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# A Preliminary Prediction of Covid-19 Cases in India by April 2020 Using Exponential Mathematical Modelling

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## Abstract

We are in the midst of covid-19 pandemic, the number of cases has exceeded 6,00,000 and continues to increase rapidly. India experienced Level 1 and 2 transmissions between January and March 2020. Consequently, a spike in the number of cases may be expected any time from now and if not well prepared for, is likely to overwhelm our healthcare service capacity. We aimed at developing a prediction algorithm for estimating the potential number of COVID-19 cases in India due to community transmission. This algorithm is based on the number of infections recorded in the initial days and further containment interventions like social distancing and complete lockdown. Exponential growth modeling is adapted to fit the data into the curve. 95% confidence interval depicts the precision of new cases daily. We modelled that the growth factor could be reduced due to the strict implementation of social distance and lockdown. 70% reduction in growth factor shows the flattening of the curve, a positive sign for the complete reduction of community spread. Further researchers can consider the impact of change in weather conditions (temperature and humidity) on virus transmission and virulence, increasing awareness for care-seeking among the general public, increasing provisions with outreach for testing in the Government and accredited centres, the country’s young demography, population density, evolving herd immunity, and endemicity of other diseases (e.g., malaria and tuberculosis) vis-à-vis virus transmissibility and virulence of the SARS-CoV-2 in India.

**Key word**: Covid 19, Exponential fit, Growth factor, Lockdown, Social distance, India

## Introduction

The entire world is experiencing the pandemic (COVID-19) by a novel corona virus (SARS-CoV-2) on an unprecedented scale. It started in the Wuhan city of Hubei province of Central China during the month of November-December 2019[1]. The outbreak was declared as Pandemic by World Health Organization on March 11, 2020[2]. Meanwhile, as of 28 March 2020, 199 countries/ areas/ territories have reported with a total of almost 600000 positive cases and 28000 deaths world-wide[3]. Clinically, the affected individual presents with fever, cough, shortness of breath and other features of respiratory viral infection. In India, the first case of COVID-19 was documented on January 30, 2020, imported from China. Towards the end of March 2020, there are more than 750 confirmed cases and 17 deaths. On March 24, 2020 the Honourable Prime Minister of India declared national wide lockdown for 21 days[4]. Maximum number of cases have been reported from the states of Kerala and Maharashtra. There was no evidence of community transmission in India as per a sentinel surveillance by the Indian Council of Medical Research (ICMR) between February 29, 2020 to March 15, 2020 though the chance of India entering Level 3 transmission was also simultaneously stated as inevitable[5]. In the current context, as India locks down as its maiden attempt to flatten the curve and bid some time for preparing its grossly inadequate tertiary care provisions, prediction of anticipated number of cases may help in more efficient planning. With the help of transmission dynamics of COVID-19 in India and other countries, we developed a mathematical model to predict the magnitude of the pandemic in India vis-à-vis Government of India efforts efforts at containment (lock down) and social distancing.

## METHODOLOGY

### Why Exponential Growth?

"The reason to use Exponential Growth for modeling the Coronavirus outbreak is that epidemiologists have studied those types of outbreaks and it is well known that the first period of an epidemic follows Exponential Growth". The Exponential Growth will only fit the epidemic at the beginning. At some point, healed people will not spread the virus anymore and when (almost) everyone is or has been infected, the growth will stop[6].

We have tried prediction with other fitting models like polynomial and Gaussian but these models yield less correlation between actual and prediction scores.

$$f_{poly}(x) = a_0 * x^0 + a_1 * x^1 + a_2 * x^2$$

The above equation represents the second order polynomial, and $a_0, a_1$ and $a_2$ represent the fitting coefficients.

$$f_{gau}(x) = \ a_g * e^{\frac{-(x-b_g)^2}{c_g{}^2}}$$

The aforementioned equation represents the Gaussian fitting, and $b_g$ and $c_g$ represent the characteristics of Gaussian. These models yield the correlation lesser than exponential fitting. The robustness of exponential fitting motivated us to utilize in our approach. In such models, scientists choose to fit $R_0$ to time series data with exponential growth assumptions. Since the basic reproduction number of SARS-CoV-2 has been consistently above 2.0 in most parts of the world with the virus infecting increasing number of people with every passing day, and given that in India, we are expecting an early epidemic growth profile, we have modeled the spread data of 15 days with the exponential fitting.

We have used the following formula:

$f(x)=a * e^{b*x}$ [7]

where, 'b' represents the growth parameter and 'a' represents the initial parameter. If |b|>1, it indicates an epidemiological curve that is shorter on the x-axis and higher on the y-axis indicating a 'spike' in the number of cases. On the other hand, if 0<|b|<1, then we get a flatter curve. x represents the number of days and f(x) represents the cumulative count of COVID-19 cases. This model learns from x and f(x) data to estimate a and b values with 95% confidence intervals. This model is related to the conventional r-curve fitting method but has the additional advantage of understanding the initial phase of virus spread. The 'a' value provides the information of origin phase of the COVID-19 spread. In our analysis, we observed that 'a' and 'b' values vary with respect to the country's COVID-19 cumulative data.

We retrieved data regarding COVID-19 cases along with timelines (March 1st -15th , 2020) from the website maintained by COVID-19 India Resource Center, ICMR, National Institute of Epidemiology, Chennai[8]. They are updating the data based on Ministry of Health and Family Welfare official website. We modeled the data by utilizing the exponential fit and computed the growth parameter to estimate the rise in cumulative count over the time period (March 1st -15th). We utilized the estimated a and b values from March 1st to 15th data to compute the scores. The algorithm thus developed was compared with trends in actual data between March 16th - 21st, 2020, to validate. Subsequently, predictions were made for future case load between March 22nd -31st, 2020 by fitting interventions at various thresholds i.e., social distancing only (20% and 50% reduction in b) and social distancing with lock down (20%, 50% and 70% reduction in b).

## RESULT

Data regarding COVID 19 cases have been collected from website maintained by COVID-19 India Resource Center, ICMR National Institute of Epidemiology, Chennai. (8) Table 1 shows the cumulative count of COVID 19 spread in India between the month of March 1st and 15th. We used Matlab toolbox in our analysis. It is clear that the proposed algorithm accurately fits the data, and we experienced the growth rate b = 0.1540.

**Box 1. Interventions undertaken by the Government of India for containment of surge in COVID-19 cases**

*Travel advisory to travellers visiting China dt **17-01-2020** [9]

All regular (sticker) Visas/e-Visa (including Visa on arrival for Japan and South Korea) granted to nationals of Italy, Iran, South Korea, Japan and issued on or before 03.03.2020 and who have not yet entered India, stand suspended with immediate effect. Such foreign nationals may not enter India from any Air, Land or Seaport ICPs. Those requiring to travel to India due to compelling reasons, may seek fresh visa from nearest Indian Embassy/Consulate dt **03-03-2020.** All foreign and Indian nationals entering into India from any port are required to furnish duly filled self declaration form (including personal particulars i.e. phone no. and address in India) and travel history, to Health officials and Immigration officials at all port[10]

*All existing visas issued to nationals of any country except those issued to Diplomats, Official passport holders, those in UN / International organizations, those on Employment, Project visas and those who are operating aircrew of scheduled commercial airlines, and who had not yet entered India, stand suspended w.e.f. 1200 GMT on March 13, 2020 till April 15, 2020.

*All incoming travellers, including Indian nationals, arriving from or having visited China, Italy, Iran, Republic of Korea, France, Spain and Germany after Feb. 15, 2020 shall be quarantined for a minimum period of 14 days as per the Bureau of Immigration (BoI), Government of India. This came into effect from 1200 GMT on March 13, 2020 at the port of departure.

*Advisory on Social distancing dt 16.03.2020[11]

*Janata Curfew on 22.03.2020

*Complete lock down in India from 23.03.2020 till 14.04.2020

**Figure 1: Proposed model fit on COVID-19 affected cumulative count between March 1st to 15th, 2020.**

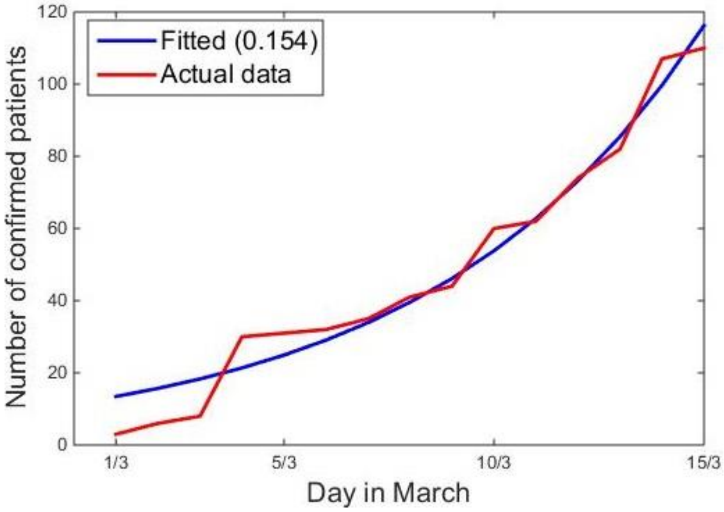
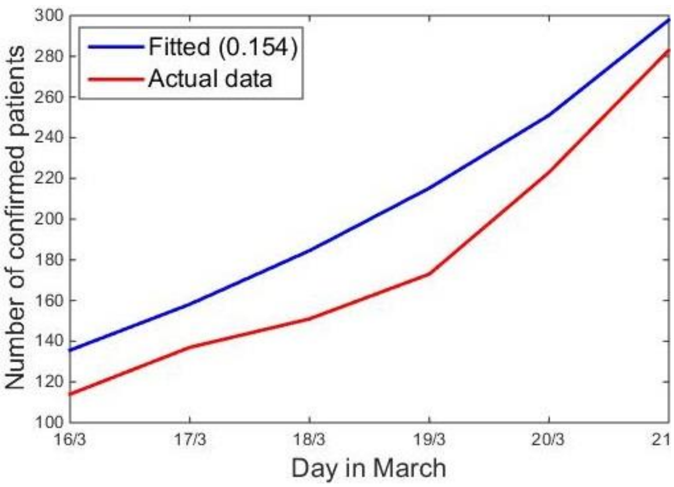



**Table 1: COVID-19 spread count between March 1st to 15th in India (As per NIE- ICMR data)**

| Date | Cumulative | Date | Cumulative |
|---|---|---|---|
| 01-Mar | 3 | 09-Mar | 44 |
| 02-Mar | 6 | 10-Mar | 60 |
| 03-Mar | 8 | 11-Mar | 62 |
| 04-Mar | 30 | 12-Mar | 74 |
| 05-Mar | 31 | 13-Mar | 82 |
| 06-Mar | 32 | 14-Mar | 107 |
| 07-Mar | 35 | 15-Mar | 110 |
| 08-Mar | 41 | | |

**Figure 2 : Comparison plot between estimated and actual cumulative count**




We tested the efficacy of proposed algorithm by computing the confirmed cases on the days between March 16th to March 21st. We utilized the estimated a and b values from March 1st to 15th data to compute the scores. Table 2 and Figure 2 shows the comparison between estimated COVID-19 spread count and actual COVID-19 cases. It is clear that the proposed algorithm accurately estimates the spread count between the dates, and also we experienced correlation score 0.9895 between predicted and actual scores. This correlation score clearly highlights the efficiency of proposed algorithm to estimate the cumulative spread in future days.

**Table 2: Comparison between proposed algorithm prediction and actual COVID-19 cumulative count between March 16st to 21th in India**

| Date | Cumulative | Prediction with confidence interval (95%) |
|---|---|---|
| 16-Mar | 114 | 135 |
| 17-Mar | 137 | 158 |
| 18-Mar | 151 | 184 |
| 19-Mar | 173 | 215 |
| 20-Mar | 223 | 251 |
| 21-Mar | 283 | 297 |

**Figure 3: Cumulative count prediction between March 22nd to March 31st. Comparison with actual data between March 22nd to March 25th**

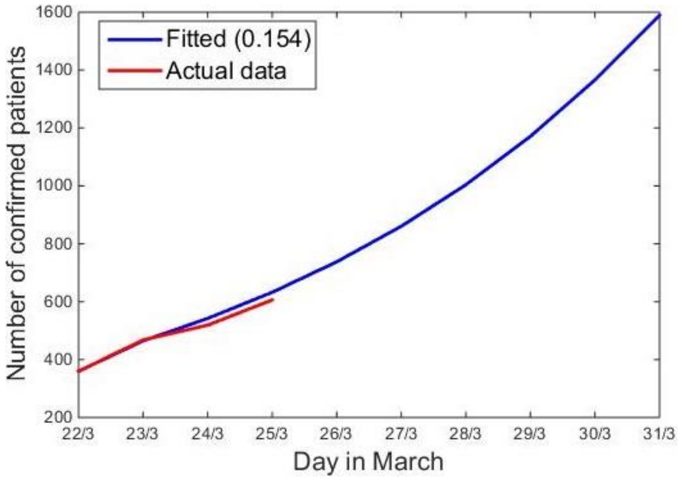



**Table 3: COVID-19 spread prediction in future days**

| Date | Cumulative | Prediction with confidence interval (95%) |
|---|---|---|
| 22-Mar | 360 | 359 |
| 23-Mar | 468 | 465 |
| 24-Mar | 519 | 542 |
| 25-Mar | 606 | 632 |
| 26-Mar | 694 | 737 |
| 27-Mar | - | 860 |
| 28-Mar | - | 1003 |
| 29-Mar | - | 1171 |
| 30-Mar | - | 1366 |
| 31-Mar | - | 1589 |

Table 3 and Figure 3 shows the predicted COVID 19 spread count between March 22nd to March 31st. Also, we have compared with actual scores between March 22nd and March 25th. It is following the trend.

Figure 4 shows the predicted, actual cases, 20% reduction and 50% reduction because of social distancing intervention. As on date 25.03.2020, the actual confirmed cases are bit closer to the predicted score. The reduction in number of cases is <20% due to social distancing.

**Figure 4: Comparison plot between estimated, actual cases, 20% reduction and 50% reduction after implementing social distancing.**

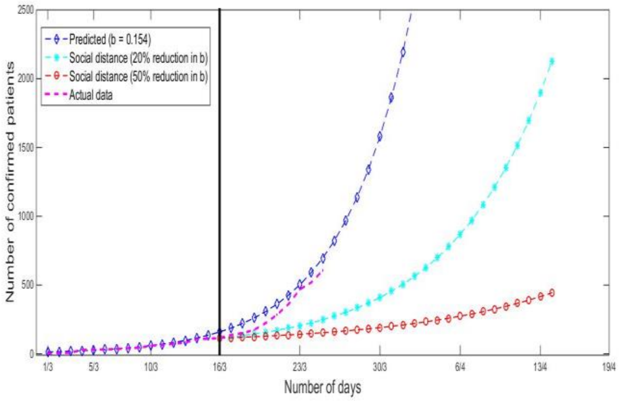



**Figure 5: Comparison plot between estimated if no effect, actual cases, 20% reduction, 50% reduction and 70% reduction after implementation of social distancing and Lock down of country**

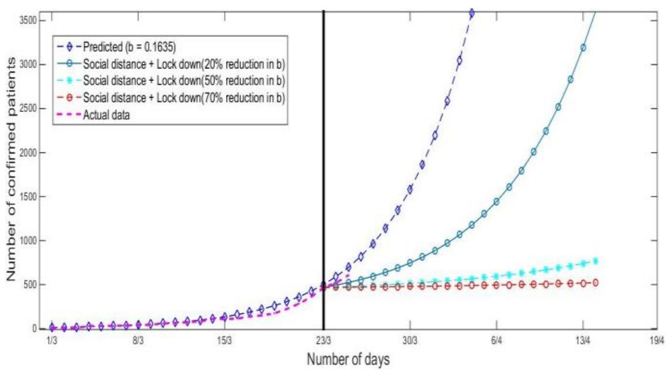



Figure 5 shows the predicted cases if there is no effect, actual cases, 20% reduction, 50% reduction and 70% reduction because of social distancing and Lock down of country from 23.03.2020. As on 25th March 2020, the actual confirmed cases was 468.

We computed the growth parameter ‘b’ using the data between March 1st and March 23rd and we experienced b= 0.1635. Further, we enhanced our analysis by reducing the b value by 20%, 50% and 70% to calculate the theoretical spread variation during the lockdown period between March 23rd to April 14th. Table 4 shows the predicted cumulative COVID 19 spread with different b values.

**Table 4: COVID-19 spread prediction in future days**

| Date | If there is no change in growth parameter (b) | 20% reduction in growth parameter | 50% reduction in growth parameter | 70% reduction in growth parameter |
|---|---|---|---|---|
| 30/03 (1 week after lock down) | 1581 | 747 | 514 | 480 |
| 06/04 (2 weeks after lock down) | 4983 | 1608 | 611 | 498 |
| 13/04 (3 weeks after lock down) | 15706 | 3195 | 740 | 518 |

As on 26.03.2020, 694 confirmed cases of COVID 19 were recorded in India.

## DISCUSSION

Our modelling predicts that India may be able to achieve a flatten curve even if the interventions (social distancing and lock down along with other interventions) achieve modest levels of implementation (50%) and a plateau at 70% implementation. This will posit India on a track similar to that of South Korea and achieve a break in chain of transmission for SARS-CoV-2 though the latter took on a universal testing and tracking strategy while the same was not as much feasible with our huge population of 1.3 billions. Our model also seems to be more pragmatic given the concerns raised by various quarters that social distancing and complete lock down may not be implementable in our context in the absolute way and that there will be defaulters. The success of lock down intervention depends on people’s behaviour.

“Flattening the curve,” will delay and reduces the peak of the outbreak. This will slow the rate at which a disease moves through a population so that the health-care system is better equipped to handle it[12].

Our model has the limitations that we have not considered the impact of change in weather conditions (temperature and humidity), increasing awareness for care seeking among the general public, increasing provisions with outreach for testing in the Government and accredited centres, the country’s young demography, population density, evolving herd immunity, and endemicity of other diseases (e.g., malaria and tuberculosis) vis-à-vis virus transmissibility and virulence of the SARS-CoV-2 in India. When we have more data, subsequent modelling will be better. The changes in the confirmed cases of COVID-19 from April 2020 will be estimated separately using separate modelling with due consideration of these factors.

**Academic Interest:** This model can be used for academic purpose for predicting a new disease using Exponential modelling and for planning and preparedness activities.

**Competing interests:** The authors declare that they have no competing interests.

**Disclaimer:** The views expressed in the article are the authors’ own and do not represent that of their respective organizations. All mathematical models of infectious diseases epidemiology are based on some strict assumptions. Please interpret the findings carefully. Currently the spread of COVID-19 is in a very dynamic state, based on the change in growth parameter final outcome will also differ.

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