Prediction of Coronavirus Infected People During Coronavirus Outbreak In India And Hence Deciding Whether This Is An Epidemic Or Not In India

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Abstract: Differential equation is a mathematical tool to model the growth of two populations which interact, such as a population of sick people infecting the healthy people around them. Differential equations can be used to predict when an outbreak of a disease will become so severe that it is called an epidemic [4] [6]. Currently in India, newly found coronavirus in China have infected many people all over India. The rate of increase of infected people is slowly but steadily growing day by day. This development of coronavirus outbreak in India can follow the world where WHO (WORLD HEALTH ORGANISATION) had already declared it as a pandemic which refers to the epidemic all over the world [5]. To control the epidemic, it is critical to predict how many people will get infected and when. The aim of this research paper is the prediction of coronavirus infected people in India using differential equations and to take steps toward controlling an epidemic.

Keywords: Differential equation, Epidemic, Coronavirus, Coronavirus Outbreak, Susceptibles, Infecteds, Recovered or Removed, Population, Population of India, People, Disease, The CV-trajectory

Introduction: In medical language, an epidemic means a sudden outbreak that affects more than the expected number of cases occurring in a community or region during a given period of time. An epidemic may be restricted to location however, if it spreads to other countries or continents and affects a substantial number of people, it may be termed as a pandemic [1] [6].

A sudden coronavirus outbreak, spread in the city of Wuhan in China late in the last year 2019, has shifted to other countries in the world and worst affected the countries like China mainland, Italy, Spain, Germany, France, other EU countries and United States of America (USA) in January, February and March in the year 2020 and still continuing in some of those countries. This coronavirus outbreak has entered in India in the month of March, 2020. Since then, it has gripped whole of India affecting several people and still continues to affect [5].

In current situation as on 15th July, 2020, it has not taken the shape of an epidemic yet which is fortunate for a country like India with a whopping population of 138 crores of people. At present the population of India is standing at $P = 1{,}380{,}493{,}070$. This is a very big population to control during an epidemic situation. If it spreads like an epidemic, it will be difficult to contain this coronavirus outbreak in India. In this situation in India, there can be an ample number of infected people and among them more number of people may be died if situation worsens and if people are susceptible to the disease.

It is the responsibility of the subject of mathematics to calculate and predict the number of people to be affected by this coronavirus outbreak in India through using differential equations which can model the current situation [4]. This responsibility ultimately passes towards the authors of this research paper who are mathematics people in India.

Differential Equation as Model of the Coronavirus Outbreak:

This is most commonly used model for an epidemic called the $S - I - R$ model as it involves the Susceptibles (S), Infecteds (I) and Recovered or Removed (R). This model can be applicable to the current situation of coronavirus outbreak in India [4]. It will decide whether the given situation is an epidemic or not in India. The population of India is divided into three groups:

S = The number of *Susceptibles*, the people who are not yet sick but who could become sick

I = The number of *Infecteds*, the people who are currently sick

R = The number of *Recovered* or *Removed*, the people who have been sick and can no longer infect others or be reinfected or the people who have been died.

Assuming that those people who have recovered from the disease are no longer susceptible to the disease, the total population of India remains $S + I + R$.

Now, as the outbreak spreads, the number of infecteds increase with time. The number of susceptibles decrease with time as people become infected with time. We assume that the rate at which people become infected is proportional to the number of contacts between susceptibles and infected people. It is expected that the number of contacts between the two groups, susceptibles and infecteds to be proportional to both S and I. Thus, we assume that the number of contacts is proportional to the product SI.

In other words, the rate of change of susceptibles with time is proportional to SI. Thus, we obtain $\frac{dS}{dt} = -aSI$, for some constant $a > 0$ [4].

Here, a is the constant of the rate at which susceptibles get sick or be infected and the sign is negative because S is decreasing.

As on 15th July, 2020, 9,36,181 people have been infected by the coronavirus outbreak in India followed by more people getting infected the next day and the days ahead. The number of infecteds $I = 9{,}36{,}181$ as on 15th July, 2020 in India.

So, a can be the ratio of I is to P, where P being the total population of India at present.

That is, $a = \frac{9{,}36{,}181}{1{,}380{,}493{,}070} = 0.00068$. Thus,

$$\frac{dS}{dt} = -0.00068SI. \quad (1)$$

This is the differential equation involving the rate of change of susceptibles with time.

The number of infecteds changes in two different ways. Firstly, the newly sick people are added to the infected people group and secondly, the others are getting well from the disease i.e. recovered or getting died. The newly sick people are those people who are leaving the susceptibles group and so they accumulate at a rate aSI. The sign is positive because the number of infecteds is increasing.

On the other hand, the infected people group is decreasing as people leave the group either because they recover or die or because they are removed from the group and can no longer infect others. We assume that people are removed at a rate proportional to the number of sick people or bI, where b is a positive constant. Here, b is the constant of the rate at which infecteds get removed.

At present, the number of recovered or removed is $R = 6{,}16{,}341$ among $I = 9{,}36{,}181$ infected people as on 15th July, 2020 in India. So, b can be the ratio of the number of recovered or removed R and infected people I. That is, $b = \frac{R}{I} = \frac{6{,}16{,}341}{9{,}36{,}181} = 0.6584$.

Thus, the rate of change of infecteds with time is increasing with the product SI and decreasing with I. That is

$$\frac{dI}{dt} = aSI - bI.$$

$$\therefore \quad \frac{dI}{dt} = 0.00068SI - 0.6584I \text{ [4]}. \quad (2)$$

This is the differential equation involving the rate of change of infecteds with time.

Because of our assumption, R, the recovered or removed group increases at the rate of bI, so

$$\frac{dR}{dt} = bI = 0.6584I \text{ [4]}. \quad (3)$$

Here, it is assumed that the recovered person cannot be infected again at least in the short run. In the long run, the same person can get the infection again but we exclude this case in the context of the current coronavirus outbreak in India.

During the outbreak, the total population $S + I + R$ does not change since we assume that the number of new born childs and the number of people who are dying from other illnesses, are negligible and cannot be infected. Thus, if we know S and I, we can calculate R easily. So, we consider the two differential equations

$$\frac{dS}{dt} = -0.00068SI$$

And $$\frac{dI}{dt} = 0.00068SI - 0.6584I.$$

We know that S and I are the variables depending on time t. We expect to draw the graphs of S and I against t. However, S and I are interdependent and so we will first look at a graph of I against S.

The SI-Plane for the CV-Trajectory:

To analyse how the coronavirus outbreak progresses in the country, we plot a point (S, I) representing the number of susceptibles and number of infecteds at any point of time. The points are plotted on SI-Plane on which the point (S, I) moves as S and I change. The path along which the point moves is called the trajectory or orbit of the point [4]. This trajectory is specially named for coronavirus disease as the CV-trajectory or the CV-orbit.

Now, our work is to find CV-trajectory which will give us the progress of the coronavirus disease in India. To study the CV-trajectory, we require a differential equation relating to S and I. We think I as a function of S and S as a function of t and use chain rule to obtain

$$\frac{dI}{dt} = \frac{dI}{dS}\frac{dS}{dt} \text{ which gives}$$

$$\frac{dI}{dS} = \frac{\frac{dI}{dt}}{\frac{dS}{dt}}.$$

Thus, giving $$\frac{dI}{dS} = \frac{0.00068SI - 0.6584I}{-0.00068SI}.$$

As I is not zero, this equation becomes $$\frac{dI}{dS} = -1 + \frac{968.24}{S} \text{ [4].} \qquad (4)$$

This equation will give the solution for the CV-trajectory by simply integrating with respect to S. We yield

$$I = -S + 968.24 \ln S + C.$$

Initially, the spread of coronavirus have infected 9,36,181 people as on 15th July, 2020 i.e. we use $I_0 = 9{,}36{,}181$ and $S_0 = P - I_0 = 1{,}379{,}556{,}889$. Using these initial values, we yield a relation

$$I = -S + 968.24 \ln S - 968.24 \ln(1{,}379{,}556{,}889) + 1{,}380{,}493{,}070$$

Or $$I = -S + 968.24 \ln\left(\frac{S}{1{,}379{,}556{,}889}\right) + 1{,}380{,}493{,}070. \qquad (5)$$

This equation gives the relation between I and S during coronavirus outbreak in India. The graph of I against S is given by the following figure-1.

Solving the equation $\frac{dI}{dS} = -1 + \frac{968.24}{S} = 0$, we yield $S = 968.24$ [4].

The graph shows that if a trajectory starts with initial value $S_0 > 968.24$ then I first increases and then decreases to zero. On the other hand, if $S_0 < 968.24$, then I decreases right away. In other words, S decreases and I increases first and then I decreases as S decreases continuously.

The peak value of infecteds I always occurs at this value of S. This value $S = 968.24$ is called a *threshold value*. It is denoted by $S_{threshold}$. So, $S_{threshold} = 968.24$.

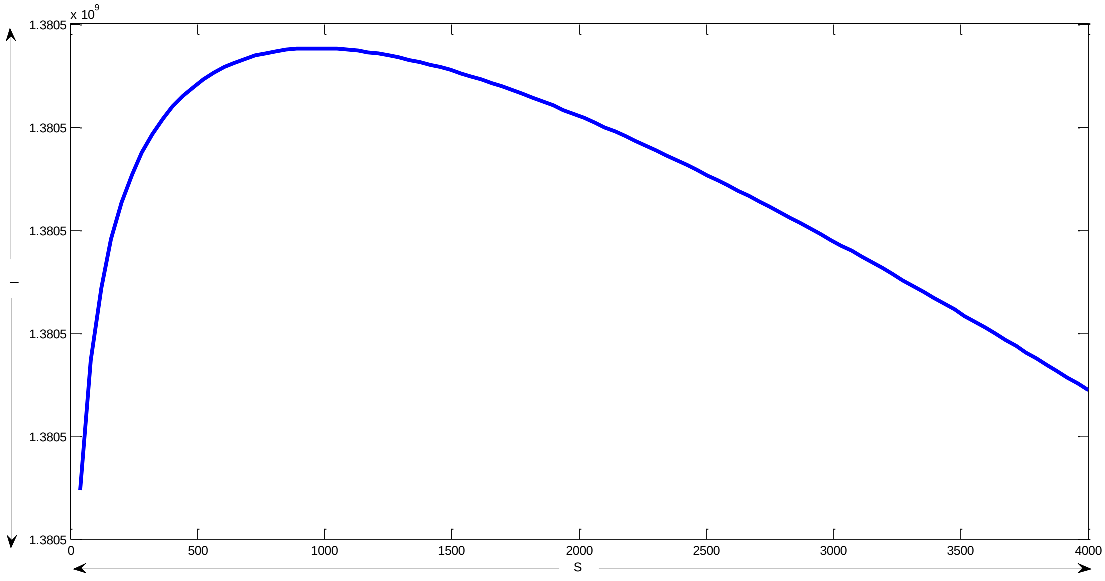

figure-1

By studying the CV-trajectory, we conclude that if S_0 is around or below $S_{threshold}$, there is no epidemic in India. If S_0 is significantly higher than $S_{threshold}$, we say that it is an epidemic in India [4]. The graph shows the total number of people of India who are expected to get INFECTED (Prediction of infected people) during the epidemic. The point at which the CV-trajectory crosses the S-axis, represents the time when the epidemic has passed since $I = 0$ on this axis. The S-intercept indicates how many people get the disease due to coronavirus outbreak in India.

Graphs of S and R against time t:

The solution of the equation (2) gives the exponential growth of I over the time. The two graphs given below explain the progress of the coronavirus disease over the time. This progress shows that the number of susceptibles S decreases throughout the coronavirus disease as healthy people get sick. The number of recovered or removed R increases as the outbreak runs over the course of time.

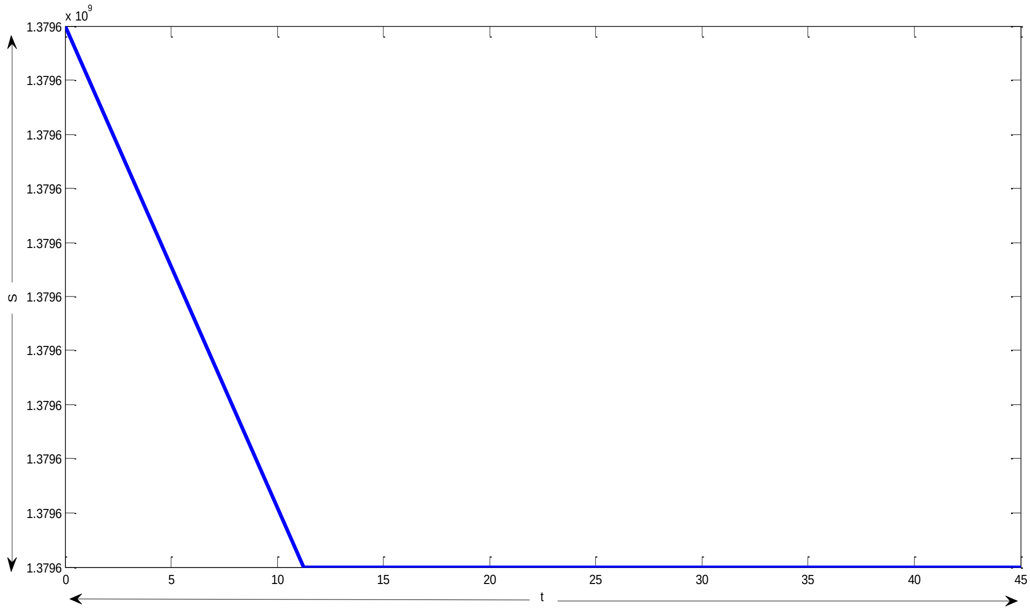

figure-2

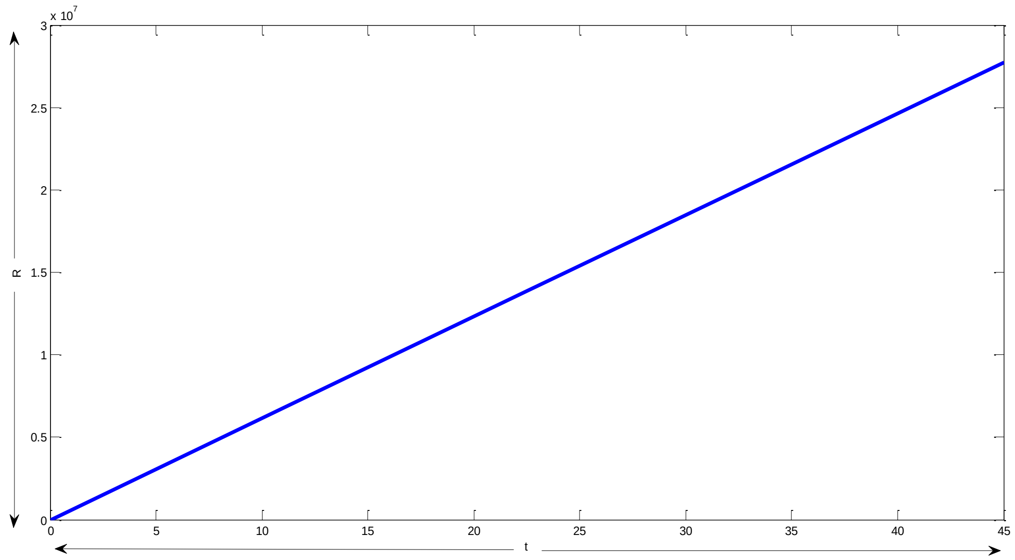

figure-3

Conclusion:

The prediction of the coronavirus infected people stands at the maximum number of people of India as per the CV-trajectory. After reaching this level of infected people at the *threshold value*, the number of infecteds decreases. This suggests that the coronavirus outbreak can be controlled over the course of time. As it is experienced in other countries, it can take some more days but the disease situation will be under control definitely.

The number of susceptibles, when reaches above the *threshold value* $S_{threshold} = 968.24$, it can be declared as an epidemic in India. This research paper concludes that the coronavirus outbreak is an epidemic in India in current situation as the number of susceptibles is high. Currently, single-day spike of 83,341 fresh coronavirus cases were reported on 4th of September, 2020 with total cases crossing 39 lakhs mark in India. The number of deaths among single-day spike is 1096 in a day according to union health ministry data. This situation could be harder to control in India with this high level of population.

The number of infected people can be predicted and treated at the medical facilities of India. India has enough medical infrastructure to control this level of the disease. The infected people can be recovered quite comfortably with this kind of facilities.

Even if India reaches to the further stage of the epidemic in near future, the treatment can be provided on the war footing. However, Indian government have taken the precautionary step to impose the lockdown on the entire country that could have saved the people of India as yet.

Over the time, the coronavirus outbreak can be contained and eventually the number of infected people gets to zero in India.

Time by time the CV- trajectory for India can be studied by medical personnel and the steps can be taken to contain the coronavirus disease in India.

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