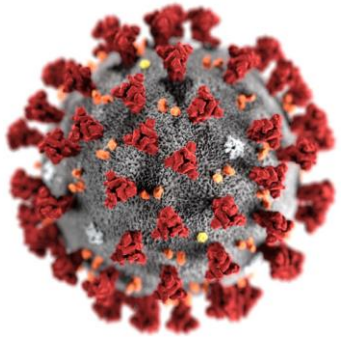

The Future of Coronademic: Predicting the Trajectory of COVID-19 Epidemic in India

By Ayushi Sharma (0729)
MBA HM-23 (Hospital)
Organization: IQVIA Delhi

Under the Guidance of
Dr. Piyusha Majumdar

IIHMR UNIVERSITY

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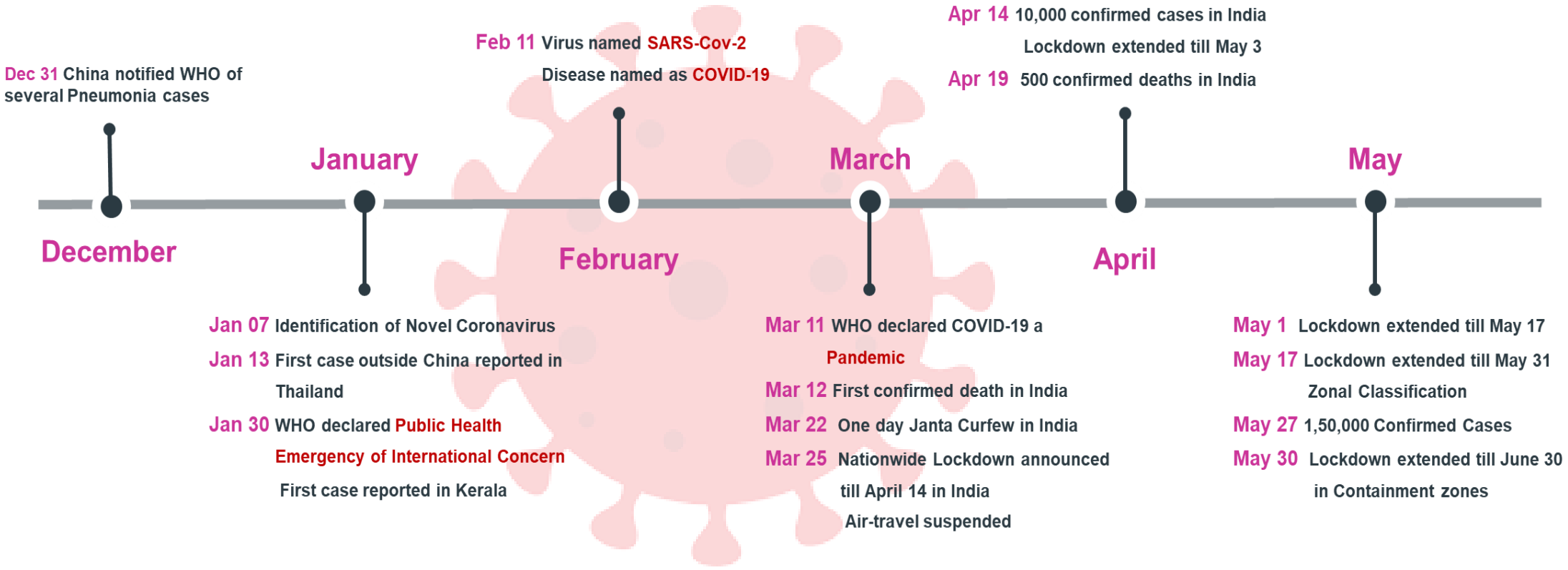
Background

A history of Coronavirus Disease 2019



Epidemiology of COVID-19: India

- India saw its first COVID-19 positive case on 30th January 2020 in Kerala.

2.83%

Case Fatality Rate

India's CFR is relatively low compared to the global 6.12%.

4.7%

Test positivity Rate

India has tested 38,37,207 samples as of May 31st 2020

2.3

Reproduction Number

The reproduction number decreased during the lockdown period

48%

Recovery Rate

has improved astonishingly from 11.42% in mid-April to 48% in May end

- As of May 31, 2020:

182143
Total Number of Cases

5164
Total Deaths

86984
Cured/Discharged

3837207
Number of Tests Done

Mathematical Modelling of Epidemics

- The history of mathematical modelling of spread of disease goes down to 1760 when Daniel Bernoulli, formulated a mathematical model to evaluate the impact of variolation on life expectancy
- Mathematical models are used to understand how a virus spreads within the host population, both in time and space
- It involves developing a set of mathematical equations that simulate reality
- Mathematical models of epidemics are essentially of two types:

➢ **Stochastic models** are useful in estimating probability distributions of potential outcomes by allowing for chance variations

➢ **Deterministic/Compartmental models** do not entail any element of chance

Aims & Objectives

Epidemic forecasting using predictive modelling plays a crucial role in studying patterns, planning and evaluating public health response measures. Predictive modelling counters the unpredictable nature of the COVID-19 outbreak and can considerably help the government in planning and evaluating through informed decisions.

Aim: To understand the growth trajectory of the COVID-19 outbreak in India by forecasting the impact of the outbreak using a deterministic modelling approach

Objectives:

- To understand the transmission dynamics of COVID-19 Epidemic in India using SEIRD Model
- To forecast the trajectory of COVID-19 Epidemic in India for the next one year using SEIRD Model
- To compare the estimated trajectory with Actual data
- To explore a way forward in terms of public health preparedness with the help of SEIRD model

Literature Review

The literature reviewed for this study included attempts made in predicting the COVID-19 outbreak using the Kermack-McKendrick's SIR model and its role in studying the epidemiology of the outbreak especially in capturing spread of the disease and estimating impact of the pandemic. These studies revealed that such models provide insights on time dependence pattern and the time trend of the disease-incidence. Outbreak dynamics like Reproduction Number, Herd Immunity, Cases, Recoveries, Deaths etc. varied over the period of time across different regions. Earlier studies were able to calculate the disease dynamics aid in predicting the later stages of outbreak. The SIR model was able to predict the size and end of the outbreak however these predictions changed across the studies conducted at different time periods. Few studies set out to suggest interventions that could mitigate the impact of outbreak based on the predictions made. A study that captured infections and deaths in Sweden due to COVID-19 using multiple models (8) and a similar manner of study done in India (3) suggested an association between testing rate and accuracy of the model. SIR model has been applied to study the outbreak dynamics at state level as well, especially in the worst hit states such as Maharashtra, Gujarat and Delhi (12), (13), (14).

Methodology

- *Research Question*: What is the trajectory of COVID-19 epidemic growth in India as per transmission dynamics modelled through SEIRD Model?
- *Research Design:* Predictive study on secondary data is adopted for the purpose of this study
- *Data Source:* Data on number of confirmed cases, deaths and recoveries is extracted from MoHFW and Our World In Data for the time period of 30th January 2020 to 31st May 2020
- *Material & Tools:* MATLAB software is used to execute the model

Model

- **SEIRD Model** divides the host population into five compartments based on their epidemiological status.

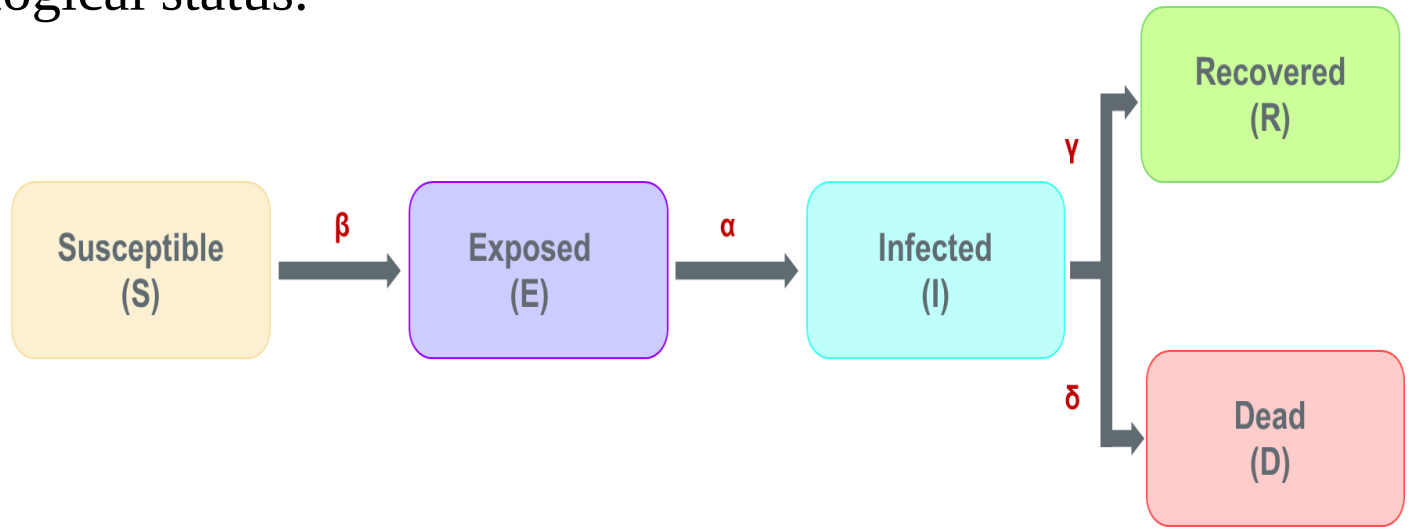


Figure: Diagrammatic Representation of SEIRD Model

- Susceptible (**S**) population consists of people vulnerable of contracting an infection
- Exposed (**E**) population is infected but not yet infectious
- Infected (**I**) population includes the people are capable of transmitting the infection to others
- Recovered (**R**) population are the people who move out of the infected category after recuperation
- Dead (**D**) population includes people who die of the infection

Equations

1. $dS/dt = -\beta SI$

- *Where, β, controls the tr*ansmissibility or rate of spread. The Basic R0 used in this study is 2.25 and R0 during lockdown is taken to be 1.5.

2. $dE/dt = \beta SI - \alpha E$

- Incubation rate $\boldsymbol{\alpha}$, is the rate of latent individuals becoming infectious. The incubation period used in this study is 5.2 days.

3. $dI/dt = \alpha E - \gamma I - \delta I$

- Recovery rate $\gamma = 1/D$, is determined by the average duration of recovery D, of infection. The Duration used in this study is 7.

- δ represents the death rate associated with the disease. The death rate used in this study is 2.83%.

4. $dR/dt = \gamma I$

5. $dD/dt = \delta I$

Initial Conditions

- S(0)= 138e7 - 100
- E(0)= 67
- I(0)= 30
- R(0)= 3
- D(0)= 0

Assumptions

- The model assumes a closed population, that the population remain the same for the time period and nor birth or death take place.
- There is no immunity against the infection amongst the population
- The R0 post lockdown will be same as pre lockdown

Results

COVID-19 Outbreak Trend in India

In India, after the first case was reported on 30th January in Kerala, no significant growth in the cases was observed in February. It was only after 5th March 2020 that a consistent surge in the number of reported cases was observed in many parts of the country. In view of this sudden growth of cases, Government of India imposed a nation-wide lockdown from 25th March 2020 which was extended till 31st May 2020. The transmissibility of COVID-19 reduced considerably along with lockdown as indicated by the lowering of R0. However, the infection has been growing rapidly in the country with 182,143 cases, 86984 recoveries and 5164 deaths as of 31st May 2020.

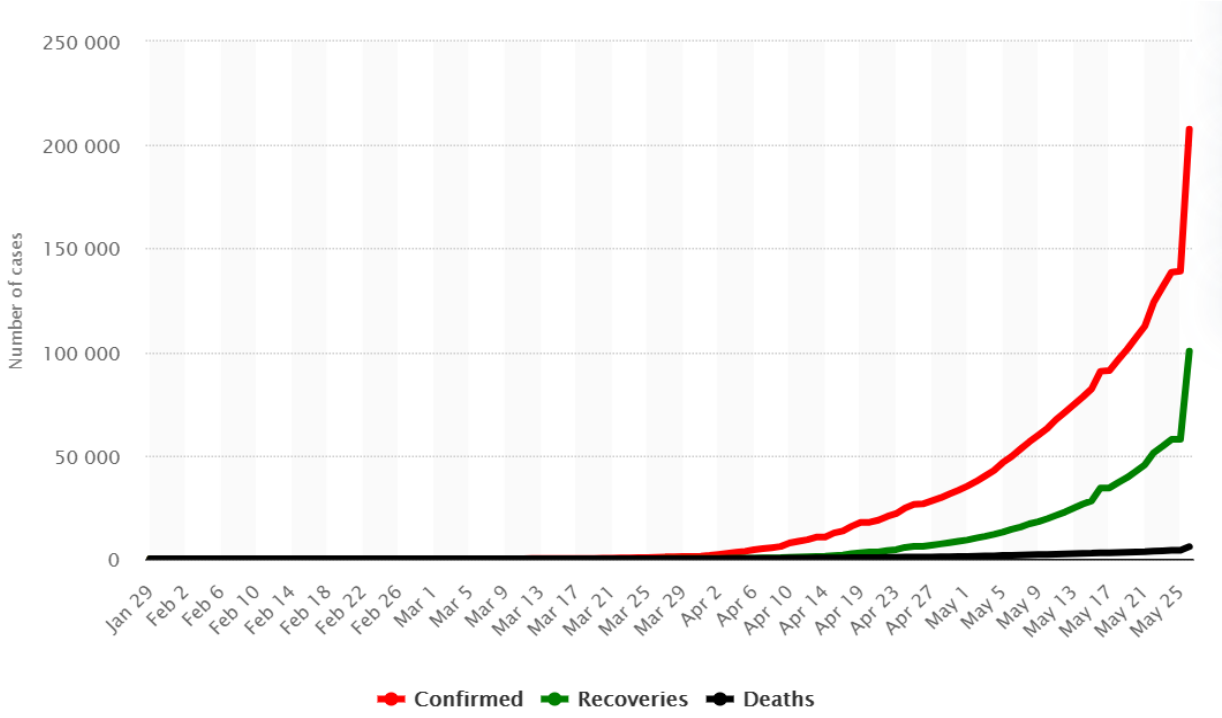


Figure : Daily Cumulative Confirmed Cases, Recoveries and Deaths recorded in India from January to May 2020 (Source: Statista)

Estimating the Trajectory of COVID-19 in India

1. Predicting the Uninterrupted Course of COVID-19 in India

As per the projections:

- With the S curve having a downward slope, almost 50% population will remain susceptible by the first week of September 2020. The curve begins to flatten around October 2020 as per the graph.
- The peak of pre-infectious state will be observed on 20th July 2020 at a population of 148 million.
- The bell shaped I (Infected) curve has its peak at 184,500,000 near to 16th August 2020 (164 days).
- The R (Recovered) curve shows an upward trend with a total of 1,168,900,000 people estimated to recover in next one year
- Approximately 30 million people would succumb to the disease in one year.

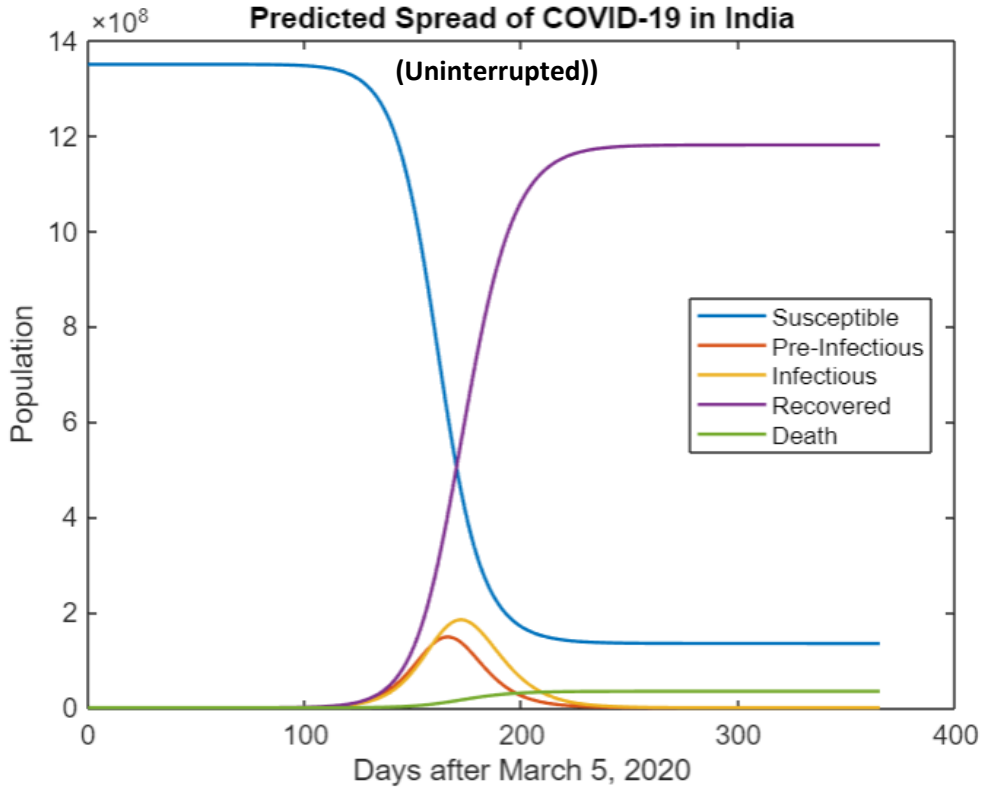


Figure: Predicted Spread of COVID-19 in India without considering the effect of lockdown

2. Predicting the Course of COVID-19 in India (With Lockdown)

As per the projections:

- The susceptible population will reduce to 50% by last week of September. The S curve is flattening around 13th November 2020.
- The E curve has a peak at 104 million people around 1st September 2020 post which the curve begins to decline.
- The peak of I curve is estimated at 184,450,000 on 185th day of the graph i.e. 6th September 2020. The I curve begins to flatten around first week of November 2020.
- A total of 1,168,900,000 people will recover from COVID-19 in the next on year.
- Nearly 30 million would become the victim of COVID-19 in the next one year

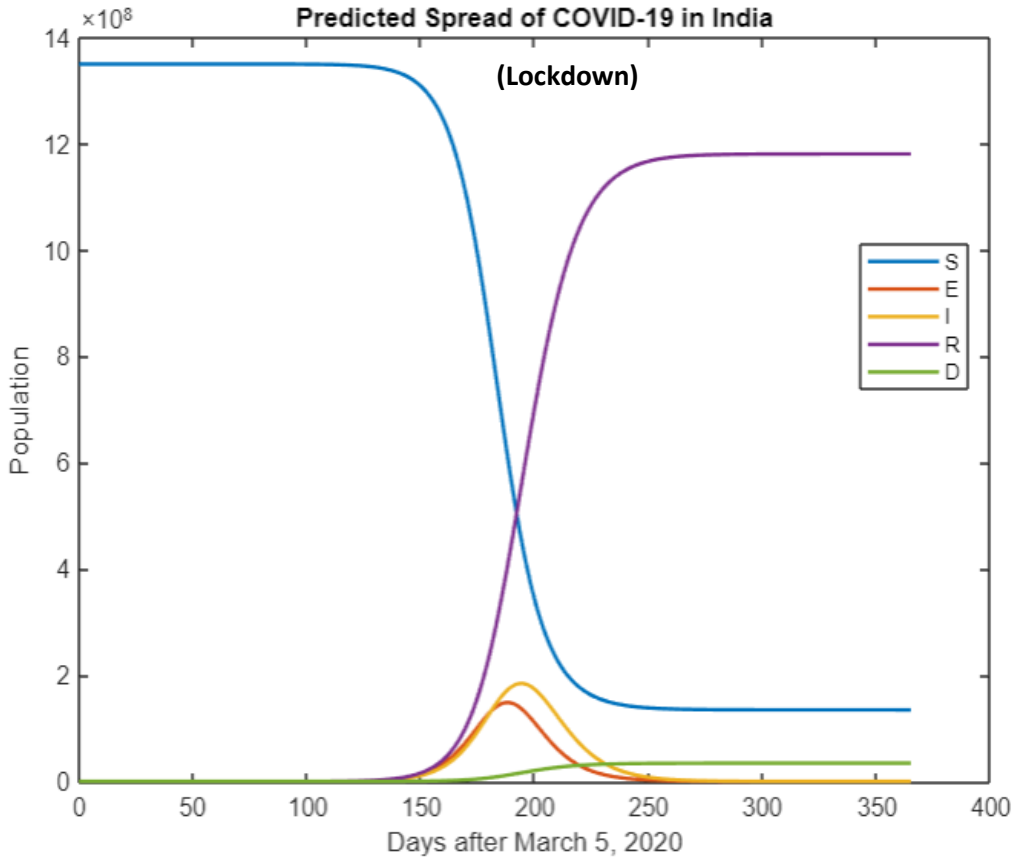


Figure: Predicted Spread of COVID-19 in India considering the nationwide lockdown

Actual and Predicted Impact: A Comparison

The actual and predicted curves of total confirmed cases for the time period of 5th March 2020 to 31st May 2020 show a significant gap in both the graphs.

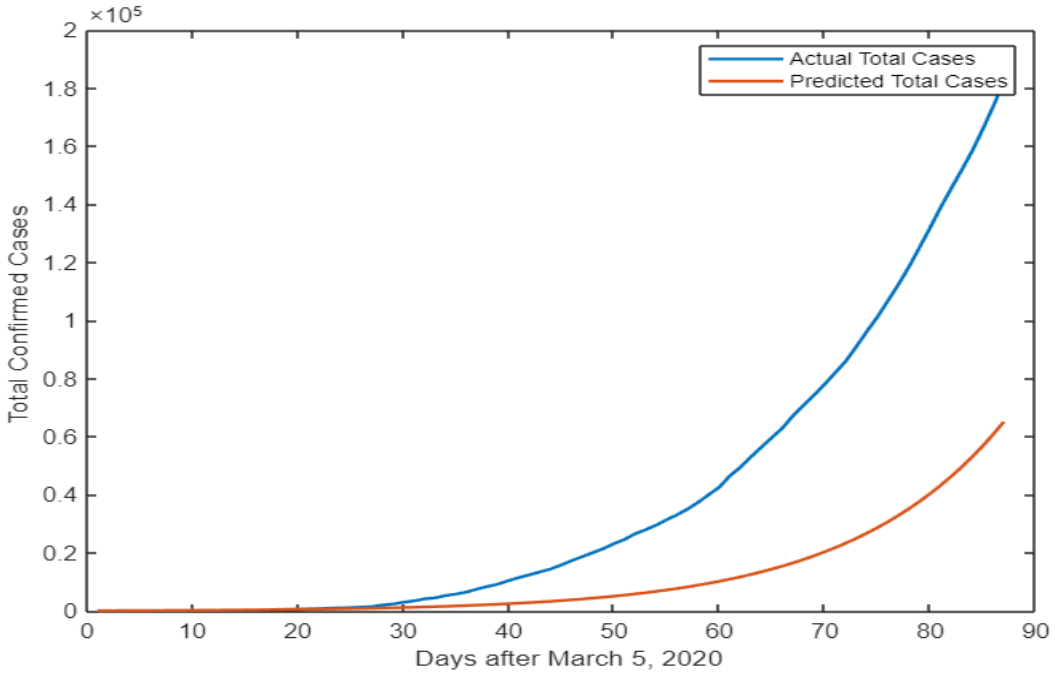


Figure :Actual VS Predicted Spread considering Lockdown of COVID-19 in India

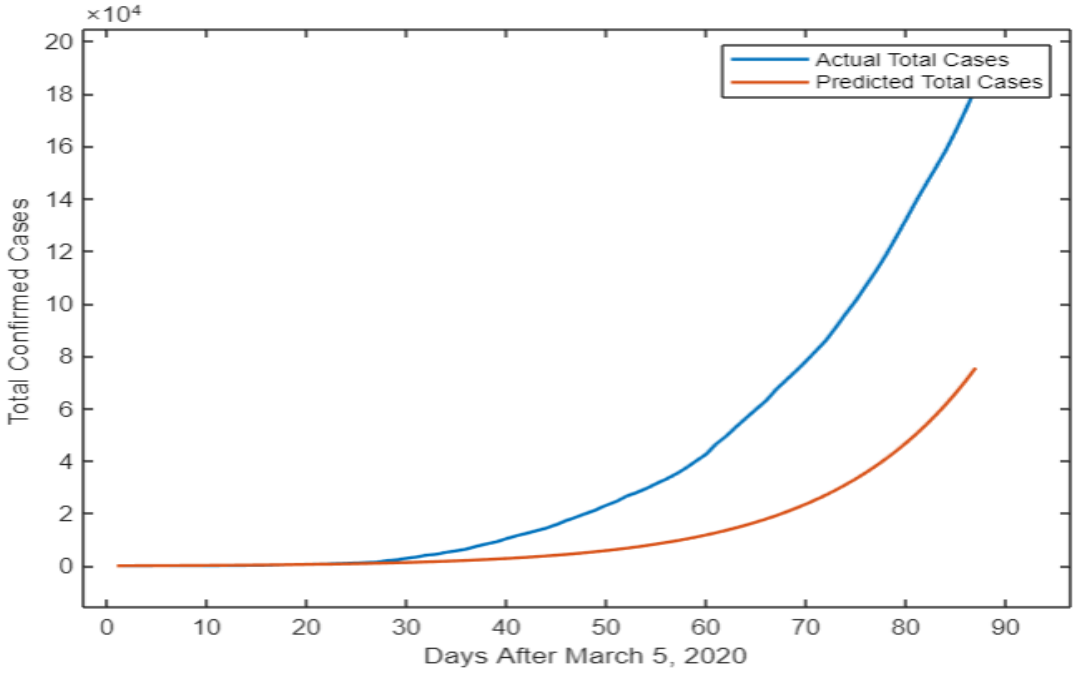


Figure: Actual VS Predicted (Uninterrupted) Spread of COVID-19 in India

The curve depicting the actual confirmed cases shows faster growth than the curve depicting the predicted number of confirmed cases for the same time period in both the figures.

Discussion

- As seen in the COVID-19 Outbreak trend in India graph, the outbreak is growing rapidly across India. It is an alarming situation for the nation as along with the health of the population, the economic and social ramifications will be enormous
- If the number of cases continue to grow exponentially in this manner, it will be a never-seen-before public health disaster for India.
- According to the estimations made in the study, unchecked, the epidemic will infect almost 70-80% of the population.
- The results are suggestive that the lockdown is able to interrupt the transmission of COVID-19. However, in order to achieve appreciable effects in long run, sustainable strategies need to be devised.
- The lockdown has resulted in shifting of the peak of outbreak by almost a month. The overall impact however, remains approximately the same in both the cases.

- To avoid the explosive growth of cases post lockdown, the government has to plan stringent epidemiological solutions meanwhile promoting research for curative interventions.
- The plot of actual vs predicted cases reveals a gap between actual and predicted data. The gap could be attributed to the lack of testing in the beginning of the outbreak, which increased later in April when the number cases started to explode when the testing rate was significantly higher. This alludes to the possibility that the infection was sprawling across the nation, undetected.
- The coefficients that govern the course of epidemic as per the model can be used to devise mitigation strategies as elucidated below:
- Increasing the recovery rate, γ, by discovering curative medicines such as anti-viral drugs and therapies
- Decreasing the rate of infection, β, by implementing social distancing measures, isolation of suspected persons, which invariably requires robust testing and hence detecting the cases.
- The predictions of the course of an epidemic are of great importance as they not only provide estimates of numbers of cases but aid in informed decision making.

Conclusion

In this study, SEIRD model is used to understand the transmission dynamics of COVID-19 outbreak in India and also make predictions on the trajectory of COVID-19 outbreak in India over the next year. The effect of lockdown in slowing the growth rate of the epidemic is seen with the help of this study. The study suggests that lockdown is effective in slowing down the growth of cases but however it is not a permanent solution. The study has also made efforts to compare the estimated results with actual data. The model leverages the time dependent nature of disease growth in the population and suggests methods to plan future mitigation strategies.

Thankyou