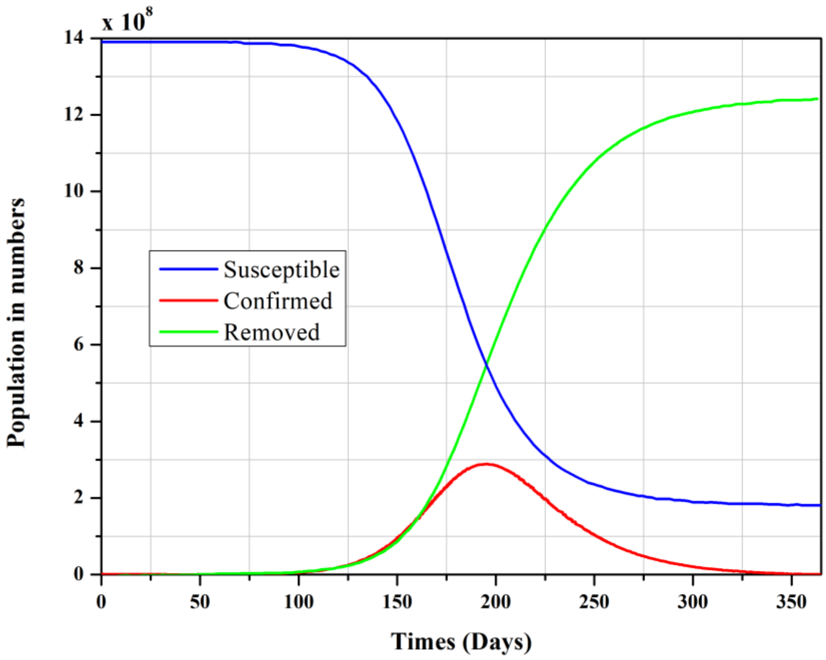


Figure 7: Number of susceptible, infected and recovered individuals for the second wave of COVID- 19 in India.

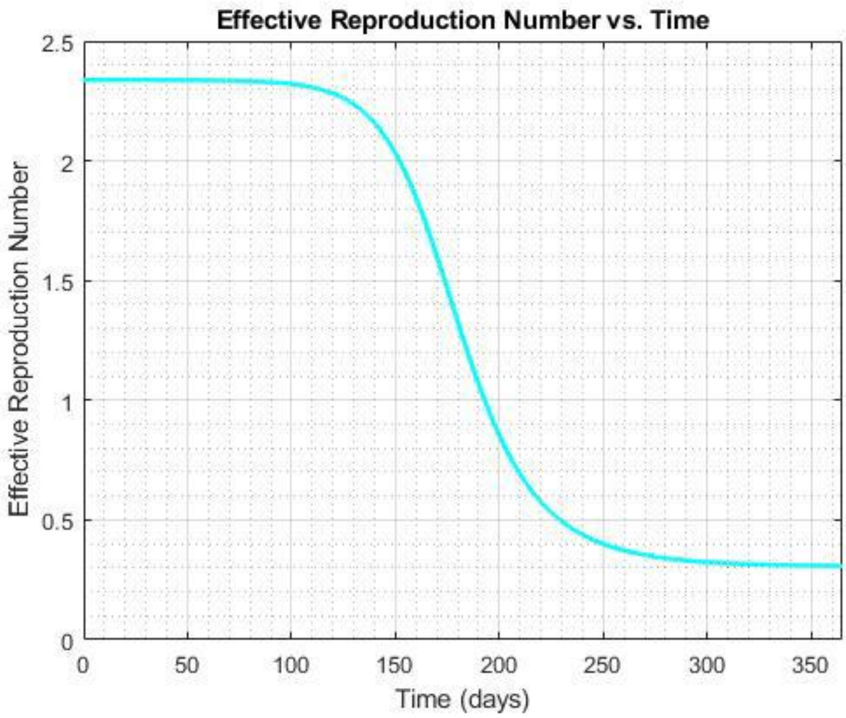


Figure 8: Effective reproduction number for the second wave of COVID-19 in India.

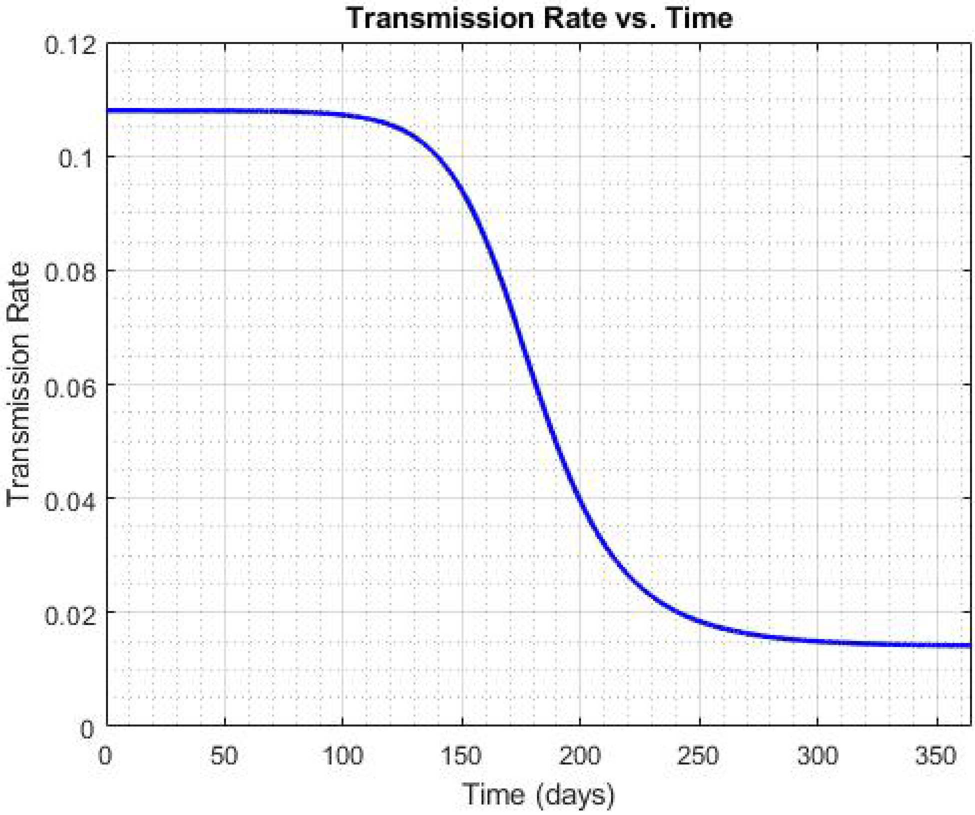


Figure 9: Transmission rate for the second wave of COVID-19 in India.

The model parameter α represents the interaction among the population and hence a decrease in its value will demonstrate the lockdown effect. In figure 11, the αvalue is decreased and we can see that confirmed cases (I) reduces and more individuals become susceptible to the disease. Further, the I curve becomes flatter as the interaction (or the strength of the lockdown) decreases (increases). Further, the peak also shifts rightwards with decreasing α and hence the government will have adequate time to improve healthcare facilities.

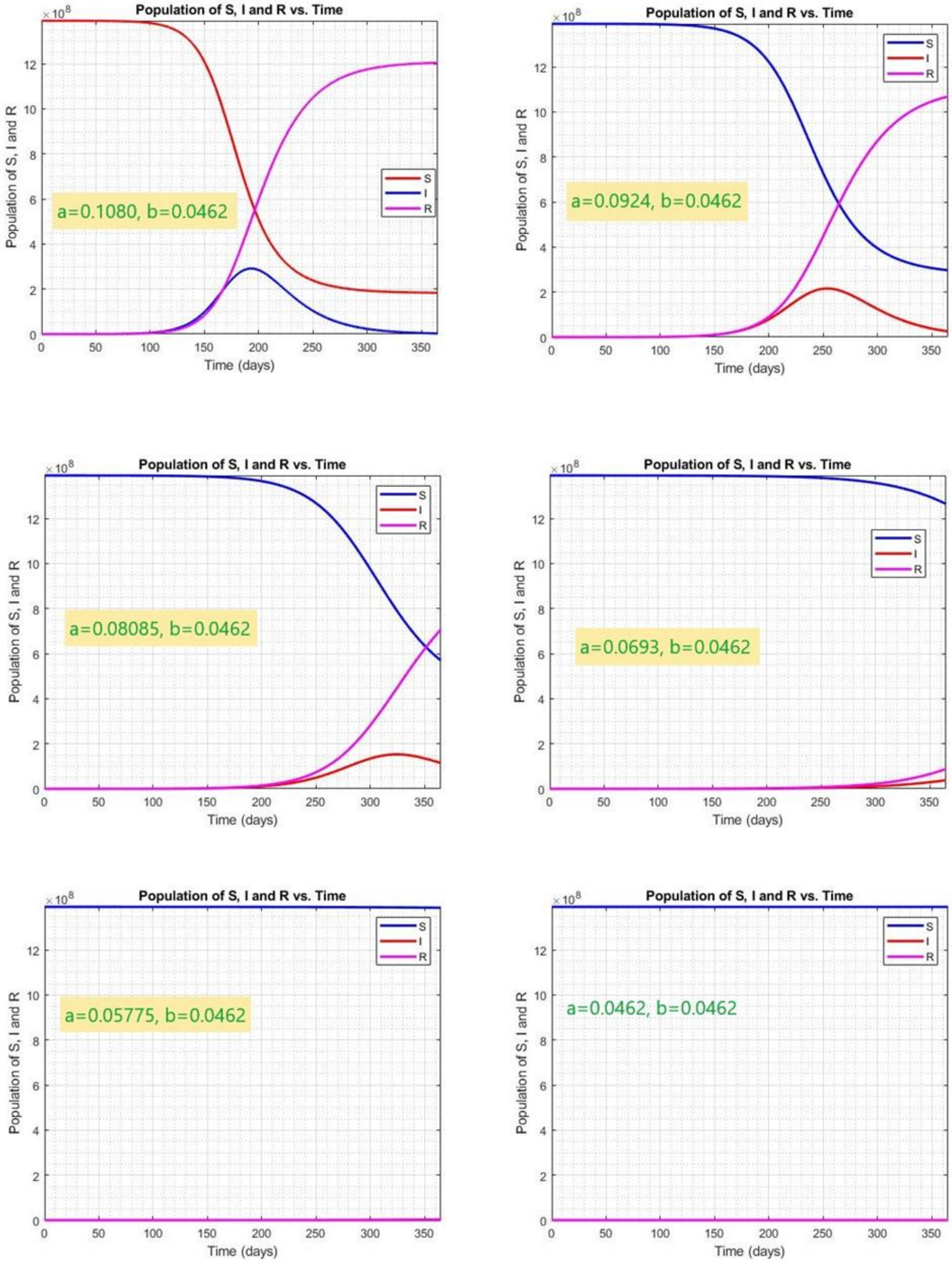


Figure 11: Effect of decreasing α.

We plot the S, I and R curves for T equals 20, 17, 14 and 10 days as against the present 22.64 days in figure(12). If the infected individual receives medicines and proper treatment in due time, the epidemic curve will certainly flatten.

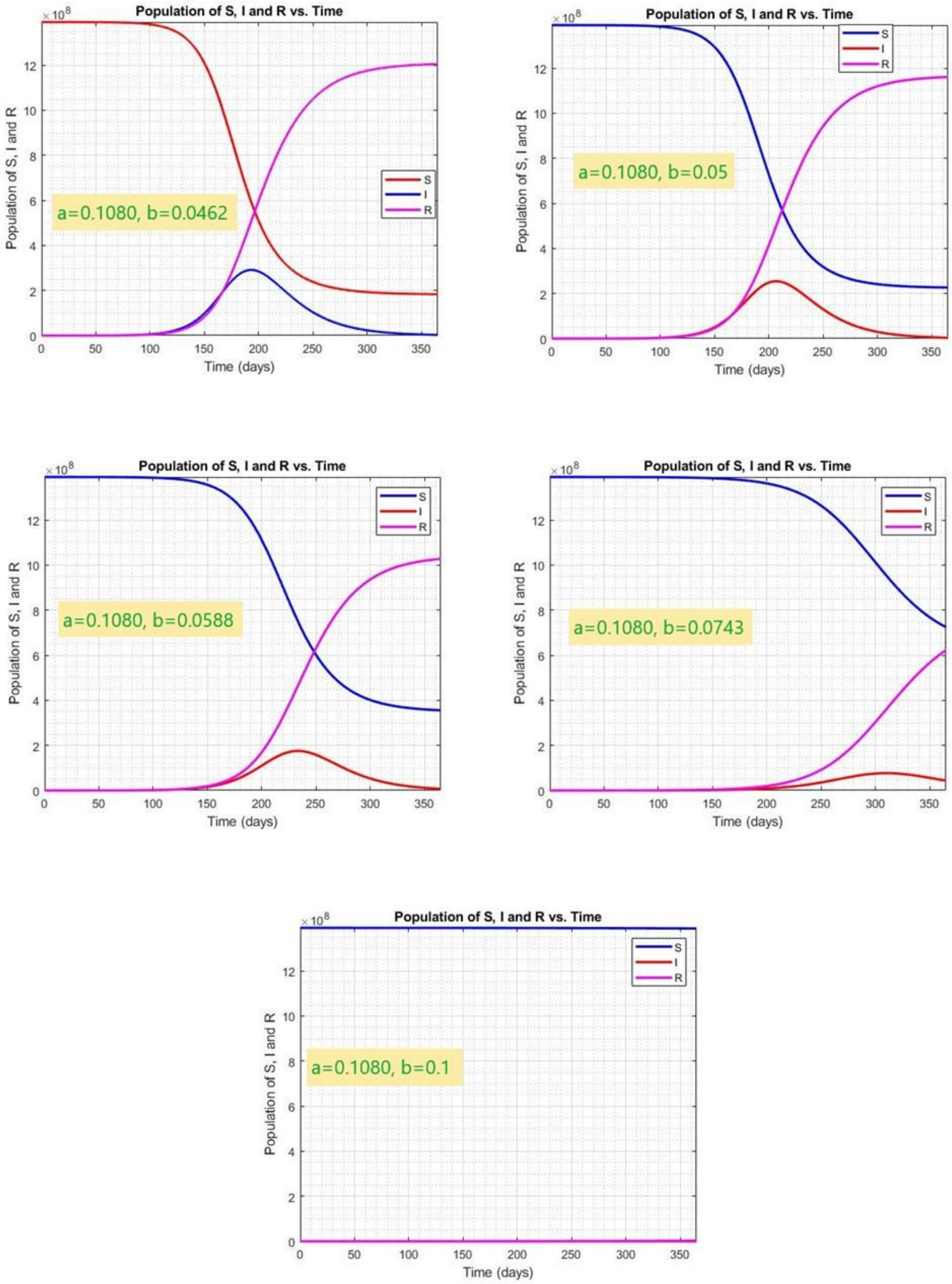


Figure 12: Effect of increasing $\boldsymbol{\beta}$.

CONCLUSIONS:-

Models using MATLAB simulations can help predict the details of the epidemic. The model that we are developed will give the predictions which will help us understand the number of susceptible-incidence rates. Our SIR model can provide a theoretical frame work and predictions of the spread of COVID-19 .This prediction is useful for public and government authorities to control the spread of COVID-19 in large populated country like India.

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