Modeling and Predictions for COVID 19 Spread in India

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Abstract

We investigate the problem of modeling of new corona virus (Covid19) spread in constrained or practical scenario in India. It is noticed that lock-down and isolation are the important techniques to prevent the spreading of the disease. We study the effect of these prevention techniques on the spread of Covid19 mathematically, and propose a new mathematical model to predict the new cases or total infected cases in practical scenario. This prediction is very much required to prepare medical set-ups and proceed for future plan-of-action. A new model for constrained scenario is proposed for Covid19 spread. A tree-based model is considered, in which some people are quarantined and few are left undetected (hidden nodes) because of various reasons like symptoms not shown, hiding travel history, etc.; and these hidden nodes spread the disease in community. It is proved by the analysis and available results that there is no community spread in the India so far, i.e., majority of people are not infected or spreading the disease because of lock-down or quarantined. An approximate prediction of new cases can be performed easily by using the proposed model. It is evident from the results that lock-down plays an important role to control the spread of the disease. A close match between analytical results and the available results shows the correctness of derived model.

Index Terms: COVID19, prediction, mathematical modeling

I. INTRODUCTION

Currently, the world is under a threat from Covid19 which is a new disease spread by a virus of corona family. Majority of countries of world have noticed a huge number of Covid 19 cases from December 2019 onwards. People with low immunity, old age, and medical problems specially related to lungs are more prone to Covid 19 disease. The symptoms of Covid19 are cough, cold, breathing problem very similar to flu. It is observed by the doctors that a person infected by Covid19 is recovered within 14 -16 days because the incubation period of novel corona virus is of fourteen days. Preventive measures for Covid19 are to protect oneself by washing hands frequently, avoiding touching the mouth, nose, and face, and by maintaining social distancing (1 meter or 3 feet) with other people. Covid19 is now a pandemic as declared by World Health Organization (WHO) [1]. Therefore, preparation regarding medial facility should be adequate worldwide. Since there is no vaccine of Covid19 available and disease is contagious, therefore, the number of new infected persons increases rapidly. If hospitals are not well prepared, then it is not possible for health workers to operate efficiently. In this situation it is inevitable to have an accurate estimation of new Covid19 cases, which can help the medical and administrative authorities. Further, it is also very important two know that which country is facing how much severity of this disease. It is reported that there are two important stages of Covid 19; stage-II and stage-III. In stage-II, there is person-to-person transmission and in stage-III, there is a community transmission. According to the stage of Covid19, plan of action by different countries can be decided. An important question for Covid19 is that what is the effect of lock-down?

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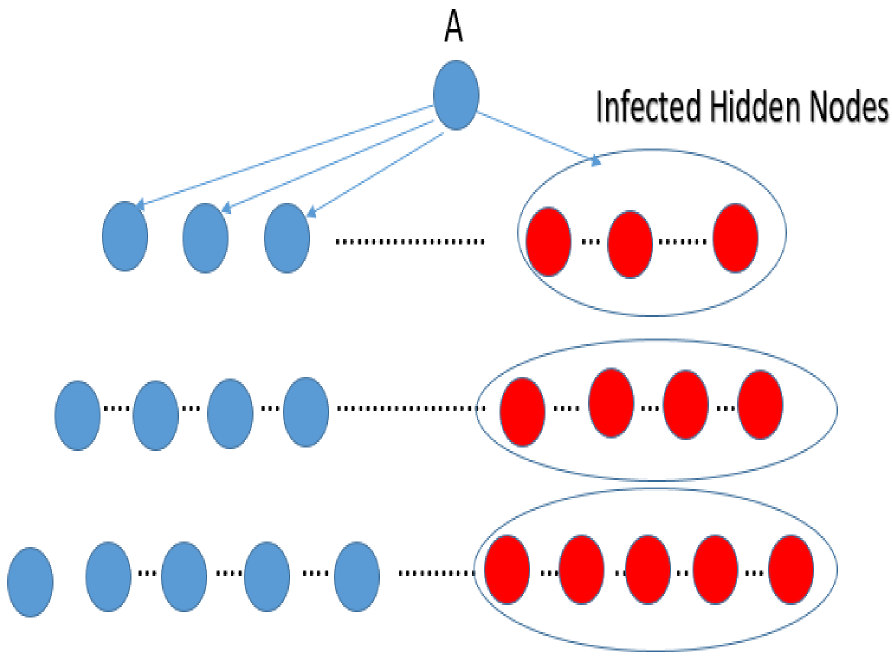

Fig. 1. Proposed model for spread of COVID19 in constrained scenario.

In India, the first case of Covid19 was reported on 30 January 2020, originating from China. After two months this disease spread in almost all parts of the country. At present, total cases are 1397, among them 124 are recovered and 35 deaths are reported [2]. The rate of infection is approximately 1.9 in India which is comparatively lower than other countries.

In this paper, we propose a mathematical model for constrained scenario, i.e., with lock down, quarantine, self-isolation assumptions. This model can approximately predict the number of new Covid19 cases and can tell the stage of Covid19 in a particular country

II. Proposed Model for COVID19 in constrained Scenario

We assume that a positive corona patient comes into a country and comes into the contact of other people. Since it is an infectious disease, therefore, it spreads in others. Let us assume that it spreads the disease to t number of persons. Later lock-down and testing starts, we assume that because of testing and symptoms q persons are quarantined and will not be in contact of any other person; but $d=t-q$ persons break lock-down and neither show the symptoms nor get quarantined. Therefore, these behave like hidden active nodes. Each hidden node (an infected person) can infect t other nodes (person) in 1 unit time (unit may be day, hour, minute). Again q active nodes (persons) show symptoms and testing and quarantine and some hidden node left and chain reaction starts and each active node among these d active hidden nodes infect t number of more persons. These hidden nodes increase by a constant number C because of several reasons like testing, symptoms not shown, hiding travel history etc., or some new active nodes into the system. Now, number of hidden nodes is increased by d+C; then in the next unit time hidden nodes will be increased by d+2C and so on. Since there is no identification of these hidden active node, therefore, these persons constantly remain in contact with all other healthy persons. A tree based structure is shown to clarify the considered scenario in Fig. 1.

It is clear from the figure that node A (an infected person) can infect t other nodes (person) in one unit time. Therefore, we can write total number of active nodes or infected persons as

$$T_{\{cases\}} = 1 + t + \{dt + (d + C)t + (d + 2C)t + (d + 3C)t..\}. \quad (1)$$

It can be observed from (1) that after first two terms, i.e., 1 and t, rest of the series follows the arithmetic progression (AP) of *(N-2)* terms with common difference *Ct, defined as rate of infection, i.e., r=Ct.* Here, N is the total number of terms in the series given by (1). By using the formula of sum of N terms of AP in (1) [2], we get

$$T_{\{cases\}} = 1 + t + \frac{(N-2)[2td + (N-3)Ct]}{2}. \quad (2)$$

It can be observed from the proposed model that as far as hidden nodes exist in the system, total cases will keep on increasing as given by (2). Let us consider a case when total cases including all active nodes, whether quarantine, hidden or isolated is 2000 on 02/04/2020 with t=10, d=2, and C=2. We want to calculate the required period of lockdown in this situation. Hence, by using (2), the value of N is approximately 47. It shows to quarantine all active nodes, 47 more days are needed. So lock down period in this case is from 03/04/2020 to 19/05/2020 to control Covid19. If total more cases are estimated then a large period of lock-down is required. Therefore, by estimating total number of cases, hidden nodes d, and rate of increase of hidden nodes (C); the period of lockdown can be calculated. The lock-down can be performed in one phase and in more phases also.

III. Results

In this section, we consider the study of spread of COVID19 disease in India. India is observing an increase in the number of patients each day. It is reported that Covid19 is in stage-II and there is no community transmission. A constrained scenario is considered, specifically lock-down is imposed from 25/03/2020. Even then some hidden active nodes (infected person) exist and these nodes are increasing day-by-day. A mathematical model, given by (2), is considered and shown in Fig. 2. The accuracy of our proposed model, is validated by using the official data of India from [3].

In Fig. 1, we have plotted the curves between the total number of COVID19 cases versus days (till March 29, 2020) in India based on the actual data [3] and the proposed model. The rate of spread is taken as 2.3 per day, i.e., one infected node takes 2.3 days to infect another node. Also, we consider the value of $t = 1$, i.e., one node can infect only one node in 2.3 days. This scenario is considered from 1st March 2020 to 22nd March 2020. It can be observed from the figure that the official data is closely matched with the analytical data of the proposed unconstrained model given in [4].

From 23rd March to 30th March lock-down situation is considered, and it is assumed that the rate of infection r=0.15. It means in lockdown situation also rate of increase of hidden node is 0.15, i.e., one infected hidden node spreads the infection in 0.15 nodes in one day. It can be observed from Fig. 2 that the proposed model validates the official data. This shows the correctness of the proposed model.

Then a rapid increase in hidden active nodes is observed on 1st April due to relaxation in lockdown or social gathering etc. It can be observed from the figure that this increase changes the rate of reaction from 0.15 to 0.65. Therefore, the number of infected persons increases rapidly, i.e. on 1st April 2020, 11:54 GMT, the official data is 1637 [3] and analytical data (including full day of 1st April 2020) is 1731, which is very close to actual value. A religious gathering is reported in India on 31st March and 1st April 2020. Therefore, the proposed model shows a very accurate modelling.

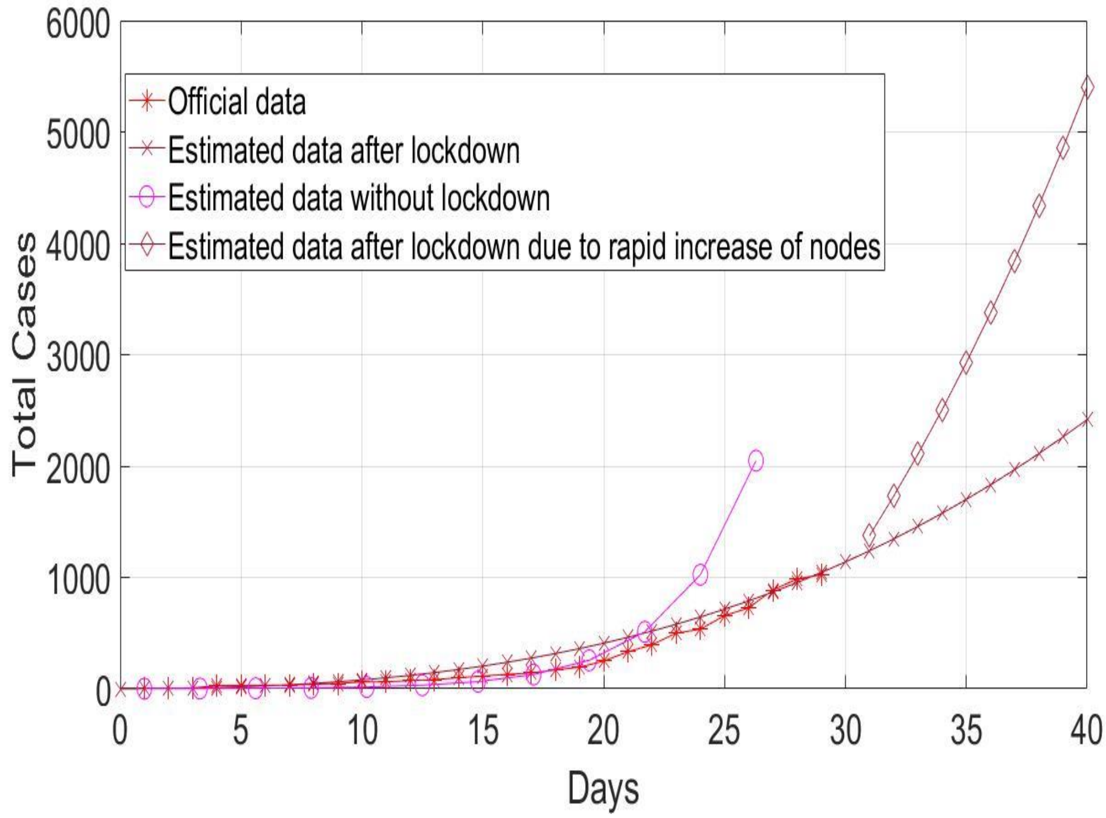

Fig. 2. COVID19 spread in India in Constrained Scenario.

Figure 3 Shows the effect of lock-down. We assume that a strict lock-down (all nodes are quarantined) is imposed when 2000 total cases are present, the recovery rate is assumed to be 0.26, i.e., on an average one person needs approximately 4 days to recover. It can be observed from the figure that at least 40 days complete lock-down is needed to make total cases equal to zero. If medical facilities are better and recovery rate is 0.35, 0.45, and 0.535, respectively, then 40 days complete lock-down is required for 3000, 4000, and 5000 infected cases.

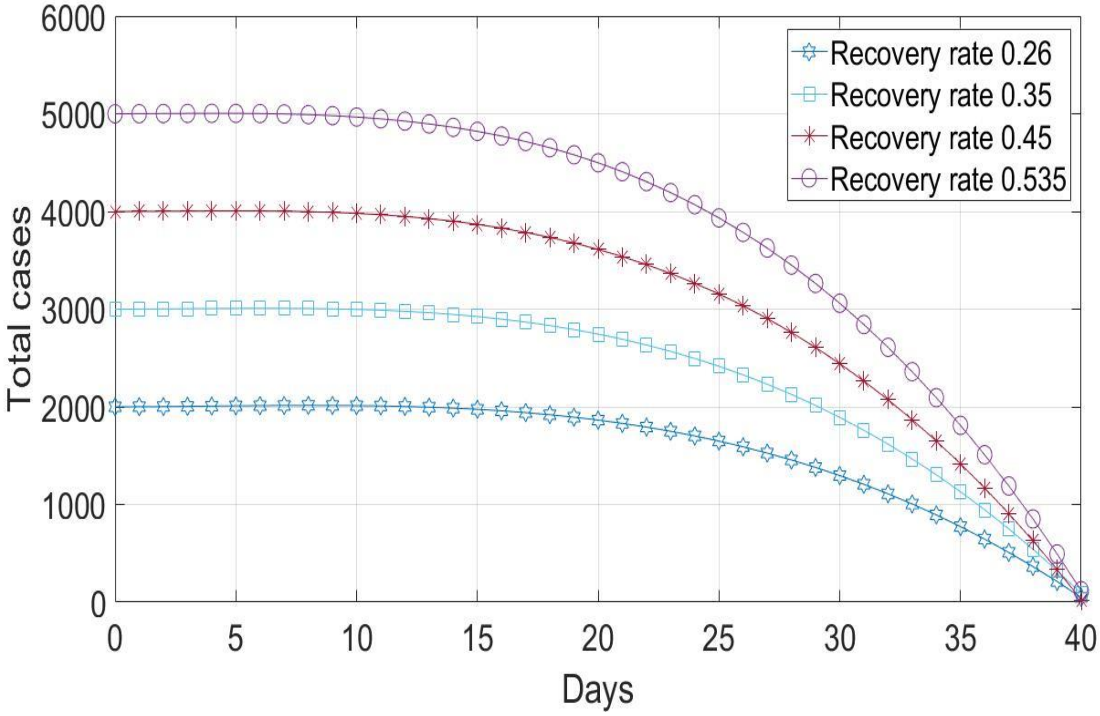

Fig. 3. COVID19 spread in India for different recovery rates.

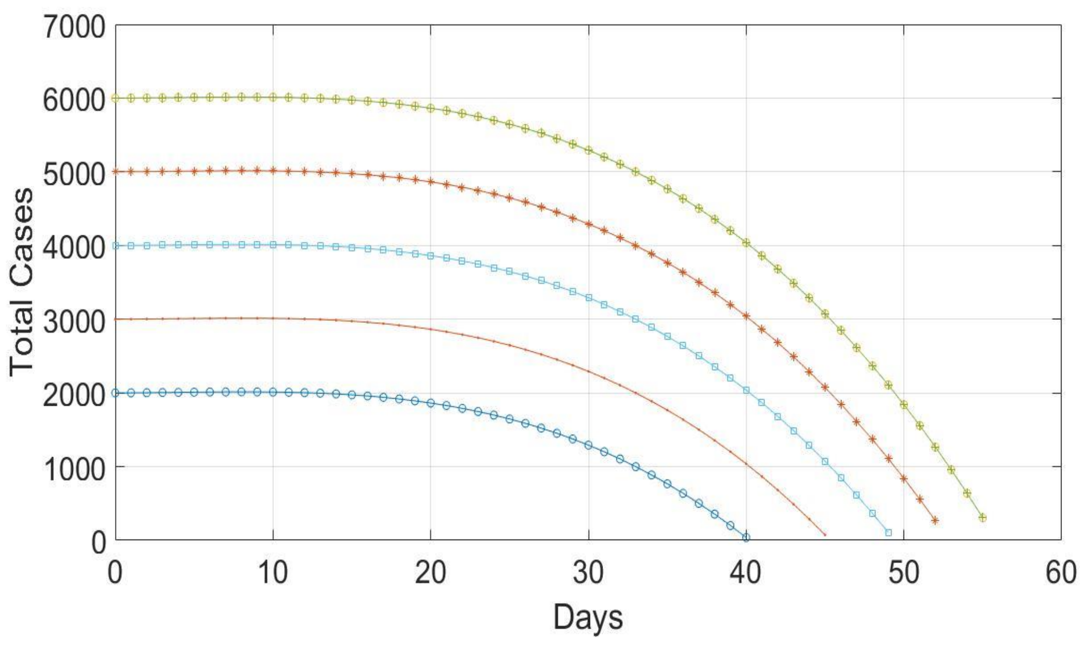

Fig. 4. COVID19 spread in India for different number of total cases.

Figure 4 shows the required number of lock-down days with 2000, 3000, 4000, and 5000 total infected cases with recovery rate 0.26. It is shown in the figure that if number of total cases increases, then required days of lock-down also increases. Approximate 54 days of complete lock-down is required for 5000 total infected cases. It can be concluded from this figure that with increase in infected cases, lock-down period will also increase.

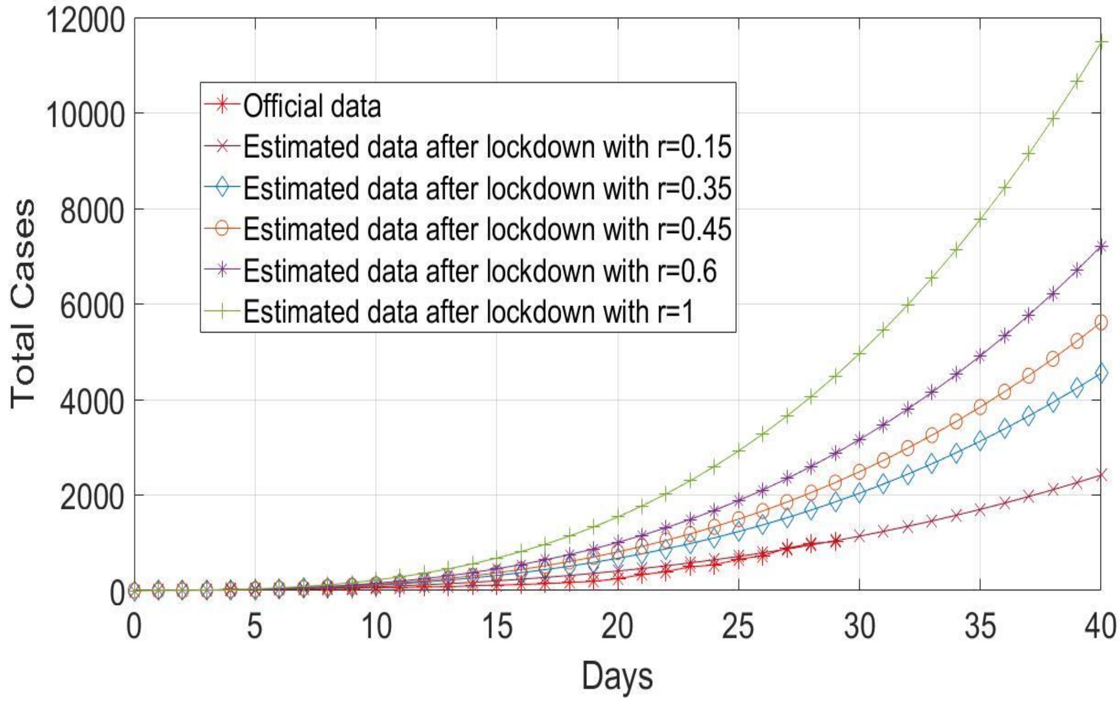

Fig. 5. COVID19 spread in India with different infection rates.

Plots between total infected cases versus days with different infection rates, i.e., $r=Ct$ =0.15, 0.35, 0.45, 0.6, 1 is shown in Fig. 5. It can be observed from the figure that total number of cases increase rapidly with small increase in infection rate. For example, if infection rate r increases from 0.15 to0.35; total number of cases increases from 2100 to approx.. 4100 on 40th day, as seen from Fig. 5. Therefore, 2000 new persons get infected due to increment of 0.2 in infection rate.

Figure 6 shows the effect of lock-down in multiple phases on total number of infected cases, i.e., if 30 days lock-down is imposed in first phase and then six days relaxation is given by the authorities; and then again 15 days lock-down is imposed. This situation is shown in Fig. 6. It is assumed that in first phase, recovery rate is one. After first phase, infection rate is one [], then in second phase of lock-down recovery rate is two. It can be observed from the figure that after 30 days, total cases are 3072, whereas, after six day relaxation total number rises to 197200. To recover this large number of infected cases; a very large period of lock-down is required. Therefore, it can be concluded from the figure that lock-down in multiple phases is not a good strategy to deal with Covid19.

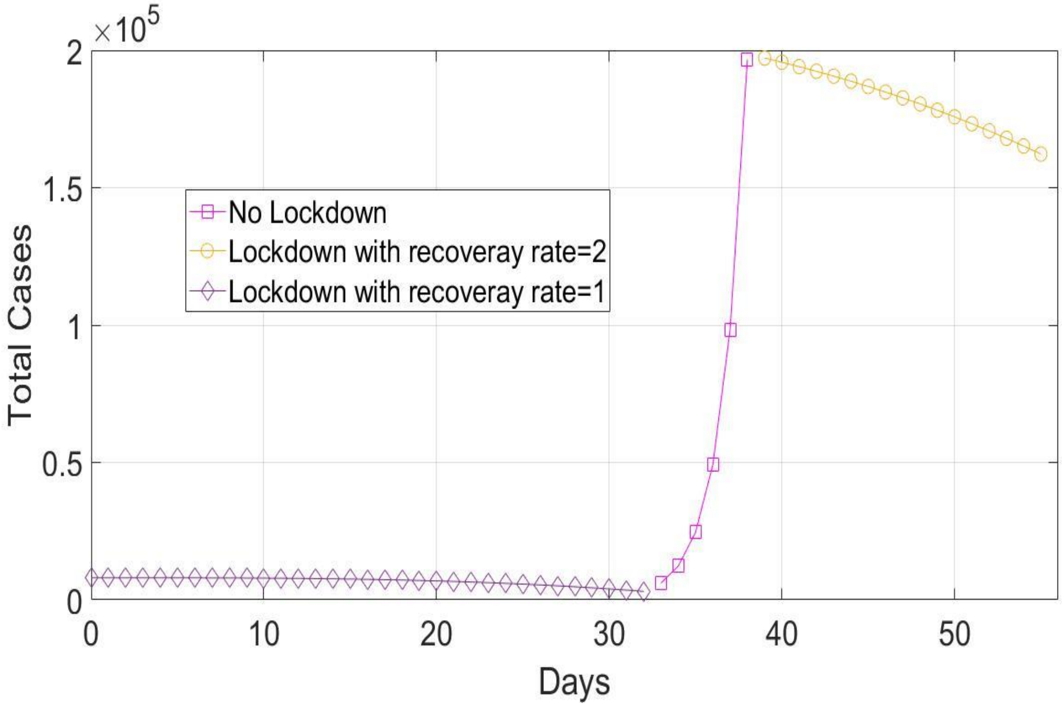

Fig. 5. COVID-19 spread in India with lock-down in multiple phases

IV. CONCLUSIONS

We have investigated the problem of Covid19 spread in India in practical scenarios. A mathematical model has been established, which follows the actual data trend of Covid19 spread in India. It has been proved from analytical (based on mathematical modelling) and simulation results that lock-down and social distancing plays an important role to prevent from this disease.
The effect of lock-down has been discussed with different recovery rates and different infection rates. It has been also concluded that sudden increase in hidden nodes (infected people) may rise to a serious situation in terms of total cases, which may lead to burden on the medical set-ups. The effect of lock-down in multiple phases has also been studied and it is shown by the simulation results that lock-down in multiple phases is not a good strategy to deal with Covid19.

IV. REFERENCES

[1] https://www.who.int/emergencies/diseases/novel-coronavirus-2019 [Accessed on March 30, 2020].
[2] I. S. Gradshteyn and I. M. Ryzhik, *Table of Integrals, Series, and Products*, 6th ed. San Francisco, CA, USA: Academic, 2000.
[3] https://www.worldometers.info/coronavirus/countries [Accessed on March 30, 2020].
[4] Manav R. Bhatnagar, "COVID-19: Mathematical Modeling and Predictions", submitted to ARXIV. Online available at: http://web.iitd.ac.in/~manav/COVID.pdf [Accessed on April 01, 2020].